

1997

A comparison of incidence of injury and recovery profiles of intercollegiate women basketball players sustaining anterior cruciate ligament ruptures

Alice McNeill McLaine
Iowa State University

Follow this and additional works at: <https://lib.dr.iastate.edu/rtd>

 Part of the [Leisure Studies Commons](#), [Occupational Health and Industrial Hygiene Commons](#), [Recreational Therapy Commons](#), and the [Surgery Commons](#)

Recommended Citation

McLaine, Alice McNeill, "A comparison of incidence of injury and recovery profiles of intercollegiate women basketball players sustaining anterior cruciate ligament ruptures " (1997). *Retrospective Theses and Dissertations*. 11727.
<https://lib.dr.iastate.edu/rtd/11727>

This Dissertation is brought to you for free and open access by the Iowa State University Capstones, Theses and Dissertations at Iowa State University Digital Repository. It has been accepted for inclusion in Retrospective Theses and Dissertations by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.

INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

UMI

A Bell & Howell Information Company
300 North Zeeb Road, Ann Arbor MI 48106-1346 USA
313/761-4700 800/521-0600

**A comparison of incidence of injury and recovery profiles of intercollegiate
women basketball players sustaining anterior cruciate ligament ruptures**

by

Alice McNeill McLaine

**A dissertation submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of
DOCTOR OF PHILOSOPHY**

Major: Education (Higher Education)

Major Professor: Larry H. Ebbers

Iowa State University

Ames, Iowa

1997

Copyright © Alice McNeill McLaine, 1997. All rights reserved.

UMI Number: 9725439

**Copyright 1997 by
McLaine, Alice McNeill**

All rights reserved.

**UMI Microform 9725439
Copyright 1997, by UMI Company. All rights reserved.**

**This microform edition is protected against unauthorized
copying under Title 17, United States Code.**

UMI
300 North Zeeb Road
Ann Arbor, MI 48103

**Graduate College
Iowa State University**

**This is to certify that the Doctoral dissertation of
Alice McNeill McLaine
has met the dissertation requirements of Iowa State University**

Signature was redacted for privacy.

Major Professor

Signature was redacted for privacy.

For the Major Program

Signature was redacted for privacy.

For the Graduate College

DEDICATION

To Larry, Lexie, and Mandy whose unwavering love and belief in me gave me the determination to see this project through to its conclusion.

To Mom and Dad whose unconditional love and support gave me the foundation on which I have built my successes.

To the memory of James Allan Doerr, a dear friend, who also aspired to complete a doctorate at Iowa State.

TABLE OF CONTENTS

LIST OF NOMENCLATURE AND ABBREVIATIONS	v
ACKNOWLEDGMENTS	vi
ABSTRACT	vii
CHAPTER 1. INTRODUCTION	1
Purpose of the Study	6
Limitations of the Study	6
Research Hypotheses	7
Significance of the Study	7
CHAPTER 2. LITERATURE REVIEW	9
Injury Rates in Women's Basketball	9
Injury Rates in NCAA Division I, II and III	14
Predisposing Factors	15
Comparison of Conservative and Surgical Treatment	22
Rehabilitation	33
Prevention Tactics	38
Summary	40
CHAPTER 3. METHODOLOGY	43
CHAPTER 4. RESULTS	48
CHAPTER 5. DISCUSSION	54
Suggestions for Future Research	59
Summary/Recommendations	60
APPENDIX A. INSTITUTIONAL SURVEY INSTRUMENT	62
APPENDIX B. INDIVIDUAL SURVEY INSTRUMENT	63
APPENDIX C. STATISTICAL ANALYSIS CODES	66
REFERENCES	67

LIST OF NOMENCLATURE AND ABBREVIATIONS

Anterior cruciate ligament of the knee ACL

Posterior cruciate ligament of the knee PCL

Medial collateral ligament of the knee MCL

Lateral collateral ligament of the knee LCL

Medial meniscus of the knee MM

Lateral meniscus of the knee LM

National Collegiate Athletic Association NCAA

Certified athletic trainer ATC

An allied health professional whose responsibilities include the prevention, care, and rehabilitation of injuries in active individuals. The ATC is frequently employed in a college or university setting to provide care for the athletes on intercollegiate teams.

ACKNOWLEDGMENTS

I would like to thank my committee members, Dr. Larry Ebbers, Dr. Tony Netusil, Dr. Rich Engelhorn, Dr. Phil Pearson, and Dr. Shirley Wood. Your willingness to assist me in meeting critical deadlines is greatly appreciated!

I am also extremely grateful to my colleagues at California State University, Northridge. Dr. Bill Vincent, you are a true friend and mentor! Your help with the statistical analysis and the use of presentation software have been wonderful. Special thanks go to Susan Hall, Tami Abourezk, Bill Vincent, and especially to Jean O'Sullivan, for providing valuable editorial comments. The friendship and support of Carolyn Barbian and Barbara Swerkes have made this last term go a bit smoother. Thanks to both of you for taking on some tasks for me to allow me more time to write. The pep talks and encouragement given by Tami Abourezk, Steven Loy, George Holland, Bill Whiting, Jennifer Romack, Don Bethe, Paulette Shafranski, Tommie White, Nick Breit, Bob Hiegert, and Barry Devine will always be remembered and, someday, passed on to another poor soul who is juggling as many responsibilities as I did the past few months.

Thanks to Rhonda Lowry and Ken Howat for letting me "slide" a little this term in the Athletic Training Education Program. I owe you both more than I can ever tell you. Likewise, to the athletic training students, your patience with my preoccupation this semester has been greatly appreciated. I'll try to make it up to you.

My good friend, Mary Painter, thank you for pep talks and for being a great sounding board. Thanks especially for making me realize it's okay to ask for help.

Larry, Lexie, and Mandy your patience and support gave me strength and reminded me why I set this goal in the first place.

Last, but certainly not least, special thanks go to my parents, Melba and Robert McNeill. Your willingness to give us your time and energy has made this possible. You did an excellent job of "running my household." But, even more than that, you've always been excellent role models of what parents should be. Thank you for all your love and support. I love you both very much.

ABSTRACT

Injuries to the anterior cruciate ligament (ACL) in women basketball players have come under recent scrutiny as it has become apparent that women athletes sustain more ACL injuries than their male counterparts. The purposes of this study were to examine a) the effectiveness of intervention techniques in relation to sport return rates among women basketball players, b) the effectiveness of injury prevention tactics in limiting anterior cruciate ligament injury rates, and c) differences in these factors among NCAA Divisions I, II, and III.

Data were collected from certified athletic trainers at forty-eight institutions across the nation. Representation was equally spread among each of the NCAA divisions and four separate geographical regions. Information regarding team and individual injury profiles was obtained for the past six basketball seasons (1990-91 through 1995-96). A total of 81 athletes at the represented institutions sustained ACL injuries during the period.

Findings indicated that surgical intervention was the most important factor in allowing an athlete to return to her previous level of activity. Neither previous injury nor concomitant injury affected an athlete's ability to return to activity. No statistical differences in injury rates or recovery profiles were found among the three NCAA divisions. Prevention tactics, including routine pre-season and in-season strength training, pre-season strength screening, and inclusion of technique modification showed no correlation to reducing injury rates.

CHAPTER 1

INTRODUCTION

One of the most feared injuries among athletes is a rupture of the anterior cruciate ligament (ACL) of the knee. This structure is critical to the stability of the knee joint. If the ligament is damaged, the athlete will often describe a sensation of the joint "giving out" and a loss of confidence in the knee (Hawkins et al., 1986). Such difficulties have ended the competitive careers of many collegiate athletes.

The growth in sports participation by women makes it inevitable that ACL ruptures are affecting many female athletes. The knee joint is the most commonly injured area in the female athlete (DeHaven & Lintner, 1986). Internal derangement of the knee, including ACL sprains, accounts for over 20% of all knee injuries sustained by female athletes (DeHaven & Lintner, 1986). In collegiate women basketball players specifically, injury to the knee joint comprises 18% of all injuries (National Collegiate Athletic Association [NCAA], 1996). ACL injuries occur in 29% of those reported knee injuries (Arendt & Dick, 1995).

Much of the research to date on ACL ruptures has been done on male athletes. The results of these studies can rarely be generalized to the female athlete population due to gender-related differences in strength, conditioning and experience, intercondylar notch measurements, psychological components, and sport-specific factors (Arendt & Dick, 1995; Weiss & Troxel, 1986). Additionally, Arendt and Dick (1995) reported the incidence of ACL injuries in women basketball players was more than four times

that of male basketball players during a five year study from 1989 to 1993 (29% vs. 7%). Data gleaned from a thirty month review of patient charts in a sports medicine clinic also demonstrated dramatically greater numbers of ACL tears in female basketball players than in male basketball players (Gray et al., 1985). Research on female athletes is needed to help understand the impact of such injuries on this population.

Data on injuries sustained by women basketball players have been collected by the National Collegiate Athletic Association (NCAA) since the 1988-89 season. A compilation of that data, as well as unpublished data collected by Morrison et al. (1988), indicates that athletes participating on teams in NCAA Division I are more likely to sustain injury than athletes participating on teams in NCAA Divisions II or III. The higher risk of injury is true in both practice and game settings (NCAA, 1996). In conversations with this researcher, athletic trainers have expressed the opinion that the intensity of play in Division I makes it more difficult for those athletes to return to their previous level of activity following ACL injury than players in Divisions II and III.

The preceding data suggest the need to determine why women are more prone to ACL tears and to find effective prevention measures. Athletic trainers and coaches have long emphasized improvement of quadriceps and hamstring muscle strength ratios in order to provide protection to the ACL. In general, it has been thought that the hamstring muscle group needs to have 66% of the strength of the quadriceps muscle group, but some athletic trainers and strength and conditioning coaches are now recommending greater hamstring strength (Moore & Wade, 1989) in order to protect the ACL more effectively. Knapik et al. (1991) provided support to this belief. They noted

that females with quadriceps/hamstring muscle imbalances were more likely to sustain injury. Additionally, Loudon et al. (1996) found an increased likelihood of ACL rupture in women displaying anterior pelvic tilt, knee hyperextension, and foot pronation. Postural training and the use of foot orthoses can reduce these risk factors (Loudon et al., 1996). Finally, since the majority of ACL injuries involve landing from a jump, cutting, or sudden deceleration (Noyes, Mooar, et al., 1983), it seems logical that development of ways to modify these activities or to train athletes to perform them more safely would likely reduce the number of injuries.

The female collegiate athletes who sustain ACL ruptures are forced to decide whether the best treatment option is a conservative approach, involving extensive rehabilitation and protective strapping or bracing, or an aggressive approach, involving surgical reconstruction followed by an extensive rehabilitation process. Often the decision is made by the consulting orthopedic surgeon with little input from the athlete (Noyes & McGiniss, 1985). Recently, there has been increasing interest in the athlete's immediate athletic goals (i.e., return to competitive basketball) as well as her future career and activity plans when making the decision about which course of action to follow. Many experienced athletic trainers feel that reconstructive surgery following such injury is necessary to allow the athlete to return to her previous level of physical activity. This clinically based opinion has been supported by research in the past several years (Andersson & Gillquist, 1992; Bonamo et al., 1990; Buss et al., 1995; Daniel et al., 1994; Hawkins et al., 1986).

If treatment following an ACL tear includes reconstructive surgery, there are

several different surgical methods utilized. Each surgical technique has specific advantages and disadvantages and is appropriate for specific problems related to the ACL rupture (Bach et al., 1994; Simonet & Sim, 1984). The choice of the appropriate surgical technique is one that a competent, experienced orthopedic surgeon has the expertise to make.

Rehabilitation programs following ACL rupture are similar whether or not the athlete has reconstructive surgery. The common rehabilitation program following an ACL rupture which is treated without surgical intervention is general muscular strengthening with particular attention to the hamstring muscle group. A significant function of the ACL is to prevent anterior translation of the tibia with respect to the femur (Kannus et al., 1992). The hamstring muscle group prevents anterior tibial translation and may also limit the characteristic pivoting phenomenon experienced by ACL deficient individuals (Ciccotti et al., 1994b). The hamstring muscle group, therefore, performs the same general function as the ACL, but in a dynamic fashion (Kannus et al., 1992). There is also emphasis on proprioceptive training for the knee. Proprioceptive training programs the muscles to respond to unusual stresses at the knee joint and protect the knee after an ACL injury has occurred (Ihara & Nakayama, 1986). Such training has had some success but its application in vigorous athletic situations is minimal (Ihara & Nakayama, 1986). Hawkins et al. (1986) reported only 4% of the patients studied were able to return to unlimited athletic activities despite thorough rehabilitation programs following an unrepaired ACL rupture. Several other researchers have found similarly poor results (Andersson & Gillquist, 1992; Buss et al.,

1994; Odensten, Hamberg et al., 1985; Puddu et al., 1984; Simonet & Sim, 1984; Tibone et al., 1986). This information suggests a need for individuals with ACL ruptures to receive more aggressive treatment if they intend to maintain a vigorous level of athletic activity.

Most orthopedic surgeons who are involved in ACL reconstruction utilize similar protocols in the healing and rehabilitation stages after surgery (Bilko et al., 1986). The rehabilitation protocols have become quite aggressive in the past few years. Most post-surgical patients now follow what has been described as an "accelerated" rehabilitation program. This program was initially detailed by Shelbourne and Nitz (1990). The basic program is similar to that followed by non-surgical patients, however, special care is taken to protect the healing surgical graft (Bynum et al., 1995) and to avoid common post-surgical complications such as excessive scar tissue formation or loss of patellar mobility (Shelbourne et al., 1991).

Although there is a plethora of information regarding the causes of ACL tears and the surgical techniques and rehabilitation programs which provide treatment for such tears, there is little research that identifies tactics proven to limit ACL injuries (Garrick & Requa, 1996). Additionally, women's basketball is recognized as a sport which has a high incidence of ACL ruptures, yet there is little research suggesting what intervention methods give an athlete the highest chance of returning to her previous level of activity following such an injury. Given the complexity of issues involved in preventing and coping with ACL ruptures and the importance of understanding these issues as they impact female basketball players, more research in this area is warranted.

Purpose of the Study

The purposes of this study were to examine a) the effectiveness of intervention techniques in relation to sport return rates among women basketball players, b) the effectiveness of injury prevention tactics in limiting ACL injury rates, and c) differences in these factors among NCAA Divisions I, II, and III.

Limitations of the Study

The limitations of this study were as follows:

1. In most cases, the data collected were retrospective so manipulation of variables and measurement of predisposing factors was not possible.
2. Not all subject institutions had six seasons of data due to turnover in athletic training staff and difficulty interpreting injury records.
3. It was difficult to quantify compliance with prevention techniques.
4. Reports on athlete level of return were made by the athletic trainer, not the coach or the athlete.
5. Not all variables which might affect injury rates could reasonably be included in the survey. Some of the most interesting excluded variables include: years of basketball experience, position played at the time of injury, fatigue at the time of injury, playing surface at the time of injury.
6. Long-term follow-up of function when competitive athletics has ended was not within the scope of this investigation.

Research Hypotheses

The study was designed to test the following hypotheses:

1. Division I programs will have a greater number of athletes who sustain ACL ruptures than will Division II or III programs.
2. Ligamentous or meniscal injuries to the knee which occurred prior to the index injury will decrease an athlete's ability to return to intercollegiate basketball.
3. Injury to multiple structures within the knee at the time of ACL rupture will decrease an athlete's level of performance upon return to activity.
4. Athletes who have surgery will have a higher level of performance upon return to activity than those who do not have surgery.
5. Regardless of intervention technique, athletes in Division I programs will be less likely to return to their previous level of activity than athletes in Division II or III programs.
6. Use of pre-season physical strength testing, routine strength training programs, and modification of cutting and jumping techniques will limit the number of injuries.

Significance of the Study

Results from this study may be useful in determining the effectiveness of frequently used prevention techniques in reducing the number of ACL injuries in women basketball players. Findings from this study can provide information that will assist the athlete, her athletic trainer, and her orthopedic surgeon in determining what

courses of action have been demonstrated to be most helpful for recovery after an ACL tear. Finally, recommendations are made regarding prevention tactics and intervention techniques which have demonstrated effectiveness.

CHAPTER 2**LITERATURE REVIEW****Injury Rates in Women's Basketball**

Title IX of the 1972 Educational Assistance Act served as a major impetus for large numbers of women to enter the collegiate sports arena. By the time of Title IX's implementation in 1975, women's sports, under the governance of the Association of Intercollegiate Athletics for Women (AIAW), were quickly growing. AIAW held its first national championships in 1978 and continued to host national championships until 1982. The NCAA first hosted women's sports championships in 1982 and has been the governing body for major athletics programs for women since 1983.

Prior to this great influx of females into the competitive sports arena, many people felt that women should not engage in vigorous sports activities for "safety" reasons. Since women's participation in such sports was limited until the late 1970's, little research on their injury rates was available. The legal and financial ramifications of Title IX encouraged many colleges and universities to support women's teams and studies on injuries in female athletes became possible and more common. The research has focused on frequencies of various types of injuries, comparisons of injury rates among women's sports, and comparisons of injury rates between male and female athletes in similar sports.

The first significant studies of injury rates in women athletes concluded that well-trained female athletes were not more likely to be injured than their male

counterparts (Haycock & Gillette, 1976; Whiteside, 1980). Whiteside (1980) did note, however, that women were slightly more likely to sustain sprains and contusions. In 1981 Shively et al. noted that high school female athletes had a higher rate of knee sprains than their sport-matched male counterparts, but the overall injury rates were similar.

The intervening years have seen an increase in research on injuries in female athletes. When the scope of inspection is narrowed to the specific sport of basketball, several pertinent studies emerge. Even the popular press has addressed the incidence of ACL injuries in women's collegiate basketball (McCallum, 1995).

As early as 1976, Haycock and Gillette noted that female basketball players had the highest frequency and greatest severity of injury compared with women participating in other sports. They further noted that 61% of institutions in their survey had athletes who had sustained knee injuries. This study made no specific reference to ACL injuries. The authors concluded that "in general, women athletes sustained the same injuries in relatively the same numbers as their male counterparts."

Garrick and Requa (1978) collected data from four Seattle high schools to determine injury rates. In this study, 25% of female basketball players sustained injuries. Half of those injured required referrals to physicians. In this study, the knee was the second most frequently injured body area and sprains were the most common category of injury. No specific information was reported on knee sprains specifically or on ACL tears as a portion of knee injuries.

One of the first reports on increased incidence of knee injury among female

athletes was published in a study conducted by Shively et al. (1981). Their comparison of similar sports in 79 Oklahoma high schools determined that female basketball players had the highest overall rate of injury (6.54%). The study found that knee sprains were the second most frequent injury type among female athletes, and that they were also the second most common major injury among females in general. Of the twelve injuries requiring surgery in female athletes, six were for knee sprains. No specific mention of the ACL was made.

A 1980-81 survey of 22 Iowa high schools' varsity boys and girls basketball programs found that girls suffered significantly more knee injuries (Wirtz, 1982). In this study, 15 females sustained ACL ruptures compared to only one male. The author, an orthopedic surgeon, pointed to some unique aspects of the Iowa girls' six-on-six basketball game as factors which contributed to the difference.

Analysis of data collected over a two year period by the National High School Injury Registry noted that while girls and boys had approximately the same number of total injuries, girls had slightly more moderate and severe injuries (Zillmer et al., 1992). Knee injuries comprised 58% of the major injuries sustained by girls in this review. Though specific mention of the ACL was not made, Zillmer et al. (1992) do allude to the fact that the ACL rupture is one of the most likely causes of major knee injury.

Injury rate comparisons between a men's and a women's professional basketball team again demonstrated that the knee was the second most frequently injured body part among female athletes (Zelisko et al., 1982). Additionally, the knee was injured over

twice as often per exposure in female athletes than in males. Ligamentous sprains comprised 27% of all injuries in the women while the same injury represented less than 9% of the total for the men. This study did not specifically address ACL injuries.

Gray et al. (1985), in a retrospective review of a sports medicine clinic's charts over a thirty month period, found nineteen female participants in basketball had sustained ACL ruptures while only four males had. The population in this study included 76 female basketball players (55 knee injuries) and 151 male basketball players (total number of knee injuries not given) who sought care for injuries at this particular clinic.

A study of athletic injuries treated over a seven year period was reported by DeHaven and Lintner (1986). This study found internal derangement of the knee was the most frequent diagnosis in both the 16-19 year old and the 20-24 year old age groups. ACL sprains comprised 4% of all injuries and 6.7% of all knee injuries in the female subjects. ACL sprains accounted for nearly 21% of injuries in the female basketball athletes. It should be noted that this study did not specify severity of ACL sprains. Any trauma to the ACL from slight stretching to complete rupture could be classified as a sprain.

In a sport matched comparison of injury and disability rates among collegiate athletes at one institution, Lanese et al. (1990) found that women athletes were twice as likely as their male counterparts to injure their knees. They also noted that women sustained slightly more sprains. However, they did not find any statistical difference in injury rates between male and female basketball players.

When focusing on basketball players of high caliber who participate at relatively high levels of intensity, the injury rates are staggering. Malone et al. (1993) found in a review of basketball injuries in premier collegiate basketball conferences that women were eight times more likely to sustain ACL ruptures than men. In a comparison of elite athletes at the 1988 Olympic trials, less than 4% of the 80 male participants suffered ACL tears while more than 20% of the 64 female participants succumbed to the injury (Hutchinson & Ireland, 1995).

Two articles utilizing data collected in the NCAA Injury Surveillance System noted that 29% of knee injuries in women involve ACL ruptures while only 7% of knee injuries in men involve the ACL (Arendt & Dick, 1995; Hutchinson & Ireland, 1995). The Arendt and Dick (1995) study was based on a five year compilation of NCAA data. One interpretation of the NCAA data is that a collegiate women's basketball team will, on average, lose a player to an ACL tear once every three seasons, while for a comparable men's team, such a loss will occur once every eleven seasons (Garrick & Requa, 1996).

These remarkably high levels of injury indicate a need for further research into causes of ACL tears in women basketball players. Although early research suggested that women were not more likely to experience injury than sport matched men (Haycock & Gillette, 1976), more recent studies refute that finding. It is likely, as noted by Garrick and Requa (1996), that the differences in injury rate have existed for the past twenty years but the early studies did not elicit the information.

Injury Rates in NCAA Divisions I, II and III

The previously cited studies clearly demonstrate the high incidence of ACL rupture in female basketball players. Review of those studies finds similar incidence whether the athlete is interscholastic, intercollegiate, or elite (Arendt & Dick, 1995; Gomez et al., 1996; Hutchinson & Ireland, 1995; Wirtz, 1982). Yet, sports medicine practitioners who deal with such injuries on a daily basis have expressed to this researcher the opinion that athletes who compete at a higher level are more likely to sustain such injury than those who compete at lower level.

There is little information specifically targeted at this assumption in the literature. The data that is routinely available from the NCAA Injury Surveillance System does not provide a breakdown of ACL injuries by division. The NCAA data does indicate overall game and practice injury rates by division, but differences are inconclusive.

The Malone et al. (1993) study notes that 16.1% of women participating in Division I basketball programs have sustained ACL tears. Oliphant and Drawbert (1996) in a survey of collegiate basketball programs in Wisconsin, which they described as consisting of "primarily Division III athletes," found an ACL injury rate in women of 4.8%. In this study, eleven institutions responding were Division III, one was Division II and two were Division I. No breakdown in their statistics was given to account for the differences between the divisions, however, in the discussion the impression was given that the data reported were based primarily on the Division III athletes. The difference between these two studies suggests that Division I female

basketball players do, in fact, have a higher incidence of ACL tears.

In unpublished data collected and reported to responding institutions (Morrison et al., 1988), some comparisons can be made between ACL injury rates of Division I and Division III athletes. Their data indicate that over the three year period 1985 to 1988, a greater number of the Division I players sustained ACL injuries than did the Division III players (2.7% to 1.9%). It is unfortunate that this survey did not include any Division II institutions.

Although athletic trainers and other health care providers have expressed the opinion that Division I players sustain a higher incidence of ACL injuries, research to address this point is needed because there is little hard data to support this contention.

Predisposing Factors

Factors which increase an individual's susceptibility to ACL rupture have been addressed in several articles (Gray et al., 1985; Malone et al, 1993; Oliphant & Drawbert, 1996; Potera, 1986; Weesner et al., 1986). Among the most common issues considered when examining predisposing factors are various aspects of muscular strength. Athletic training students are taught from their earliest course work that muscular weakness and agonist/antagonist imbalance increases the likelihood of injury (Arnheim & Prentice, 1997; Booher & Thibodeau, 1994; Pfeiffer & Mangus, 1995).

Potera (1986), in a review specific to female athletes, cites lack of adequate strength and endurance in the leg musculature as a factor in many knee and lower extremity injuries. A prospective study of 138 women athletes at a Division III

institution found that those with right to left hamstring strength imbalance greater than 15% had a higher incidence of lower extremity injury (Knapik et al., 1991). This study also noted that subjects with a hamstring/quadriceps strength ratio of less than 75% were more likely to sustain a lower extremity injury. The significant strength measurements in the preceding study were true only at speeds of 180 degrees/second. Additionally, no specific mention of ACL injuries was made.

Berg et al. (1985) reported muscular fitness profiles of 13 women on a Division I basketball team. This study measured the average hamstring/quadriceps ratio in the women at 180 degrees/second as 71.8%. If this population is representative of the typical female basketball player, then application of the Knapik et al. (1991) findings would suggest that the "average" woman player would be at risk for lower extremity injury.

Both anterior tibial translation and excessive stretch on the ACL are factors in ACL rupture (Ciccotti et al., 1994b; Noyes, Mooar et al., 1983). It has been established that the hamstring muscle group dynamically prevents forward translation of the tibia under the femur (Ciccotti et al., 1994b). If the hamstrings are weak, they cannot perform this function as effectively. Further, Arendt and Dick (1995) point out that maintaining slight flexion in the knee, as well as keeping the feet under the hips while cutting, protects the ACL from being put on stretch. Hamstring strength, particularly eccentric strength, is necessary to maintain this protective position (Arendt & Dick, 1995). In addition to hamstring strength, quadriceps strength is critical to an athlete's ability to maintain activity with a flexed knee (Ciccotti et al., 1994a).

Basketball coaches emphasize this flexed knee position as optimal for playing defense and for readiness in changing direction. The ability to perform this activity for several minutes requires not only muscular strength, but also muscular endurance. It becomes apparent to out-of-shape participants that maintaining this position contributes to rapid fatigue in both the quadriceps and hamstring muscle groups. Although several studies mention the effects of inadequate "conditioning" as a factor in ACL tears (Arendt & Dick, 1995; Garrick & Requa, 1978; Gomez et al., 1996; Hutchinson & Ireland, 1995; Malone et al., 1993; Oliphant & Drawbert, 1996; Rochman, 1996; Wirtz, 1982), the specific effects of muscular fatigue in the quadriceps and hamstring muscle groups are rarely discussed. In an investigation of the neuromuscular effects of fatigue, Wojtys et al. (1996), noted an increase in anterior tibial translation. Although some increased anterior tibial translation could be attributed to increased extensibility of ligaments following exercise, some appeared to be due to fatigue of the quadriceps and hamstrings. This study also measured increases in both quadriceps and hamstring reaction time following exercise to fatigue. Delay in muscular response was significant enough to allow ACL rupture. It appears that specific muscular fatigue may be a factor in ACL rupture.

In addition to strength deficits and imbalances, problems with flexibility in particular muscle groups is often a cause of injury (Arnheim & Prentice, 1997). While lack of flexibility is typically a factor in increased incidence of muscle strains, Malone et al. (1993) indicate that highly flexible hamstrings have been related to increased incidence of ACL tears. Loudon et al. (1996) found that the majority of female athletes

in their study had tight hamstrings, yet there was no difference in incidence of ACL tears between groups with and without hamstring tightness. Likewise, quadriceps and hamstring flexibility were not significantly related to lower extremity injury in the study by Knapik et al. (1991).

The preceding factors, quadriceps strength, hamstring strength, quadriceps to hamstring strength ratios, and flexibility can all be improved or altered by conditioning programs. However, several other factors implicated as predisposing athletes to ACL tears are not so readily addressed.

For example, anatomical characteristics of the femur, tibia, and patella as well as their alignment to each other have been cited in several studies as possible components in ACL injury (Arendt & Dick, 1995; Gray et al., 1985; Hutchinson & Ireland, 1995; Oliphant & Drawbert, 1996).

An anatomical feature of the knee which has received a great deal of attention for both its effect on injury and its influence on post-surgical recovery, is the width and shape of the femoral intercondylar notch (Arendt & Dick, 1995; Gomez et al., 1996; Hutchinson & Ireland, 1995; Jackson & Drez, 1987). Arendt and Dick (1995) reviewed eight articles pertaining to intercondylar notch width and the ratio between intercondylar notch width and femoral condyle width. Although their review indicated that athletes who had a narrower intercondylar notch are more susceptible to ACL tears, smaller notch width was not unique to females in the studies they reviewed (Arendt & Dick, 1995). Hutchinson and Ireland (1995) report that not only is overall notch width important, but notch shape may also be important. They suggest that an

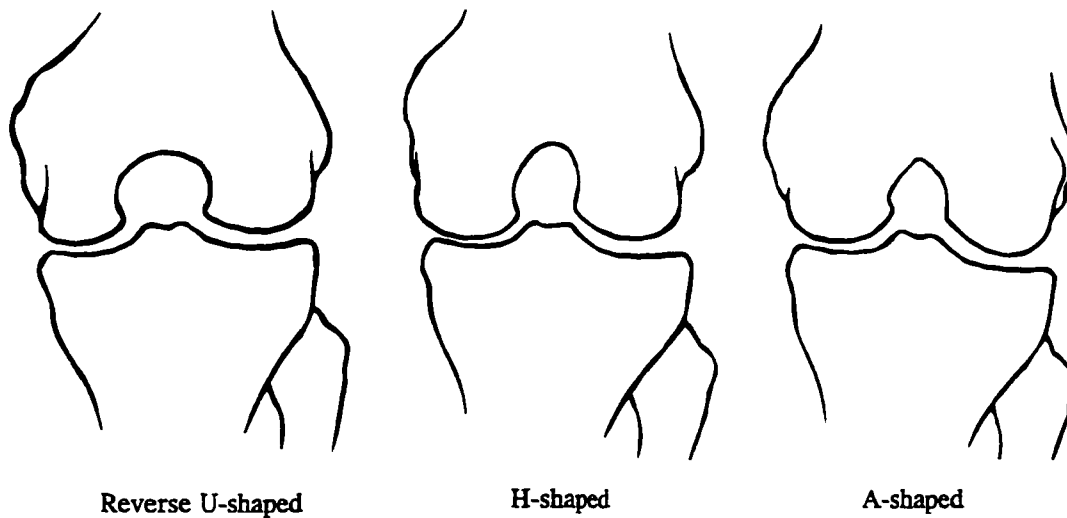


Figure 1. Femoral notch shapes.

A-shaped notch may be an indicator of increased risk for noncontact ACL injury.

Examples of the three most common notch shapes are shown in Figure 1.

Genu recurvatum is one component of bony alignment at the knee. Genu recurvatum is a measurement of knee hyperextension greater than 5° . According to Loudon et al. (1996) genu recurvatum was positively correlated with incidence of ACL tears.

Another measure of bony alignment at the knee is the Quadriceps angle (Q-angle). Q-angle is a way to quantify the relationship between the angle of pull of the quadriceps and the line of the patellar tendon from the midpoint of the patella to its insertion on the tibial tuberosity (Starkey & Ryan, 1996). In women, Q-angle measurements exceeding 18° in full knee extension and 8° in 90° of knee flexion are considered abnormal. The Q-angle is depicted in Figure 2. Although Q-angle

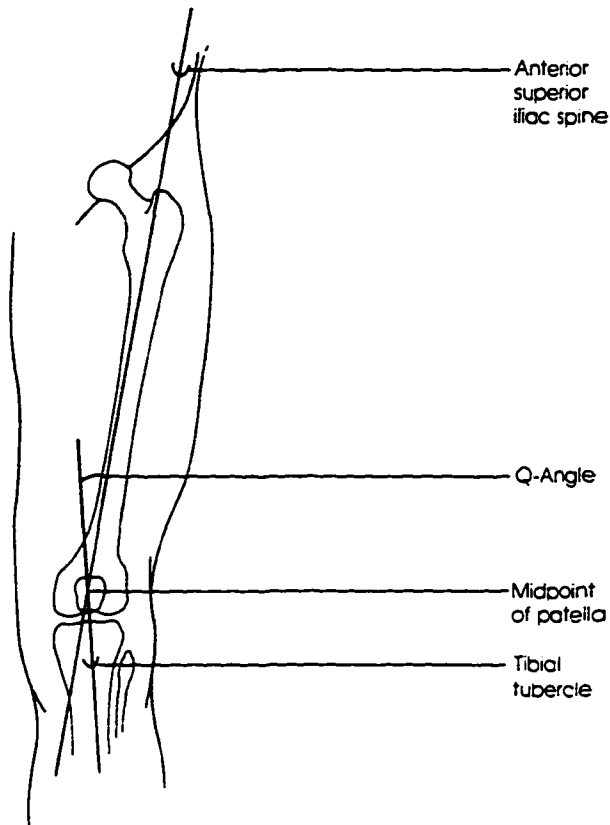


Figure 2. Quadriceps angle measurement.

abnormalities are positively correlated with patellofemoral injury incidence in women athletes (Hutchinson & Ireland, 1995), the women sustaining ACL tears reported by two separate studies (Gray et al., 1985; Loudon et al., 1996) had no Q-angle problems.

Besides alignment abnormalities at the knee, postural imperfections at the hip and foot may contribute to ACL ruptures (Hutchinson & Ireland, 1995; Loudon et al., 1996). In a comparison of twenty ACL-injured women with age-matched controls, the women with ACL tears had significantly greater amounts of anterior pelvic tilt, knee hyperextension, and subtalar joint pronation (Loudon et al., 1996). It was noted that the combination of knee hyperextension and subtalar joint pronation was a greater risk

than pronation alone. Also, biomechanical alterations in response to anterior pelvic tilt resulted in knee hyperextension (Kendall et al., 1993) which was demonstrated by statistical differences when anterior pelvic tilt was analyzed in a univariate versus a multivariate fashion (Loudon et al., 1996).

Intrinsic ACL laxity is the final predisposing factor to be discussed. The work by Steiner et al. (1986) showed that increased antero/postero (AP) laxity did occur in women basketball players after ninety minutes of practice. However, the study of fatigue and its effect on anterior tibial translation previously cited (Wojtys et al., 1996) found that a large portion of this AP motion was caused by muscular fatigue, not by ligamentous laxity. In a comparison of normal and ACL deficient subjects, Grana and Muse (1988) described significant increases in anterior laxity in both groups following an intense workout on a bicycle ergometer. Whether this increased laxity was sufficient to put the ACL at risk was not addressed.

One of the earliest explorations of gender differences in ACL laxity compared male and female high school basketball players and found no significant differences based on gender (Weesner et al., 1986). This study did not attempt to predict likelihood of injury. Several authors (Gray et al., 1985; Hutchinson & Ireland, 1995; Rochman, 1996) have referred to limited scientific knowledge of the cyclical effects of estrogen and progesterone on connective tissue. The ACL does contain receptors for both hormones and there has been speculation that fluctuations of these hormones throughout the menstrual cycle could influence injury rate (Rochman, 1996). Further research in this area is certainly warranted. It is interesting to note that while female athletes have

more general ligamentous laxity than do male athletes; they have less general ligamentous laxity than do female nonathletes (Hutchinson & Ireland, 1995).

Comparison of Conservative and Surgical Treatment

When an athlete sustains an ACL rupture, several decisions must be made. The first decision is whether or not surgical reconstruction will be done. If the athlete opts against such major surgery, she is described as following a conservative treatment course. In conservative treatment, the athlete receives care which is initially focused on controlling pain and swelling, regaining range of motion in the joint, and minimizing loss of muscular strength and function. Once the acute phase of the injury has passed (generally the first 72 hours), more emphasis is given to increasing strength and proprioception in the joint.

Conservative treatment of ACL ruptures has been the subject of numerous studies (Barrack et al., 1990; Bonamo et al., 1990; Buss et al., 1995; Clancy et al., 1985; Giove et al., 1983; Hawkins et al., 1986; McDaniel & Dameron, 1980; Noyes, Matthews et al., 1983; Noyes, Mooar et al., 1983). Researchers have focused on the differences between individuals who responded well or poorly to this treatment (Barrack et al., 1990; Bonamo et al., 1990; Clancy et al., 1985; Daniel et al., 1994; Giove et al., 1983; McDaniel & Dameron, 1980; Noyes, Matthews et al., 1983; Noyes & McGiniss, 1985; Odensten, Lysholm & Gillquist, 1985; Puddu et al., 1984) and on the types of problems which occurred if a conservative approach was followed (Fetto & Marshall, 1980; Hawkins et al., 1986; Odensten, Hamberg et al., 1985).

The individuals who responded best to conservative treatment of ACL rupture were those who participated in only recreational or non-sports activities. Bonamo et al. (1990), in a review of 79 recreational athletes, found 49% were able to continue in their chosen sport activity. Additionally, Noyes, Matthews et al. (1983) noted that the individuals with the greatest success in their study of patients following a conservative course were those who demonstrated the greatest compliance to the prescribed rehabilitation program. Finally, Odensten, Lysholm and Gillquist (1985) found a significant difference in outcome between those with partial tears of the ACL and those with complete tears. Partial tears did not create the magnitude of problems seen with complete tears and yielded good or excellent results in all twenty-one of their subjects. This difference emphasizes the necessity for an early and accurate diagnosis of the severity of injury.

The individuals who had poor results with conservative treatment were those who placed great demands on their knees or refused to modify (i.e., decrease) their level of activity (Noyes, Matthews et al., 1983; Noyes & McGiniss, 1985; Noyes et al., 1989). Several researchers (Barrack et al., 1990; Giove et al., 1983; Noyes & McGiniss, 1985; Puddu et al., 1984) arrived at the conclusion that the greatest difficulty with return to activity with an unrepaired ACL occurred in sports, such as basketball, which required cutting, sudden stopping, jumping, and lateral movement. Barrack et al. (1990) found that 40% of subjects in their study could not turn or cut and that 29% could not jump without experiencing pain or instability. They noted that only 5.5% of their subjects could return to their pre-injury level of activity. Only 11% of the subjects

in the study of Buss et al. (1995) were able to maintain activity described as "vigorous." Of forty young ($\bar{x} = 22$ y/o) subjects in the Hawkins et al. (1986) study only 14% had full return to activity. Sixteen of fifty-one athletes (31%) in the Puddu et al. (1984) study completely gave up sports activity.

In addition to sport demand, laxity created at the time the ACL was ruptured or concomitant injury to the menisci are factors which affect level of recovery. If the athlete has significant anterior tibial translation, there is a greater likelihood of a poor recovery result (McDaniel & Dameron, 1980; Noyes & McGiniss, 1985). Rotational instability is another sign of laxity created by ACL rupture. Rotational instability is measured by several specific orthopedic tests including the anterior drawer, the pivot shift, and the jerk test. When an athlete tests positively for rotational instability, poor recovery is more likely (Bonamo et al., 1990; Hawkins et al., 1986; McDaniel & Dameron, 1980; Noyes & McGiniss, 1985; Puddu et al., 1984). Finally, several studies found that individuals whose initial injury required partial or total meniscectomy were more likely to have poor results than those who had no meniscal injury (Barrack et al., 1990; McDaniel & Dameron, 1980; Noyes & McGiniss, 1985; Puddu et al., 1984).

The preceding studies provided valuable information regarding the factors which make athletes appropriate or inappropriate candidates for conservative treatment. The other concern when considering this treatment approach is the risk of complications which are likely to occur if conservative treatment is chosen. The biggest risk for individuals who maintain a high level of activity (e.g., competitive basketball) is joint degeneration. Noyes and McGiniss (1985) found that individuals who continued a high

level of activity and who experienced episodes of giving way were more likely to demonstrate degenerative changes in the joint. Arthritic and/or degenerative changes in the articular cartilage was also noted by Bonamo et al. (1990), McDaniel and Dameron (1980) and Noyes, Mooar et al. (1983). There were indications that the degenerative changes were related to concomitant meniscal damage and not to isolated ACL rupture (McDaniel & Dameron, 1980). Further, it appears that reconstructive surgery can slow or prevent such degeneration in the knee joint (Fetto & Marshall, 1980).

Another complication following unrepaired ACL rupture is repeated episodes of the knee "giving way." Reports of the incidence of such episodes ranged from 53% (Puddu et al, 1984) to 86% (Hawkins et al., 1986). Repeated incidents of instability can cause increased valgus and/or varus instability with time (Hawkins et al., 1986) and can create secondary meniscal injuries (Giove et al., 1983; Hawkins et al., 1986; McDaniel & Dameron, 1980; Odensten, Hamberg et al., 1985). Odensten, Hamberg et al. (1985) found that 20% of those treated conservatively required surgery at a later date to correct significant instability and/or meniscal injury.

If the athlete opts for initial surgical treatment of her ACL rupture, her orthopedic surgeon will recommend the surgical procedure deemed most appropriate for the athlete's injury profile. Although it is not within the scope of this research to analyze surgical techniques, several factors which may influence successful recovery following surgical reconstruction should be mentioned.

The most commonly utilized surgical reconstructions of the ACL include patellar tendon intra articular autograft, semitendinosus/gracilis intra articular autograft,

iliotibial band intra articular autograft, iliotibial band extra articular tenodesis, and patellar tendon intra articular allograft. An autograft utilizes tissue from the injured patient while an allograft consists of tissue from a donor. The intra articular repair involves drilling tunnels through the femur and tibia in an attempt to duplicate the position of the original ACL with the replacement structure. The extra articular repair may also involve drilling through the femur to add stabilization externally. This discussion is limited to the methods most frequently used in a young, active population: patellar tendon intra articular autograft (PT-AUTO), semitendinosus/gracilis intra articular autograft (SEMI), and iliotibial band extra articular tenodesis (ITB-EX).

Several investigations of recovery following PT-AUTO (Bach et al., 1994; Good et al., 1994; Howe et al., 1991; Shelbourne et al., 1990; Shelbourne et al., 1994) reported good results. Howe et al. (1991), in a long-term ($\bar{x} = 5.5$ years) follow-up of 83 patients, noted good graft strength and lack of any graft deterioration. This study of 83 patients found that 77% could return to their preinjury level of sport performance. Formal rehabilitation for a minimum of four months was noted to increase patient satisfaction with their outcome. Shelbourne et al. (1994) found that patients regained 86% of normal quadriceps strength by 12 months post-surgery. They also noted that the ability to regain quadriceps strength was not affected by the size of the PT-AUTO that was harvested to complete the reconstruction. Bach et al. (1994) followed sixty-two patients for an average of three years and found that a high strength PT-AUTO yielded excellent stability and high patient satisfaction with their outcome. They concluded that extra articular reinforcement was unnecessary if the graft utilized had

adequate strength.

Use of specific operative techniques can enhance recovery following PT-AUTO (Good et al., 1994; Shelbourne et al., 1990). Tibial anteroposterior translation (i.e. laxity) is reduced by careful placement of the femoral tunnel for graft fixation (Good et al., 1994). If the femoral tunnel approximated closely the femoral attachment of the normal ACL, knee stability was significantly better. In a retrospective study of 155 athletes, Shelbourne et al. (1990) found excellent return rates. Of the varsity athletes who desired to return to their sport, 98% were able to do so (level of return was not specified). This study also emphasized the importance of careful placement of the femoral and tibial tunnels. They also noted that enlargement of the intercondylar notch at the time of repair was routinely utilized to allow adequate room for the PT-AUTO. Further, they recommended removal of the torn ACL stump to prevent overfilling the notch.

The use of the SEMI reconstruction also appears to provide good conditions for recovery (Anderson et al., 1994; Karlson et al., 1994; Yasuda et al., 1995). Nearly all (93%) of patients evaluated by Anderson et al. (1994) were able to return to full athletic participation. This study had an average follow-up of seven years. It is interesting to note that the specific surgical procedure utilized in this study combined the SEMI and the ITB-EX. The authors felt that augmentation of the intra articular repair with the extra articular tenodesis enhanced the stability of the knee joint. Use of the SEMI alone was reviewed in sixty-four patients with an average follow-up of nearly three years (Karlson et al., 1994). Fifty-five of these patients (86%) returned to their pre-injury

sports. Yasuda et al. (1995) also indicated good results with the SEMI. They noted that hamstring strength returned to normal by one year post-surgery.

Regardless of surgical technique used, reported post-injury return rates to sport following ACL reconstruction ranged from 77% to 98% (Anderson et al., 1994; Howe et al., 1991; Shelbourne et al., 1994; Shelbourne et al., 1990; Karlson et al., 1994). Conversely, return to sport rates for athletes following a conservative course ranged from 5.5% to 49% (Barrack et al., 1990; Bonamo et al., 1990; Buss et al., 1995; Hawkins et al., 1986). Based on these comparisons, it appears that surgical intervention following ACL rupture provides a higher probability of an athlete being able to continue in her sport.

In addition to surgical type and the specific surgical techniques utilized, the effects of previous injuries or injuries concomitant with the ACL rupture on an athlete's recovery are of interest. Several researchers (Anderson et al., 1994; Bach et al., 1994; Daniel et al., 1994; Karlson et al., 1994; Marcacci et al., 1995; Wasilewski et al., 1993) excluded patients from their research who had previous or concomitant injuries. This exclusion demonstrated the belief or clinical experience that such injuries can adversely affect recovery from ACL injury. Good et al. (1994) noted that presence of pre-existing or concomitant meniscal injuries in their two year follow-up of twenty-four patients did not compromise the stability of the knee following PT-AUTO. Likewise, Howe et al. (1991) determined that meniscectomy (medial, lateral, or both) during or prior to PT-AUTO had no effect on satisfactory outcome following surgery. Medial or lateral partial meniscectomy created no additional difficulties in the patients who had

ACL repair (Odensten, Hamberg et al., 1985), however, partial removal of both menisci reduced knee stability at follow-up ($\bar{x} = 18.2$ months). Anderson et al. (1994), with an average follow-up of seven years, found that the best results were obtained in patients with no meniscal injury and that all of the results rated as poor or fair occurred in patients who had previous meniscal surgery. This study excluded patients with ligamentous injury other than the index ACL. These conflicting reports indicate the need for further research into the effect of meniscal injury on recovery following ACL reconstruction.

When examining research which includes concomitant ligamentous injuries, similar conflicting results are noted (Andersson & Gillquist, 1992, Howe et al., 1991; Noyes & Barber-Westin, 1995). A study of eighty-three patients followed for an average of five and one-half years following PT-AUTO found reduced post-surgical success if collateral ligament repair or reconstruction accompanied the ACL reconstruction (Howe et al., 1991). Noyes and Barber-Westin (1995) compared patients who had sustained complete ACL tears and complete MCL tears with patients who had sustained complete ACL tears and partial MCL tears. Those patients with complete MCL tears were treated surgically and those with partial MCL tears had no surgery for the MCL. All patients had patellar tendon allograft treatments for their ACL injuries. Their findings indicated normal valgus stability for both groups at an average of five years follow-up. They noted, however, that only 58.8% of those with MCL surgery had good or excellent results for their ACL repair while 91.7% of those with no MCL surgery had similar outcomes. Conversely, Andersson et al. (1992) found that knees

which required repair of both the ACL and the medial collateral ligament (MCL) recovered as well as knees in which only the ACL required surgery (follow-up $\bar{x} = 4.3$ years). This study also noted that repair of the MCL without repair of the ACL had results typical for conservative treatment of an ACL rupture. These inconsistent results also support the need for further investigation into the effects of concomitant injury on recovery following reconstruction of ACL rupture.

The optimal amount of time which elapses between injury of the ACL and reconstructive surgery has been investigated recently and is the final factor that may affect post-surgical recovery to be addressed. Shelbourne et al. (1990) noted that delaying reconstructive surgery for up to sixty-eight days following injury did not reduce level of recovery following PT-AUTO. Surgery within this time frame is still described as surgery for acute ACL injury if there was no return to usual activities. This definition of acute ACL injury is based on the usual amount of time required for the bloody effusion and pain of the acute injury to diminish. They also stated that during this ten week period the patient should perform pre-surgical rehabilitation which emphasizes range of motion and strength.

The stated purpose of the previous study (Shelbourne et al., 1990) was to determine the effectiveness of a particular surgical approach and rehabilitation plan for effective recovery and return to activity of an active population. The finding regarding surgical timing was serendipitous. In a retrospective study designed to explore optimal timing of PT-AUTO in young athletes, Shelbourne et al. (1991) determined that delaying surgery until three to eight weeks after injury improved several components of

recovery. These subjects regained flexion and extension of the knee joint more quickly and had greater strength at thirteen weeks post-surgery than did subjects whose PT-AUTO was performed within one week post-injury or eight to twenty-one days post-injury. There was no statistical difference between the groups pertaining to joint stability and there was no relationship between concomitant injury and reduced post-surgical results. Additionally, the group which had surgery within one week of injury required nearly three times as many arthroscopic procedures for removal of scar proliferation (12.5% to 4.2%).

A study of 87 SEMI patients who were categorized as acute repair (one to thirty days post-injury, 92.7% between five and ten days), sub-acute repair (one to six months post-injury) or chronic repair (at least six months post-injury) found that the sub-acute repair group consistently performed better than the other two groups on range of motion and strength in early measurements (Wasilewski et al., 1993). Differences among the three groups in these variables diminished by eighteen months post-surgery. In addition to the early strength and range of motion deficits, both the acute and chronic group had higher incidence of scar proliferation (22% acute; 0 sub-acute; 12.5% chronic) and surgical scar resection (9.8% acute; 6.2% chronic). The chronic group had more secondary injuries, presumably due to recurrent instability prior to reconstruction. There were no post-surgical differences in joint stability among any of the groups.

A retrospective study of patients undergoing intra articular autogenous pes anserine reconstruction divided the group into acute (seven to twenty-one days post-injury, $\bar{x} = 9.6$ days, $N = 22$) and chronic (six weeks to six years, $\bar{x} = 22.5$ months,

N = 29) reconstruction (Sgaglione et al., 1993). The acute group had no secondary meniscal lesions, significantly better joint stability following reconstruction, and better return to preinjury activity level.

Marcacci et al. (1995) reported findings following PT-AUTO or augmented fascia lata reconstruction on patients divided into early (within fifteen days of injury, N = 23) or late (three to twenty-one months post-injury, \bar{x} = eleven months, N = 59) reconstruction. No statistically significant differences were found between the two groups. However, the early reconstruction group did show a trend toward better stability and full return to activity. Additionally, the late reconstruction group had more meniscal injuries at the time of reconstruction than did the early group. There were no significant differences between the types of surgical reconstruction.

Another study comparing differences between early (two to twenty-one days post-injury, \bar{x} = 11 days; N = 64) and late (twenty-two to ninety-two days post-injury, \bar{x} = 40 days; N = 79) PT-AUTO found that quadriceps muscle strength returned significantly faster in the late group (Shelbourne & Foulk, 1995). By six months post-surgery there was no longer a significant difference in the quadriceps strength of the two groups although the late group still maintained a higher mean. The early return of quadriceps strength allowed earlier progression to sport-specific activities which was thought to improve patient compliance with the rehabilitation program.

When reviewing the preceding data on timing of surgery, the following points become apparent: 1) reconstruction performed prior to the resolution of acute hemarthrosis frequently results in scar tissue proliferation, slower return of range of

motion, and slower return of muscular strength; 2) reconstruction performed greater than six months post-injury has complications due to secondary injuries, particularly meniscal lesions, and greater post-surgical scar tissue proliferation, especially if return to some level of activity was attempted; and 3) reconstruction performed three weeks to six months post-injury brings the earliest return of range of motion and strength, the least risk of scar tissue proliferation, and, if return to activity is avoided, the least risk of secondary injuries. Although most of the differences between groups faded at six to eighteen months, the early delays could affect the athlete's ability to cope psychologically with the injury and recovery process. Also, delays in strength restoration or range of motion return could interfere with the timing of an athlete's return to her sport. Finally, secondary injuries which may occur during long-term delays of surgery could compromise the overall success of the reconstruction.

Rehabilitation

Rehabilitation following ACL rupture is similar whether the athlete is treated conservatively or operatively. Early emphasis is placed on controlling swelling and pain and regaining range of motion. Once these goals are achieved, their maintenance plus development of muscular strength, muscular endurance, proprioception, and joint stabilization becomes the focus of rehabilitation. Formal rehabilitation for conservative treatment is typically of shorter duration than formal rehabilitation following surgical intervention. Post-surgical rehabilitation includes safeguards for the healing graft (Bynum et al., 1995) although some recent work suggests that the patellar tendon

autograft may not undergo necrotic changes and weaken as had been previously believed (Rougraff et al., 1993).

Current concepts in post-surgical rehabilitation focus on early range of motion, especially early full extension, and early weight bearing (Shelbourne et al., 1990; Shelbourne et al., 1991; Shelbourne & Nitz, 1990). This basic type of program is referred to as "accelerated" rehabilitation since athletes are moved to functional activity at a rapid pace. An outline of conventional ACL rehabilitation typically used until the mid 1980's is provided in Table 1. An outline of the "accelerated" ACL rehabilitation program which is in current usage is provided in Table 2.

The orthopedic surgeons, athletic trainers, and physical therapists at the Methodist Sports Medicine Center in Indianapolis were pioneers in "accelerated" ACL rehabilitation (Shelbourne & Nitz, 1990). Although their protocol was first described for PT-AUTO patients, it has been utilized successfully with other surgical approaches. The benefits of early range of motion and early weight bearing include fewer problems with achieving terminal extension, decreased anterior knee pain, decreased incidence of post-surgical arthrofibrosis, and reduced necessity of scar resection surgery (Shelbourne et al., 1990; Shelbourne et al, 1991; Shelbourne & Nitz, 1990). Despite some early concerns, use of this aggressive approach has not compromised knee joint stability (Shelbourne et al., 1990).

In addition to emphasis on quickly regaining range of motion, current rehabilitation techniques utilize closed kinetic chain exercises (CKCE) rather than open kinetic chain exercises (OKCE) for the majority of the rehabilitation program (Bynum et

Table 1. Conventional rehabilitation program

Date post-surgery	Rehabilitation activities
1-3 days	Continuous passive motion unit Passive range of motion 0-60° Toe-touch weight bearing w/crutches & splint
5 days	Hospital discharge Passive range of motion 0-90° Wall slides, heel slides, straight leg raises (all directions)
1-2 weeks	Partial weight bearing w/crutches & splint Straight leg raises w/weight Hamstring curls
3-4 weeks	Light resistive extension exercises Passive range of motion 0-100°
5-6 weeks	Full weight bearing as tolerated Straight leg raises, increase weight Short arc knee extension Prone hangs Biking, no tension, swimming
8-10 weeks	Terminal extension Step-ups, calf raises, partial squats Leg press Biking, moderate tension
12-14 weeks	Range of motion 0-120°
4 months	Range of motion 0-130° Increase intensity Isokinetic exercise, high speed Jump rope
5 months	Isokinetic exercise, medium speed Distance walking
6 months	Lateral shuffle Progressive jogging program
7-8 months	Progressive running program: backward, hills, figure eights Agility drills KT-1000 evaluation
9-12 months	Continue functional progression Return to activity w/strength 80%

Table 2. Accelerated rehabilitation program

Date post-surgery	Rehabilitation activities
1-3 days	Continuous passive motion unit Passive range of motion 0-90° emphasize extension Weight bearing as tolerated
2-4 days	Hospital discharge Wall slides, heel slides, straight leg raises (all directions)
7-10 days	Knee bends, step-ups, calf raises Hamstring curls Partial to full weight bearing
2-3 weeks	Range of motion 0-110° Unilateral knee bends Stairmaster, biking, swimming Leg press, 1/4 squats
5-6 weeks	Range of motion 0-130° Isokinetic evaluation, 20° block high speed Strength at 70%: lateral shuffles, carioca, jog, jump rope, agility
10 weeks	Full range of motion Isokinetic evaluation, medium speed KT-1000 evaluation Jog/run progression Sport specific activities
16 weeks	Complete jog/run progression Increase agility Increase sport specific activities
4-6 months	Return to full sports when patient meets criteria

al., 1995; Irrgang, 1993; Shelbourne & Nitz, 1990). CKCE are performed with the foot fixed on a surface (e.g., leg press, squats) while OKCE are performed with the foot free (e.g., leg extension). CKCE reduce shear stress on the knee and produce more tibio-femoral joint compression which aids with joint surface nutrition (Shelbourne & Nitz, 1990). Patello-femoral pain and patello-femoral joint compression are reduced in CKCE (Bynum et al., 1995; Shelbourne & Nitz, 1990). Additionally, CKCE reduce

tibial translation and place less strain on the reconstructed ACL than do OKCE (Bynum et al., 1990; Irrgang, 1993). Finally, CKCE are similar to normal weight bearing and are more functional than OKCE (Irrgang, 1993; Shelbourne & Nitz, 1990).

Proprioception and reflex hamstring contraction are neurophysiological components of the recovery profile which are also emphasized in post-surgical and conservative rehabilitation. Proprioception is described as knowing where a body part is in space and in relation to other body parts. Smooth, coordinated movement and dynamic joint stabilization are facilitated by proprioception (Irrgang, 1993). Dynamic joint stabilization occurs when the athlete can recognize joint position and has the ability to react to stabilize or reposition the joint at a subconscious level (Wilk et al., 1994). Irrgang (1993) notes that effective proprioceptive training requires much repetition. With a very small subject group ($N = 9$), Ihara and Nakayama (1986) demonstrated improved proprioception following a three month proprioceptive training program.

Beard et al. (1993) examined functional instability in ACL deficient knees and found such instability to be directly related to slower response in reflex hamstring contraction. The ACL deficient knees demonstrated slower reflex response to controlled passive movement than the subjects' uninjured knees or normal controls. The increase in reaction time was attributed to loss of proprioceptive input from the ACL or other proprioceptors in the joint. The proprioceptive training program developed by Ihara and Nakayama (1986), significantly decreased hamstring reaction time. Wojtys et al. (1996) noted increased reaction time as a factor of neuromuscular fatigue. These studies emphasize the necessity of including proprioceptive training and

muscular endurance work in rehabilitation programs.

Functional testing is the tool that physicians and athletic trainers utilize to determine when an athlete is ready to return to various types of activity. Although several researchers report the value of including high speed hamstring work in ACL rehabilitation (Irrgang, 1993; Kannus et al., 1992; Walla et al., 1985; Wilk et al., 1994), little correlation has been found between isokinetic test results and functional status (Walla et al., 1985; Wilk et al., 1994). Performance on sport specific and plyometric-type activities have shown positive correlation to subjective self-assessment scales and ultimate return to activity (Wilk et al., 1994). Risberg and Ekeland (1994) recommend periodic functional testing. They advocate two-leg hops, figure eights, and stair running at approximately three months post-surgery to confirm readiness for "daily life" activities. At approximately six months post-surgery one-leg hops, triple jump, and stair hopping are used as a measure of strength and stability appropriate for sport specific activities. Functional testing provides a measure of the level of recovery attained and can also enhance the athlete's confidence in the affected knee.

Prevention Tactics

Despite the amount of research done on ACL injuries, little can be found in refereed literature regarding prevention of the injury. It seems that prevention of ACL injuries would be the simplest way to avoid the complications created when the injury occurs. Moore and Wade (1989) recommend strength goals for quadriceps and hamstrings that are based on the athlete's body weight for three separate speeds of

motion. A representation of these recommended values is found in Table 3. These goals were based on a three year strength training and testing program of collegiate athletes. The study did not report effects of the program on injury rates in its subjects; it appears that the purpose of the study was to establish norms, not to examine changes in injury incidence.

Table 3. Strength Goals for Women's Basketball

	Centers	Forwards	Guards
60°/second			
Knee Extension (KE)	1.20 x weight	1.20 x weight	1.30 x weight
Knee Flexion	0.70 x KE	0.70 x KE	0.70 x KE
180°/second			
Knee Extension (KE)	0.75 x weight	0.80 x weight	0.85 x weight
Knee Flexion	0.83 x KE	0.83 x KE	0.83 x KE
300°/second			
Knee Extension (KE)	0.55 x weight	0.60 x weight	0.65 x weight
Knee Flexion	1.00 x KE	1.00 x KE	1.00 x KE

Hutchinson and Ireland (1995) report reduction in risk of ACL injury in a prospective study of junior college basketball players by instituting rounding turns, flexed-knee landing, and a three-step stop in place of plant-and-cut, straight leg landing, and the jump-stop. Athletic trainers stress the importance of landing on two feet; if the choice is falling or landing on one foot, the athlete should fall and roll (McCallum, 1995).

Moore and Wade (1989) recommend keeping the knees slightly flexed to avoid the anterior tibial translation which accompanies knee hyperextension (Zavatsky et al.,

1994). As mentioned previously, maintaining a flexed knee position is advocated by basketball coaches for optimal basketball performance. This position does, however, contribute to fatigue. Keeping the feet under the hips when cutting and stopping reduces tension in the ACL and is the final preventative tactic recommended by Moore and Wade (1989). This reduction of tension in the ACL reduces risk of rupture. The common thread among these prevention tactics is motor control. ACL injuries frequently occur when the level of play is up tempo and the players are "out of control" (McCallum, 1995). If motor control can be improved, then perhaps injury rates can be reduced.

Summary

It is apparent from reviewing the pertinent literature that women basketball players have significantly more ACL tears than their male counterparts (Arendt & Dick, 1995; Gray et al., 1985; Hutchinson & Ireland, 1995). The reasons for this difference in incidence are not readily apparent. Although there is evidence that the high incidence of ACL tears occurs in females at all levels of basketball participation from high school to elite players (Gomez et al., 1996; Hutchinson & Ireland, 1995; Malone et al., 1993; Wirtz, 1982), there is little specific research comparing incidence rates among various levels of play. Research into differences in incidence among levels could provide some assistance in discovering why women sustain more ACL ruptures than their male counterparts.

Several factors which predispose athletes to ACL ruptures have been explored

(Gray et al., 1985; Malone et al., 1993; Oliphant & Drawbert, 1996; Potera, 1986; Weesner et al., 1986). Lack of overall muscular strength and imbalances in strength between the quadriceps and hamstrings have been cited as significant factors which increase an athlete's likelihood of sustaining an ACL injury (Arendt & Dick, 1995; Hutchinson & Ireland, 1995; Potera, 1986). Strength goals have been suggested for women basketball players to help reduce their risk of injuries (Moore & Wade, 1989). However, the prevalence of pre-season strength testing and pre-season and in-season strength training and the value of these tactics in actually preventing ACL ruptures is unknown. It has been hypothesized, and demonstrated on a limited basis (Hutchinson & Ireland, 1995), that technique modifications in cutting and jumping may reduce incidence of ACL injuries. However, little is known about how many women's basketball programs actually implement such technique modifications. Implementation of such alternative techniques needs to be measured so that their value can be assessed.

It is well documented that allowing at least three weeks to elapse between the injury and the reconstructive surgery enhances early post-surgical recovery (Sgaglione et al., 1993; Shelbourne et al., 1990; Shelbourne et al., 1991; Shelbourne & Foulk, 1995; Wasilewski et al., 1993). Use of an "accelerated" rehabilitation program incorporating closed kinetic chain exercises has yielded excellent recovery profiles (Bynum et al., 1995; Irrgang, 1993; Shelbourne & Nitz, 1990). Finally, treatment protocols for athletes who sustain ACL ruptures have also been thoroughly documented. It appears that individuals involved in activities, such as basketball, which put high demands on the knee, are more likely to be able to return to those activities following

an ACL tear if surgical reconstruction is performed (Barrack et al., 1990; Giove et al., 1983; Noyes & McGiniss, 1985; Puddu et al., 1984). However, most of the studies focusing on intervention procedures which were reviewed did not focus exclusively on women athletes. Research into the effects of various treatment and rehabilitation protocols on the recovery profiles of collegiate women basketball players will provide valuable information to the physicians and athletic trainers who provide their care following an ACL rupture.

CHAPTER 3

METHODOLOGY

Data were collected pertaining to female varsity basketball athletes in NCAA Divisions I, II and III who had sustained complete ACL ruptures. Since any given institution is likely to have only one or two such injuries per year, certified athletic trainers (ATCs) at numerous colleges and universities around the nation were involved in the data gathering phase of the study. Further, since isolated ACL injuries are not typical (Barber et al., 1990) and the effects of multiple injuries on recovery were of interest, athletes who damaged other knee structures at the same time as the ACL rupture were included in the sample group. Information was collected for each of the following basketball seasons for which the athletic trainer was able to provide accurate information: 1990-91, 1991-92, 1992-93, 1993-94, 1994-95, 1995-96.

Institutions involved in the study were randomly selected based on NCAA division and geographical location. Use of geographical region was implemented as a way to insure that the sample group accurately reflected current prevention and treatment tactics nationwide. Four geographical locations were defined using the same parameters the NCAA utilizes in their annual injury surveillance system. The four regions are east, south, midwest, and west. Four institutions were selected in each region and each NCAA division, yielding a total of sixteen institutions per division and a total of 48 institutions. The breakdown by region and the sample institutions are listed in Table 4. If each institution had been able to provide six seasons of data, there

Table 4. Participant Institutions and Seasons Available.

East Region-- Connecticut, Delaware, Dist. of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York Pennsylvania, Rhode Island, Vermont		
Division I	Division II	Division III
U Massachusetts (6)	Bloomsburg U (4)	Smith Col (6)
U Pittsburg (6)	Slippery Rock U (6)	Bates Col (6)
Brown U (6)	Springfield Col (6)	Ithaca Col (6)
Syracuse U (6)	New Hampshire Col (6)	Alfred U (4)
South Region--Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, Virginia, West Virginia		
Division I	Division II	Division III
U Alabama (6)	Barry U (2)	Centre Col (5)
Louisiana St U (6)	Delta St U (3)	E. Mennonite U (6)
William & Mary Col (6)	E. Texas St U (6)	N.C. Wesleyan U (6)
U Texas-ElPaso (6)	U South Car.-Spartanburg (3)	Roanoke Col (6)
Midwest Region--Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, Oklahoma, South Dakota, Wisconsin		
Division I	Division II	Division III
Iowa State U (6)	NW Missouri St U (6)	Ohio Northern U (6)
Ohio U (6)	Central St (6)	Capital U (2)
Illinois St. U (6)	Wayne St U (2)	Augustana Col (2)
U Illinois (6)	Wayne St Col (6)	Buena Vista U (6)
West Region--Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming		
Division I	Division II	Division III
CSU-Northridge (6)	CSU-Dominguez Hills (6)	Chapman U (6)
U Nevada-Las Vegas (6)	U Denver (1)	Lewis & Clark Col (6)
U Washington (6)	Regis Col (4)	Seattle U (3)
U Colorado (6)	Seattle Pacific U (6)	Laverne U (6)

would have been 288 total seasons of data. Twelve of the institutions were unable to provide six seasons of data due to turn over in athletic training staff and difficulty in interpreting athlete injury records, thus 251 seasons of data were available. Although Shambaugh et al. (1991) had some success in predicting overall likelihood of lower extremity injury, no success has been reported in predicting ACL ruptures specifically,

therefore, the number of individual athletes to be included in this research was not predicted.

Data were collected by means of two pencil and paper instruments. The certified athletic trainer at the institution who worked most closely with the women's basketball team was asked to provide the information. No athlete names were used. If the athletic trainer preferred, all information was collected via telephone with this researcher recording all information on the forms.

The first questionnaire focused on institutional factors. This information included the number of players on the team, total number of ACL ruptures, whether there was routine collection of pre-season leg strength information, whether there was performance of routine strength training, and if any technique modifications, particularly for cutting and jumping, were taught. Instructions for completing the questionnaire were given to the athletic trainer during initial telephone contact. A copy of the institutional questionnaire is found in Appendix A.

The second questionnaire collected data pertaining to the particular athletes who sustained complete ACL ruptures. Athlete information included the following: year of eligibility during which the injury occurred, previous injuries sustained to the same knee, previous injuries sustained to the opposite knee, other structures injured at the time of the ACL rupture, specific rehabilitation programs (post-injury, pre-surgical, and/or post-surgical), type of surgery (if applicable), length of rehabilitation, compliance with rehabilitation, level of activity achieved upon completion of rehabilitation, and any type of bracing or support which was used. Athletic trainers

referred to athletic training room records to verify their recollections of the details of each athlete's case. A copy of the individual athlete data collection form is located in Appendix B. This form utilized typical abbreviations used in injury records to insure brevity. Instructions for completing the form were provided during telephone contact with the responding athletic trainers.

The data were analyzed using a personal computer based program, Simplified Statistics (Vincent, 1995), and the statistical software libraries of BMDP 2D, 8D, and 1V (Dixon, 1990). Descriptive data for pertinent factors were reported. Data collected on previous injuries to the knee did not lend itself to statistical analysis, discussion of the data was offered.

A student's t-test was performed to examine the differences in level of return to activity between athletes who were treated conservatively and those who were treated surgically. A student's t-test was also used to examine the effect of concomitant injuries on the level of return to activity an athlete is able to achieve following ACL rupture. Responding athletic trainers described level of return with a percentage comparing post-injury level with pre-injury level. In order to analyze that data the following scale was used: full competitive return ranked as one, 80 to 95% of previous level ranked as two, 70 to 75% of previous level ranked as three, and 50 to 65% of previous level ranked as four. This grouping system allowed parametric analysis of the level of return data. A complete breakdown of statistical analysis codes is listed in Appendix C.

An analysis of variance (ANOVA) was used to examine differences in incidence of ACL ruptures across NCAA divisions. An ANOVA was also performed to examine

the differences in level of return to activity among NCAA divisions.

Finally, a correlation was computed to measure the effects of the various prevention tactics on incidence of ACL ruptures.

CHAPTER 4**RESULTS**

Data were collected from ATCs at forty-eight institutions with intercollegiate women's basketball programs. Each NCAA division was represented by sixteen programs. If the ATC was able to provide accurate information, data were collected for the past six basketball seasons. All sixteen of the Division I (D-I) programs were able to provide six seasons of data, providing a total of ninety-six seasons. The Division II (D-II) programs were able to provide 73 seasons of data, and the Division III (D-III) programs were able to provide 82 seasons of data. A total of 251 seasons of data was available for evaluation. The representative schools and the seasons of data each provided are provided in Table 4 (page 41).

A total of 3,321 athletes participated on the basketball teams over the six year period ($\bar{x} = 13.23$ players/team/season). 1,278 were D-I ($\bar{x} = 13.31$ players/team/season), 982 were D-II ($\bar{x} = 13.45$ players/team/season), and 1061 were D-III ($\bar{x} = 12.94$ players/team/season).

Eighty-one ACL tears occurred in the six seasons surveyed (2.4% of participants). Nine teams reported no ACL tears during the time frame, five of those had data for all six seasons. One team with data for all six seasons reported seven ACL ruptures. Twenty-three (28.4%) injuries were to athletes in their first year of eligibility, seventeen (21.0%) to second year players, twenty-seven (33.3%) to third year athletes, thirteen (16.0%), to fourth year athletes, and one (1.2%) occurred to a

player in her fifth year of eligibility. Twenty-nine ACL ruptures occurred to D-I athletes, twenty-five were to D-II athletes, and 27 to D-III. The incidence of ACL tears for the entire population was .3227 ruptures/team/season. Incidence for D-I was .3021 ruptures/team/season, for D-II .3425 ruptures/team/season, and for D-III .3293 ruptures/team/season. One-way ANOVA indicated no significant difference in incidence among the three divisions ($F[2,248] = .1353, p = .8735$).

Eight athletes who tore their ACLs had previously injured the same knee (9.88%). Three had torn the medial meniscus, two had suffered isolated ACL injuries, two had sustained MCL/ACL injuries, and one had ACL and medial meniscus injury. Of the five with prior ACL injuries, two had PT-AUTO, one had SEMI, and two had arthroscopy without reconstruction. Two of these athletes did not return to play due to the knee injury, one was at the end of her eligibility, and two returned at a level judged by the ATC to be 80-95% of their pre-injury level. Both of those athletes had PT-AUTO.

Eleven athletes had previously sustained meniscal or ligamentous injury to their opposite knee (13.58%). One had injured her medial meniscus. Six had previously had an isolated ACL tear. Four of these athletes had the ACL reconstructed (three, PT-AUTO; one, SEMI). Four athletes had previous ACL/MCL injury. Three of those athletes had the ACL reconstructed (two, PT-AUTO; one, SEMI). Of the ten athletes with ACL tears to the opposite knee, four returned fully, four returned at 80-95% of their pre-injury level, one returned at 70-75% of her previous level, and one retired from competitive athletics. It is important to remember that these ten athletes were

coping with bilateral ACL injury.

These nineteen knees which had previous injury were distributed among seventeen athletes. One of the athletes who had sustained previous injuries to both knees had previously torn both ACLs. After the ACL injury which included her in this cohort, she retired from competitive athletics.

Thirty-nine athletes (48.15%) were reported to have damaged at least one other structure in their knee at the time of the index ACL injury. These concomitant injuries are listed in Table 5. Of these athletes, twenty-one (53.85%) returned to play competitive basketball. Two (5.13%) who did not return, retired because of their knee injuries. The others who did not return had exhausted their athletic eligibility (17.95%) or retired for personal reasons not related to their knees (23.07%).

Table 5. Incidence of Concomitant Injuries.

MM 13	MCL 9	MM/MCL 5	LM/MCL 4	LM 4	MM/LM 2	MM/LM/MCL 1	ALL OTHERS 1
----------	----------	-------------	-------------	---------	------------	----------------	-----------------

Of the forty-two athletes with isolated ACL injuries, thirty (71.43%) returned to competitive basketball. Three (7.14%) who retired, did so because of the ACL injury. The others who did not return had exhausted their eligibility (16.67%) or retired for personal reasons not related to their knees (4.76%).

A student's t-test was performed to examine the differences in level of return between those with isolated ACL tears and those with concomitant injuries. When measured on a one to four scale (one being 100% return and four being 50% return

compared to previous level of activity), there was no significant difference between the groups. The isolated ACL group had an average return of 1.500 and the concomitant injury group had an average return of 1.714 ($t[df=49] = 1.081, p = .285$). Concomitant injury did not significantly decrease the level of return of those athletes who chose to return.

Fifteen of the athletes (18.52%) attempted to return to play without having reconstruction of their ACL. Twelve of these were able to compete. Additionally, twelve of the fifteen subsequently underwent surgical reconstruction of the knee. Of the three who did not have surgical reconstruction, one had returned fully to competitive basketball without reconstruction, one had returned at 70-75% of her previous level to complete her final year of eligibility (she subsequently had arthroscopic surgery for meniscal injury, but no reconstruction), and one had been unable to compete and retired from basketball due to her knee injury.

If an athlete attempted conservative treatment and later underwent reconstruction of the ACL, her results were evaluated in both of the treatment categories. Sixty-four of the athletes (79.01%) had PT-AUTO, nine (11.11%) had SEMI, one athlete (1.23%) had a patellar tendon allograft, one (1.23%) had an extra articular repair, three (3.70%) had non-reconstructive arthroscopy, and three (3.70%) had no surgery on the knee.

A student's t-test was performed to examine the differences in level of return between those who were treated conservatively and those who were treated surgically. When measured on a one to four scale (one being 100% return and four being 50% return compared to previous level of activity), those who had surgical repair had a

significantly higher level of return. The surgical group had an average return of 1.577 while the conservative treatment group had an average return of 2.750 ($t[df=62] = 4.879, p = .000$). Surgical intervention significantly improved the level of return for those athletes who chose to return.

Return rates to competitive basketball based on NCAA division were examined with an ANOVA. For those athletes who had surgical intervention and returned to competitive basketball, there were no significant differences ($F(2,49) = 2.6874, p = .0781$). When measured on the one to four scale previously described, D-I had an average return score of 1.4737, D-II had an average return score of 1.8824 and D-III had an average return score of 1.3750. There was a trend indicating greater difficulty to return to D-II when compared to D-III. However no trend was noted between D-I and either of the other divisions.

The effect of routine strength training programs, pre-season strength screening, and technique modification on incidence of ACL tears was examined using Pearson's Product-moment correlation coefficient. No significant correlations were found between any of the prevention tactics, or any combinations of the prevention tactics and incidence of ACL tears.

Additional analysis of the prevention tactics used during the 251 reported seasons found that while all of the D-I programs did routine strength training, only 48.96% of them did pre-season screening, and only 10.42% routinely included technique modification. 86.3% of the D-II programs included routine strength training, 10.96% utilized pre-season strength screening, and 19.18% incorporated technique

modification into their training practices. For D-III, 76.83% did routine strength training, 7.32% utilized pre-season strength screening, and only 9.76% included technique modification. Of the three prevention tactics, only routine strength training was commonly included in the care of these athletes.

CHAPTER 5**DISCUSSION**

This study was conducted to determine which ACL intervention techniques best enhanced sport return rates and which injury prevention tactics were most effective in limiting injury rates among women basketball players at colleges and universities across the nation . It was also designed to determine whether significant differences exist between NCAA D-I, D-II, and D-III. It was hoped that examination of these factors would lead to recommendations regarding the effectiveness of prevention tactics and treatment choices.

The purposeful inclusion and examination of data from all three NCAA divisions made this research unique. The first research hypothesis was that D-I women's basketball programs would have a greater number of athletes sustaining ACL ruptures than would D-II or D-III programs. Since the level of competition is reputed to be different among the three divisions, it was logical to expect some differences in incidence of injury between them. This hypothesis, however, was not supported. The data reported by the NCAA (1996) also demonstrated a similar lack of variation. The overall incidence rate of ACL injuries found in this research was .3227 ruptures/team/season. Analysis of the NCAA data reported by Arendt and Dick (1995) found an incidence of 0.29 over a five year period. In another analysis of the NCAA data, Garrick and Requa (1996) extrapolate that an athlete on a typical women's basketball team will sustain an ACL tear approximately once every three seasons. The

findings from this study also support that estimate of injury rates.

Another research hypothesis which was not supported pertained to decreased likelihood of D-I players being able to return to their previous level of play when compared with D-II and D-III athletes. A lack of significant difference was found when examining differences in return to activity level among the three NCAA divisions. Although there was a trend toward D-II athletes having more difficulty returning than D-III athletes, the hypothesized decrease in return level of D-I athletes did not materialize. The lack of significant differences in incidence of injury and return to activity by NCAA division would seem to indicate that players who were injured are playing at an NCAA division level that is appropriate for their ability.

The second research hypothesis was that previous ligamentous or meniscal injuries would decrease the athlete's ability to return to intercollegiate basketball. Previous injuries to the same knee and previous injuries to the opposite knee did not appear to decrease the likelihood that an athlete would attempt to return to play basketball. Even bilateral ACL rupture only deterred one athlete from continuing in competitive basketball and that athlete had sustained her third ACL injury.

Likewise, concomitant injury had no significant effect on level of return to competitive basketball. The third research hypothesis was that injury to multiple structures in the knee at the time of the ACL rupture would decrease the athlete's level of performance if she returned to competitive basketball. Discussion in the literature suggests that joint stability and overall post-surgical success is decreased if multiple ligaments are affected, especially when the subjects are followed for several years

(Howe et al., 1991, Noyes & Barber-Westin, 1995). The subjects in this study, however, were able to effectively play intercollegiate basketball. Since follow-up on these athletes terminated when their basketball eligibility ended, this study could not address the possible deterioration of their results over time.

As was hypothesized, surgical repair of the knee did significantly improve the athlete's post-injury performance. The average performance score (based on a one to four scale) of the surgical treatment group who returned to competitive play was 1.17 points higher than the average performance score of the conservative treatment group who attempted to return to intercollegiate basketball. The use of the one to four scale, although not perfect, was an effective way to quantify level of return. The performance differences between treatment groups (i.e., conservative vs. surgical) was similar to the findings of numerous previous studies (Barrack et al., 1990; Buss et al., 1995; Giove et al., 1983; Noyes, Matthews et al., 1983, Noyes & McGiniss, 1985; Noyes et al., 1989; Puddu et al., 1984).

Although timing of the repair (Marcacci et al., 1995; Sgaglione et al., 1993; Shelbourne et al., 1990; Shelbourne et al., 1991; Shelbourne & Foulk, 1995; Wasilewski et al., 1993) and type of post-surgical rehabilitation (Bynum et al., 1990; Irrgang, 1993; Shelbourne et al., 1990; Shelbourne et al., 1991; Shelbourne & Nitz, 1990) have received a great deal of attention in previous research, they had no impact on the recovery results in this research since nearly every athlete followed a similar post-injury, pre-surgical, and post-surgical program. Reports on the success of delaying surgery at least three weeks from the time of the injury and following an "accelerated"

rehabilitation program have been given at numerous professional conferences and it appears that most sports medicine practitioners are adopting those protocols.

The final research hypothesis was that use of pre-season physical strength testing, routine strength training programs, and modification of cutting and jumping techniques would limit the incidence of ACL injuries. The lack of correlation between any of the prevention tactics, individually or in any combination, on incidence of ACL tears was the most surprising finding from this study. Further, the low percentage of use of pre-season screening and technique modification education was an interesting finding. Strict definitions of both pre-season strength testing and technique modification education were given to respondents. It is possible that some programs which actually do some form of pre-season screening or technique modification education misidentified their status in response to the strict definition. Hutchinson and Ireland (1995) discussed some success in reducing incidence of ACL injury following technique modification. Their research was prospective. Since this study was primarily retrospective, it is possible there was some error made by respondents in reporting past procedures.

As addressed in the introduction, there were some limiting factors associated with this study. Although the sample size was adequate, not all respondents were able to provide six seasons worth of data. The lower number of seasons reported for D-II and D-III limits the comparability of some findings among the three NCAA divisions. As the comparisons showed, D-II and D-III had a higher incidence of ACL ruptures and D-II had a lower level of return to play following ACL injury. This occurred despite having fewer total seasons reported and actually lends credibility to the measured lack

of significance.

The retrospective nature of the study, besides potentially affecting the reporting of prevention tactics, made it impossible to manipulate variables. This study is reporting common practices and their results. It was also impossible to measure many predisposing factors. Since most of the programs did not do pre-season strength testing, inadequate data were available regarding strength deficits and imbalances. The injury and subsequent treatment may have obscured some predisposing factors such as intercondylar notch width and shape, genu recurvatum, and Q-angle. It is reported by several researchers (Arendt & Dick, 1995; Lephart et al., 1992; Loudon et al., 1996; Wilk et al., 1994) that prospective studies addressing predisposition are currently in process. The results of these studies are awaited with interest.

The respondents to the questionnaires were the ATCs who worked most closely with the women's basketball team at each institution. Although the ATCs were very conscientious in responding to the questions, the long time-frame and the large numbers of athletes treated by these individuals in the six year span of this study, makes some reporting error possible. Additionally, questions regarding level of return to basketball might have been more accurately answered by the coach or the athlete. The level of compliance with the prevention tactics was impossible to quantify. Although the ATC could report if a formal pre-season and in-season strength training program was prescribed, there was no way to determine how hard an athlete worked at improving or even if each athlete on the team followed the program at all. Finally, the follow-up reported was of short duration. This research measured level of return to sport, not

long-term stability of the knee. Although respondents were asked if the athlete had any recurrent problems or injuries, affirmative answers did not influence the variables being reported for this study.

Suggestions for Future Research

The results of this study have raised some interesting questions. Future research that will address the effects of the purposeful inclusion of prevention tactics into the drills which are routinely utilized in teaching skills to women basketball players will provide useful information for coaches and ATCs. Additional research on levels of return following conservative and surgical treatment of ACL injuries in which coaches and athletes can provide the rating of level of return will also be of value. Long-term follow-up of athletes for several years after the completion of their collegiate basketball eligibility will allow exploration of their ability to maintain activity and will help in determining whether or not their early good results deteriorated with time. Long-term follow-up has tended to find deterioration of post-surgical results, especially if there was concomitant injury at the time of the ACL rupture (Howe et al., 1991; Noyes & Barber-Westin, 1995).

Prospective research on the factors predicting which athletes will have the greatest likelihood of good recovery following ACL injury is of interest. Factors which are of great interest in such predictive research are the athlete's commitment to the sport and the psychological impact of the injury on the athlete. Pre-injury measures of commitment and locus of control would contribute to such research.

The review of literature identified several other factors which could impact incidence of and recovery from ACL injury (Arendt & Dick, 1995; Garrick & Requa, 1996; Hutchinson & Ireland, 1995). Among these factors are years of basketball experience, playing position (forward, guard, center), fatigue level at the time of injury, playing surface (shoe/surface interface), and influence of the phase of the menstrual cycle. Future research should be structured to examine these areas.

Summary/Recommendations

ACL tears have been and continue to be a significant problem for women athletes. It has been shown that women basketball players have a substantially higher level of ACL tears than their male counterparts (Arendt & Dick, 1995). If a female athlete participates in a sport, such as basketball, which places high demand on the knee, she has more difficulty returning to her sport after a knee injury than an athlete who participates in a less demanding sport (Barrack et al., 1990; Giove et al., 1983; Noyes & McGiniss, 1985; Puddu et al., 1984) .

Research has shown that surgical intervention provides a greater likelihood of favorable recovery following an ACL tear. An accelerated rehabilitation program following surgical reconstruction has given excellent results. Any differences in incidence of ACL tears or level of return following such injuries between NCAA divisions is negligible. Likewise, previous ligamentous or meniscal injury to either knee and concomitant ligamentous or meniscal injury do not appear to reduce likelihood of effective recovery following ACL injury. It appears that the most important factor in

recovery is skillful reconstruction of the knee. This research confirms that collegiate women basketball players who wish to continue at a high level of activity should have their knee surgically reconstructed following an ACL rupture.

Techniques aimed at preventing ACL injuries, although interesting, are minimally performed by women basketball players. More exploration of appropriate and effective techniques is needed. Although the findings of this study regarding prevention tactics are inconclusive, the continued use of such activities is recommended. Since the activities are benign, and there is theoretical as well as limited experimental data that they may be helpful, the old adage "can't hurt, might help" can be applied to their use.

APPENDIX A

INSTITUTIONAL SURVEY INSTRUMENT

Year	# Players	# ACL Ruptures	Strength Prog.	Pre-season Test	Tech. Mod.
1990-91			Y / N	Y / N	Y / N
1991-92			Y / N	Y / N	Y / N
1992-93			Y / N	Y / N	Y / N
1993-94			Y / N	Y / N	Y / N
1994-95			Y / N	Y / N	Y / N
1995-96			Y / N	Y / N	Y / N

Instructions for completing form:

For each year that you are able to provide accurate data please indicate the following information:

- # Players Number of players on the roster that year.
 # ACL Ruptures Number of complete ACL tears sustained.
 Strength Prog Did the team do routine pre-season & in-season strength conditioning? Y=yes, N=no.
 Pre-season Test Did the team undergo routine pre-season strength screening to discover imbalances and deficits? Y=yes, N=no.
 Tech. Mod Did the coach include technique modifications in routine training in an effort to reduce risk of ACL injury? Y=yes, N=no.

APPENDIX B

INDIVIDUAL SURVEY INSTRUMENT

Yr/Inj	90-91	91-92	92-93	93-94	94-95	95-96
Yr/Sch	Fr	Soph	Jr	Sr	Grad	//////////
Prev Same	MM	LM	MCL	LCL	ACL	PCL
	Other		//////////	//////////	//////////	//////////
Prev Opp	MM	LM	MCL	LCL	ACL	PCL
	Other		//////////	//////////	//////////	//////////
Now	MM	LM	MCL	LCL	PCL	Other
Post-inj Rehab		Length		Comply	Type	
No Sx: Time to Return				No Sx: Level of Return		
Brace?	Type		Time	Tape?	Time	//////////
No Sx: Confidence in Knee at Return						
Pre-sx Rehab		Length		Comply	Type	
Surgical Type						
Post-sx Rehab		Length		Comply	Type	
Post sx: Time to Return				Post sx: Level of Return		
Brace?	Type		Time	Tape?	Time	//////////
Post sx: Confidence in Knee at Return						

Instructions for completing Individual Information Form

For each member of the women's basketball team who sustained a complete ACL rupture during the time of this study please indicate the following information:

- Yr/Inj Circle the basketball season during which the injury occurred.
- Yr/Sch Circle the academic level of the athlete at the time of injury.
- Prev Same Circle any structures which had been injured in the same knee prior to this injury. If other, indicate what structures were injured.
- Prev Opp Circle any structures which had been injured in the opposite knee prior to this injury. If other indicated what structures were injured.
- Now Indicate any structures which were injured at the same time as the ACL rupture which includes the athlete in this study.

Answer the following questions ONLY if the athlete attempted to return to basketball prior to undergoing surgical intervention.

- Post-inj Rehab Indicate (yes, no) if the athlete performed post-injury rehabilitation exercises.
- Length Indicate number of days of this rehab.
- Comply Indicate (fully, partially, not at all) if the athlete was compliant with this rehab.
- Type Briefly describe the type of rehab performed.
- No Sx: Time to Return If the athlete attempted to return to basketball without surgical intervention how long elapsed from injury to this attempt.
- No Sx: Level of Return Quantify the athlete's level of return as a percent of her pre-injury level of play.
- Brace? Did the athlete wear a brace: Yes, No.
- Type If yes, list the type of brace.
- Time For how long did she wear that brace?
- Tape? Was the athlete's knee taped: Yes, No.
- Time For how long did she get taped?
- No Sx: Confidence in Knee at Return Quantify the athlete's confidence in her knee compared with her pre-injury confidence.

Answer the following questions ONLY if the athlete had surgical reconstruction of her knee.

- Pre sx Rehab Indicate (yes, no) if the athlete performed pre-surgical rehabilitation exercises.
- Length Indicate number of days of this rehab.

Comply	Indicate (fully, partially, not at all) if the athlete was compliant with this rehab.
Type	Briefly describe the type of rehab performed.
Surgical type	Describe the type of surgical intervention performed on the athlete's knee.
Post-sx Rehab	Indicate (yes, no) if the athlete performed post-surgical rehabilitation exercises.
Length	Indicate number of days of this rehab.
Comply	Indicate (fully, partially, not at all) if the athlete was compliant with this rehab.
Type	Briefly describe the type of rehab performed.
Post Sx: Time to Return	If the athlete attempted to return to basketball following surgical intervention how long elapsed between the injury to this attempt.
Post Sx: Level of Return	Quantify the athlete's level of return as a percent of her pre-injury level of play.
Brace?	Did the athlete wear a brace: Yes, No.
Type	If yes, list the type of brace.
Time	For how long did she wear that brace?
Tape?	Was the athlete's knee taped: Yes, No.
Time	For how long did she get taped?
Post Sx: Confidence in Knee at Return	Quantify the athlete's confidence in her knee compared with her pre-injury confidence.

APPENDIX C

STATISTICAL ANALYSIS CODES

Surgery Types

- 0--None
- 1--ACL, patellar tendon
- 2--ACL, semitendinosus, intra-articular
- 3--ACL, other intra-articular
- 4--Allograft
- 5--ACL--extra-articular
- 6--Scope--meniscus
- 7--Scope--look, patello-femoral
- 9--Unknown information

Rehab Compliance

- 0--No rehab
- 1--Good compliance
- 2--Moderate compliance
- 3--Poor compliance
- 9--Unknown information

Support

- 0--None worn
- 1--Don Joy, custom (defiance)
- 2--Don Joy, off the shelf (gold point)
- 3--CTI
- 4--Bledsoe
- 5--Lennox Hill
- 6--Unknown derotation
- 7--Lateral support
- 8--Sleeve
- 9--Unknown information

Length of Time Support Used

- 0--None used
- 1--< 3 months
- 2--3-6 months
- 3--6-12 months
- 4--> 12 months

Level of Return

- 0--No return, due to injury
- 1--Full, competitive return
- 2--80-95% competitive return
- 3--70-75% competitive return
- 4--50-65% competitive return
- 5--Less stressful competitive sport
- 6--Recreational sports only
- 7--No return, end of eligibility
- 8--No return, personal reasons
- 9--Unknown information

Psychological Confidence in Knee

- 0--No Confidence
- 1--Excellent
- 2--80-95%, good
- 3--70-75%, ok
- 4--Poor
- 9--Unknown information

Post-surgical Rehabilitation Type

- 0--None done
- 1--Accelerated
- 2--Moderate
- 3--Conservative
- 4--Complicated
- 5--Brief, stopped short
- 9--Unknown information

Reinjuries

- 0--None prior to graduation
- 1--Reinjured ACL/repair
- 2--Injured meniscus
- 3--Patello-femoral problems
- 4--Capsule
- 9--Unknown information

REFERENCES

- Anderson, A. F., Snyder, R. B. and Lipscomb, Sr., A. B. (1994). Anterior cruciate ligament reconstruction using the semitendinosus and gracilis tendons augmented by the loose iliotibial band tenodesis. *The American Journal of Sports Medicine*, 22, 620-626.
- Andersson, C. and Gillquist, J. (1992). Treatment of acute isolated and combined ruptures of the anterior cruciate ligament. *The American Journal of Sports Medicine*, 20, 7-12.
- Arendt, E. and Dick, R. (1995). Knee injury patterns among men and women in collegiate basketball and soccer. *The American Journal of Sports Medicine*, 23, 694-701.
- Arnheim, D. D. and Prentice, W. E. (1997). *Principles of Athletic Training, 9th ed.* Madison, WI: Brown & Benchmark Publishers.
- Bach, Jr., B. R., Jones, G. T., Sweet, F. A. and Hager, C. A. (1994). Arthroscopy-assisted anterior cruciate ligament reconstruction using patellar tendon substitution. *The American Journal of Sports Medicine*, 22, 758-767.
- Barber, S. D., Noyes, F. R., Mangine, R. E., McCloskey, J. W. and Hartman, W. (1990). Quantitative assessment of functional limitation in normal and anterior cruciate ligament-deficient knees. *Clinical Orthopaedics and Related Research*, 255, 204-214.
- Barrack, R. L., Bruckner, J. D., Kneisl, J., Inman, W. S. and Alexander, A. H. (1990). The outcome of nonoperatively treated complete tears of the anterior cruciate ligament in active young adults. *Clinical Orthopaedics and Related Research*, 259, 192-199.
- Beard, D. J., Kyberd, P. J., Fergusson, C. M. and Dodd, C. A. F. (1993). Proprioception after rupture of the anterior cruciate ligament: an objective indication of the need for surgery? *The Journal of Bone and Joint Surgery*, 75B, 311-315.
- Berg, K., Blanke, D. and Miller, M. (1985). Muscular fitness profile of female college basketball players. *The Journal of Orthopaedic and Sports Physical Therapy*, 7(2), 59-64.

- Beynon, B. D., Johnson, R. J., Toyama, H., Renström, P. A., Arms, S. W. and Fischer, R. A. (1994). The relationship between anterior-posterior knee laxity and the structural properties of the patellar tendon graft. *The American Journal of Sports Medicine*, 22, 812-820.
- Bilko, T. E., Paulos, L. E., Feagin, J. A., Lambert, K. L. and Cunningham, H. R. (1986). Current trends in repair and rehabilitation of complete (acute) anterior cruciate ligament injuries. *The American Journal of Sports Medicine*, 14, 143-147.
- Bonamo, J. J., Fay, C. and Firestone, T. (1990). The conservative treatment of the anterior cruciate deficient knee. *The American Journal of Sports Medicine*, 18, 618-623.
- Booher, J. M. and Thibodeau, G. A. (1994). *Athletic Injury Assessment, 3rd ed.* St. Louis: Mosby-Year Book, Inc.
- Buss, D. D., Min, R., Skyhar, M., Galinat, B., Warren, R. F. and Wickiewicz, T. L. (1995). Nonoperative treatment of acute anterior cruciate ligament injuries in a selected group of patients. *The American Journal of Sports Medicine*, 23, 160-165.
- Bynum, E. B., Barrack, R. L. and Alexander, A. H. (1995). Open versus closed chain kinetic exercises after anterior cruciate ligament reconstruction. *The American Journal of Sports Medicine*, 23, 401-406.
- Ciccotti, M. G., Kerlan, R. K., Perry, J. and Pink, M. (1994). An electromyographic analysis of the knee during functional activities. Part I. The normal profile. *The American Journal of Sports Medicine*, 22, 645-650.
- Ciccotti, M. G., Kerlan, R. K., Perry, J. and Pink, M. (1994). An electromyographic analysis of the knee during functional activities. Part II. The anterior cruciate ligament-deficient and -reconstructed profiles. *The American Journal of Sports Medicine*, 22, 651-658.
- Clancy, W. G., Ray, J. M. and Zoltan, D. J. (1985). Acute third degree anterior cruciate ligament injury: a prospective study of conservative nonoperative treatment and operative treatment with repair and patellar tendon augmentation [Abstract]. *The American Journal of Sports Medicine*, 13, 435-436.
- Daniel, D. M., Stone, M. L., Dobson, B. E., Fithian, D. C., Rossman, D. J. and Kaufman, K. R. (1994). Fate of the ACL-injured patient. *The American Journal of Sports Medicine*, 22, 632-644.

- Davies, G. J. (editor). (1984). *Rehabilitation of the Surgical Knee*. Ronkonkoma, NY: CYBEX.
- DeHaven, K. E. and Lintner, D. M. (1986). Athletic Injuries: Comparison by Age, Sport, and Gender. *The American Journal of Sports Medicine*, 14, 218-224.
- Dick, R. W. and Arendt, E. (1993). Gender specific knee injury patterns in collegiate basketball and soccer athletes [Abstract]. *Medicine and Science in Sport and Exercise*, 25 (supplement), S159.
- Dixon, W. J. (Chief editor), Brown, M. B., Engelman, L. and Jennrich, R. I. (Ass't editors). (1990). *BMDP Statistical Software Manual, Volume 1*. Berkeley, CA: University of California Press.
- Ferretti, A., Papandrea, P. Conteduca, F. and Mariani, P. P. (1992). Knee ligament injuries in volleyball players. *The American Journal of Sports Medicine*, 20, 203-207.
- Fetto, J. F. and Marshall, J. L. (1980). The natural history and diagnosis of anterior cruciate ligament insufficiency. *Clinical Orthopaedics and Related Research*, 147, 29-38.
- Fridén, T., Egund, N. and Lindstrand, A. (1993). Comparison of symptomatic versus nonsymptomatic patients with chronic anterior cruciate ligament insufficiency. *The American Journal of Sports Medicine*, 21, 389-393.
- Garrick, J. G. and Requa, R. K. (1978). Girls sports injuries in high school athletics. *The Journal of the American Medical Association*, 239, 2245-2248.
- Garrick, J. G. and Requa, R. K. (1996). ACL injuries: gender inequality. *Sports Medicine Update, Spring*, 6-7.
- Giove, T. P., Miller, S. J., Kent, B. E., Sanford, T. L. and Garrick, J. G. (1983). Nonoperative treatment of the torn anterior cruciate ligament. *The Journal of Bone and Joint Surgery*, 65A, 184-192.
- Gomez, E., DeLee, J. C. and Farney, W. C. (1996). Incidence of injury in Texas girls' high school basketball. *The American Journal of Sports Medicine*, 24, 684-687.
- Good, L., Odensten, M. and Gillquist, J. (1994). Sagittal knee stability after anterior cruciate ligament reconstruction with a patellar tendon strip. *The American Journal of Sports Medicine*, 22, 518-523.

- Grana, W. A. and Muse, G. (1988). The effect of exercise on laxity in the anterior cruciate ligament deficient knee. *The American Journal of Sports Medicine*, 16, 586-588.
- Gray, J., Taunton, J. E., McKenzie, D. C., Clement, D. B., McConkkey, J. P. and Davidson, R. G. (1985). A survey of injuries to the anterior cruciate ligament of the knee in female basketball players. *International Journal of Sports Medicine*, 6, 314-316.
- Greenfield, B. H. (1993). *Rehabilitation of the Knee: A Problem-Solving Approach*. Philadelphia: F. A. Davis Company.
- Griffin, L. Y. (editor). (1995). *Rehabilitation of the Injured Knee, 2nd ed.* St. Louis: Mosby-Year Book, Inc.
- Hall, S. J. (1995). *Basic Biomechanics, 2nd. ed.* St. Louis: Mosby-Year Book, Inc.
- Hawkins, R. J., Misamore, G. W. and Merritt, T. R. (1986). Follow-up of the acute non-operated isolated anterior cruciate ligament tear. *The American Journal of Sports Medicine*, 14, 205-210.
- Haycock, C. E. and Gillette, J. V. (1976). Susceptibility of women athletes to injury, myths vs. reality. *The Journal of the American Medical Association*, 236, 163-165.
- Howe, J. G., Johnson, R. J., Kaplan, M. J., Fleming, B. and Jarvinen, M. (1991). Anterior cruciate ligament reconstruction using quadriceps patellar tendon graft. *The American Journal of Sports Medicine*, 19, 447-457.
- Hutchinson, M. R. and Ireland, M. L. (1995). Knee injuries in female athletes. *Sports Medicine*, 19, 288-302.
- Ihara, H. and Nakayama, A. (1986). Dynamic joint control training for knee ligament injuries. *The American Journal of Sports Medicine*, 14, 309-315.
- Ireland, M. L. and Wall, C. (1990). Epidemiology and comparison of knee injuries in elite male and female United States basketball athletes [Abstract]. *Medicine and Science in Sports and Exercise*, 22(supplement), S582.
- Irrgang, J. J. (1993). Anterior cruciate ligament reconstruction: nonoperative and postoperative management. *Clinics in Sports Medicine*, 12, 796-811.

- Jackson, D. W. and Drez, D. (1987). *The Anterior Cruciate Deficient Knee: New Concepts in Ligament Repair*. St. Louis: The C. V. Mosby Company.
- Kannus, P., Järvinen, M., Johnson, R., Renström, P., Pope, M., Beynnon, B., Nichols, C. and Kaplan, M. (1992). Function of the quadriceps and hamstrings muscles in knees with chronic partial deficiency of the anterior cruciate ligament. *The American Journal of Sports Medicine*, 20, 162-168.
- Kaplan, M. J., Howe, J. G., Fleming, B., Johnson, R. J. and Järvinen, M. (1991). Anterior cruciate ligament reconstruction using quadriceps patellar tendon graft. *The American Journal of Sports Medicine*, 19, 458-462.
- Karlson, J. A., Steiner, M. E., Brown, C. H. and Johnston, J. (1994). Anterior cruciate ligament reconstruction using gracilis and semitendinosus tendons. *The American Journal of Sports Medicine*, 22, 659-666.
- Kendall, F. P., McCreary, E. K. and Provance, P. G. (1993). *Muscles: Testing and Function, 4th ed.* Baltimore: Williams and Wilkins.
- Knapik, J. J., Bauman, C. L., Jones, B. H., Harris, J. M. and Vaughan, L. (1991). Preseason strength and flexibility imbalances associated with athletic injuries in female collegiate athletes. *The American Journal of Sports Medicine*, 19, 76-81.
- Lanese, R. R., Strauss, R. H., Leizman, D. J. and Rotondi, A. M. (1990). Injury and disability in matched men's and women's intercollegiate sports. *American Journal of Public Health*, 80, 1459-1462.
- Lephart, S. M., Perrin, D. H., Fu, F. H., Gieck, J. H., McCue, III, F. C. and Irrgang, J. J. (1992). Relationships between selected physical characteristics and functional capacity in the anterior cruciate ligament-insufficient athlete. *The Journal of Orthopaedic and Sports Physical Therapy*, 16(4), 174-181.
- Loudon, J. K., Jenkins, W. and Loudon, K. L. (1996). The relationship between static posture and ACL injury in female athletes. *The Journal of Orthopaedic and Sports Physical Therapy*, 24(2), 91-97.
- Malone, T. R., Hardaker, W. T., Garrett, W. E., Feagin, J. A. and Bassett, F. H. (1993). Relationship of gender to anterior cruciate ligament injuries in intercollegiate basketball players. *Journal of Southern Orthopaedic Association*, 2, 36-38.

- Marcacci, M., Zaffagnini, S., Iacono, F., Neri, M. P. and Petitto, A. (1995). Early versus late reconstruction for anterior cruciate ligament rupture. *The American Journal of Sports Medicine*, 23, 690-693.
- McCallum, J. (1995). Out of Joint. *Sports Illustrated*, 82(6), 44-53.
- McCarrol, J. R., Shelbourne, K. D. and Patel, D. V. (1995). Anterior cruciate ligament injuries in young athletes: recommendations for treatment and rehabilitation. *Sports Medicine*, 20, 117-127.
- McDaniel, W. J. and Dameron, T. B. (1980). Untreated ruptures of the anterior cruciate ligament: a follow-up study. *The Journal of Bone and Joint Surgery*, 62A, 696-705.
- Moore, J. R. and Wade, G. (1989). Prevention of anterior cruciate ligament injuries. *National Strength and Conditioning Association Journal*, 11(3), 35-40.
- Morrison, N. L., Boyd, H. S. and Boyd, L. A. (1988). [Comparison of division I and division III women's basketball injury rates]. Unpublished data.
- National Collegiate Athletic Association. (1989). *1988-89 Women's Basketball Injury Surveillance System*. Mission, KS.
- National Collegiate Athletic Association. (1990). *1989-90 Women's Basketball Injury Surveillance System*. Mission, KS.
- National Collegiate Athletic Association. (1991). *1990-91 Women's Basketball Injury Surveillance System*. Mission, KS.
- National Collegiate Athletic Association. (1992). *1991-92 Women's Basketball Injury Surveillance System*. Mission, KS.
- National Collegiate Athletic Association. (1993). *1992-93 Women's Basketball Injury Surveillance System*. Mission, KS.
- National Collegiate Athletic Association. (1994). *1993-94 Women's Basketball Injury Surveillance System*. Mission, KS.
- National Collegiate Athletic Association. (1995). *1994-95 Women's Basketball Injury Surveillance System*. Mission, KS.

- National Collegiate Athletic Association. (1996). *1995-96 Women's Basketball Injury Surveillance System*. Mission, KS.
- Noyes, F. R., Barber, S. D. and Mooar, L. A. (1989). A rationale for assessing sports activity levels and limitations in knee disorders. *Clinical Orthopaedics and Related Research*, 246, 238-249.
- Noyes, F. R. and Barber-Westin, S. D. (1995). The treatment of acute combined ruptures of the anterior cruciate and medial ligaments of the knee. *The American Journal of Sports Medicine*, 23, 380-391.
- Noyes, F. R., Matthews, D. S., Mooar, P. A. and Grood, E. S. (1983). The symptomatic anterior cruciate-deficient knee. Part II. The results of rehabilitation, activity modification, and counseling on functional disability. *The Journal of Bone and Joint Surgery*, 65A, 163-174.
- Noyes, F. R. and McGiniss, G. H. (1985). Controversy about treatment of the knee with anterior cruciate laxity. *Clinical Orthopaedics and Related Research*, 198, 61-76.
- Noyes, F. R., Mooar, P. A., Matthews, D. S. and Butler, D. L. (1983). The symptomatic anterior cruciate-deficient knee. Part I. The long-term functional disability in athletically active individuals. *The Journal of Bone and Joint Surgery*, 65A, 154-162.
- O'Connor, J. J. (1993). Can muscle co-contraction protect knee ligaments after injury or repair? *The Journal of Bone and Joint Surgery*, 75B, 41-48.
- Odensten, M., Lysholm, J. and Gillquist, J. (1985). The course of partial anterior cruciate ligament ruptures. *The American Journal of Sports Medicine*, 13, 183-186.
- Odensten, M., Hamberg P., Nordin, M., Lysholm, J. and Gillquist, J. (1985). Surgical or conservative treatment of the acutely torn anterior cruciate ligament. *Clinical Orthopaedics and Related Research*, 198, 87-93.
- Oliphant, J. G. and Drawbert, J. P. (1996). Gender differences in anterior cruciate ligament injury rates in Wisconsin intercollegiate basketball. *Journal of Athletic Training*, 31, 245-247.
- Pfeiffer, R. P. and Mangus, B.C. (1995). *Concepts of Athletic Training*. Boston: Jones and Bartlett Publishers.

- Potera, C. (1986). Women in sports: the price of participation. *The Physician and Sportsmedicine*, 14(6), 149-153.
- Puddu, G., Ferretti, A., Mariani, P. and LaSpesa, F. (1984). Meniscal tears and associated anterior cruciate ligament tears in athletes: course of treatment. *The American Journal of Sports Medicine*, 12, 196-203.
- Risberg, M. A. and Ekeland, A. (1994). Assessment of functional tests after anterior cruciate ligament surgery. *The Journal of Orthopaedic and Sports Physical Therapy*, 19(4), 212-217.
- Rochman, S. Gender inequity. (1996). *Training and Conditioning*, 6(5), 11-20.
- Rougraff, B., Shelbourne, K. D., Gerth, P.K. and Warner, J. (1993). Arthroscopic and histologic analysis of human patellar tendon autografts used for anterior cruciate ligament reconstruction. *The American Journal of Sports Medicine*, 21, 277-284.
- Rubinstein, Jr., R. A., Shelbourne, K. D., VanMeter, C. D., McCarroll, J. R., Rettig, A. C. and Gloyeske, R. L. (1995). Effect on knee stability if full hyperextension is restored immediately after autogenous bone-patellar tendon-bone anterior cruciate ligament reconstruction. *The American Journal of Sports Medicine*, 23, 365-368.
- Sgaglione, N. A., Pizzo, W. D., Fox, J. M. and Friedman, M. J. (1993). Arthroscopically assisted anterior cruciate ligament reconstruction with the pes anserine tendons. *The American Journal of Sports Medicine*, 21, 249-256.
- Shambaugh, J. P., Klein, A. and Herbert, J. H. (1991). Structural measures as predictors of injury in basketball players. *Medicine and Science in Sports and Exercise*, 23, 522-527.
- Shelbourne, K. D. and Foulk, D. A. (1995). Timing of surgery in acute anterior cruciate ligament tears on the return of quadriceps muscle strength after reconstruction using an autogenous patellar tendon graft. *The American Journal of Sports Medicine*, 23, 686-689.
- Shelbourne, K. D. and Nitz, P. (1990). Accelerated rehabilitation after anterior cruciate ligament reconstruction. *The American Journal of Sports Medicine*, 18, 292-299.

- Shelbourne, K. D., Rubinstein, Jr., R. A., VanMeter, C. D., McCarroll, J. R. and Rettig, A. C. (1994). Correlation of remaining patellar tendon width with quadriceps strength after autogenous bond-patellar tendon-bone anterior cruciate ligament reconstruction. *The American Journal of Sports Medicine*, 22, 774-778.
- Shelbourne, K. D., Whitaker, H. J., McCarroll, J. R., Rettig, A. C. and Hirschman, L. D. (1990). Anterior cruciate ligament injury: evaluation of intraarticular reconstruction of acute tears without repair. Two to seven year follow-up of 155 athletes. *The American Journal of Sports Medicine*, 18, 484-489.
- Shelbourne, K. D., Wilckens, J. H., Mollabashy, A. and DeCarlo, M. (1991). Arthrofibrosis in acute anterior cruciate ligament reconstruction. *The American Journal of Sports Medicine*, 19, 332-336.
- Shively, R. A., Grana, W. A. and Ellis, D. (1981). High school sports injuries. *The Physician and Sportsmedicine*, 9(8), 46-50.
- Simonet, W. T. and Sim, F. H. (1984). Current concepts in the treatment of ligamentous instability of the knee. *Mayo Clinic Proceedings*, 59, 67-76.
- Skinner, H. B., Wyatt, M. P., Stone, M. L., Hodgdon, J. A. and Barrack, R. L. (1986). Exercise-related knee joint laxity. *The American Journal of Sports Medicine*, 14, 30-34.
- Starkey, C. and Ryan, J. L. (1996). *Evaluation of Orthopedic and Athletic Injuries*. Philadelphia: F. A. Davis Company.
- Steiner, M. E., Grana, W. A., Chillag, K. and Scheiberg-Karnes, E. (1986). The effect of exercise on anterior-posterior knee laxity. *The American Journal of Sports Medicine*, 14, 24-29.
- Tibone, J. E., Antich, T. J., Fanton, G. S., Moynes, D. R. and Perry, J. (1986). Functional analysis of anterior cruciate ligament instability. *The American Journal of Sports Medicine*, 14, 276-284.
- Vincent, W. J. (1995). *Statistics in Kinesiology*. Champaign, IL: Human Kinetics.
- Walla, D. J., Albright, J. P., McAuley, E., Martin, R. K., Eldridge, V. and El-Khoury, G. (1985). Hamstring control and the unstable anterior cruciate ligament-deficient knee. *The American Journal of Sports Medicine*, 13, 34-39.

- Wasilewski, S. A., Covall, D. J. and Cohen, S. (1993). Effect of surgical timing on recovery and associated injuries after anterior cruciate ligament reconstruction. *The American Journal of Sports Medicine*, 21, 338-342.
- Weesner, C. L., Albohm, M. J. and Ritter, M. A. (1986). A comparison of anterior and posterior cruciate ligament laxity between female and male basketball players. *The Physician and Sportsmedicine*, 14(5), 149-154.
- Weiss, M. and Troxel, R. K. (1986). Psychology of the injured athlete. *Athletic Training*, 21, 104-109.
- Whiteside, P. A. (1980). Mens's and women's injuries in comparable sports. *The Physician and Sportsmedicine*, 8(3), 130-140.
- Wilk, K. E., Romaniello, W. T., Soscia, S. M., Arrigo, C. A. and Andrews, J. R. (1994). The relationship between subjective knee scores, isokinetic testing, and functional testing in the ACL-reconstructed knee. *The Journal of Orthopaedic and Sports Physical Therapy*, 20(2), 60-73.
- Wirtz, P. D. (1982). High school basketball knee ligament injuries. *Journal of the Iowa Medical Society*, 72, 105-106.
- Wojtys, E. M., Wylie, B. B. and Huston, L. J. (1996). The effects of muscle fatigue on neuromuscular function and anterior tibial translation in healthy knees. *The American Journal of Sports Medicine*, 24, 615-621.
- Yasuda, K., Tsujino, J., Ohkoshi, Y., Tanabe, Y. and Kaneda, K. (1995). Graft site morbidity with autogenous semitendinosus and gracilis tendons. *The American Journal of Sports Medicine*, 23, 706-714.
- Zavatsky, A. B., Beard, D. J. and O'Connor, J. J. (1994). Cruciate ligament loading during isometric muscle contractions. *The American Journal of Sports Medicine*, 22, 418-423.
- Zelisko, J. A., Noble, H. B. and Porter, M. (1982). A comparison of men's and women's professional basketball injuries. *The American Journal of Sports Medicine*, 10, 297-299.
- Zillmer, D. A., Powell, J. W. and Albright, J. P. (1992). Gender-specific injury patterns in high school varsity basketball. *The Journal of Women's Health*, 1, 69-76.