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ACL Injuries in the Female Athlete

Mary Lloyd Ireland, Michael Gaudette, and Scott Crook

The high rate of noncontact ACL injuries in female athletes has become a prominent and controversial subject. This article attempts to provide insight into this trend in athletic injuries. Anatomic, physiological, and biomechanical differences are discussed as possible causative factors. Epidemiological data regarding ACL injuries are reviewed, comparing the genders. The discussion also includes anecdotal findings that support current research. This review is intended to raise awareness of the problem and promote screening for risk factors and implementation of more thorough and aggressive preventive programs.

She plays, she jumps, she lands, she hears a pop. Why are we seeing an increased rate of noncontact ACL tears in the female athlete? Is it alignment? Is it physiological laxity? Is it lack of strength, balance, and conditioning? Is it hormonal influence? Or is it all of the above? Surgically, the injured knee can be stabilized ligamentously but cannot be made normal. When the athlete's ACL-injured side is reconstructed, she is more likely to tear the opposite ACL. Does this happen because she is now placing more stress on the uninjured knee, because the ACL-reconstructed ligament is bigger and stronger, because the reconstructed side has greater strength and neuromuscular control following rehabilitation, or because she is unlucky and uncoordinated?

In the past, many female knee injuries were written off as chondromalacia or patellofemoral problems. Were ACL injuries misdiagnosed or were female injuries just not taken seriously enough? In the military, stress fractures occurred more often when women first entered, but rates have now equalized (11). However, the rates of ACL tears in the female athlete are not equalizing. Has the problem of ACL tears in female athletes always existed at the present level, or has the increasing number of female participants shed new light on an old problem?

In 1972, the Title IX ruling of the Education Assistance Act was passed, ensuring equal rights to male and female athletes at federally funded institutions. Since that time, there has been a significant increase in female participants in all sports and at all levels. Prior to Title IX, there were fewer than 10,000 female college athletes. Within 20 years, that number had risen to nearly 100,000 women

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competing for nearly 10,000 athletic scholarships totaling a net worth of over 51 million dollars (21). In 1994–95, the National Collegiate Athletic Association (NCAA) reported 186,607 male participants and 107,605 female participants in 16 sports (37). Despite this increase in the number of sports offered and the number of females participating, it is clear that there has been a lack of equality in appropriated funds, research, coaching, and conditioning resources for female athletes (18). Could the disparity in ACL injuries between the sexes reflect the historical inequality in athletics?

Epidemiology

Knee injury rates of males and females have been compared at the high school, collegiate, recreational, and elite levels. Previously reported data indicated that the injury rates tended to be more related to the sport than to gender (8). Collins, whose study involved female flag football players, drew conclusions that seem to be geared more toward recreational sports than intercollegiate or professional sports (9). Collins felt that the participants sustained injuries due to their lack of experience and the skill demanded by the sport. In other words, these recreational athletes were learning the skill during the competition, and in the process they became injured. The article was published in 1987, and more recent information seems to refute its conclusions.

Zilmer et al. found no significant difference between male and female high school basketball players regarding injury rates during practice, but females had a greater injury rate in games with 58% of injuries involving the knee. The authors also reported that male participants were more likely to sustain minor knee injuries, whereas females were more likely to sustain moderate knee injuries resulting in greater time lost from sport (44). Garrick and Requa showed three times more injuries in practice than in games, with 59% of injured athletes returning to play within 1 week (17). Gomez et al. showed that one half of all injuries occur during games (19).

Some authors have compared the incidence of knee injuries in high school athletes participating in girls' basketball and boys' football. The knee surgery rate was determined as the percentage number of knee surgeries divided by the number of participants. Statistically, the surgery rate was significantly greater in girls' basketball compared to boys' football (Table 1) (13, 19, 22). Harrer et al. reported that at the high school level, the female basketball athlete was 2.6 times more likely to injure the ACL compared to the male (22).

Although ankle and patellofemoral problems account for more injuries, ACL injuries are the most devastating due to the greater cost of care and the amount of time lost from sport (19, 43). Time loss is much less with ankle and patellofemoral problems because they are much more likely to respond to conservative care and rehabilitation (20). While there remain some differences in rank order depending on the sample studied, it appears that female soccer players, gymnasts, and basketball players are at the greatest risk for an ACL injury (3, 11, 12, 17–19, 36, 37, 41, 43, 44). Female basketball players are 5–8 times more likely to sustain an ACL injury than their male counterparts (20, 35).

Yearly, the NCAA surveys 18% of its member institutions in 16 different sports. In a recent report, male and female injury rates were compared in soccer and basketball (1). In soccer players, the female to male ratio of ACL tears was 2:4

Table 1 Texas High School Study

	Football[a]	Girls' basketball[b]
Number schools	100	80
Number athletes	4,399	890
Number injuries	2,228	436
Number (%) injuries		
Serious injuries	137	34
Surgery	97 (71)	25 (74)
Knee surgery	59 (61)	16 (76)
Cruciate injury	37 (63)	11 (69)
Injury rate per athlete per season		
Overall	.51	.49
Severe	.031	.038
Exposure per player per hour		
Overall	.003	.0041
Severe	.0002	.00035
Knee surgery rate		
Percentage number knee surgeries/participants	.0134	.0180

[a]Adapted from J.C. DeLee and W.C. Farney. Incidence of injury in Texas high school football. *Am. J. Sports Med.* 20(5): 575-580, 1992.
[b]Adapted from E. Gomez, J.C. DeLee, and W.C. Farney. Incidence of injury in Texas girls' high school basketball. *Am. J. Sports Med.* 24(5): 684-687, 1996.

overall; for noncontact ACL tears, there was a 3:4 ratio. Basketball showed a 4:1 female to male ratio in overall ACL tears and a 5:3 ratio in noncontact injuries (Table 2).

In the U.S., female soccer and basketball athletes sustain the greatest numbers of noncontact ACL tears. In Europe, females experience 3–4 times the number of injuries compared to males in skiing and team handball (personal communication, ACL Study Group, 1996).

An extensive questionnaire was filled out by all U.S. participants in the 1988 Olympic Trials. These 80 males and 64 females were the elite athletes in the U.S. as judged by their coaches. Three of the 80 males and 13 of the 64 females had sustained an ACL tear. Six of the males required six knee surgeries and 20 of the females required 25 knee surgeries. The number of knee injuries and need for surgery was statistically greater in the female athletes (Table 3) (25, 28). Of the participants, 2.5% of the males compared to 12.5% of the females had undergone ACL reconstruction.

Male and Female Differences

There are more differences between men and women than just physical size. The female has a wider pelvis, increased femoral anteversion, less muscular

Table 2 Knee Injuries Reported by the NCAA—1989–93 (Number of Injuries per 1,000 Athletic Exposures)

	Soccer			Basketball		
	Females	Males	F:M Ratio	Females	Males	F:M Ratio
ACL	$.31^a$	.13	2.4*	$.29^b$	.07	4.1*
Noncontact	$.17^a$	.05	3.4	$.21^b$	.04	5.3
Knee (overall)	1.6^a	1.3	1.2	1.0^b	.7	1.4

Note. Adapted from E. Arendt and R. Dick. Knee injury patterns among men and women in collegiate basketball and soccer. NCAA data and review of literature. *Am. J. Sports Med.* 23(6): 694-701, 1995.
*Statistically significant. Like superscripts indicate significant differences, $p < .05$.

Table 3 Injuries Sustained During 1988 Olympic Basketball Trial

Parameter	Males	Females	Total
Number of participants	80	64	144
Athletes with knee injuries	11*	34	45
ACL injuries	3	13	16
Number of athletes requiring surgery	6**	20	26
Number of procedures	6	25	31
Type of procedure			
Arthroscopy	3	17	20
ACL reconstruction	3	8	11

Note. From "Knee Injuries in Female Athletes," by M.R. Hutchinson and M.L. Ireland, 1995, *Sports Medicine*, **19** (4), p. 296. © 1995 Adis International Ltd., Auckland, New Zealand. Reprinted with permission.
Statistically significant difference between male and female athletes: $*p < .0001$, $**p < .0007$.

development, a less developed vastus medialis obliquus, increased flexibility, increased genu recurvatum and genu valgum, a more narrow intercondylar notch, more external tibial torsion, and more forefoot pronation (Figure 1A).

A wider pelvis can create several potential biomechanical alignment problems for the female athlete. Structurally, there is a greater coxa varum/genu valgum alignment with a concurrent rotational force at the tibiofemoral joint. This component is common to both pronation in the lower extremity and the ACL injury mechanism. Hip weakness can allow additional femoral internal rotation to occur both too fast and too far, forcing more rotational stress on the knee and compensatory pronation at the foot and ankle. Tibial, rearfoot, and forefoot varum can cause excessive pronation. Approximately 85% of the general population have a varus

rearfoot–forefoot malalignment, although there is no significant difference between males and females or in right to left comparisons (16).

Males have a more narrow pelvis, more developed musculature with vastus medialis obliquus (VMO) hypertrophy, less flexibility, more muscle dominant genu varum, a wider intercondylar notch, and more internal or neutral tibial torsion (27) (Figure 1B).

Genu recurvatum, along with hyperextension at other joints in the body, generally indicates increased joint laxity. Genu recurvatum results in an impingement of the ACL in the intercondylar notch and increases the tensile strain on the ACL. Loudon et al. (34) showed a high correlation between genu recurvatum and ACL injuries, while Woodford-Rogers et al. (42) found anterior knee laxity to be highly correlated to ACL injuries.

Females have more hamstring flexibility than males across all age groups (10, 38), which may predispose them to hyperextension on landing. The position of knee flexion during landing will determine the mechanical ability of the quadriceps to act eccentrically. The quadriceps plays a major role in controlling the deceleration of landing to limit abnormal forces through the knee. Equally important from a biomechanical perspective is that the hamstrings need to fire quickly to help stabilize the knee during the aggressive landings associated with sports (6, 23). Inability to decelerate the hip, knee, or ankle in all planes of motion is a major factor in ACL tears.

Athletic females tend to have less ligamentous laxity than nonathletic females. It has been hypothesized that ligamentous laxity may have as much to do with conditioning as it does with genetics (5, 30). While Jones (30) showed no relationship between laxity and injuries, other authors have reported a correlation

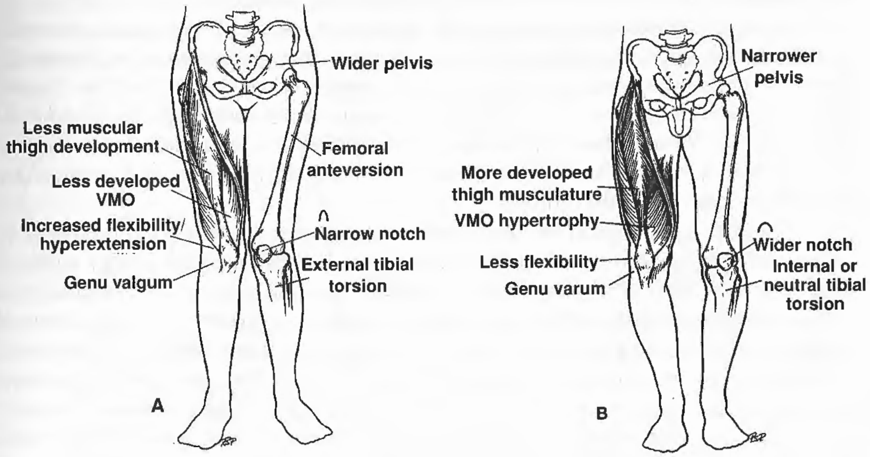

Figure 1 — Lower extremity alignments that may predispose athletes to overuse problems of the hips and knees, especially ACL and patellofemoral injuries: (A) females, (B) males. From *Sports Injuries: Mechanisms, Prevention, Treatment* (p. 154), by F.H. Fu and D.A. Stone, 1994, Philadelphia: Williams & Wilkins. ©1994 by Williams & Wilkins. Reprinted with permission.

(23, 42). Beck and Wildermuth (5) found that females are more vulnerable to overuse and noncontact ACL injuries. Females tend to be more ligament dominant, relying more on their ligaments for support. Males tend to be more muscle dominant, relying on muscle mass as a major support for their joints. However, the absolute strength of an athlete may not be as important as neuromuscular firing order and timing (24). Likewise, overtraining the quadriceps from both a strength and a neuromuscular perspective without a parallel development of the hamstrings could potentially cause more harm to the female athlete's knee. Further proprioceptive assessment and training devices are needed to determine a more exact correlation between strength, neuromuscular control, and ACL injuries.

Risk factors have recently been studied prospectively, and there appears to be a high correlation between a positive navicular drop test and ACL injuries. Navicular height is taken in a seated, subtalar joint neutral position and again in a full weight-bearing, compensated position. The difference, recorded as the navicular drop, indicates the degree of pronation. ACL-injured subjects demonstrated an 8.4 mm navicular drop, while non-ACL-injured subjects dropped 5.9 mm (34, 42).

The static pelvic position has shown some correlation with ACL injuries (34). In the absence of appropriate strength or neuromuscular control, gravity will cause the pelvis to assume an anterior tilt. This position not only negatively affects the lumbosacral spine and sacroiliac (SI) joints but also influences lower extremity position by causing the gluteus medius and hip external rotators to work harder to maintain a neutral lower extremity alignment as opposed to assuming an internally rotated position. Hamstring flexibility appears to have no influence on standing pelvic posture; Li et al. reported that as hamstring muscle length increased, there was no concomitant improvement in pelvic posture (32). However, Li et al. did not look at the neuromuscular component and the effect of an education and strengthening program on maintaining better pelvic posture.

Factors that can be seen or easily measured, such as limb length, strength, power, aerobic capacity, and flexibility, are important components of performance. However, psychological factors should be considered in the care of the female athlete. Past surveys have shown that men play sports for the competition and their desire to win. Women have historically participated in sports more for socialization (6). More recent studies show that this trend is changing, and women are reporting more motivation to win.

Strength gain, cardiovascular fitness, and proprioception are ingredients to being well prepared for participation in any sport. The specific energy systems used in the sport should be stressed to improve their efficiency and endurance as well as the efficiency and endurance of the neuromuscular system. Cox et al. showed that females improve their initial level of fitness faster than males (11). However, this is probably due to their lower initial levels of fitness. Females have been shown to improve their strength by 44% without a significant increase in muscle mass.

Research is presently being done regarding hormonal influence on ligaments. There are estrogen and progesterone receptors on the ACL, but the effect or level of activity of those receptors is not well understood. Liu et al. showed that estrogen inhibits collagen synthesis and proliferation of ACL fibroblasts in vitro (33). Can the ACL adapt to the stresses placed on it? Monthly hormonal changes may have a small effect on collagen tissue; however, this is unlikely to be a major factor contributing to ACL tears. Anecdotally, many females will state that an ACL injury occurred a couple of days before menses. The hormone relaxin produced during pregnancy certainly increases ligamentous laxity, especially the pubic symphysis. Collagen tissues change with age and with changing hormonal levels. The hyperlaxity phase in young females, characterized by patellar hypermobility and physiological shoulder laxity, progresses to gradual tightening of retinacular structures of the knee and adhesive capsulitis of the shoulder in the perimenopausal and menopausal ages.

A relationship has been shown between having a small intercondylar notch and sustaining an ACL tear (31, 39, 40). These studies did not show a difference between genders for notch width index (ratio of intercondylar notch width to the width of the distal femur at the level of the popliteal groove on the tunnel view). Measurement of the notch width or notch width ratio is two-dimensional, but the actual notch and ACL are three-dimensional. The different shapes are shown in Figure 2: a very wide reverse U or C shape, an intermediate narrowed H shape, or the more stenotic A shape.

The notch forms in response to the size and shape of the ACL. A small ligament lives in a small notch, and a smaller ligament is weaker. Females are smaller than males, but the forces generated by noncontact ACL tear mechanisms are similar in proportion to the forces males generate and will easily pop this smaller ligament.

We really do not know the natural history of ACL development—growth, size, and strength. It may be possible for the ligament to hypertrophy, increasing the strength and size in response to increased activity, changing hormonal levels, genetic influences, and other factors. The medial humeral epicondyle in the Little League baseball pitcher increases in size due to the repetitive stresses of throwing. Is such an increase possible with the ACL? Magnetic resonance imaging studies need to be done to assess size of the ACL in subjects who are skeletally immature or who have one intact and one torn ACL.

Knowing about gender differences in regard to ACL injury should not bias the sports medicine professional in making treatment decisions; nor should it bias

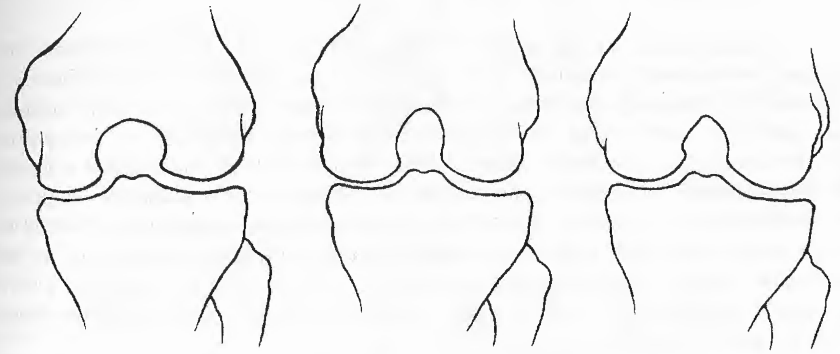

Figure 2 — Three types of notch shapes: reverse U or side C, H, and A. The more narrow A shape and a low notch-to-femur ratio on notch views are common with ACL tears. From *Sports Injuries: Mechanisms, Prevention, Treatment* (p. 164), by F.H. Fu and D.A. Stone, 1994, Philadelphia: Williams & Wilkins. ©1994 by Williams & Wilkins. Reprinted with permission.

the female athlete regarding which sport to participate in (21). Rather, this knowledge should serve as a resource in setting up strength and conditioning programs for preseason and in-season, in developing rehabilitation programs, and in choosing bracing or orthotics to help control abnormal forces.

Mechanism of Injury

Besides genetic differences, there are multiple factors that contribute to the increased rate of noncontact ACL injuries. These are classified as intrinsic (not controllable), extrinsic (potentially controllable), and both (partially controllable).

Intrinsic (not controllable)

- physiological rotatory laxity
- size of ACL
- valgus alignment
- hyperextension
- proprioception
- neuromuscular firing order
- hormonal influences

Extrinsic (potentially controllable)

- strength
- conditioning
- shoes
- motivation
- deceleration forces during injury

Both (partially controllable)

- skill
- coordination

Analysis of ACL injuries requires a breakdown of the mechanism into contact and noncontact categories. Only noncontact mechanisms are considered in this article. Contact injuries involve external forces that make injuries unavoidable and, therefore, unrelated to gender. Noncontact injuries almost always occur during deceleration of the body. These occur when the athlete lands from a jump, decelerates during the sudden lowering before initiating acceleration into the jump, or decelerates on the plant leg prior to a cutting motion. Deceleration needs to occur quickly, through a relatively small excursion of joint motion, and in the transverse, sagittal, and frontal planes of motion. The knee is influenced by a lack of control and stability from forces above and below. The excessive strain and rate of strain play a prominent part in ACL failure.

In a review of mechanisms of ACL tears in 40 videotapes, Boden and Garrett noted that the most common knee flexion angle was 20° and that the quadriceps acted eccentrically (7). Arnheim stated that the ACL is most vulnerable when the tibia is externally rotated and the knee is in a valgus position (2). Fu and Stone noted that same position is also the most frequent injury mechanism in soccer, football, and skiing, but that the most common ACL injury mechanism in basketball is hyperextension with tibial internal rotation (15).

The mechanism of ACL tears in basketball and gymnastics has been analyzed. The lower extremity goes through a forward-flexed, out of control motion. The component parts of these noncontact ACL injuries are the same as the kinetic chain component parts during pronation. The main difference is the degree of motion and the speed with which it occurs. Normal pronation in the lower extremity kinetic chain is generally referred to as the decelerating or shock-absorbing phase of movement. Excessive pronation will cause the tibia to internally rotate following plantar flexion and adduction of the talus. When the tibia moves forward over the foot and the ankle dorsiflexes, the foot and ankle resupinate and the tibia externally rotates (14). Structural malalignment of the rearfoot and forefoot can cause excessive pronation of the foot and ankle as well. Acronyms for malalignment seen during noncontact ACL tears are POP (planted, out of control, pop) or VAROOM (valgus, rotation, out of control movement or muscular disynchrony). The hip is in flexion, the foot is abducted and pronated, and the tibia is fixed in external rotation as the body falls forward and toward the opposite side and the femur goes into internal rotation (26) (Figure 3). One can easily see the uncontrolled movement by watching a film of this mechanism frame by frame (Figure 4). By observing these mechanisms, we have learned that motor control is the key and

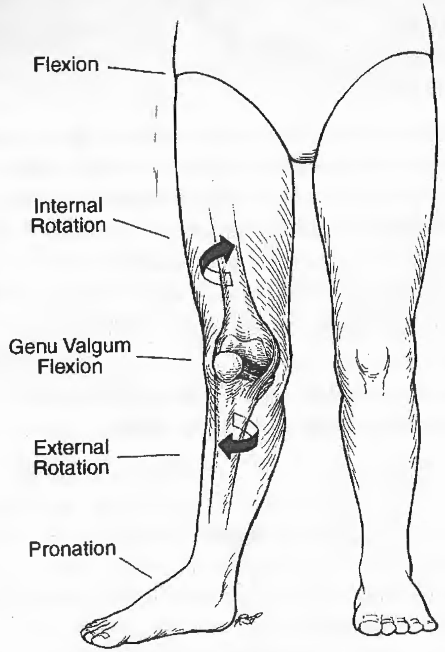

Figure 3 — The position of no return for the ACL. The lower extremity position is one of body forward flexion, hip adduction, internal rotation, 20–30° knee flexion, external rotation of the tibia, and forefoot pronation. As the knee buckles, the athlete usually falls forward and toward the opposite side with a rapid distal deceleration. From "Anterior Cruciate Ligament Injuries in Young Female Athletes," by M.L. Ireland, 1996, *Your Patient & Fitness*, 10(5), p. 29. ©1996 by The McGraw-Hill Companies. Reprinted with permission.

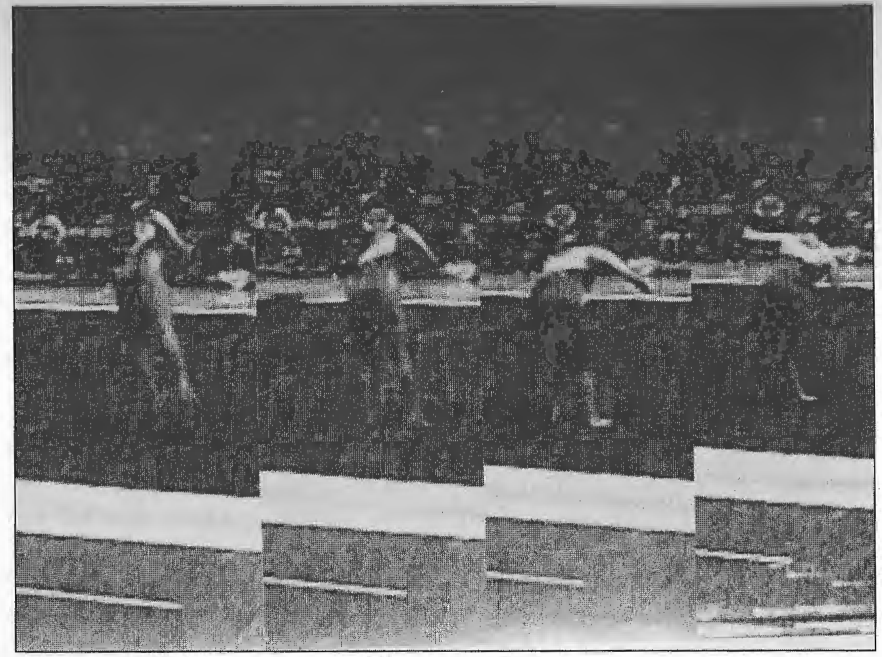

Figure 4 — This gymnast tore her ACL in a classic mechanism. From left to right, the landing is shown with the body forward flexed and the foot externally rotated and pronated. As she lands, her body weight is initially forward on her foot; the tibia externally rotates, the femur internally rotates, and the hip and knee flex. There is loss of control proximally of the body, and the foot does not move on the rug surface. The foot on the right side is maximally pronated, the knee is in valgus position, and the hip is flexed, with internal rotation of the femur and forces of the pronator foot on the floor causing rotation of the tibia. From "Anterior Cruciate Ligament Injuries in Young Female Athletes," by M.L. Ireland, 1996, *Your Patient & Fitness*, 10(5), p. 29. ©1996 by The McGraw-Hill Companies. Reprinted with permission.

that we need to design programs to address proprioception so that these athletes do not find themselves in this miserably malaligned position. Perhaps sport-specific, virtual reality–type training could be beneficial. Avoidance of these positions may be possible with strength and proprioceptive training. For example, uprighting oneself by going into extension of the trunk with abduction and extension of the hip would decrease the likelihood of a significant knee injury. The primary restraint to these forces in a valgus, externally rotated leg is the ACL, not the medial collateral ligament.

Clinical Experience in ACL Reconstructions

Reviewing 5 years of Kentucky Sports Medicine ACL reconstructions showed that 40% involved the sport of basketball (Kentucky Sports Medicine Clinic, Lexington, KY, unpublished research data). Of 174 basketball athletes, 71 were

females and 103 were males. Forty-two (59%) of the females and 23 (22%) of the males were between the ages of 15 and 18. The college group, age 19–22, included 12 females (17%) and 11 males (11%). After age 22, 15 of the females (21%) and 69 of the males (67%) underwent ACL reconstruction. Is this a social statement that males in Kentucky who play basketball after age 22 tend to hurt their knees? Or is it a statement that 15- to 18-year-old females participating in high-risk sports after a recent growth spurt are physically unprepared from their low-impact, sedentary lifestyles? The rate of meniscal injuries in this basketball population was extremely high, with 59 (83%) of the females having meniscal tears and 83 (81%) of the males having meniscal tears, the incidence being more lateral, then both lateral and medial, then medial. The majority of injuries occurred during games in both genders: 90 males (87%) and 42 females (59%). Possible reasons for the higher number of game injuries are that the athlete participates at a higher all-out level where fatigue plays more of a role, or that the athlete cannot predict and react with control to the opponent's actions. Noncontact injuries were by far the most common, with 90 of the males (87%) and 58 of the females (82%) injured in a noncontact mechanism.

We believe that the female with a torn ACL ligament is at high risk for significant problems such as meniscal injury and articular surface injury if there is no modification of activity level. She should be considered for reconstruction with whatever graft the surgeon prefers. Females and males do equally well following ACL reconstruction. A vigorous comparison of results and complications between the sexes following ACL reconstruction was done by Barber-Westin, Noyes, and Andrews (4). Forty-seven males and 47 females were compared following autogenous bone–central third patellar tendon–bone graft. At 26 months postoperative, both groups had the same outcome according to the Cincinnati Knee Scale. They had no difference in complications, females required six more rehabilitation visits, and failures were 6% in females compared to 4% in males (4).

The accuracy of diagnosis based on medical history was recently reported by Johnson et al. (29). The highest predictive values for diagnosing a torn ACL were loss of recreational activities, activity limitations, previously regular radiographs, inability to fully move the knee, other orthopedic problems, and pain that occurred all day, that was relieved by rest, or that was worse with activities. Knee buckling while pivoting or walking was not among the top 30. Further studies are necessary, specifically on the female knee.

Research

Several prospective research studies are underway. The purpose of these studies is to compare the incidence of injury to certain anatomic factors to develop a risk equation. Specific anatomic and physiological measurements are being taken on high school basketball and soccer athletes from the 9th through 12th grades. Knee injuries will be correlated to measured factors. At the collegiate level, a similar preseason screening and subsequent follow-up of all sports for noncontact ACL injury is underway. Yet another study is being conducted under the direction of the National Collegiate Athletic Association (NCAA). When an individual tears one ACL, he or she is put into the study and followed for tearing of the other ACL. Outcome studies and follow-up comparing males' and females' return to activity and functional levels should also be carried out to justify current treatments.

Control of Forces

Since most of these injuries occur in the absence of outside forces, it should be possible to prevent some of them. Looking at gender differences, we can target the areas that appear to offer the most potential for injury reduction in females. These are core stability to maintain proper pelvic alignment in a neutral range, strengthening of the gluteus medius and external rotators to control femoral adduction and internal rotation, and strengthening of the quadriceps, hamstrings, and ankles. Balance and proprioceptive training is also essential, because neuromuscular control is as important to lower extremity function as strength itself. Low force deceleration and control can begin with the subject jumping up to a height to avoid impact while still working on strength and power development and lower extremity control in landing. Use of proper shoes and foot orthotics after biomechanical assessment is important to reduce pronation.

Conclusion

The reasons for the increased incidence of ACL injuries are multiple. High on the list are physiological rotatory laxity, ligament size, timing of neural input to control lower extremity deceleration, and strength and proprioceptive control. Needed are more thorough developmental and biomechanical assessments to identify risk factors for injury. The athlete and his or her family should be notified of the identified risk factors, and prevention programs should be implemented for the athlete at an early age. We have a captive audience in these teams: The coaches certainly would like to reduce the rate of injury to their athletes, and the athletes would like to remain uninjured and keep playing. The challenge is to reduce this excessively high rate of injury through specific strengthening and neuromuscular training programs, make coaches and athletes aware of the importance of these programs, and continue to research this issue and develop a plan to keep all athletes in the game.

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Recent Advances in ACL Rehabilitation: Clinical Factors That Influence the Program

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Rehabilitation following ACL reconstruction focuses on treatment of impairments and functional limitations. Clinical pathways that have been developed for rehabilitation of the knee are useful for identifying and classifying impairments and functional limitations following ACL reconstruction. Application of these clinical pathways will enable the physical therapist or athletic trainer to select the most appropriate treatment for an individual. Knowledge of secondary pathology and concomitant surgery allows the clinician to modify application of the clinical pathway. The purpose of this manuscript is to describe modifications for rehabilitation of individuals following ACL reconstruction, based on knowledge of secondary pathology and/or concomitant surgery.

The disablement scheme developed by Nagi (20) provides a useful framework for rehabilitation of individuals following anterior cruciate ligament (ACL) reconstruction. In this scheme, disablement may be classified as pathology, impairment, functional limitation, or disability. Impairment is loss or abnormality of the structure or function at the organ or body system level and includes an individual's presenting signs and symptoms. Functional limitations are limitations in the performance of the whole person, while disability is the person's limitation in performing socially defined roles in a sociocultural and physical environment (20, 17).

Impairments following ACL reconstruction include pain, swelling, loss of motion, and weakness. Functional limitations include limitations in performing basic activities of living and sports, such as difficulty walking and climbing stairs and the inability to run, jump, and pivot. Disability may include restriction in work and school activities and the inability to participate in sports and recreational activities. It is assumed that impairment of the knee following ACL reconstruction is directly related to the patient's disability and loss of function. As a result, rehabilitation for patients following ACL reconstruction is geared toward treatment of knee impairments (i.e., reducing pain and swelling and restoring range of motion and strength) with the anticipation that this will restore function and eliminate disability.

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