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Strength and Neuromuscular Characteristics of Female and Male High School Basketball Players

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**Strength and Neuromuscular Characteristics
of Female and Male High School Basketball Players**

By

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THESIS

Submitted to the Department of Physical Therapy and the Department of Health
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Master of Health Science**

1997

Strength and Neuromuscular Characteristics of Female and Male High School Basketball Players

ABSTRACT

The purpose of this study was to identify possible differences in strength ratios and neuromuscular performance between high school female and male basketball players, as tested by concentric isokinetic testing using the Biodex® isokinetic system. We recruited high school basketball players, females (N=26) and males (N=27). All participants underwent isokinetic concentric testing of bilateral hamstrings and quadriceps at five speeds (60, 180, 240, 300, 450 degrees per second). Female subjects demonstrated lower hamstring/quadriceps ratios than males at 60 and 240 degrees per second. Compared with male subjects, the female subjects took significantly longer to generate maximum hamstring muscle torque during isokinetic testing at all speeds except 450 degrees per second. The results of this study suggest that there are differences between hamstring/quadriceps ratios and time to peak torque of the hamstrings by gender. The variable of strength should continue to be investigated in relationship to injuries of the ACL in the female athlete.

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TABLE OF CONTENTS

	Page
ABSTRACT.....	i
ACKNOWLEDGMENT.....	ii
LIST OF TABLES.....	v
LIST OF FIGURES.....	v
LIST OF GRAPHS.....	v
LIST OF APPENDICES.....	vi
DEFINITION OF TERMS.....	vii
CHAPTER	
1. INTRODUCTION.....	1
2. LITERATURE REVIEW.....	4
Historical Perspective.....	4
Factors that Contribute to ACL Injury.....	5
A. Intrinsic Factors.....	6
1. Ligament (joint) laxity.....	6
2. Limb Alignment.....	7
3. Notch Dimensions (Width/Shape).....	8
B. Extrinsic Factors.....	9
1. Motor Skill in Sport.....	10
2. Shoe Surface Interface.....	11
3. Muscular Strength.....	11
4. Conditioning.....	13
Mechanisms and ACL Injuries in Children.....	14
Isokinetics.....	14
A. Isokinetics- normative data for hamstring/quadriceps ratio.....	16
B. Isokinetic testing.....	16
1. Peak torque.....	16
2. Time to peak torque.....	17
3. Testing speeds.....	17
4. Stabilization.....	18
5. Warm-up and rest intervals.....	18
6. Gravity correction.....	19

	Page
7. Test repetitions.....	19
8. Patient testing position.....	19
3. METHODS AND MATERIALS.....	21
Subjects.....	21
Materials.....	21
Procedures.....	22
Data Analysis.....	23
4. RESULTS.....	25
5. DISCUSSION AND IMPLICATIONS.....	30
Comparison to Previous Studies.....	30
A. Comparison to normative data for hamstring/quadriceps ratios.....	30
B. Trends in hamstring/quadriceps ratios.....	31
C. Specificity of sample.....	32
D. Trends in time to peak torque.....	33
E. Gender differences in time to peak torque.....	33
F. Gender differences in hamstring/quadriceps ratios.....	33
Limitations and Recommendations for Further Study.....	34
Conclusio.....	36
REFERENCES.....	38
APPENDICES	
A. Contact Letter.....	43
B. Pre-test Questionnaire.....	44
C. Acceptance Criteria.....	45
D. Consent Form.....	46
E. Parent Information Letter.....	48
F. Instruction for Isokinetic Testing.....	49
G. Hamstring/quadriceps ratio as per Davies (1992).....	51
H. Hamstring/quadriceps ratio as per Wyatt and Edwards, (1981).....	52
I. Normative Isokinetic Data for Hamstring/quadriceps ratios, Moore and Wade, (1989).....	53

LIST OF TABLES

	Page
4.1 Demographic Summary.....	25
4.2 Isokinetic Data for Hamstring/quadriceps Ratio.....	27
4.3 Isokinetic Data for Hamstring Times to Peak Torque.....	28
4.4 Values for Mann-Whitney-U test for Hamstring/quadriceps Ratios Isokinetic Data.....	29
4.5 Values for T-tests for Independent sample for Time to Peak Torque Isokinetic Data.....	29

LIST OF FIGURES

	Page
2.1 Radiographic Measurement of NWI=A/B.....	9
2.2 Classification of Notch Shape.....	10

LIST OF GRAPHS

	Page
4.1 Distribution of Team Classification by Gender.....	26
4.2 Distribution of School Class by Gender.....	26

LIST OF APPENDICES

Appendix	Page
A. Contact Letter.....	43
B. Pre-test Questionnaire.....	44
C. Acceptance Criteria.....	45
D. Consent Form.....	46
E. Parent Information Letter.....	48
F. Instruction for Isokinetic Testing.....	49
G. Hamstring/quadriiceps ratios as per Davies, (1992).....	51
H. Hamstring/quadriiceps ratios as per Wyatt and Edwards, (1981).....	52
I. Normative Isokinetic Data for Hamstring/quadriiceps ratios, Moore and Wade, (1989).....	53

DEFINITION OF TERMS

ACL- anterior cruciate ligament

Biodex® System 2- a company name for an isokinetic system

Concentric- a muscle contraction resulting in shortening of the muscle

Eccentric- a muscle contraction resulting in lengthening of the muscle

Hamstring/Quadriceps ratio- a mathematical calculation of hamstring strength divided by quadriceps strength, utilizing peak torque measurement

Healthy- no musculoskeletal injury to a foot, knee, hip, or back that required medical treatment or that kept the athlete out of practice for more than one week, within the past one year

Isokinetic System- a piece of equipment designed to measure strength. It consists of a fixed speed of movement with an accommodating resistance

Medical Treatment- involved a visit to see a doctor

Peak Torque- the single highest torque, measured in foot pounds, produced by a muscle group through a range of motion

Time to peak torque- the amount of time, measured in milliseconds, it takes the muscle to produce its peak torque during isokinetic testing

Torque- the movement of forces that causes rotation or twisting

CHAPTER 1

INTRODUCTION

Women's participation in sports has increased in recent years. With this increase in participation, the incidence of injuries to women has come under review (Huston & Wojtys, 1996; Arendt & Dick, 1995; Hutchinson & Ireland, 1995; Ciullo, 1993; Souryal & Freeman, 1993; Moore, & Wade 1989; DeHaven & Lintner, 1986; Zelisko, Noble, & Porter, 1982; Clarke & Buckley, 1980; Whiteside, 1980; Garrick & Requa, 1978; Haycock & Gillette, 1976). At the top of the list is the problem of injuries to the anterior cruciate ligament (ACL). In addition to the athlete's physical pain, mental pain, and inability to participate in her sport, some require surgery and extensive rehabilitation.

Researchers have noted an increased incidence of ACL injuries to female basketball players when compared to male basketball players. This ratio has been reported to be as high as 8:1 (Malone, & Sanders, 1993) in the college level female basketball player. With the growing number of females participating in athletics at all levels, and the increasing occurrence of ACL injuries, research into the causes is essential so preventative measures can be employed. The female athletes' injury to the ACL occurs primarily without contact (i.e. while decelerating, landing from a jump, cutting, or knee hyperextension) and secondarily with physical contact. Male athletes primarily injure their ACL's through contact and secondarily without contact (Arendt & Dick, 1995; McBride, Meade, & Ryan, 1993). Injuries in children and adolescence are not as prevalent as they are in adults, but the mechanism of injury, hyperextension involving a twist, remains the same for children and adults (Lastihenos & Nicholas, 1996).

Many theories have been presented as to the causes of ACL injuries in

females, including:

- (1) increase in Q-angle
- (2) decreased size of the intercondylar notch
- (3) wider pelvis in females than males
- (4) decreased overall strength
- (5) increased joint laxity
- (6) interplay between female hormones and joint laxity
- (7) altered neuromuscular performance
- (8) shoe surface interface
- (9) increased quickness of the game as imposed by a 30 second shot clock for women college basketball players vs. a 45 second shot for males
- (10) inadequate conditioning

Inadequate conditioning may be a primary factor contributing to the higher injury rate in female basketball players (Moore & Wade, 1989). Clinically, we the authors, have observed that athletes with a torn ACL have weak hamstrings in relationship to the quadriceps on the uninjured leg, which may indicate that the injured leg may also have had a weakness or muscular imbalance prior to the injury. Quadriceps strength is needed to allow the athlete to stay in the bent knee position while cutting and stopping. Hamstring strength is necessary to assist in stabilizing the knee (Moore & Wade, 1989). Hamstring and quadriceps peak torque are often compared in the form of a ratio. "Several authors have suggested that screening of athletes to examine these ratios may identify athletes who may be at risk for injury due to their ratios being below these reported norms" (Fleck & Falkel, 1986, p.66).

A problem exists in the lack of normative strength and neuromuscular data on the female high school basketball player. It was the intent of this study to determine if high school female basketball players:

- (a) have a decreased concentric hamstring/quadriceps ratio, as compared to high school male basketball players,
- (b) have a decreased time to peak torque of the hamstrings as compared to high school male basketball players,

The authors hypothesized that a difference existed in strength as measured by isokinetic concentric hamstring/quadriceps ratio at five different speeds when compared between high school female basketball players and high school male basketball players. A second hypothesis was that differences between genders would also exist for hamstring time to peak torque data, a measure of neuromuscular performance, at five isokinetic speeds.

The study was significant because it provided objective data regarding possible strength deficits, and decreased neuromuscular performance (as measured in time to peak torque) in female high school basketball players as compared to male high school basketball players. This information will benefit clinicians, coaches, and athletes in the planning of their strength programs.

CHAPTER 2

LITERATURE REVIEW

Historical Perspective

American females had limited opportunities in athletics prior to World War II. During that time and in the post war era, girls participated in Girl's Athletic Associations (GAA) in local high schools. The GAA was essentially an intramural program. Females experienced their first major break through in organized sports participation in 1972 as the result of the passage of Title IX of the Educational Amendment. The project on the Status and Education of Women states, "Sex discrimination is prohibited in any education program or activity receiving Federal financial assistance" (as stated in Lutter, 1993, p.2). This amendment forced the general public to re-examine the role of females in society. Athletic achievement encouraged self-confidence, leadership, and physical strength (Lutter, 1993). These attributes were not considered a part of a female's traditional social role. A Connecticut judge, in 1971, commented in the project on the Status and Education of Women,

"The present generation of our younger male population has not become so decadent that boys will experience a thrill in defeating girls in running contests, whether the girls be members of their own team or an adversary team...Athletic competition builds character in our boys. We do not need that kind of character in our girls, the women of tomorrow" (as in Lutter, 1993, p.3).

The Title IX Amendment has unofficially been identified as the starting point for female athletics. As with any new opportunity, "growing pains" are experienced. Increased sports participation for females instantly had psychological, social, physical, and financial implication in the United States (Lutter, 1993). "Problems exist in three areas: social, competition, and illness

and injury" (Ireland, 1993). As participation in female sports increases so have the injuries.

"What problems do female athletes encounter? Lack of recognition and support are the most significant problems. This means less ink, less air time, less applause, less fame and adulation. At the professional level of competition, women receive much less money. The female athlete is continually faced with certain 'lacks' at many levels. This includes lack of encouragement to compete, lack of family, peer, and financial support, lack of recognition by fans and journalists, and lack of social acceptance" (Ireland, p. 11).

Researchers began documenting injury rates in high school (Garrick & Requa, 1978) girl's sports and college women sports as early as 1973 (Gillette, 1975). Gillette's 1975 data showed that college women had the greatest amount of injuries in the ankle and knees followed by contusions, low back injuries, and muscle pulls and strains. The most common women's sports producing injuries were basketball, volleyball, field hockey, gymnastics, and track and field. As injury data has been gathered on females and males in sports, it has shown sport injuries to be sport specific, not gender specific (Ciullo, 1993; Ireland, 1993; Albohm, 1976). Females tend to have a greater frequency of injuries but not different types of injuries (Garrick & Requa, 1978; Albohm, 1976). However, there is data that suggests that females have a greater proportion of knee disorders that involve the patellofemoral joint and ACL (Ireland, 1993).

Factors that Contribute to ACL Injury

Researchers have suggested that there may be multiple factors that contribute to ACL injuries in the female athlete. These mechanisms of injury have been divided into categories of intrinsic and extrinsic factors (Arendt & Dick, 1995; Hutchinson & Ireland, 1995). Some intrinsic factors have included: joint laxity, limb alignment, notch dimension, and ligament size. Extrinsic factors have

included: body movement in sport, skill level, shoe interface, and muscular strength (Arendt & Dick, 1995). Additional authors have added several other possible physiological differences between men and women including endurance, muscle recruitment order, and muscle reaction time as possible causative factors (Huston & Wojtys, 1996).

A. Intrinsic Factors

1. Ligament (joint) Laxity

Female athletes have less ligament laxity when compared with non-athlete females (Jones, 1980). In 1985, Beck and Wildermuth and in 1995 Arendt and Dick suggested that this can be a function of conditioning or genetics. Results vary from study to study regarding knee laxity and injury. Nicholas (1970) suggested there is an increase in knee ligament injury with loose-jointed athletes (male or female). "Greater knee joint laxity and subtalar pronation may be associated with an increased risk of ACL injury." (Woodford-Rogers, Cyphert, & Denegar, 1994, p. 345). Other studies showed no correlation (Grana & Moretz, 1978). In their 1996 study, Huston and Wojtys found knees of athletic females to have greater laxity than males with statistically significant higher anterior translation of the tibia on the femur. However, in the same study, both control groups (male and female non-athletes) had increased laxity as compared to their gender matched elite athletes.

Nicholas (1970) studied 139 professional football players to determine whether there was a relationship to knee joint laxity and stability in football players relative to injury. His results were: 37 athletes out of 139 sustained knee ligament rupture requiring surgery. Seventy-two percent of athletes that had at least three indices of looseness sustained ligament rupture.

Grana and Moretz (1978) tried to make a correlation between ligament laxity and the occurrence or type of injury. Their subjects were all members of

varsity football and boys and girls varsity basketball with a mean age of 15.9 years. The testing included upper extremity rotation, lower extremity rotation, palms to the floor, genu recurvatum and the lotus position. The testing occurred over two seasons and included a control group of 167 boys and 223 girls, not involved in interscholastic athletic competition. The results were: the girl's control group had more laxity than the boy's control group, there was no significant difference in the male basketball players and football players when compared to the control group;

"...female athletes were demonstrated to have looser joints than the boys, but they had tighter joints than girls not participating in sports ($P < .01$). Female basketball players sustaining sprains had significantly looser joints than the female athletes as a group ($P < .05$), but there was no significant difference in their laxity when compared with that of the non-participating girls" (Grana & Moretz, 1978, p.1976).

The effects of cyclical hormones in females and their relationship to ligament laxity has been being investigated (Liu, Ali-Shaikh, Panossian, Finerman, & Lane, 1996) in basic science experimentation. In rabbit ACL fibroblast (in culture), the presence of estrogen inhibited collagen synthesis and proliferation of fibroblasts, in vitro. Clinically, these cellular and matrix alterations may translate into a weaker ACL during its constant exposure to changing hormonal patterns. Further studies in vitro and in vivo are needed to confirm the significance of estrogen-collagen interaction as a possible explanation for ligament laxity, contributing to higher ACL injuries in female athletes (Liu et al., 1996).

2. Limb Alignment

Females have a variety of alignment and body composition issues that are in direct contrast to most males. Females have a wider pelvis, less muscular development, increased flexibility, knee hyperextension, genu valgum, femoral

neck anteversion with a varus hip, external tibial tubercle rotation, and pronation of the hind foot (Ciullo, 1993). Typically, limb alignment in females includes an increased Q-angle--the angle from the anterior, superior iliac spine and the patellar line to the tibial tubercle. The Q-angle is reported to be an average of eight to ten degrees for males and 12 to 16 degrees for females (Klafs & Lyon, 1978). Increased Q-angle causes (greater) lateral forces to be placed on the quadriceps mechanism, (Hutchinson & Ireland, 1995) and excessive rotary limb alignment (Woodford-Rogers et al., 1994), which may correlate with increased patellofemoral disorders, and altered muscular demands. It has been suggested that internal rotation of the tibia with a knee hyperextension and hyperpronation, may predispose an athlete to an ACL injury (Woodford-Rogers et al., 1994; Moore & Wade 1989). "Because of the anatomical functions of the ACL, prolonged pronation of the foot and ankle complex produces excessive internal tibial rotation, and thus may produce a preloading effect on the ACL," (Beckett, Massie, Bowers & Stoll, 1992, p. 60).

3. Notch Dimensions (Width/Shape)

The ACL passes between the medial and lateral condyles of the femur, as it connects the tibia to the femur. The "tunnel" through which it passes is called the intercondylar notch. Notch width is a measurement in millimeters using an anterior view radiograph. A measurement of the width of the intercondylar notch related to total width of the distal femur is referred to as the notch width index (NWI), (Souryal, Moore, & Evans, 1988). Researchers have defined intercondylar notch stenosis as defined by a NWI equal to .20 or less in males and .18 or less in females as a possible cause for ACL rupture (Arendt & Dick, 1995; Souryal & Freeman, 1993).

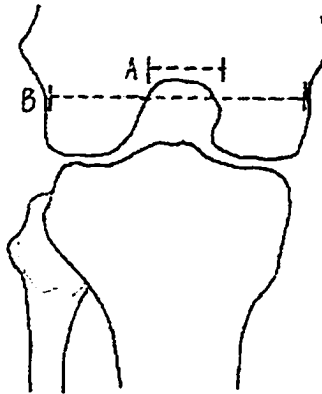


Figure 2.1 Radiographic Measurement of NWI = A/B

In 1993, Souryal and Freeman examined 902 female and male athletes from all sports in two high schools in Mesquite, Texas. The authors measured thigh girth, height, and weight. A complete knee examination was also performed including the Lachman test, the pivot shift test, varus-valgus stressing at zero degrees and 30 degrees, and a reverse Lachman test, and NWI was measured radiographically as described above. The authors purpose was to determine if there was an association between ACL injuries in athletes and NWI. The results were:

- (1) intercondylar NWI for men was larger than that for women,
- (2) athletes [male and femal] sustaining non-contact ACL tears had statistically significant intercondylar notch stenosis,
- (3) all women with non-contact ACL injuries had statistically significant stenotic intercondylar notches,
- (4) those athletes who sustained contact injuries had NWI measurements similar to the general population of athletes.

The shape of the notch was also examined and classified in three categories:

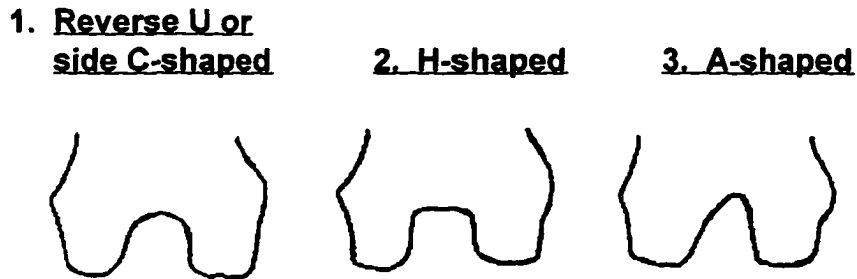


Figure 2.2 Classifications of Notch Shape

Previous authors have also speculated that the shape of the notch may vary with gender and contribute to injury. The A-shaped notch may be a sign of a congenitally smaller ACL, placing the female athlete at risk for a non-contact ACL injury (Hutchinson & Ireland, 1995).

B. Extrinsic Factors

1. Motor Skill in Sport

Motor skill and skill level in sport affect the athlete's ability to perform. Motor skills necessary for basketball include planting, starting and stopping, cutting and turning, and landing from a jump (deceleration). In a ten year study of Division I female basketball players, Griffis, Vequist, & Yearout (1989) reported three major "no-hit" mechanisms of ACL injury; planting and cutting (29%), straight knee landing (28%), one-step stop landing with the knee hyperextended (26%). All of these are learned motor skills which may be prevalent in the female basketball player.

Current research has also been conducted on possible neuromuscular causes of alterations in motor performance. Possible physiological

neuromuscular differences between females and males were explored by Huston and Wojtys (1996), including muscle recruitment order and muscle reaction time. The authors compared elite female athletes, elite male athletes, and non-athlete gender matched controls with isokinetic concentric testing. The authors found time to peak torque differences ($p < 0.001$) in average knee flexion time to torque at 60 and 240 degrees per second in female and male athletes. Females were slower than the males. They also found an altered pattern of muscle recruitment in response to involuntary anterior tibial translation in female athletes as compared to male athletes and controls. Female athletes used the order:

quadriciceps-> hamstrings-> gastrocnemius.

Male athletes and controls used the order:

hamstrings->quadriciceps-> gastrocnemius.

In their article, Huston and Wojtys (1996) describe the female order as a "quadriciceps first" (p. 7) trend, which is exactly opposite of males and controls. The authors indicated that training of female athletes must be critically reviewed (Huston and Wohtys, 1996).

2. Shoe Surface Interface

Interface between the players shoe and the playing surface has been suggested to have an effect on the incidence of ACL injuries. A higher friction rate of the shoe surface interface may correlate with a higher incidence of ACL injury (Arendt & Dick, 1995).

3. Muscular Strength

Dynamic stability of joints is accomplished with muscle contraction (Baratta, Solomonow, Ahou, Letson, Chuinard, & A'Mbrosia, 1988). Weakness of the leg muscles has been investigated as a possible cause of ACL injury (Arendt & Dick, 1995; Moore & Wade 1989). The "balance of power" between quadriciceps and hamstring muscles is crucial to normal knee function because

the quadriceps muscles can produce forces in excess of those needed for ligament rupture of the ACL (Huston, 1996). The role of the hamstring muscles for joint stability may also be key in prevention of ACL injuries by:

- (1) Anatomical position within the knee allowing dynamic muscular support to excessive anterior translation of tibia on the femur (Backhouse & Hutchings, 1986)
- (2) Co-contraction/activation of hamstrings with the quadriceps resulting in increased joint congruency (Baratta et al., 1988)
- (3) Forming thick medial and lateral masses to the knee and giving vital collateral support to the knee joint, while in flexion each component can give medial and lateral rotation or, rotary stability (Backhouse & Hutchings, 1986)

Previous studies have suggested that hamstring/quadriceps strength ratios to be less in female athletes than in male athletes (Moore & Wade, 1989; Holmes & Alderink, 1984; Dibrezzo, Gench, Hinson, & King, 1985). A study (Baratta et al., 1988) on the role of antagonistic musculature in maintaining knee stability was done using simultaneous EMG recordings from flexor and extensor muscles of the knee during maximal effort slow isokinetic contractions. This was done to quantify the coactivation pattern of knee flexor and extensor muscles. In reviewing the study, it should be taken into consideration that the sample size of the subjects and control group were small, gender mixed and included athletes from a variety of sports. The control group included non-athletes. This control group "demonstrated that the antagonist exerts nearly constant opposing torque throughout joint range of motion" (Baratta et al., 1988, p. 113). The athletes who routinely exercise their hamstrings had results similar to the control group. Athletes with hypertrophied quadriceps "demonstrated strong inhibitory effects on the hamstrings coactivations" (Baratta et al., 1988, p. 113). The authors concluded that coactivation of antagonistic muscles is necessary to aid

ligaments in maintaining joint stability (Baratta et al., 1988). Optimal hamstring/quadriceps ratios were suggested by Moore and Wade in their 1989 article. They suggested achieving the ratios would assist in prevention of ACL injuries. If an optimal ratio exists, a muscle re-balancing conditioning program for the lower extremity appears to be a rational first step for female athletes playing high risk sports (Huston & Wojtys, 1996).

4. Conditioning

Poor conditioning is related to an increased incidence of injury (Hutchinson & Ireland, 1995). The baseline level of female's conditioning has been significantly less than it has been for men (Whiteside, 1980; Garrick & Requa, 1978). Female athletes are typically more prone to overuse syndromes than males (Malone & Sanders, 1993). Fitness programs need to be balanced with muscular strength, endurance and flexibility in addition to aerobic fitness (Malone & Sanders, 1993). In the Huston and Wojtys study (1996), the female athletes who participated were in division I NCAA sports, where training and conditioning programs are sophisticated and among the best available. High school athletes receive training and conditioning that is typically far less than the college athlete. If the problem is a deficit in early training, then the current emphasis on women's sports should correct this problem. If however, women are substantially different than males physiologically, then male conditioning programs may not be the answer, and further research may be needed to address these issues (Huston & Wojtys, 1996).

It is clear that both intrinsic and extrinsic factors affect the frequency and distribution of ACL injuries. What remains unclear is the relative contribution of each factor and whether alteration of any given extrinsic factor can affect an athlete's potential for injury.

Mechanisms and ACL Injuries in Children

Lastihenos and Nicholas (1996) addressed ACL injuries in children. Although injuries to the ACL were not as common in children as they were in adults, they may cause chronic instability in adults. Stanitski (1993), studied 70 patients aged 18 years and younger with acute hemarthrosis injuries. The results of the study were a 63% incidence of ACL tears (as in Lastihenos & Nicholas, 1996). "The most common mechanism of injury is knee hyperextension coupled with a twisting force, similar to the mechanism seen in adults" (as in Lastihenos & Nicholas, 1996, p.61). It is clear that ACL injuries occurred in the age group of the high school athlete and when they did occur were a significant physical problem for the athlete.

Isokinetics

The concept of isokinetics was first introduced by James Perrine in the late 1960's (Davies, 1992). The concept utilized a dynamic pre-set fixed speed with accommodating resistance throughout the range of motion.

Most sporting activities involve the use of closed-chain movements, meaning the distal segment of the extremity is fixed, while the proximal segment moves over the fixed distal segment (Fu, Woo, & Irrgang, 1992). Running, jumping, squatting and walking are examples of closed chain activities. Testing of isokinetic strength has traditionally been done in an open-chain fashion, due to current equipment design for testing. In open-chain activities, the distal segment is free and the proximal segment is fixed as with kicking a ball. "All strength studies to date have been done in an open chain fashion because of our present limitation in muscle testing technique" (Arendt & Dick, 1995, p.695). Valid and reliable closed chain testing equipment is not currently available.

Isokinetic testing can measure concentric muscle strength, eccentric muscle strength, or isometric strength, in an open-chain manner (Biodex®, 1990). Predetermined speeds are used with isokinetic testing and are measured in degrees per second of movement around an axis of rotation. Torque measured by the dynamometer varies in relation to muscle-length tension changes, moment arm variation, fatigue, and pain during the motion (Biodex®, 1990).

Elftman, in 1966 described a predictable relationship between eccentrics, isometrics, concentrics, and force muscle potential. He suggested eccentrics had greater force production than isometrics and isometrics were greater than concentric contractions (eccentrics>isometrics>concentrics), (as in Davies, 1992). Data from numerous scientific studies of eccentric/concentric force production showed a range of 146% to 300% greater eccentric torque than concentric force production (Davies, 1992). Based on normative data (Davies, 1992), males should be able to produce 100% torque to body weight at 60 degrees per second concentrically. The population being tested could potentially overpower the equipment available. Studies reviewed for comparison (Davies, 1994; Moore and Wade, 1989; Dibrezzo et al., 1985) all utilized concentric testing. Additionally, eccentric contractions have a higher potential for production of delayed onset muscle soreness (Albert, 1992).

Measurements of peak torque, mean peak torque, average power, single repetition work, total work and percentage of peak torque to body weight and agonist to antagonist ratios have been proven reliable from 60 degrees per second to 450 degrees per second (Feiring, Ellenbecker, & Dersheid, 1990; Wilk, et al., 1988).

A. Isokinetics--normative data for hamstring/quadriceps ratios

Several authors have published normative data for hamstring/quadriceps ratios (Davies, 1992; Moore & Wade, 1989; Dibrezzo et al., 1985; Wyatt & Edwards, 1981).

Davies (1992) original hamstring/quadriceps ratio norms were described for women and men (age 15-40) and reported as the following:

<u>Speed</u>	<u>Hamstring/quadriceps ratio</u>
60 deg/sec	60%-69%
180 deg/sec	70%-79%
240 deg/sec	80%-89%
300 deg/sec	85%-95%

In Wyatt & Edwards (1981) article, they reported the following hamstring/quadriceps ratio separated by gender:

<u>Speed</u>	<u>Males</u>	<u>Females</u>
60 deg/sec	72%(+/-11%)	71%(+/-11%)
180 deg/sec	78%(+/-11%)	79%(+/-11%)
300 deg/sec	83%(+/-14%)	85%(+/-16%)

They also stated that the ratios were similar for both sexes, even though there were large differences in the actual amount of torque produced. In both males and females, the hamstring/quadriceps ratio moved closer to unity ($p < 0.01$), as the speed of the exercise increased. It must be noted that the above normative data was collected without utilizing a gravity correction.

B. Isokinetic testing

1. **Peak torque:** Peak torque refers to the single highest torque produced by a muscle group through a range of motion (Kannus & Yasuda, 1992). There has been an "overshoot" phenomenon described in the literature when peak torque has been used. The "overshoot" phenomenon produces an artificial spike in the fast portion of a torque curve. (Perrin, 1993). The

"overshoot" can be avoided by the use of average torque or the use of "windowed data" (Biodex® 1990). "The term 'isokinetic window' refers to filtering out all data that have not been obtained at the preset isokinetic speed or 95% of that speed," (Wilk, Arrigo, & Andrews, 1992, p. 108). The Biodex® computer, using windowed data records only torque production that occurs when the testing speed maintains 95% of desired speed (Biodex®, 1990). Biodex® (1990) claims that using windowed data negates the overshoot phenomena. Additionally, peak torque data has been chosen to compare to existing normative data.

2. Time to peak torque: Time to peak torque, measured in milliseconds, has been defined as the time it takes for a muscle to produce its peak torque during isokinetic testing (Biodex®, 1990). Time to peak torque was first discussed in the literature by Huston and Wojtys in 1996. Huston and Wojtys (1996) demonstrated that female athletes had slower hamstring time to peak torque than male athletes at two isokinetic speeds, 60 and 240 degrees per second. No trends of time to peak torque in relation to isokinetic testing speeds were available in the literature.

3. Testing speeds: Isokinetic test speeds range from zero degrees per second to 450 degrees per second depending on the manufacturer of the machine. The Biodex® company has recommended the use of the following testing speeds for knee testing: 60, 180, and 240 degrees per second for non-athletes and 300, 360, and 420 degrees per second for athletes (Biodex®, 1990). Recommended testing speeds for knee flexion and extension are 60 to 90, 180, and 300 degrees per second by Davies (1992). He further suggested that testing speeds from 300 to 600 degrees per second would provide data closer to speeds at which functional activities were performed. The faster the testing speeds, the less joint compression and the less discomfort during testing.

Testing at speeds below 60 degrees per second may cause the patient discomfort due to high patellofemoral joint compression forces (Davies, 1992). Research has shown (Wilhite, Cohen, & Wilhite, 1992) that testing from the lowest speeds to the highest speeds affected the reliability of muscle performance data and suggested slow speeds be introduced first before fast speeds. Timm and Fyke's (1993), test results on concentric isokinetic test speeds sequence on knee extensor muscle groups concluded that; test speed order did not affect concentric peak torque measurements, there were specific differences between test speeds, and that the procedures afforded a high degree of muscle performance measurement consistency.

4. Stabilization: In order to prevent unwanted movements from the hip and trunk, consistent position and stabilization of the patient is necessary (Nosse, 1982). Davies (1992) suggested proper stabilization be used to prevent substitution of stronger muscles for weaker muscles, and maintain reliability. Biodex® (1990) recommended stabilization by straps around the thigh, waist and trunk with arms folded across the chest. Magnusson, Geismar, Gleim, and Nicholas (1993) found that maximum knee extension/flexion torque production was achieved with the trunk strapped to the back support and the hands grasping the seat.

5. Warm-up and rest intervals: Utilization of warm-up sessions that include submaximal and maximal repetitions at each test speed have been recommended by Perrin (1993) and Davies (1992). Johnson and Siegal (1978) concluded that three submaximal and three maximal warm-ups must be done prior to testing for peak torque measures to be reliable and to become familiar with the isokinetic machine. Perrin (1993) found three submaximal and three maximal was necessary for reliability purposes in testing total work, average power and peak torque. A study by Mawdsley and Croft (1982) showed that

warm-up did not effect the peak torque results, but some subjects experienced discomfort in the group without warm-up. Warm-ups have been used as a safety precaution. When multiple isokinetic speeds are being used for testing, rest intervals are a potential variable. It has been found that rest intervals result in 5% higher measurements with greater reliability (Stratford, Bruulsema, Maxwell, Black, & Harding, 1990). Perrin (1993) suggested intervals of 30 second to one minute following endurance testing but there were no recommendations for rest intervals between speeds for tests of peak torque.

The use of general body warm-up procedures has been traditional in sports and has been advocated by many rehabilitation professionals as the means of preparing the body physiologically and psychologically for exercise (as in Arnheim & Prentice, 1993). The main purposes of warming up has been to raise both the general body and the deep muscle temperatures and to stretch collagenous tissues to permit greater flexibility. This reduces the possibility of muscle tears and ligamentous sprains and helps to prevent muscle soreness (Arnheim & Prentice, 1993).

6. Gravity correction: According to Nelson and Duncan (1983) and Perrin (1993), gravity correction accounted for the weight of the isokinetic dynamometer lever arm and the limb being tested when the movement was in a gravity dependent position. Error ranging from 26% to 43% for extension and from 55% to 510% for knee flexion were demonstrated in tests without gravity corrections. (Winter, Wells, & Orr, 1981).

7. Test repetitions: The number of test repetitions affects reliability. Perrin (1993) suggested three to four repetitions to get reliable peak torque. Davies (1992) recommended five test repetitions.

8. Patient testing position: test positions have varied amongst researchers for hip angle and knee axis. Bohannon, Gajdosik, & LeVeau (1986)

determined that isokinetic knee extensor torque was not significantly greater in a sitting position when compared to the semi-reclined position. Brinks, DeLong, & Stout (1995) also determined that supine or sitting positions could be used for isokinetic testing. A study by Wilk and Andrews (1993) used a hip flexion angle of 115 degrees, since that appeared to be optimal for quadriceps femoris torque generation (Currier, 1977). The knee has a dynamic axis of rotation. As a result, Biodex® (1990) suggested the best compromise was placement of the dynamometer axis through an imaginary line drawn through the femoral condyles, in the coronal plane.

In conclusion, the review of literature showed female basketball players have a higher rate of ACL injuries than male basketball players. There was a similar mechanism of injury in children and adolescents as compared to adults. Injuries that occur to the ACL in children will have an impact as they enter adulthood. Many factors, both intrinsic and extrinsic may contribute to ACL injuries in female athletes. There appears to be special concern for basketball players as a high risk group for sustaining ACL injuries (Arendt & Dick 1995; Hutchinson & Ireland, 1995; De Haven & Litner, 1986; Zelisko et al., 1982; Clark & Buckley, 1980; Whiteside, 1980).

More research was needed on the role strength may play in ACL injuries in the high school female basketball player. By looking at strength ratios and time to development of peak torque in high school female and male basketball players, some predisposing muscular strength and balance factors may be identified. This research may assist coaches, players, and trainers in designing appropriate strength and conditioning programs and ultimately aid in ACL injury prevention.

CHAPTER 3

METHODS AND MATERIALS

Subjects

A convenience sample of 53 subjects was obtained by contacting athletic directors, coaches and/or athletic trainers, athletes (Appendix A), and by a published solicitation in the newspaper. Twenty-six females and 27 males ages 13-18 years old, met inclusion criteria for participation in the study. All subjects were members of a freshman, junior varsity or varsity high school basketball team.

The subjects were chosen from a convenience sample of Class A, B, C and D high schools within 60 miles of downtown Grand Rapids, Michigan. Potential subjects filled out a pre-test questionnaire (Appendix B). All participants accepted for the study (see Appendix C for acceptance criteria), signed a consent form (Appendix D) before proceeding. Participants who were minors (under 18 years old), had a parent read the parent information letter (Appendix E), sign the pre-test questionnaire (Appendix B) and the consent form (Appendix D). Parents were encouraged to attend the testing session. In order to maintain anonymity, each subject was given an identification number to be used throughout the study.

Materials

A Schwinn Airdyne exercise bicycle was used for warm-up prior to testing. The warm-up was used to prepare musculature for maximal effort testing and prevent after test soreness.

A Biodex® System II isokinetic dynamometer was used to test the subjects quadriceps and hamstring concentric strength and time to peak torque. Eccentric torque maximum is 150 foot pounds on authors' available isokinetic

equipment. Timm, Gennrick, Burns, & Fyke (1992), concluded that the Biodex® demonstrated high levels of test/retest reliability during mechanical and/or physiological assessments of respective concentric, isokinetic functions. For valid comparisons, prevention of delayed onset muscle soreness and equipment reliability, concentric testing was chosen for this study. Biodex® was chosen for this research over other isokinetic systems due to its test-retest reliability and face validity established in the literature (Wilk, Johnson & Levine, 1988), as well as its' availability to the researchers. Hamstring/quadriceps ratios and time to peak torque data of each limb was collected at five different testing speeds. Data was recorded and reduced, using the Biodex® software version 3.2. All data was printed using Biodex® comprehensive report.

Procedures

The Biodex® system was calibrated before each testing day per Biodex® calibration protocol. One of two Biodex® machines was used throughout the testing.

Subjects were weighed in pounds and measured in inches, in their street clothing without shoes. The subjects then performed a warm-up prior to strength testing. For consistency, the warm-up consisted of 10 minutes on a Schwinn Airdyne exercise cycle. The seat height was placed so there was approximately 15 degrees of flexion in the knee that was extended toward the floor. The intensity level was 1.0 work load on the airdyne gauge.

The isokinetic test immediately followed warm-up on the bicycle. The subject was seated with 115 degrees of hip flexion, measured goniometrically and stabilization straps were applied to the trunk, waist and thigh per the Biodex® (Biodex®, 1990) protocol. Range of motion of the knee was measured by the tester with a goniometer and set at 110 degrees flexion and 0 degrees

extension. Range of motion stops were then set on the Biodex®. The dynamometer powerhead was positioned so the axis of motion corresponded to an imaginary line through the coronal plane of the knee, from the lateral to the medial femoral condyles of the knee. For consistency the ankle pad was positioned four inches superior to the distal tip of the lateral malleolus. Subjects were instructed to cross their arms across their waist during testing to prevent use of trunk and upper extremity musculature. The isokinetic Biodex® testing was performed by any of the three researchers for all subjects.

The Biodex® isokinetic test was explained to the subject (Appendix F). After five repetitions at 60 degrees per second to familiarize the subject with the machine, the subject performed three practice submaximal repetitions followed by three practice maximal repetitions prior to performing each testing speed. The subject then performed five maximal effort repetitions for concentric quadriceps and hamstrings at 60, 180, 240, 300 and 450 degrees per second. We have chosen speeds of 60, 180, 240, 300 degrees per second for comparability with previous studies and 450 degrees per second to test the fastest available isokinetic speed. Subjects completed their normal excursion of knee flexion/extension range of motion within the set ranges. The subject's legs were tested in random order determined by coin toss. No attempt was made to determine leg dominance.

Data Analysis

Isokinetic data from the Biodex® software 3.2 package was manually entered by the researchers into SPSS for MS WINDOWS Release 6.1. Descriptive statistics were computed for the subject population, hamstrings/quadriceps ratios, and time to peak torque data at all speeds for all subjects. Mann-Whitney-U tests were used to determine the difference between

females and males hamstring to quadriceps ratios. Paired t-tests were used to determine the difference between females and males time to peak torque.

Informal qualitative analysis between means of data produced in this research for hamstring/quadriceps ratios and available normative data was described.

CHAPTER 4

RESULTS

Concentric isokinetic bilateral knee flexor and extensor data was obtained from 26 females and 27 males ranging in age from 13 to 18 years. Paired t-tests for time to torque data ($p < .05$) and Wilcoxon Matched-Pairs Signed-Ranks Test for hamstring/quadriceps ratio data ($p < .05$) demonstrated no difference between tested limbs. As a result, to prevent a biased sample, only the data from one of the tested limbs (group A) was used for data analysis. Group A is composed of randomly assigned limbs by categories of left or right and first or second tested limb.

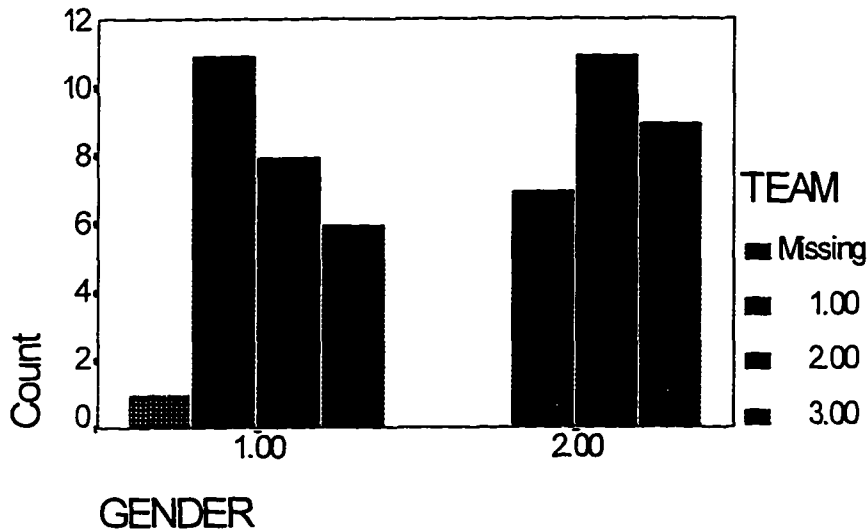
Table 4.1 summarizes, by gender, the mean, standard deviation, and range for subject's age, height and weight.

TABLE 4.1 DEMOGRAPHIC SUMMARY

Variable	Mean	Standard deviation	Range
<u>Male (n=27)</u>			
Age	15.52	1.05	14.00-18.00
Height (in)	71.41	2.71	66.00-78.00
Weight (lbs)	159.19	19.48	15.00-205.00
<u>Female (n=26)</u>			
Age	15.33	1.20	13.00-18.00
Height (in)	67.04	3.11	61.00-73.00
Weight (lbs)	132.67	17.40	104.00-189.00

Descriptive data for team level and school size classification are summarized by gender in the graphs below.

Graph 4.1 Distribution of Team Classification by Gender



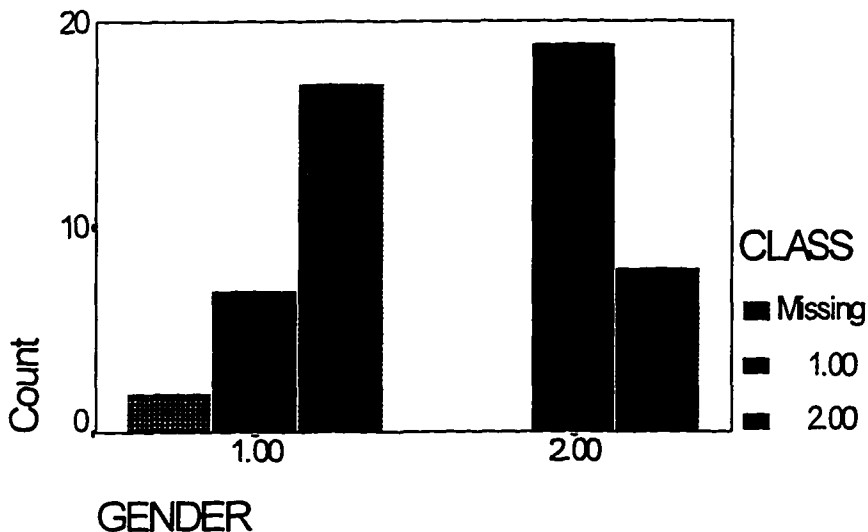
Key for gender

1= Females
2= Males

Key for team

1= Varsity 3= Freshmen
2= Junior Varsity Missing= Unavailable Data

Graph 4.2 Distribution of School Class by Gender



Key for Gender

1= Females
2= Males

Key for School Class

1= Class A School Missing= Class C or
2= Class B School Unavailable Data

Table 4.2 summarizes the mean, standard deviation, and range for hamstring/quadriceps ratio isokinetic data at 60, 180, 240, 300, and 450 degrees per second. As isokinetic speed increased, mean hamstring/quadriceps ratio increased until 450 degrees per second, where the ratio decreased for both genders.

Table 4.3 summarizes the mean, standard deviation, and range for time to peak torque isokinetic data at 60, 180, 240, 300, and 450 degrees per second. As isokinetic speed increased mean hamstring time to torque decreased until 450 degrees per second where the time increased for both genders.

Table 4.2 Isokinetic Data For Hamstring/quadriceps Ratios

<u>Variable</u>	<u>Mean</u>	<u>Standard Deviation</u>	<u>Range</u>
<u>Males (n=27)</u>			
HQ60	49.50	7.39	40.60-74.90
HQ180	50.70	7.68	36.50-71.30
HQ240	52.14	7.83	39.20-75.90
HQ300	53.16	10.27	39.70-87.40
HQ450	40.27	16.43	00.00-93.50
<u>Females (n=26)</u>			
HQ60	44.40	9.03	29.30-69.60
HQ180	47.31	11.09	32.40-72.20
HQ240	47.62	12.10	28.90-82.50
HQ300	48.31	11.82	27.2-78.00
HQ450	36.90	16.91	00.00-79.40

HQ= hamstring/quadriceps ratio (%), for each speed listed in degrees per second

Table 4.3 Isokinetic Data For Hamstring Times to Peak Torque

Variable	Mean	Standard Deviation	Range
<u>Males (n=26)</u>			
TT60	452.96	104.66	260.00-664.00
TT180	236.04	81.78	100.00-410.00
TT240	171.73	46.28	110.00-270.00
TT300	156.19	39.82	98.00-270.00
TT450	177.81	53.64	00.00-320.00
<u>Females (n=26)</u>			
TT60	732.54	267.37	369.00-1410.00
TT180	319.31	116.17	115.00-560.00
TT240	221.12	86.62	115.00-420.00
TT300	192.77	56.36	120.00-340.00
TT450	205.69	60.05	00.00-300.00

TT= time to peak torque (msec) for each speed listed in degrees per second

Table 4.4 summarizes results of statistical analysis of data for hamstring/quadriceps ratios between genders using Mann-Whitney-U analysis. Statistically significant differences ($p < 0.05$) were found at 60 and 240 degrees per second. Other tested speeds were not statistically significant.

Table 4.5 summarizes results of statistical analysis of data for hamstring time to peak torque values between genders using a t-test for Independent Samples. Statistically significant differences ($p < 0.05$) were found at 60, 180, 240, and 300 degrees per second. Differences between the means for males and females at 450 degrees per second were not statistically significant.

TABLE 4.4 Values for Mann-Whitney-U test for Hamstring/quadriceps Ratio Isokinetic Data

Variable	2-Tailed P
HQ60	*0.0313
HQ180	0.2001
HQ 240	*0.0443
HQ 300	0.0944
HQ 450	0.6824

HQ= hamstring/quadriceps ratio (%), for each speed listed in degrees per second
 *= statistical significance

Table 4.5 Values for T-tests for Independent Samples for Time to Peak Torque Isokinetic Data

Variable	2-Tailed Significance
TT60	*0.000
TT180	*0.004
TT240	*0.014
TT300	*0.009
TT450	0.084

TT=time to peak torque (msec), for each speed in degrees per second
 *= statistical significance

CHAPTER 5

DISCUSSION AND IMPLICATIONS

Clinically, we observed that athletes with a torn ACL have weak hamstring muscles in relationship to the quadriceps muscle on the uninjured leg. Clinically this is described as a decreased hamstring/quadriceps ratio. We believed that this muscular ratio may be different in females than in males. This imbalance may be a predisposing factor to the ACL tear in the female basketball player. Our results support this theory and offer data related to other potential contributing factors.

Comparison to previous studies

A. Comparison to normative data for hamstring/quadriceps ratios

Davies (1992) published normative values for hamstring/quadriceps ratios for males and females (reported together) ages 15-40 years old at 60, 180, 240, and 300 degrees per second (see Appendix G for specific values). Wyatt and Edwards (1981) reported hamstring/quadriceps ratios for males and females, but separated them by gender (see Appendix H for specific values). In their 1989 article Moore and Wade also published data on high school basketball athletes' hamstring/quadriceps ratios separated by gender (see Appendix I for specific values). In addition to published hamstring/quadriceps ratios, Moore and Wade (1989) published the following "goals" for hamstring/quadriceps ratios for basketball athletes:

60 degrees per second: 0.67- 0.77 (or 67-77%)

180 degrees per second: 0.80- 0.91 (or 80-91%)

300 degrees per second: 0.95- 1.11 (or 95-111%)

Moore and Wade did not describe how they arrived at the values for goals, nor did they separate the goals for gender. We believe that it is inappropriate to establish goals based on non-statistically analyzed data.

When values published in earlier studies were qualitatively compared to the results of our study, we found our mean hamstring/quadriceps ratios were significantly lower at all tested speeds than those of previous authors' for both genders. The differences may be attributed to the fact that our subjects were tested with gravity correction. Gravity correction was shown to dramatically decrease the overestimation of torque production by the hamstrings (Perrin, 1993, Winter et al, 1981). Moore and Wade (1989) acknowledged that their data was not gravity corrected and that gravity correction affected hamstring/quadriceps ratios. Davies (1992) also did not utilize a gravity correction. We believe that it is important to utilize a gravity correction when testing hamstrings and quadriceps isokinetically. We also believe the use of a gravity correction in our study has provided more accurate results than previous published studies. As a result, it is inaccurate to compare our results with previously published non-gravity corrected data. Further studies are needed to establish gravity corrected hamstring/quadriceps ratio goals.

B. Trends in hamstring/quadriceps ratios

Hamstring/quadriceps ratios increased (approaching 1.0 or 100%) as isokinetic speed increased in previous studies (Davies, 1992, Moore & Wade, 1989). Data from our study supported a minimal increase in mean hamstring/quadriceps ratio as test speed increased for the subjects:

Males: 49.5% - 53.16% (60-300 degrees per second)

Females: 44.4% - 48.31% (60-300 degrees per second)

as compared to the trends published in the study by Wyatt and Edwards (1981):

Males: 72%- 83%

Females: 71% - 85%.

No previous research on hamstring/quadriceps ratios was available for comparisons at the 450 degree per second speed.

The trend of increased ratios did not continue at the 450 degree per second test speed. One explanation for the change in trend was that at 450 degrees per second the subjects lacked the motor control to move the lever arm with a maximal effort, and register torque. This was demonstrated by three subjects who were unable to move the lever at 450 degrees per second which, resulted in a score of zero for torque. Another possible explanation may be that subjects demonstrated a lack of concentration and/or fatigue at higher speeds which may play a role in inability to generate maximal torque.

C. Specificity of sample

Another source of variance between this study and previous studies was the age range and specificity of the sample. The subjects from our study were all between the ages of 13 and 18 years old and were high school basketball players. Davies' (1992) subjects used for normative data estimates, ranged in age from 15-40 years old. Specific information about activity level and athletic status of Davies' (1992) normative subjects was not available for comparison. The subjects used for research by Moore and Wade (1989) more closely resembled the subjects used in our study: high school boy and girl basketball players (n=16 males, n=28 females). Mean hamstring/quadriceps ratios from this study differed considerably from the values obtained by Moore and Wade, probably due to utilization of gravity correction.

D. Trends in time to peak torque

There were no published descriptions of trends in time to peak torque data known to the authors. It was hypothesized that as the isokinetic testing speed increased, the time to peak torque in milliseconds would decrease, or follow an inverse relationship. Data from our study supported the hypothesized trend for speeds 60 through 300 degrees per second, for both males and females. However, at 450 degrees per second the mean time to peak torque increased for both genders. This can be partially explained by fatigue. The 450 degree per second test speed was the fifth and final test speed in the test series.

Another potential explanation of the increase in time to peak torque at 450 degrees per second would be that there may be a point at which torque speed no longer decreases. This phenomenon could be referred to as a ceiling effect. We did not find past research that addressed a ceiling effect in time to peak torque. If a ceiling effect existed, and there was a point at which no decrease in time to peak torque took place, it may explain the increase in time to peak torque at 450 degrees per second.

E. Gender difference in time to peak torque

Huston and Wojtys (1996) reported time to peak torque differences for the knee flexors between elite female athletes, elite male athletes, and non-athlete gender matched controls with isokinetic concentric testing. They found time to peak torque differences ($p < 0.001$) in knee flexion time to peak torque at 60 and 240 degrees per second. This study also demonstrated significant differences ($p < 0.05$) for mean time to peak torque values of the hamstrings at 60, 180, 240, and 300 degrees per second during concentric isokinetic testing. There was no significant difference at 450 degrees per second.

F. Gender differences in hamstring/quadriceps ratios

Previous studies suggested that hamstring/quadriceps strength ratios were lower in females than in males (Moore & Wade, 1989; Dibrezzo et al, 1985; Holmes & Alderink, 1984). Our study demonstrated statistically significant differences in hamstring/quadriceps ratios between males and females at test speeds of 60 and 240 degrees per second. The authors were unclear as to why the differences were significant at those two speeds and were not significantly different at the other tested speeds. No apparent pattern was identifiable. Based on clinical experience by the authors of this study, 60 degrees per second has been a speed that the majority of clients generate a consistent maximal effort due to the slow speed.

The subjects in this study performed five repetitions at 60 degrees per second to familiarize themselves with the machine. Prior to testing at any speed the subjects then performed three submaximal efforts followed by three maximal efforts to familiarize themselves with the speed. The second test speed, 180 degrees per second, required quicker movement of the lever arm. Motor learning may have occurred at the 180 degrees per second. This may have allowed for a more consistent maximal effort at the next test speed of 240 degrees per second. Moore and Wade (1989) hypothesized a potential cause for high speed isokinetic differences (at 300 degrees per second) between genders as a decrease in muscular excitation or muscular inhibition of the hamstrings by the quadriceps in females. This theory would not account for lack of difference at 300 and 450 degrees per second in our study.

Limitations and recommendations for further study

We, the authors acknowledge that the correlation between concentric isokinetic testing and function remains questionable. Reliable eccentric

isokinetic testing equipment was not available. An ideal improvement to this study would be to perform eccentric testing of hamstring/quadriceps ratios and hamstring time to peak torque and relate eccentric data to function.

Closed kinetic chain strength was an aspect that was not investigated in this study. Reliable and accessible closed kinetic chain testing equipment was also not available. Another future improvement to this study would be to include a closed kinetic chain measure of strength, combined with eccentric function.

As with any sample of convenience, the subject pool used in this study is a potential source of limitation. It was the intention of the authors that all classes (Class A, B, C, and D) and team levels (freshman, junior varsity and varsity) would have approximately equal representation within the sample. The sample used in this study had minimal representation of class C, and no representation of class D. It also had unequal representation of team levels. Utilization of a stratified random sample to achieve equality between classes and team levels may improve the subject population used in future studies and improve generalizability.

Another potential source of variation between gender samples was that all female athletes tested responded to an article published in the local paper requesting volunteers. Many of the male subjects had to be recruited specifically through coaches, athletic trainers, and via personal contact. Ideally, all subjects would have been recruited identically. Selection from a large sample of volunteers (who met inclusion criteria), drawn randomly, would provide greater randomness of the sample and therefore greater application to the general population. In this study all volunteers who met inclusion criteria and presented for testing were used as part of the sample.

Another suggestion for further research is to attempt to correlate time to peak torque data to function. It is unknown what differences in mean time to

peak torque of the hamstrings between genders means clinically. It was also unknown whether time to peak torque values will change with training, and what types of conditioning/training may optimally affect time to peak torque. Before any recommendations could be made about training for change of this factor, these questions must be addressed. The relationship between concentric time to peak torque data and mechanisms of ACL injury have not been investigated. Ideally, eccentric hamstring time to peak torque should be studied and related to ACL injury. The relationship between time to peak torque data and proprioception also remain undefined, and may be an important link to injury prevention.

Since hamstring/quadriceps ratio differences were seen between genders at two test speeds, it would seem logical that females could address this deficit via conditioning. It is our hope that gender specific conditioning and prevention programs may address the surplus of ACL injuries in females. Therefore, another area of study may be the relationship of gender specific conditioning on hamstring/quadriceps ratios. If conditioning can improve these ratios, then altering the ratios should make a long term difference in ACL injury prevention.

Conclusion

The purpose of this study was to determine if there were differences between female and male high school basketball players strength and neuromuscular performance. Strength factors are believed to be a potential extrinsic variable which may contribute to the relative surplus of ACL injuries in the female athlete.

When tested isokinetically the results were statistically significant for differences between females and males hamstring/quadriceps ratios at 60 and 240 degrees per second, and hamstring time to peak torque at 60, 180, 240, and

300 degrees per second. As a result of these differences found by gender, the extrinsic factor of strength should continue to be investigated as a potential contributing factor in ACL injuries in the female athlete.

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APPENDIX A
CONTACT LETTER

Dear (Athletic director, coach, athletic trainer),

We are graduate students in Grand Valley State University's Masters of Physical Therapy program and are looking for volunteers of high school female and male basketball players.

Sports Illustrated recently highlighted the incidence of anterior cruciate ligament (ACL) injuries in female basketball players. There may be several factors that contribute to the knee injury. Strength of leg muscles and neuromuscular conduction are two areas that have been suggested.

The results of this study could have national implications for prevention of ACL injuries in high school female and male basketball players.

We need volunteers to test hamstring/quadriceps strength ratios and reaction time. They must be a member of a high school basketball team, freshman, junior varsity or varsity. The athletes will receive a free strength test valued at approximately \$125.00 in exchange for confidential information to be used in this study.

If any members of your team are interested, please contact Saint Mary's Sports Medicine department main office at 752-6182 to receive the necessary consent forms the athletes need signed to be eligible for participation. Testing will be performed in Saint Mary's Sports Medicine department at the downtown location.

Thank You,

Diane Beach A.T.,C., S.P.T.
Certified Athletic Trainer
Student Physical Therapist

Barb Hoogenboom P.T., SCS, A.T.,C.
Physical Therapist,
Sports Clinical Specialist
Certified Athletic Trainer

Lisa Rose S.P.T.
Student Physical Therapist

APPENDIX B
PRE-TEST QUESTIONNAIRE

Subject's Name: _____ **Age:** _____
Address: _____ **Date of birth:** _____

Sex: Male or female (circle one)

Basketball team: freshman, junior varsity, varsity (circle one)

1. Have you injured any of the following joints in the past one year?
(circle yes or no)

- | | | |
|----------|----|-----|
| a. knee | no | yes |
| b. hip | no | yes |
| c. ankle | no | yes |
| d. foot | no | yes |

2. Did your injury keep you out of practice or a game for more than one week?

- | | | |
|----------|----|-----|
| a. knee | no | yes |
| b. hip | no | yes |
| c. ankle | no | yes |
| d. foot | no | yes |

3. Do you have any health restrictions? No or Yes, please describe below

4. Did you pass your high school physical for the school year 1996-97?

Yes or No

5. List any medications you currently take. _____

6. Check here if you want a copy of the research results _____.

subject signature

parent signature

APPENDIX C

ACCEPTANCE CRITERIA

1. The subject did not have an injury to his/her knee, hip, ankle or foot, that kept him/her out of a practice or game for more than one week in the past one year.
2. The subject is not currently under any health restrictions.
3. The subject passed his/her high school physical for the school year 1996.

APPENDIX D

CONSENT FORM

I understand that I am participating in a study that will measure strength of the hamstring and quadriceps muscles of the thigh (upper leg), using an isokinetic testing machine. Isokinetic testing is a way to measure strength. It consists of a fixed speed(s) with an accommodating resistance. The resistance is determined by how hard the subject pushes during each testing speed. I also understand that the knowledge gained from the strength measurements is expected to help physical therapists, certified athletic trainers, coaches, doctors, and athletes to better identify where weaknesses exist.

I also understand that:

1. I was selected because I have not had a knee injury in the past one year that kept me out of practice or a game for more than one week.
2. it is not anticipated that this testing/study will lead to physical risk to myself.
3. there is potential for muscle soreness following the testing procedure.
4. information I provide will be kept strictly confidential and that the data will be coded so that identification of individual participants will not be possible.
5. a summary of the results will be made available to me upon my request.
6. I will "warm-up" on an exercise bicycle before testing on the Biodex isokinetic machine.
7. I will be given verbal and written instructions about the testing procedure before testing.

I acknowledge that:

"I have been given an opportunity to ask questions re: this research study and that those questions have been answered to my satisfaction."

"In giving my consent, I understand that my participation in this study is voluntary and I may discontinue the study at any time during the testing."

"I hereby authorize the investigator(s) to release information obtained in this study to scientific literature. I understand that I will not be identified by name."

"I have been given the investigators names, Diane Beach, Lisa Rose, and Barb Hoogenboom, phone numbers, (616) 752-6182 so that I may contact them if I have questions."

"I acknowledge the I have read and understand the above information and that I agree to participate in the study."

If you have any questions concerning your human rights as a participant in this study, you may contact the Chair of Saint Mary's Institutional Review Board at 752-6567.

Signature of athlete

Signature of parent (if athlete < 18 years old)

Signature of witness (must be 18)

APPENDIX E

PARENT INFORMATION LETTER

Dear Parents,

We are graduate students in Grand Valley State University's Masters of Physical Therapy and/or Health Science programs and are looking for volunteers of high school female and male basketball players.

Sports Illustrated recently highlighted the incidence of anterior cruciate ligament (ACL) injuries in female basketball players. There may be several factors that contribute to the knee injury. Strength of leg muscles and neuromuscular conduction are two areas that have been suggested.

The results of this study could have national implications for prevention of ACL injuries in high school female and male basketball players.

We need volunteers to test quadriceps/hamstring strength ratios and reaction time. Your son/daughter has expressed an interest in receiving a free leg test (normal cost is approximately \$125.00) in exchange for use of numerical confidential data. All testing will be performed in Saint Mary's Sports Medicine Department at the downtown location, 200 Jefferson, Grand Rapids, MI. Parking will be free.

If you are willing to allow your child to participate in this study, please call (616) 752-6182 to set up an appointment for the strength test. Your son/daughter must have the attached consent form and pre-test questionnaire signed and with them at the appointment to be allowed to participate.

Thank You,

Diane Beach A.T.,C.
Certified Athletic Trainer
Student Physical Therapist

Barb Hoogenboom P.T., SCS, A.T.,C.
Physical Therapist
Sports Clinical Specialist
Certified Athletic Trainer

Lisa Rose
Student Physical Therapist

APPENDIX F

INSTRUCTION FOR ISOKINETIC TESTING

You will be performing a strength test on this machine. The way this machine works is, the harder you push on the leg bar, or the faster you move the leg bar, the more resistance the machine will give you and the higher your score. You need to push with equal effort in both directions (up and down). You will be allowed to practice on each speed, three submaximal efforts followed by three maximal efforts. There will be a 10 second rest, then begin the test. The test will consist of five repetitions at each speed. You will be asked if you are ready. If yes, you will be instructed in a command of ready, go! Start the test when you hear the word "go."

You will repeat the same procedure for each of the next four testing speeds. Each speed gets progressively faster or "easier." We ask that you do the best that you can. If you experience any discomfort or pain during the test, please ease up or stop during the test. You are in full control of the resistance. The machine will respond to your effort.

TEST: "Do you have any questions before we begin?...We will now begin."

1. Set-up:

- a. Check balance on the Biodex® dynamometer
- b. Position the subject at 115 degrees hip flexion. (Adjust seat back accordingly).
- c. Line up the knee axis of rotation with the coronal plane through the knee axis. (Adjust seat back accordingly).
- d. Stabilize subject with hip, thigh and shoulder straps.
- e. Pull straps "snug." Tell subject "the straps should feel snug, not tight."

2. Set ROM:

Instruct the subject: "Please relax your leg while I adjust your ROM.

- a. Set the reference angle at 110 degrees flexion as measured with a goniometer.
- b. Measure 0 degrees and set ROM buttons for knee extension and knee flexion.

3. Measure the gravity effect:

"We need to weigh your leg now. Let me straighten your leg...now, completely relax your leg."....."Now let me lower your leg down.

4. "You will now be given five repetitions to learn how to use this machine. Wait until I say "ready?...go." "Ready? (yes) go!"

5. "Does everything feel okay? Is anything too loose or too tight?"...

TEST at 60 degrees/second:

- a. Practice reps: "I want you to perform three submaximal repetitions and three maximal repetitions as a warm-up. Please begin the warm-up after my command, ready?...go."
- b. "Rest 10 seconds
- c. "Now pull your leg all the way back in the starting position. You will do five test repetitions as hard as you can. Ready? go."

Repeat for contralateral limb and at all subsequent test speeds.

APPENDIX G
HAMSTRING/QUADRICEPS RATIOS PER DAVIES, (1992)

Males and Females ages 15-40 years.

<u>Speed</u>	<u>Hamstring/quadriceps ratio</u>
60 deg/sec	60%-69%
180 deg/sec	70%-79%
240 deg/sec	80%-89%
300 deg/sec	85%-95%

APPENDIX H

HAMSTRING/QUADRICEPS RATIOS PER WYATT AND EDWARDS, (1981)

Speed	Males	Females
60 deg/sec	72%(+/-11%)	71%(+/-11%)
180 deg/sec	78%(+/-11%)	79%(+/-11%)
300 deg/sec	83%(+/-14%)	85%(+/-16%)

APPENDIX I

NORMATIVE ISOKINETIC DATA FOR HAMSTRING/QUADRICEPS RATIOS, MOORE AND WADE, (1989)

Variable	Females	Males
60 degrees/second	.63 (63%)	.68 (68%)
180 degrees/second	.80 (80%)	.85 (85%)
300 degrees/second	.94 (94%)	.97 (97%)
