The quest for equal opportunity in sports has led many female athletes to equal opportunity for injuries, especially injuries to the anterior cruciate ligament (ACL).

Available evidence suggests the incidence of ACL injuries is increasing in female athletes.[12] Reasons for the increase remain unclear, but a number of factors appear to play a role.

Epidemiology and predisposing factors

Women's participation in sports has increased dramatically since 1972, when Congress passed Title IX of the Education Assistance Act, mandating equal opportunity in athletics for men and women at institutions that receive federal funding. At the college level, for example, the estimated number of female athletes in NCAA competition has risen from 10,000 in 1972[6,14] to more than 128,000 during the 1996-97 academic year (personal communication, NCAA Research Division, Overland Park, KS). However, women's athletics have lagged behind men's with respect to funding, research, coaching, and conditioning resources, all of which could contribute to an increased risk of injury.

The quest for equal opportunity in sports has led many female athletes to equal opportunity for injuries, especially injuries to the anterior cruciate ligament.

The risk of ACL injury in female athletes appears to be sport specific. Soccer, gymnastics, and basketball head the list, though their exact order varies from study to study.[12] Female basketball players are two to eight times more likely to have ACL injuries than their male counterparts.[5,7,13] Female basketball players also are more likely than males to have more serious ACL injuries that lead to greater loss of time from the sport.[15] At the collegiate level, women have more noncontact ACL injuries in basketball, a ratio of 5:3 versus men in one analysis.[1]

Data from the National Collegiate Athletic Association suggest a female preponderance of ACL injuries in basketball of 4:1 and in soccer, a ratio of 5:1.[1]

A review of five years of ACL reconstruction experience at Kentucky Sports Medicine identified basketball as the sport most often associated with ACL injury in men and women athletes in high school and college, accounting for 40% of all ACL reconstructions done at the clinic during the period reviewed (unpublished data). The majority of basketball-related ACL injuries occurred during games, as opposed to practice, for both sexes (87% of males and 59% of females). The vast majority of ACL tears resulted from noncontact injuries (87% of males and 82% of females).

A survey completed by U.S. participants in the 1988 Olympic trials clearly reflected the gender disparity in ACL injuries. Thirteen of 64 women had a history of ACL tear, compared with three of 80 men. Six men had a total of six knee surgeries versus 25 operations in 20 women. Both differences were statistically significant.[9,10]

Biomechanical differences between men and women almost certainly contribute to the risk of ACL injuries.[12] Women have wider pelvises, which can lead to several biomechanical alignment problems, including increased rotational force at the tibiofemoral joint. Genu recurvatum may predispose females to hyperextension.

Women tend to be more flexible than men, which can influence the position of knee flexion during landing. Increased hamstring flexibility is another factor that may predispose women to hyperextension. Men tend to have more muscle mass (especially in the extremities) and better developed musculature, and generally rely more on their musculature for joint support. In contrast, women are ligament dominant, and the ACL assumes much of the burden for maintaining proper tibiofemoral alignment.

The firing rate and order of muscles might also contribute to risk of injury. Specifically, studies have suggested that elite female athletes have a quadriceps dominance, as opposed to the hamstring dominance seen in men.[8] Firing of the quadriceps before the hamstrings or gluteals might accentuate the stress that leads to ACL tears.

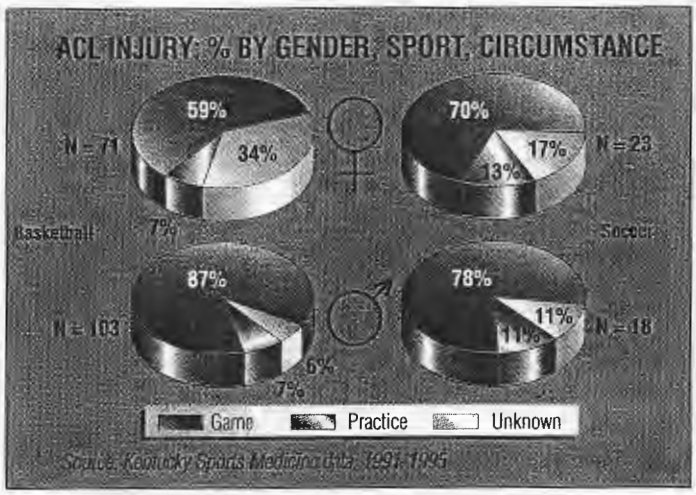
Other anatomical factors that may contribute to a female athlete's risk of ACL injury include a narrow femoral notch, a predisposition toward external tibial torsion, and excessive foot pronation. Notably, a smaller femoral notch correlates with a smaller ACL, and a smaller ligament will be weaker.[3]

Potential hormonal contributions to ACL injury remain under investigation.[11,12] The ACL has receptors for estrogen and progesterone, but the activity of the hormones or their receptors in the ligament is unclear at this time. Hormonal changes during pregnancy lead to relaxation of ligamentous structures all over the body, not just in the knee, in preparation for delivery. Anecdotal reports suggest that ACL injuries occur more often shortly before menstruation.

Mechanisms of injury

ACL injuries involve a combination of intrinsic and extrinsic factors.[12] Intrinsic factors cannot be controlled and include anatomic and hormonal differences between men and women, as discussed above. It is not clear at this time to what degree hormones may influence ligament laxity in women, or how much hormonal manipulation might influence the risk of ACL injuries. Extrinsic factors are potentially controllable and include strength, conditioning, footwear, playing surfaces, motivation, and deceleration forces during injury. A few factors, such as skill and coordination, have both intrinsic and

Photo by Tom Stewart/Stock Market



extrinsic features and may be modifiable to some extent.

Contact injuries involve application of external forces unrelated to gender, and from that perspective, the injuries can be viewed as unavoidable. Noncontact ACL injuries typically occur during deceleration of the body, such as while landing after a jump or making a sudden, sharp change of direction, as in a cutting maneuver. Attention to modifiable contributing factors might help reduce the risk of injury.

Studies of ACL injuries indicate that the ligament is most vulnerable when the tibia is externally rotated and the knee is in a valgus or outward position.[2] That position has been observed in association with ACL injuries in soccer, football, and skiing, whereas hyperextension has been noted as the most common knee position associated with ACL injuries in basketball with men and women.[3]

Analysis of ACL injuries in basketball and gymnastics has identified several typical features of the injury process.[11,12] The athlete lands with the body and knee flexed and then cuts, or changes direction. The foot remains planted, but the body flexes forward and turns in a direction opposite to the foot. The femur adducts and rotates internally. The knee flexes into valgus, the tibia rotates, and the foot pronates. This biomechanical combination might well be described as "the position of no return." Activity literally puts the body in a position from which the muscles cannot extricate it. Something has to give, and unfortunately, it is often the ACL.

As the knee buckles, the athlete falls forward and toward the side opposite the injured knee. Many times, the athlete will roll onto his or her back and clutch the injured knee in a flexed position. The athlete often describes the sound of the injury as a popping noise, an explosion within the knee, or a snap like a chicken bone breaking. When making a differential diagnosis faced with this type of presentation, an ACL tear should be foremost in the practitioner's mind.

Examination

When an ACL tear occurs, the athlete usually presents with a moderate amount of effusion in the affected joint. Tenderness tends to be greater along the lateral rather than medial patellar joint line. The patient often cannot extend the knee because of hamstring spasticity. Hemarthrosis, or bloody fluid within the knee joint, appears within a few hours after a ligament tear.

The most reliable diagnostic indicator of an ACL tear is the Lachman test.[11] To perform the test, place a rolled towel or pillow under the thigh so as to flex the knee about 30°, allowing the hamstrings to relax. When the ACL is torn, a certain amount of anterior tibial translation, or movement without an end point, can be felt.

The combination of pain, apprehension, and anticipation usually precludes the performance of more than a single pivot shift test. Medial or lateral joint line tenderness and a positive bounce-home test can help document a meniscal tear. Patellar subluxation or dislocation is rare but can be associated with an ACL injury.

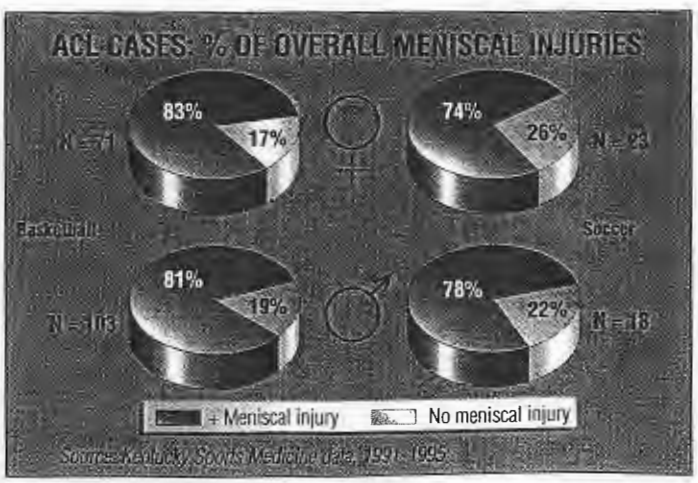
KT-instrumented arthrometry can reveal meaningful differences between the injured and opposite knee by objective measurement of anterior tibial displacement. Obtaining useful information from the test requires an experienced KT instrument operator, a relaxed hamstring in the affected leg, and a cooperative patient. The most useful results arise from testing done after hemarthrosis and hamstring spasticity have resolved.

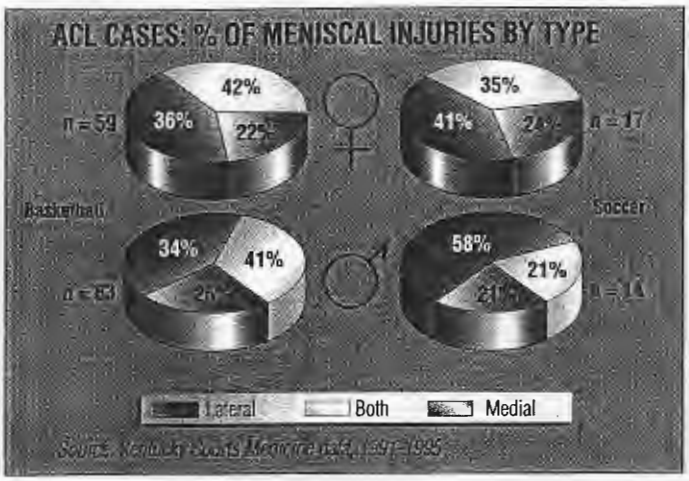
X-rays should accompany the initial physical examination of a patient who has a suspected ACL tear. The radiographic evaluation should include anteroposterior, lateral, notch, and bilateral patellar views.

Magnetic resonance imaging can be a useful adjunct to the physical examination but generally is not essential to make the diagnosis or assess the nature and severity of the injury.[4] One exception is when a patient does not favor ACL reconstruction that has been recommended by the practitioner. In such a case, MRI can provide information that helps ensure an objective decision about surgery.

ACL reconstruction

In the experience of Kentucky Sports Medicine, the vast majority of athletes, both men and women, who present with ACL injuries have complete, rather than partial, tears. The preponderance of complete tears is on the order of 90% to 95%, based on clinical experience For any competitive athlete who has designs on returning to a sport, reconstruction of a complete ACL tear is a necessity. Without surgery, further activity could lead to additional damage to cartilage and the joint surface.





Women, in particular, are at increased risk of joint instability without surgery, a byproduct of the joint laxity and ligament (as opposed to muscle) dominance that may contribute to their initial injury. Reconstructive surgery is a virtual necessity for female athletes who plan to return to high-stress, high-risk activities, such as gymnastics, cheerleading, basketball, or volleyball.

Severity of injury also figures in the surgery decision analysis. If cartilage or other joint structures have been damaged, surgery is probably warranted in most instances.

ACL reconstruction has evolved dramatically over the past two decades, so that it no longer requires major open surgery. Most procedures today can be performed arthroscopically, and the remaining surgeries involve a mini-open procedure. The latter operation requires an incision of about one inch for access to the ligament and joint.

Experience with ACL reconstruction has taught surgeons that timing is critical to a favorable outcome. In years gone by, surgery typically occurred as soon as possible after confirmation of an ACL tear. Today, surgery is delayed until the swelling has dissipated, neuromuscular control has returned, and the patient has regained total or near-total movement of the knee. Surgery on a swollen, inflamed knee that has limited range of motion frequently results in a postsurgical joint that responds more slowly to rehabilitation and that recovers range of motion more slowly.

Immediately after surgery, most surgeons recommend that patients wear knee braces for at least three to four weeks. Depending on the extent of the injury and the reconstructive procedure, a patient might require an orthotic device that provides total knee immobilization, or one that permits a degree of movement. In the first few days and weeks after surgery, a brace serves a twofold purpose: protecting the knee from further injury; and reminding the patient that the knee remains in a fragile condition that mandates avoidance of unnecessary strain or risk.

Rehabilitation

The typical return-to-activity time is six months after ACL reconstruction. Female athletes involved in certain high-risk sports, such as gymnastics or cheerleading, might require a longer rehabilitation time because of the increased stress those activities place on the knees.

In recent years, rehabilitation has become increasingly sport specific. That is, rehabilitation activities are tailored to meet the demands of an individual athlete's chosen sport. The overall emphasis remains on a combination of activities that promote strength, endurance, physical control, and balance.

Another recent trend in rehabilitation has been toward more patient-directed recovery from an ACL injury. Many athletes today are conversant with their bodies and the biomechanics associated with injuries and rehabilitation. The increased sophistication of patients means that more of the rehabilitation process can shift to the home or personal gym.

After an ACL injury, male and female athletes undergo a similar rehabilitation process. However, compared with their male counterparts, many female athletes have little experience with weight training and exercise equipment. That being so, female athletes may have a greater need for instruction in the proper technique for use of the equipment. Athletes with little prior experience using rehabilitation equipment should be monitored closely until they develop some skill and dexterity in its use.[9]

Toward prevention

The ultimate goal of athletes and their healthcare providers should be to prevent ACL injuries. Currently, the best available form of prevention comes in the form of activities designed to reduce the risk of injury. To the extent possible, athletes should practice the kinds of activities associated with their specific sports. For example, basketball players should receive instruction in and practice landing and cutting maneuvers that put less strain on the knee. Such preventive activities necessarily entail education of coaches and trainers in which factors place athletes at risk and the steps that can be taken to reduce the risk.

However, a greater need is the identification of athletes at risk for ACL injuries. Toward that end, more research (and funding for research) is needed to identify specific factors associated with increased risk of injury. Moreover, research should give more emphasis to identification of dynamic measures of risk, such as electromyographic findings associated with specific activities, movements, or body positions. Ultimately, static measurements, such as gender-specific anatomic variations, will play a lesser role in the identification of high-risk patients than will dynamic measurements that identify the movements and maneuvers that can be modified to reduce the risk of injury.

Charles Bankhead is a freelance medical writer based in Houston, TX. Mary Lloyd Ireland, MD, is an orthopedic surgeon at Kentucky Sports Medicine Clinic in Lexington, KY.

References

1. Arendt E, Dick R. Knee injury patterns among men and women in collegiate basketball and soccer: NCAA data and review of literature. Am J Sports Med 1995;23(6):694-701.
2. Arnheim DD. *Modern principles of athletic training.* St. Louis: Times Mirror/Mosby College Publishing, 1985:545.
3. Fu FH, Stone DA. *Sports injuries: mechanisms, prevention, treatment.* Philadelphia: Williams & Wilkins, 1994:153-187.
4. Gelb HJ, Glasgow, SG, Sapega AA, et al. Magnetic resonance imaging of knee disorders: clinical value and cost-effectiveness in a sports medicine practice. Am J Sports Med 1996;24(1):99-103.
5.Gray J, Taunton JE, McKenzie DC, et al. A survey of injuries to the anterior cruciate ligament of the knee in female basketball players. Int J Sports Med 1985;6:314-316.
6. Griffin LY. The female athlete. In: *Orthopaedic sports medicine: principle and practice,* vol 1. DeLee JC, Drez D, eds. Philadelphia: W.B. Saunders, 1994:356-373.
7. Harrer MF, Berson L, Hosea TM, Leddy TP. Lower extremity injuries: females vs males in the sport of basketball (Abstract). AOSSM 22nd Annual Meeting, Lake Buena Vista, FL, June 16-20, 1996.
8. Huston LJ, Wojtys EM. Neuromuscular performance characteristics in elite female athletes. The AAOS/AOSSM Specialty Day Meeting, Atlanta, Feb. 24, 1996.
9. Hutchinson MR, Ireland ML. Knee injuries in female athletes. Sports Med 1995;19(4):288-302.
10. Ireland ML, Wall C. Epidemiology and comparison of knee injuries in elite male and female United States basketball athletes (Abstract). American College of Sports Medicine Annual Meeting, Salt Lake City, UT, 1990.
11. Ireland ML. Anterior cruciate ligament injuries in young female athletes. Your Patient & Fitness 1996;10(5):26-30.
12. Ireland ML, Gaudette M, Crook S. ACL injuries in the female athlete. J Sport Rehab 1997;6:97-110.
13. Malone TR, Hardaker WT, Garrett WE, et al. Relationship of gender to anterior cruciate ligament injuries in intercollegiate basketball players. J Sou Orthop Assoc 1993;2(1):36-39.
14. National Collegiate Athletic Association. NCAA Injury Surveillance System. Overland Park, KS: NCAA, 1994-95.
15. Zilmer DA, Powell JW, Albright JP. Gender-specific injury patterns in high school varsity basketball. J Women's Health 1992;1(1):69-76.