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Anterior Cruciate Ligament Injuries In Athletes

Jennifer D. Krick
Southern Illinois University Carbondale

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Thesis Advisor: Frank Pleban

Key Terms

Anteversion - to displace (a body organ) so that the whole axis is directed farther forward than normal

Arthrofibrosis - having scar tissue in inappropriate locations which prevents normal joint motion

Arthrotomy - traditional surgery

Avulsion - tearing away of a structure or part accidentally or surgically

Extra-articular - outside of a joint

Genu valgum - knock kneed

Hemarthrosis - blood in a joint

Impinge - to encroach or infringe

Isometric - having lines of equal measure

Laxity - looseness of structure

Necrotic - death of a portion of tissue due to loss of blood supply

Notchplasty - to form a notch in a bone

Pronation - a faulty foot posture characterized by toeing out and usually associated with sagging of the inner arch and inward tipping of the ankle joint

Stenotic - having narrowing or constriction of a passage

Translation - displacement

Valgus - turned outward to an abnormal degree

Varus - turned inward to an abnormal degree

At some point in each athlete's career he or she will probably be faced with a sports injury, and given the fact that the knee has the highest injury rate in any sport, it may very well be a knee injury that is keeping an athlete sidelined. It may be something as minor as a sprain, but an increasing number of athletes are falling victim to a much more serious injury: an anterior cruciate ligament (ACL) tear. There are approximately 80,000 ACL tears reported each year in the United States, with the majority of these tears occurring in athletes between 15 and 25 years of age ("Strategies..."). Anterior cruciate ligament injuries occur in a variety of sports, in both men and women, but recently ACL tears are targeting more women athletes than men. Regardless of gender, repairing the ACL involves surgery, and the road to recovery is a long one. Additionally, athletes who have not experienced an ACL tear can take measures to protect themselves from joining the thousands of others who have had the misfortune of an ACL injury.

The anterior cruciate ligament is a powerful ligament that attaches to the anterior intercondylar area of the tibia, passes upward, posteriorily, and laterally, and attaches to the posterior part of the medial surface of the lateral femoral condyle (Snell 670). This can be seen in Figure 1, taken from Netter, plate 475 (Appendix A). The ligament is normally slack when the knee is flexed and taut when the knee is fully extended. Placement of the femoral attachment is responsible for the reciprocal tightening and loosening of the ligament during the knee's full range of motion. The tibial attachment, on the other hand, is more secure than the femoral attachment because it occupies a wide, depressed area anterolateral to the anterior tibial spine (Miller 1186). Due to the ligament's anterior attachment at the tibia (in relation to the posterior cruciate ligament) and the fact that the anterior and posterior ligaments "criss-cross" inside the knee joint, the ligament was given the name anterior cruciate ligament. Along with the posterior cruciate ligament (PCL), the ACL is the main bond between the femur and the tibia. The ACL, a strong intracapsular ligament, is actually not a single cord, but a bundle of fibers assuming a spiral configuration fanning out over a broad area of attachment (Fish and Zarino 850).

Despite its somewhat small size, the ACL plays a very important role in the healthy functioning of the knee. The ACL is one of four stabilizing ligaments of the knee, and acts as the knee's primary anterior stabilizer by controlling forward gliding of the tibia (Brezzo). When the knee is fully flexed, it prevents anterior displacement of the tibia on the femur (Miller 1189). In full extension, the ACL helps to impart side-to-side stability to the knee. Additionally, the ACL helps to prevent hyperextension and excessive degrees of rotation as well as resisting extreme varus and valgus stress (Miller 1186). According to Miller, the ACL is so important to the function of the knee, that "most surgeons would agree with the observation that anterior cruciate ligament ruptures are 'the beginning of the end for the knee'" (1186).

Injury to the anterior cruciate ligament is now recognized as one of the most common major knee injuries incurred in athletics. An ACL injury is described as a partial or complete tear, a dislocation, or a stretch of the anterior cruciate ligament from the bone attachments that form the knee or anywhere along the length of the ligament ("Anterior..."). Seventy percent of ACL injuries are considered noncontact injuries and there are common mechanisms for incurring an ACL injury. Anterior cruciate ligament injuries can be the result of planting the foot and then suddenly changing direction, landing with a straight knee, hyperextending or hyperflexing the leg, or in the case of a contact injury, lateral trauma to the knee (Brezzo and Oliver). Thus, athletes in sports where there is lots of pivoting and jumping, such as volleyball, basketball, soccer, football, and skiing have an increased chance of ACL injuries. Fu and Stone (1994) found that the most common mechanism of injury in soccer, football, and skiing is when the athlete decelerates with the tibia in external rotation and the knee is in valgus (Bonci 156). Conversely, in basketball, the common mechanism of injury is usually the result of jumping maneuvers. One mechanism shows the athlete coming down in an uncontrolled landing, either catching the ball or trying not to go out at the baseline. This results in hyperextension of the knee with the tibia in internal rotation. Mary Lloyd Ireland describes what she calls the "position of no return" in sports, which often leads to ACL injuries, " the hip abductors and extensors have shut down, and the pelvis and hip are uncontrolled. Muscle groups that would usually upright the athlete are unable to perform this function due to their mechanical disadvantages and the lengthening of the muscle group" (Ireland 152). The "position of no return" is shown in Figure 2, from Ireland, page 152 (Appendix A).

In the past three decades, the number of girls and women participating in competitive and recreational sports has increased dramatically. Unfortunately, as the number of women participating in sports has increased, the number of women suffering ACL injuries also has increased. In addition, despite improved training programs, women are still suffering proportionately more ACL injuries than men. In fact, women are approximately 3 to 5 times more likely to sustain an ACL injury than males. Arendt, Agel, and Dick (1999) confirmed this by conducting a study of NCAA athletes. The authors used the National Collegiate Athletic Association database, which has collected injury patterns in NCAA athletes. The authors studied men's and women's soccer and basketball players over a five year period from 1989 to1993 and from 1994 to1998. (The later survey was used to rule out lack of skill as a predisposing factor for ACL injuries. By that time, the training and skill level of women athletes had improved dramatically). Researchers found the average ACL injury rate in females participating in soccer was 0.33 injuries per 1000 athlete exposures, while men had an average ACL injury rate of 0.12 injuries per 1000 athlete exposures (Arendt, Agel, and Dick 88-89). (An athlete exposure is a time such as practice or games when the athlete could be injured). The study shows that women were nearly three times more likely to sustain an ACL injury then men. Results found in basketball athletes were similar; women had an injury rate of .30 injuries per 1000 athlete exposures, while men had an injury rate of 0.10 per 1000 athlete exposures (Arendt, Agel, and Dick 88-89).

There are many factors that contribute to the reason why women have a higher ACL injury rate than men. Some proposed explanations for sex differences include differences in muscular strength, hormonal influences and anatomy. According to Bonci, "Females have a wider pelvis, increased femoral anteversion, increased physiologic laxity, increased genu valgum and genu recurvatum, more external tibial torsion, and more forefoot pronation. These anatomical considerations can create faulty alignment positions that are common to ACL injury mechanisms reported in sports characterized by running, jumping, and pivoting maneuvers" (156).

The predisposing factors that make women more vulnerable to ACL injuries can be described as either extrinsic or intrinsic. Extrinsic risk factors are related to the type of sports activity, the manner in which the sport is played, environmental conditions and the equipment used to play the sport. Examples of extrinsic risk factors for women include body movement and muscular strength. Intrinsic risk factors are individual, physical and psychosocial. Limb alignment, intercondylar notch size, and hormonal factors are all examples of intrinsic risk factors.

The ratio of eccentric hamstring to quadriceps strength is an important factor that may predispose a female athlete to an ACL injury. The hamstrings and the quadriceps are important to the stability of the knee joint, and a deficit in hamstring strength relative to quadriceps strength could predispose an athlete to an ACL injury. This is particularly true during deceleration and landing maneuvers, when there are flexion movements at the knee and hip. Forceful hamstring contraction stabilizes the hip flexor moment, which helps to neutralize the tendency of the quadriceps to cause anterior translation of the tibia on the femur (Bonci 160). The hamstrings act as protagonists to the ACL in controlling tibial movement. When the stabilizing influence of the muscles is not present, inert internal tissues such as the ACL become more vulnerable. This is why it is important for women athletes to have a stable balance of hamstring and quadriceps strength. It has been found that women use their legs differently when playing sports; they tend to activate their quadriceps more. Women also land with straighter legs when they jump; this places more pressure on the quadriceps and more pressure on the knees per pound of body weight ("ACL Injuries"). One study investigated the differences between hamstring to quadriceps strength ratio in male and female NCAA Division I basketball players from the same school participating in the same conditioning programs. Females tended to rely on their quadriceps more heavily; thus, their quadriceps were usually stronger than their hamstrings, which reduced knee stability.

Another anatomical difference that leads to a higher incidence of ACL injuries in women is the Q-angle, or Quadriceps angle. Quadriceps angle is a measure of how sharply the femur angles inward from the hip to the knee. The Q-angle represents the direction of force that the quadriceps exert on the patella during lower leg extension. Research has shown that higher Q-angles make an athlete more prone to knee injuries (Marcus 55). Due to their wider hips and shorter femurs, women usually have higher Q-angles. Moul (1998) found that there was a significant difference in Q-angles between males and females when measured with the knee in 30 degrees of flexion (Moul 120). Quadriceps angle is often associated with increased tibial internal rotation, which the ACL functions to prevent. At 30 degrees of flexion, if internal rotation is increased in females, and the eccentric hamstrings-to-eccentric quadriceps strength ratio is diminished, the knee undergoes two forces that compromise the stability of the ACL during deceleration and lacks one restraint mechanism (121). This combination of structure and strength predisposes females to ACL injuries.

Association between excessive foot pronation tendencies and ACL injuries also has been made. If excessive or prolonged pronation of the foot occurs beyond the first half of the stance phase, the tibia undergoes more internal rotation than normal, which results in abnormal forces transmitted upward towards the knee. The ACL tightens with tibial internal rotation; therefore, excessive foot pronation may produce a preloading effect on the ACL (Bonci 157). A method of measuring excessive foot pronation is the navicular drop test. This test measures the distance between the original height of the navicular bone in a seated position (when the subtallar joint is in a neutral position) and the final weight bearing position of the navicular in a standing, relaxed stance (157-158). The athlete first sits in a chair with knees flexed to 90 degrees. The prominent point of the navicular tubercle is marked on an index card. The athlete then stands without changing the position of his or her feet, with equal weight on both feet. The lower position of the navicular is then marked on the same card, as shown in Figure 3, from Bonci, page 158 (Appendix A). The distance between the two lines is the navicular drop. Woodford-Rogers et al. (1994) measured navicular drop in an ACL injured group, which included 14 football players, 8 gymnasts, and a control group that was age, sex, and sport matched. It was found that ACL-injured individuals had greater amounts of navicular drop, suggesting increased pronation (157). Likewise, Beckett et al. (1992) also found subjects with ACL injuries had greater amounts of pronation as measured by navicular drop. It was concluded that hyperpronation of the foot and ankle may increase the risk of ACL injury (157). The authors reported that the mean navicular drop in 50 healthy subjects was 6.9 mm, while ACL injured subjects had a mean of 13 mm.

Excessive foot pronation in addition to genu recurvatum, or knee hyperextension can cause greater strain on the ACL. "[Genu recurvatum] is usually an acquired structural abnormality secondary to changes in distal skeletal joint alignments and compensatory movement patterns and is characterized by soft tissue laxities of the posterior, posteromedial, and postolateral joint structures" (157). Loudon et al. (1996) found an increased susceptibility to ACL injury in female athletes displaying both excessive foot pronation and genu recurvatum as opposed to athletes with only pronation and no postural faults (157-158).

Epidemiological studies have shown that gender and femoral intercondylar notch width also are factors contributing to ACL injuries. The intercondylar notch is the space between the two condyles of the femur that houses the ACL, and a narrow notch may play a significant role in ACL injuries. A stenotic intercondylar notch impinges on the ACL leaving the ligament vulnerable to tearing during cutting or hyperextension maneuvers. Stenosis results in a notch too small for the ACL to adequately maneuver during abduction and external rotation (Souryal and Freeman 537-538). The notch width can be measured using plain radiographs, and it is a ratio of the width of the intercondylar notch to the width of the distal femur at the level of the popliteal groove (Miller 1188-1189). This is shown in Figure 4, from Souryal and Freeman, page 538 (Appendix A). The normal intercondylar notch width is approximately 0.231 +/- 0.044, with the notch width index (NWI) greater in men than in women (Miller 1188-1189). In addition, in a study conducted by Souryal and Freeman (1993) involving 902 high school athletes, it was found that athletes with noncontact ACL injuries had significantly narrower notches than the general population of athletes. In fact, 10 out of 14 athletes with noncontact ACL injuries had NWI ratios that were one standard deviation below the mean. They found that the NWI for men was 0.239 and in women was 0.217. Souryal and Freeman hypothesized that the limit of "critical" stenosis is an NWI of less than .20 for men and .18 for women (538). The notch is larger in men, not simply because of the larger overall size, but because the intercondylar notch in men simply occupies more space in the distal femur than in females. Whether this indicates a larger ACL is unknown, however.

Unlike male athletes, female athletes experience cycling of hormones during their reproductive years. It has been hypothesized that female hormones during the menstrual cycle may play a role in sustaining ACL injuries. However, it should be emphasized that this is still just a hypothesis. In a study conducted by Arendt, Agel, and Dick (1999), of 42 females not on birth control, 21 reported sustaining ACL injuries on the last day of their menses, 11 during the follicular phase (days 1-9), 9 during the luteal phase (days 15-end cycle), and only 1 during the ovulatory phase (91). The authors concluded that female athletes are at a greater risk for ACL injury just before or after their menses as opposed to midcycle; although, why this occurs in uncertain. In another study, Heitz et al.

(1999) found that fluctuating levels of hormones during a female's menstrual cycle have an effect on ACL laxity. ACL laxity increased throughout the duration of the menstrual cycle. However, further research in this area is greatly needed as it is not known whether differences in ACL laxity were the direct result of the degree of circulating levels of estrogens and progesterones. Also, it is not know whether the increased laxity increases the risk of ACL injury during times of peak hormone levels. It is possible that increased laxity is a defensive mechanism to allow the ACL to elongate rather than tear (Heitz et al. 148).

Neuromuscular fatigue is an additional factor that predisposes all athletes to ACL injuries. Neuromuscular fatigue during vigorous activity may ultimately decrease the potential of the quadriceps and hamstrings to protect the knee. When the quadriceps and hamstrings are exercised to fatigue, there is increased tibial movement at the knee, causing vulnerability at the knee (Brezzo and Oliver). This is especially important to athletes playing an entire game or participating in tournaments, in which they may have to participate in several games in one day.

At the time of an ACL injury, the athlete may hear a popping sound, which is the sound of the ACL tearing. However, only about one third of patients remember hearing a popping sound (Fish and Bertram 839). As a result of the tear, there is a whiplike snap of the lower extremity as illustrated in Figure 5 from Ireland, page 152 (Appendix A). This will be followed by sudden pain, especially on the inner side of the knee. The athlete may also feel like the whole knee momentarily went out of place and may have a sense of instability and trouble walking. Additionally, severe swelling of the knee occurs within six hours of the time of injury. The athlete should seek the advise of an orthopedist immediately. The instability of the knee during certain activities could lead to the knee giving way, which could damage the supporting structures of the knee such as the medial and lateral ligaments (Ciccotti).

A wide variety of procedures can be performed to diagnose an acute, isolated ACL tear, ranging from physical examination to arthroscopy. There are three common physical exams that are used to diagnose ACL injuries.

1). In the pivot shift test, the patient lies supine and relaxed. The examiner lifts the lower limb off of the table and internally rotates it. In a nonfunctional ACL, gravity will cause the femur to fall posteriorly, resulting in anterior displacement of the tibia with respect to the femur. The examiner then places his or her other hand just below the knee and laterally, while gently applying force, resulting in valgus stress and flexion of the knee. Between 20 degrees and 30 degrees of flexion, the tibia, which was previously anteriorly displaced, spontaneously shifts back to its normal position. This differs from the normal knee which will bend smoothly with no visible shift (Reider 232-233).

2). Alternatively, the examiner may chose to use the anterior drawer test. In this test, the patient lies supine with his or her knee bent to a 90 degree angle. The examiner restrains the patient's foot by sitting with his or her thigh against the patient's toes. The examiner grips the tibia below the joint line while the patient relaxes. The examiner then pulls forward with both hands and assess the amount of anterior translation of the tibia and the quality of the endpoint. In a normal knee, the tibia will move forward a few millimeters and then stop with a hard endpoint. However, in a patient with an ACL injury, the tibia will move forward more than the unaffected knee, and the endpoint will feel soft (230-231). This is illustrated in Figure 6 from Turek's Orthopedics, page 592 (Appendix A).

3). The most reliable physical examination for diagnosing an ACL injury is the Lachman Test, which has several advantages. First, it minimizes the stabilizing effects of the bony contour of the femoral condyles and the posterior horns of the menisci. The hamstrings are also more relaxed in this test, which gives them less of a mechanical advantage. The position of slight flexion, unlike the full flexion in the anterior drawer test, is more comfortable for patients with hemarthrosis. Finally, it isolates the ACL as the majority of resistance to anterior tibial translation (Fish and Zarins 840). The Lachman Test is performed much like the anterior drawer test; however, the patient lies with his or her knee at 25 degrees of flexion. One hand is used to grip the distal tibia, and the other hand grips the proximal tibia. The examiner, applying slow pressure, moves his or her hands in opposite anterior-posterior directions (840). This test is shown in Figure 7 from Turek's Orthopedics, page 593 (Appendix A). Increased laxity in the effected knee as compared to the unaffected knee is an indication of an ACL injury. The patient must be sure to relax his or her hamstrings or the result may be a false positive.

If pain and muscle spasm prevent the examiner from performing a physical examination, special diagnostic aids such as MRI or arthroscopy may be necessary. The accuracy of MRI for reporting ACL tears has been reported to be between 70 percent and 100 percent. Tears are best visualized in the sagittal and coronal planes (843). On an MRI, an orthopedist will look for so-called "bone bruises". These "bruises" are a result of the compression of the posterior aspect of the tibia against the anterior aspect of the femoral condyle as a result of the anterior tibial displacement that occurs at the time of the ACL rupture (843). The final way to confirm an ACL injury is through arthroscopy. This method is usually used when an ACL disruption is suspected, but it is not evident from the physical examination or when a physical examination is too painful for the patient. When an ACL tear is evident from the physical examination, arthroscopy can be used to diagnose associated joint conditions such as a meniscal tear (843). After an athlete has been diagnosed with a torn ACL, surgery is the next step. It should be noted that there are other nonsurgical treatments for an ACL injury; however, in competitive athletes, surgery is the only option to return the athlete to the previous level of competition.

There are various methods of surgically repairing a torn ACL. These include primary repair, primary repair with augmentation, and reconstruction. Primary repair of the torn ACL involves simple reattachment of the torn ACL. This technique may be considered when the ACL is intact but avulsed with a piece of bone. Avulsions usually only occur from the tibial attachment. In primary repair, a suture is looped through the avulsed piece of the bone. The crater in the tibia must be cleared from clots and debris. These sutures are then passed through holes drilled in the tibia (Miller 1189-1190). Primary repair, however, is often insufficient for athletes. Feagin and Curl (1976) carried out a five year study on 32 patients who had primary repair. More than two thirds of the patients had pain, swelling, stiffness, and giving way of the knee (Fish and Zarins 848).

Primary repair with augmentation is usually used when there is inadequate tissue at the site of the tear. In this technique, the ACL is repaired with the reinforcement of another tissue. The iliotibial tract and the semitendinosus tendon are common examples of tissues used in primary repair with augmentation. This method has been shown to improve the percentage of stable knees following surgery. Marshall et al. (1982) carried out primary ACL repairs reinforced with a tube from the iliotibial tract. In a two and a half year follow up, no patient had giving way of the knee, and 93 percent were active in sports. At a five year follow up, none of the patients had giving way of the knee, and 99 percent were participating in sports (848).

Generally, ACL reconstruction is the answer for athletes. Usually very little of the ACL remains intact, thus primary repair is not an option. In ACL reconstruction, the native ACL is completely replaced by a portion of another tendon. This tendon can be obtained from the patient; this is known as an autograft. Alternatively, the tendon can be taken from another individual, usually a cadaver; this is known as an allograft. The benefit of using an allograft is that there is decreased harvest related graft site morbidity, and an allograft more closely reproduces the stresses of the intact ACL with regard to varying lengths and tensions of the intact ACL fibers throughout the range of motion (874). Despite these benefits, allografts are somewhat questionable in humans. There is some risk of obtaining the tissue from a patient carrying Human Immunodeficiency Virus (HIV). There have been five reported cases since 1988 of transferring HIV through ACL allograft surgery (873).

Anterior cruciate ligament tendon autograft is most commonly used in ACL reconstructive surgery. The goal of reconstructive surgery, of course, is to restore stability of the knee while maintaining its full range of motion. To accomplish this, all ligaments and capsular restraints must be isometric within the full range of motion. Thus, selecting the graft is important. It must provide functional stability, and harvesting the graft must not leave the patient with an additional deficit. One factor to consider when choosing a graft is tensile strength. The graft used to reconstruct the ACL should be at least as strong as the ACL, if not stronger. Graft stiffness should also be considered; this value gives a clear picture of how the graft functions within the safe zone of loading before failure (868).

Several tissues can be used as autografts to replace the ACL, including the iliotibial tract, the middle third of the patellar tendon, the gracilis tendon, and the semitendinosus tendon. Except for the patellar tendon, none of the structures when used alone have the same tensile strength as the native ACL. A normal ACL can be loaded to 1725 Newtons, while the patellar tendon can be loaded to 2900 Newtons (868). (Normal activities load the ACL to 454 Newtons). Although none of the other tendons can reach this strength when used alone, two graft tissues can be used in combination for added strength. For example, a combination of the iliotibial tract and the semitendinosus tendon, a doubled semitendinosus, or the gracilis and semitendinosus tendons may be used.

When the semitendinosus and the iliotibial tract are used, they run in a parallel course from opposite directions and are simultaneously pulled tight and sutured together along an extra-articular course (852). Although this combination of tendons offers good results and a low incidence of postoperative arthrofibrosis, it is usually not the best choice for athletes due to its inadequate strength and compliance at heavy loads.

The semitendinosus and gracilis tendons offer avoidance of disruption of the extensor mechanism and ease of harvesting. In addition, in a study by Lipscomb et al. (1982), it was shown that when both the semitendinosus and gracilis tendons were used in

ACL reconstruction, flexion after surgery was 99 percent of that of the normal knee (870). There also are some proposed advantages of using the hamstring tendons for ACL reconstruction in females. These include ease of graft harvesting, low morbidity, avoidance of cosmetic defects, avoidance of patellofemoral problems, and easier rehabilitation (Noojin et al. 787). However, this route does not allow for early rigid graft fixation, and this inability to achieve rigid fixation is a factor in early graft failure (Fish and Zarins 872).

Reconstruction of the ACL is most commonly performed via arthroscopic surgery. Arthroscopic surgery offers many advantages over traditional arthrotomy. There is avoidance of a long incision, resulting in a rapid return to normal activities. In addition, prolonged rehabilitation due to accidentally cutting the infropatellar nerve is avoided. There is a decrease in postoperative pain due to decreased periarticular incision and a decrease in potential loss in proprioceptive feedback from the knee being exposed as in arthrotomy. Thus, the patient offers better cooperation during rehabilitation (Sherman and Minkoff 34).

Use of the middle third of the patellar tendon is the most common method for reconstructing the ACL via arthroscopic surgery. This is due to its high initial strength after surgery, its low incidence of tissue rejection, high quality of repair, and small size of the incision at harvest (Cherniss 10). The following procedure is commonly used in a bone-tendon-bone autograft. First, the patient is anesthetized, the limb is scrubbed, and a surgical tourniquet is inflated. An anteromedial incision is made, and a 10 millimeter strip of the middle third of the patellar tendon is removed. If the graft is too long, it will result in anterior translation, and if the graft is too short, it will restrict the knee. A portion of both the anterior inferior patella and the tibial tuberosity are chiseled from their attachments. One team then prepares the graft for implant by sizing the bone plugs, fragments of bone the graft is secured to for implantation. The team also tubularizes the soft tissue with sutures. Meanwhile, a second team prepares the knee to receive the graft.

Three more incisions are made: one for the arthroscope, one to introduce the saline to clear the field, and one to function as an opening for instruments. The ruptured ligament is removed, and the joint is cleared of any other necrotic tissues. A femoral notchplasty is performed to minimize the chance of impinging the graft after surgery. Without this procedure, the femoral notch could be too small for the graft and anterior translation could result. A bony tunnel is drilled over a guide pin through the femur and tibia at an angle designed to approximate the anatomical orientation of the ACL. The narrower inferior bone plug is then inserted through the larger diameter femoral tunnel and is pulled downward. As the larger superior plug passes through the femoral tunnel, it becomes wedged in the femoral tunnel. The graft is set at a desired tension, and the inferior plug is secured in the tibial tunnel with a screw fixation. This is shown in Figure 8, taken from Turek's Orthopedics, page 596 (Appendix A). The surgeon then takes the knee through a full range of motion ensuring that there is proper tension in the graft and an adequate space in the femoral notch. A hemovac, which removes excess blood to prevent swelling, is inserted and the incisions are closed. The tourniquet is discontinued and the anesthesia is terminated. Next, the knee is wrapped in a sterile dressing, placed in a knee brace, and a cold pack is applied to reduce swelling (Cherniss 10-11). After surgery, the patient will see a 1-2 inch knee incision and 3 small incisions, less than a quarter of an inch in size.

Within the past five to ten years, rehabilitation times after ACL surgery have been cut in half. Rehabilitation now starts on the first postoperative day. In fact, the patient is encouraged to walk in a locked brace on the first day to reduce the amount of scarring. A full return to all pivoting activities and sports may occur about 6 months following surgery if thigh muscle strength is 85%-90% of that of the uninjured knee (Ciccotti). Ace wrap, which the surgeon placed on the patient, is removed 48-72 hours after surgery and some bruising and swelling can be expected. A continuous passive motion machine, which helps to reduce stiffness and muscle atrophy, may be used for approximately 7-10 days after surgery (Ciccotti). Patients can expect to be on nonweight-bearing status for about 3 weeks while continuing to be in a metal-hinged knee brace for immobilization. At six weeks, the brace may come off, and active exercise can start.

The overall rehabilitative process consists of five stages, with specific goals for the athlete to reach in each stage. The athlete can not proceed to the next stage without meeting the goals in the current stage. The following rehabilitative plan is accelerated specifically for the competitive athlete.

1). Stage I- Immediate Postoperative Phase (Day 1 through Day 7)
Goals: Restore full passive knee extension.
Diminish joint swelling and pain.
Restore patellar mobility.
Gradually improve knee flexion.
Reestablish quadriceps control.
Restore independent ambulation.

2). Stage II- Early Rehabilitation Phase (Week 2 through Week 4)
Goals: Maintain full passive knee extension.
Gradually increase knee flexion.
Diminish swelling and pain.
Muscle training.
Restore proprioception.
Patellar mobility.

3). Stage III-Intermediate Phase (Week 4 through Week 10)
Goals: Restore full knee range of motion (0 to 125 degrees).
Improve lower extremity strength.
Enhance proprioception and neuromuscular control.
Improve muscular endurance and balance.
Restore limb confidence and function.

4). Stage IV- Advanced Activity Phase (Week 10 through Week 16)
Goals: Normalize lower extremity strength.
Enhance muscular power and endurance.
Improve neuromuscular control.
Perform selected sport-specific drills.

5). Stage V- Return-to-Activity Phase (Week 16 through Week 22)
Goals: Gradual return to full unrestricted sports.
Achieve maximal strength and endurance.
Normalize neuromuscular control.
Progress skill training (Wilk et al. 180-181).

In addition to considering these five stages of rehabilitation, there are eight special factors to consider in ACL rehabilitation of the female athlete.

1). Female athletes have a wider pelvis and increased genu valgum. Thus, control of valgus moment at the knee joint should be gained.

2). Females recruit the quadriceps muscle more. In rehabilitation, females must work on restraining the neuromuscular pattern and using the hamstrings more. An example of a rehabilitative exercise during this phase is lateral lunges with ball catches.

3). Females generate muscular force more slowly than males. They need to work on high-speed training, especially in the hamstrings. This could be accomplished through backwards lunges and backwards running.

4). When female athletes jump, they may lose hip control upon landing. Thus, they must increase hip musculature to stabilize the knee. Examples of exercises used to accomplish this goal include the dip walk and squats performed on foam.

5). Females have less developed thigh musculature. Thus, they must train the thigh musculature to assist in stabilization. Exercises to accomplish this include bicycling and wall sits.

6). Females exhibit genu recurvatum and increased knee laxity; they must learn to control hyperextension. Plyometric jumps, for example, jumping off of a box and then jumping again, could be used for this purpose.

7). Females exhibit less effective stabilization, they must enhance their neuromuscular control and protective pattern reflexes. They could be required to do squats on a tilt board or walk on a balance beam steadied by cords.

8). Females have poorer muscular endurance rates, so they must train to enhance endurance. Stair climbing and weight training with low weight and high repetitions could be part of the rehabilitative protocol (Wilk et al. 179,185).

The success of these protocols are dependent on the athlete's hard work and cooperation with the physical therapist or athletic trainer.

As mentioned earlier, there are approximately 80,000 ACL tears annually in the United States. The cost of repairing these injuries is almost 1 million dollars ("Strategies..."). Thus, identifying risk factors and prevention methods is of widespread health and economic importance. Indeed, there are certain precautions athletes can take to protect themselves from getting an ACL injury in the first place.

"'...We do know that prevention programs that emphasize balance and motor skills show promise as a way to decrease noncontact ACL injuries,' notes Atlanta orthopedic surgeon Letha Y. Griffin. 'It appears that if people learn to stay balanced in their lower extremities, they can reduce their risk of noncontact ACL injuries'" ("Strategies..."). Staying balanced is important because it cuts down on the number of ACL injuries due to out of control movements and landings. The "position of no return," mentioned earlier stresses the importance of a get-down, knee flexed, two-footed balance position (Ireland 152). In addition, there are some training protocol that coaches can use to keep their athletes from obtaining ACL injuries. Weight training is important because it helps develop the minimum levels of strength needed and establishes the proper relationship between muscle groups. Weight programs should be designed to develop the strength and power needed for vigorous activity. Strengthening the quadriceps tends to decrease the Q angle, which may be helpful to some athletes. Coaches could also schedule specific skill training sessions. This enhances musculoskeletal control and stability and increases the athletes' experience levels. For example, basketball players could work on jumping, landing, and pivoting maneuvers and on avoiding the "position of no return." Coaches should also include a day off into the routine, especially for athletes who are not optimally conditioned (Brezzo and Oliver).

Weight training and proper technique are especially important to women, who have many predisposing factors to ACL injuries. Specifically, women need to build up the hamstrings and the inner quadriceps during weight training. This coupled with learning the proper landing and twisting techniques can help women beat their biomechanical setbacks. Explains Edward Wojtys, an orthopedic surgeon from Ann Arbor, Michigan, "'As we develop prevention programs to reduce the number of noncontact ACL injuries, we need to keep in mind that the way women jump and land contributes to a very high rate of serious knee injuries. By adapting the physical training programs, we can reduce that rate and keep more females in the game longer'" ("Strategies...").

Athletic shoe support is an important factor to consider when trying to prevent ACL injuries, and it is often overlooked by athletes. If shoe support is inadequate, overuse and structural and functional problems could occur (Brezzo and Oliver). The shoe should fit properly and should be well cared for. When the foot is in a balanced position, excessive pronation and supination should be prevented; this puts less stress on the knee. The shoe should also be appropriate for the playing surface. For example, a football player would not use cleats on artificial turf. In addition, softball, baseball, and football players should use the proper length cleats when playing on a wet field.

Despite its small size, the anterior cruciate ligament causes big problems for nearly 80,000 athletes each year. As these athlete's have learned, the ACL's functional importance to the knee in jumping, pivoting, and decelerating, ultimately leads to its downfall as these are the vary movements that lead to ACL tears. In addition, as the number of women participating in sports has risen, the number of women falling victim to ACL tears has risen unproportionately. In fact, because of anatomic factors, strength differences, and perhaps hormonal factors, women are three to five times more likely than men to incur an ACL injury despite improved training and skill levels. Athletes that fall victim to an ACL injury face surgery and approximately six months of rigorous rehabilitation to return to competitive sports. There are, however, measures athletes can take to avoid this process altogether. With proper shoe support, weight and endurance exercises, and training in sport-specific mechanics, athletes can enjoy sports without enduring an ACL injury.

APPENDIX A

Figure 1: The Anterior Cruciate Ligament

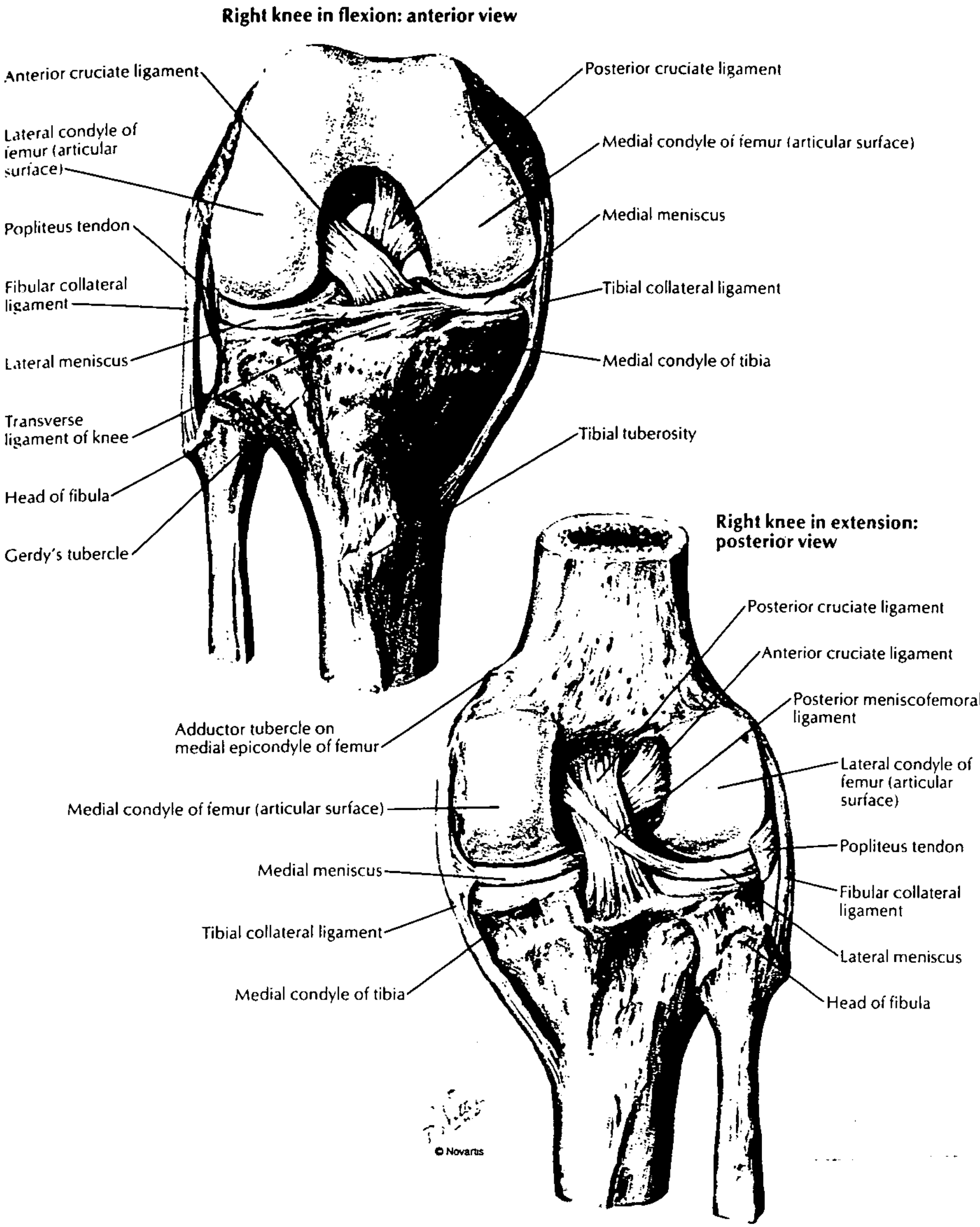


Figure 2: The Position of No Return

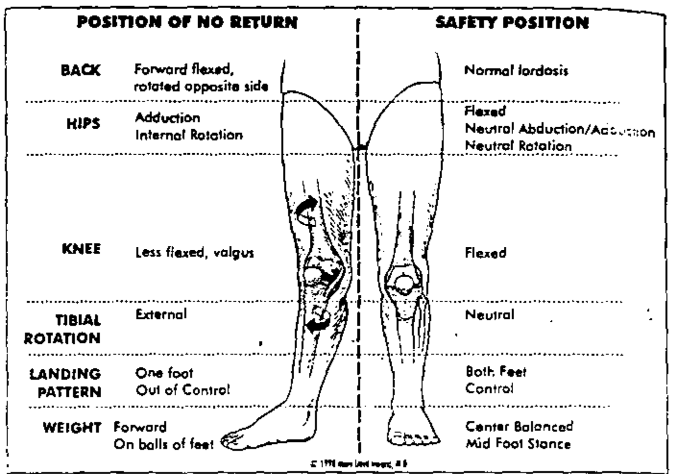


Figure 3: Measurement of Navicular Drop
(Measurement is taken first while sitting, then while standing).

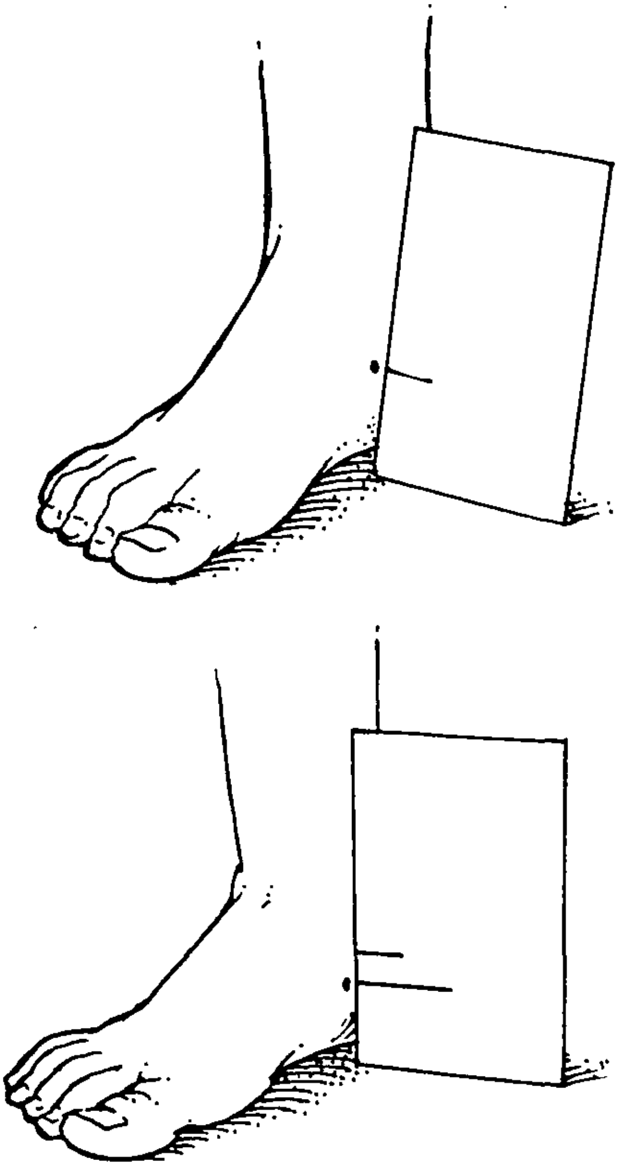


Figure 4: Measurement of the Notch Width Index

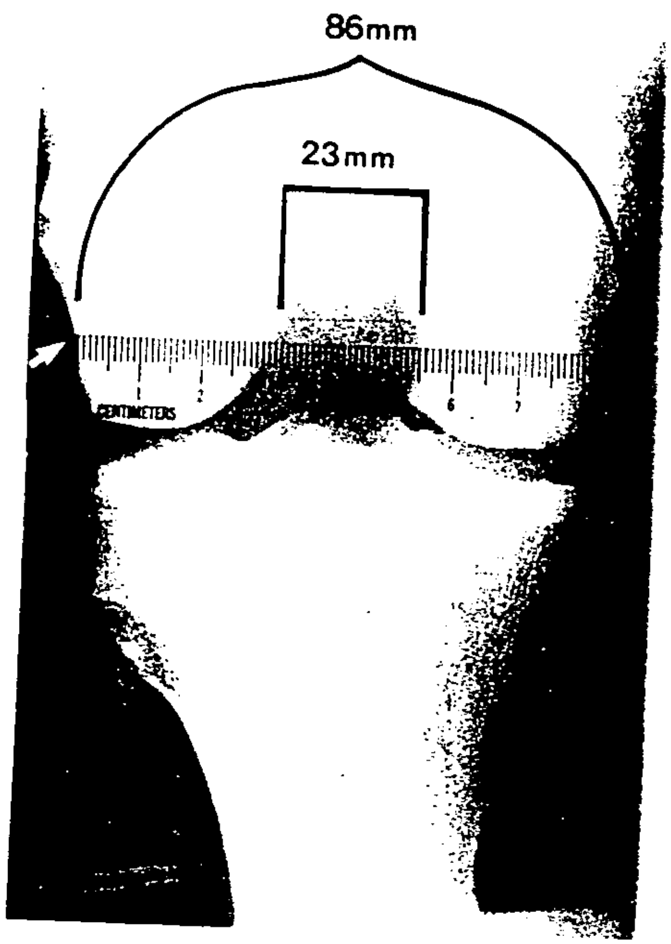


Figure 5: Whiplike Snap of the Lower Extremity in ACL Tears

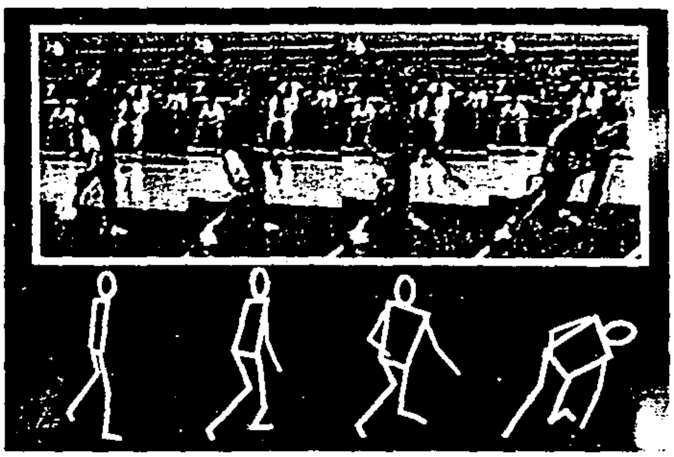


Figure 6: The Anterior Drawer Test

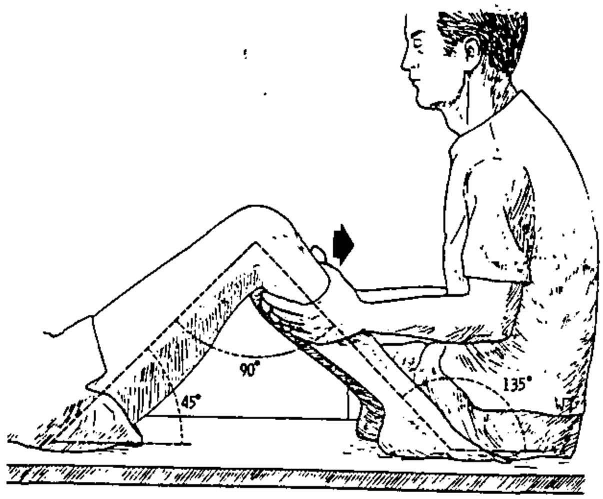


Figure 7: The Lachman Test

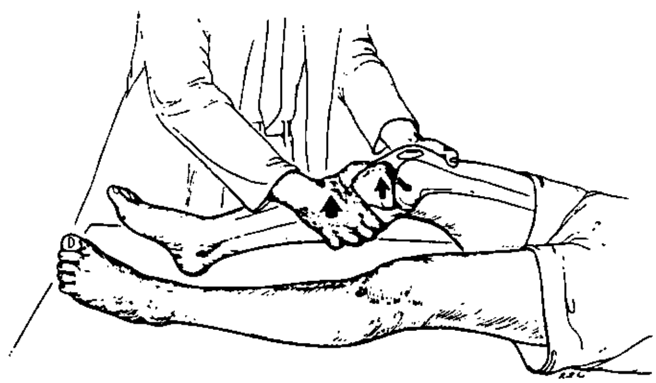
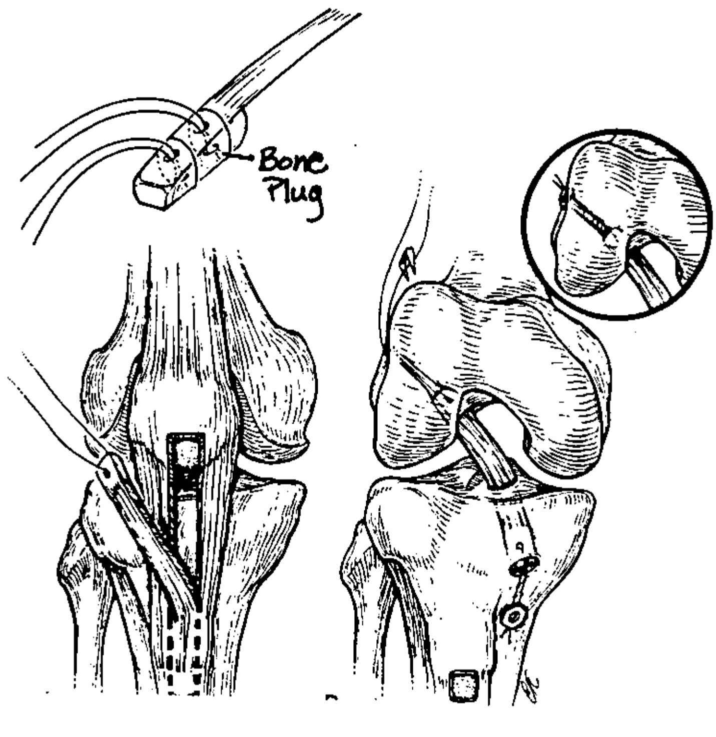


Figure 8: Bone-Patellar Tendon-Bone Autograft



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