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Linking of Injury: A Case Study of a Division I Soccer Player

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The Linking of Injury:
A Case Study of a Division I Soccer Player

Lauran Dempsey
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ABSTRACT:

I examined the sequence of injuries of Jennifer Laughridge, a former soccer player from the University of Tennessee. Beginning with an Anterior Cruciate Ligament reconstruction surgery in 2000, Jen underwent a total of four surgeries to her left knee. The repercussions of the ACL rupture extended past the ligament damage in itself. Concomitant injuries to the meniscus and bone bruising on the lateral femoral condyle proved to be catalysts for subsequent injuries. The meniscus re-tore one year later and surgery ensued. The bone bruise became of interest once again, when in fall 2002, Jen went down with an osteochondral defect. I examined medical journals to reveal what factors contribute to re-tearing of the meniscus and the impact the bone bruise might have had in the osteochondral injury. I found that from the initial ACL injury, Jen was indeed increasingly susceptible to reinjury, especially with the continuance of competitive soccer. Both the meniscal injury and the osteochondral defect seem to be strongly linked to the initial ACL tear. It would be difficult to offer a recommendation for improving outcome in this type of situation, due to the structure of the NCAA and the time pressures of the athlete. Time off after surgery is hard to fathom for someone who feels he/she needs to be practicing and improving. But, the journal review seemed to advocate an increased amount of time for the structures of the knee to recover from the intense damage done.
The Linking of Injury: A Case Study of a Division I Soccer Player

Introduction

Health care professionals and sports fans alike know how prevalent ACL tears are. Extensive research has been done to determine the relative causes of these injuries and what can be done to prevent the often season-ending injury. Studies have shown that females are the likely candidates for the ACL tear, but males are, by far, not excluded. A number of factors can contribute to the disparity between the number of males versus females who tear their ACLs, and these considerations will be briefly discussed later in this study. In this research, the focus will be on a former soccer player from the University of Tennessee, Knoxville. Jennifer Laughridge, at age twenty, tore her ACL and proceeded to have a career filled with devastating knee injuries and chronic knee pain. Looking at how the ACL tear contributed to the successive injuries and what, if anything, can be done differently to ensure that this pattern of injury will not occur again is the purpose of this study.

The Anatomy of the Knee

The foundation of this study is the structures of the knee. The knee actually consists of three joints, some more “pertinent” than others in this particular study. It includes the tibiofemoral joint (the main “knee” joint), the patellofemoral joint, and the superior tibiofibular joint. The tibiofemoral joint is a modified hinge (ginglymus) joint and holds the title of the largest joint in the body. As a synovial joint, it consists of a joint capsule, a “sleeve-like” layer of tissue connecting and enclosing the ends of both bones involved.
This encasement is lined with a fine vascular capsule that secretes synovial fluid, which lubricates the joint. The condyles (the rounded projections) of the femur are not completely congruent with the condyles of the tibia, therefore making this a “modified” hinge joint. In order for the tibiofemoral joint to reach close packed position, the tibia must laterally rotate as the joint is extended. This process is referred to as the screw-home mechanism. At 25° of flexion, the tibiofemoral joint is in resting position (also the most comfortable position after injury) 1,14.

As a modified plane joint, the patellofemoral joint exhibits a gliding motion. The capsule of the joint is continuous with the capsule of the tibiofemoral joint. The patella, located in the patellar tendon, serves as a lever for the tendon. Increased effectiveness of extension in last 30°, decreased friction of the mechanism, and guide for the quadriceps (patellar) tendon are all contributions of the patella. The patella has greatest contact area with the femoral groove between 60-90° of flexion, while the greatest amount of compressive forces exist at 30° of flexion14.

The final joint, the superior tibiofibular joint, is the least significant of the three in the movement of the knee. This joint moves with movement of the ankle. Hypomobility of this joint can illicit pain in the knee 14.

Estimated to bear as much as 45% of the total load of knee, the menisci are an important feature of this joint. The menisci are pads of fibrocartilage located on the tibial condyles. The medial meniscus is C-shaped and the lateral meniscus is O-shaped, aiding in the congruency of the tibiofemoral joint and in the prevention of hyperextension of the joint. By guiding the articular cartilage, the menisci effectuate the screw-home
mechanism. Both menisci are thicker on the outer region and get increasingly thinner toward the inner region. This setup allows for the increased weight distribution over the condyles, creating shock absorbers that decrease the cartilage wear. Being avascular in the inner two-thirds, the menisci do not regenerate well. Therefore when injury does occur, healing in these areas of the meniscus is not promising. Also, it is believed, the meniscus can be damaged without a great deal of pain, due to the minimal nerve innervations of the meniscus. Some believe that only when the coronary ligaments that attach the menisci to the tibia are damaged can one feel pain. Others have found that about two-thirds of the meniscus is sufficiently innervated and pain does occur with injury. The medial meniscus is firmly attached to the tibia by coronary ligaments, the MCL, and fibers of the semimembranosus muscle. The lateral meniscus is less firmly attached than the medial meniscus and retracts on the contraction of the popliteus muscle. During flexion, the lateral meniscus moves up to 10mm posteriorly, while the medial meniscus shifts only to 2mm posteriorly. This arrangement increases the propensity for injury of the medial meniscus. If the meniscus is removed, the amount of friction in the joint increases substantially, causing wear down of the cartilage and the lubrication and nutrition in the joint is compromised. Consequently, when surgery is performed on the meniscus, only the part damaged is removed if need be.

Other features of significance in the knee are the bursae. Bursae are sac membranes containing synovial fluid usually found between tendons and bones. There are more than ten bursae in the knee and they serve to reduce friction in the joint. During movement of the joint, synovial fluid travels through the bursa and lubricates the area. During
extension of the joint, posterior bursae are compressed and fluid shifts anteriorly, while in flexion the anterior bursae are compressed and the fluid shifts posteriorly. At 25° of flexion (open-pack), the fluid is under the least amount of pressure, thus decreasing pain caused by swelling!

Ligaments of the knee include the anterior cruciate ligament, the posterior cruciate ligament, the medial collateral ligament, and the lateral collateral ligament. Stabilization is the main purpose of the ligaments. The lateral collateral ligament (LCL) guards against varus forces to the knee. Running from the lateral epicondyle of the femur to the head of the fibula, the LCL also aids in limiting external rotation of the tibia on the femur. The medial collateral ligament (MCL) stabilizes against valgus forces. As mentioned before, the MCL is joined with the medial meniscus and also connects with the joint capsule. It stretches from the medial epicondyle of the femur to the medial tibia. This thick ligament actually consists of two layers, which are separated by a bursa. The posterior cruciate ligament (PCL) serves as resistance to posterior translation of the tibia on the femur. It also consists of two layers, a large anterolateral band and a posteromedial band. This ligament runs from the lateral anterior medial condyle of the femur to the posterior tibial intercondyloid fossa. (Thus named for the tibial position). The PCL’s counterpart, the anterior cruciate ligament (ACL), resists anterior tibial displacement of the tibia on the femur. It can also protect against hyperextension of the tibia, internal and external rotation of the tibia on the femur, and posterior translation of the femur on the tibia. Proprioception is another function of this ligament. Proprioceptors are sensory receptors found in ligaments, tendons, muscles, skin, and joints, which relay
to the central nervous system information about tissue deformation\textsuperscript{1}. These receptors monitor balance and body position and send this information to the brain. If the brain does not have enough time to respond and reposition the body to avoid harm, an injury can occur. The ACL crosses the PCL, stretching from the medial posterior lateral condyle of the femur to the anterior intercondyloid fossa of the tibia. Comprised of an anteromedial band and a posterolateral band the ACL twists on itself. With full extension, the anteromedial bundle is located anteriorly to the posterolateral bundle in regard to femoral attachment, which causes the posterolateral band to tighten. During flexion, the arrangement is transposed and the anteromedial band becomes tight. The ACL and its counterpart, the PCL, are both extrasynovial, meaning outside the capsule \textsuperscript{1,14}.

**Introduction: Jen Laughridge**

The subject of this study is a former University of Tennessee soccer player, Jennifer Laughridge. A multi-sport athlete in high school, Jen garnered a reputation for being the toughest, most competitive individual on any of her teams. While attending UT, Jen reinforced the notion by overcoming numerous injuries that could have seriously hindered her career as a soccer player.

As a teenager Jen showed signs of Osgood-Schlatter’s Disease (OSD), a common condition in athletic adolescents. This injury is caused by the constant pull of the quadriceps muscle on the tibial tubercle, causing the tubercle to become sore and enlarged. This condition did not limit Jen’s soccer participation.

In 1996, at age 15, Jen incurred her first, of many, knee injuries. Stiff and sore, Jen
was, at one point, unable to bend her left knee. After examination and x-rays the physician diagnosed Jen with a capsular sprain, finding that everything appeared normal. Three weeks later the condition had cleared up and the physician advised Jen to take some time off from training. This injury would be the least significant in a series of injuries in Jen’s left knee.

In fall of 1999, her sophomore year at UT, Jen collided with an opponent while having her foot planted on a ball, again injuring Jen’s left knee. The x-rays were normal, while the MRI showed a partial avulsion of her patellar tendon at the tibial insertion site. This finding could have been a result of the injury, but more likely, it was due to the Osgood-Schlatter Disease earlier in her life. She was allowed to progress her activities to tolerance and was released to full activity.

On March 4, 2000 in the last minute of a spring match, Jen went down with another injury to her left knee. While planting her left foot to change directions, Jen heard a loud pop in her knee, experienced immediate pain, and fell to the ground as her knee gave out. In examination, a positive Lachman’s test revealed a torn ACL. Upon the advise of her surgeon, Dr. Gregory Mathien (GM), Jen opted for a donor graft due to her earlier patellar avulsion and proceeded to have reconstructive surgery on March 17, 2000. During surgery it was determined that Jen had also torn parts of both her medial and lateral meniscus. Debridement of the inner rim of lateral meniscus was performed, while the majority of this meniscus was intact. A peripheral tear in the posterior horn of the medial meniscus was revealed and repair ensued. The damaged surface was repaired using meniscus arrow fixation. Also, an indication of bruising to the lateral femoral
osteochondral surface was noted, but no specific treatment was required for this injury. Additionally, it was revealed that Jen had remnants of an old cartilage injury on the medial femoral condyle, perhaps the result of the “capsular sprain” earlier in her career.

The ACL was then reconstructed using a donor’s graft and the surgery was deemed a success. Jen was off crutches in three weeks, while after four weeks she had excellent flexion and stability, with a slight lag (4°) in extension. Six weeks post-op, Jen was jogging in the pool and using an Elliptical machine. Jen reports running on May 2, although this was against the advise of the doctors and athletic training staff. By May 25, a little over two months post-op, Dr. Mathien limited Jen’s activity to jogging and dribbling skills and banned her from sprints, scrimmaging, or full speed kicking with her left leg as the plant foot. Four months post-op (early August 2000), Jen was released to full participation.

After red-shirting in the fall due to recurrent pain in both knees, Jen re-injured her left knee in the spring of 2001. Four weeks into the spring soccer season, Jen began experiencing soreness along the medial side of her knee, along with a feeling of the knee “giving out.” She could not pinpoint any specific time the pain had started. During an arthroscopic evaluation on May 1, 2001, it was established that Jen had re-torn the posterior horn of her medial meniscus. The tear in the meniscus had both a vertical and flap components. Fortunately, the articular surface was in good condition. A partial medial meniscectomy was performed with a motorized shaver. Dr. Mathien proceeded to contour and balance out the anterior and posterior portions of the meniscus. While surveying to rule out any further pathologies in the knee, Dr. Mathien discovered a
small meniscal cyst attached to the medial meniscus. The cyst was decompressed and the meniscus was re-checked for stability. This operation went along smoothly and Jen was released from the hospital that day. A week after surgery Jen was off crutches and had full range of motion. Activity was as tolerated until full recovery.

Eagerly awaiting a year without injury, Jen commenced her third year of soccer at the University of Tennessee. The 2001 season went uninterrupted by injury and Jen became the second all-time leader in assists at UT with 20. During the spring season Jen developed a problem in her right hip, but not to the extent of her knee injuries.

As a fifth-year senior, Jen had become the team leader in every aspect. Unfortunately, on September 20, 2002 playing against South Alabama, Jen incurred another set back when she went up for a ball. Upon landing she felt a pop in her left knee as it gave out. A probable meniscal tear was the assessment and Jen was scheduled for yet another arthroscopic evaluation. Since this season would be Jen’s final year to play collegiate soccer, she was against any surgery that we deny her playing time. Due to the pain, however, Jen assented to surgery under the condition she would be released to play the remainder of the season following rehabilitation. Undergoing the arthroscopic evaluation on September 26, Dr. Mathien determined that Jen had damaged the articular cartilage of her lateral femoral condyle. A Grade 4 status was given to the injury, indicating no articular cartilage present at the specific site. Because of Jen’s wishes to play, Dr. Mathien refrained from repairing the damage, which would have sidelined Jen for the rest of the season. Dr. Mathien removed a loose body, cleaning out the knee. Returning to action October 9, 2002, just thirteen days after surgery, Jen scored a vital
goal against the 7th-ranked Wake Forest Demon Deacons, leading the Lady Vols to a 2-0 victory. Playing the remainder of the season with a plug of articular cartilage absent from her knee, Jen was a major contributor to the most successful season in Lady Vol soccer history. In 2002, Tennessee won the SEC tournament, in which Jen was named to the All-Tournament team, and made its first-ever appearance in the sweet sixteen of the NCAA tournament. Jen finished out her career at UT as the all-time leader in assists at UT (25), all-time leader in number of matches played (83), #3 overall in shots (176), #4 overall in matches started (69), #5 overall in match-winning goals (5), #6 all-time in points (58, 16G-26A), and #7 all-time leading scorer (16). After the season, Jen went back to the operating room for her fourth surgery on her left knee. On December 13, 2002, an osteochondral allograft transplant was performed after the removal of yet another loose body. The medial meniscus and medial articular surface were both in good condition, along with the lateral meniscus. The lesion, measuring 12mm in diameter, had increased in size due to the pounding of the season. Dr. Mathien debrided the necrotic flaps at the margins. An incision was created on the lateral portion of the patellar tendon, allowing for adequate room for the transplantation. Contour was established and the surgery was completed. Jen spent six weeks on crutches, completely non-weight bearing. During this time, range of motion and strengthening exercises were performed. After four weeks post-op, Jen had full flexion of her knee. At six weeks post-op, Jen was limited to 25% weight bearing in her left leg. She continued to progress and has now made a full recovery.

Jen Laughridge now coaches soccer for a club team in Raleigh, North Carolina.
BRINGING IT ALL TOGETHER

In this section, the processes of Jen’s injuries will be evaluated, as well as the procedures taken to recover from the injuries. Any link that might occur between the injuries will be established, as well as any possible alternative to avoid this accumulation of injuries.

Starting at One: The ACL Injury (Spring 2000)

Mechanism

As stated earlier, Jen sustained her ACL injury in a non-contact situation. A common mechanism for this type of injury, Jen planted her left foot in an attempt to change directions when she felt her knee give-way. This situation contributes a large amount of valgus stress (the tibia moving away from the femur on the medial side) to the knee joint. The tension is due to the sudden stop of the lower leg, while the momentum of the body continues to push in the prior direction. Because the ACL stretches from the anterior, medial portion of the intercondyloid fossa of the tibia to the posterior, medial area of the lateral condyle of the femur, it becomes taut during a valgus stress. In Jen’s case, her body could not adjust quickly enough to compensate for this stress and the ACL could not support all the pressure, therefore tearing the ligament. During this stress, the femur slams against the tibia, tearing the meniscus and bruising the bone, particularly on the lateral side. Also of note, Jen’s injury took place in the 89th minute of the game. Kirkley et al. found that regardless of gender, fatigue can play a major role in ACL injuries. Muscle response is slower in a fatigued state and there is an increased displacement of...
the tibia when the gastrocnemius, hamstrings, and quadriceps are fatigued. Steiner et al. found an 18% to 20% increase in anterior and posterior laxity arose after 90 minutes of basketball practice in uninjured knees. Given that Jen played more than half the game, fatigue could have been a main contributor to her injury.

**Why Females?**

Why this type of injury occurs and how it can be prevented has been the subject of a myriad of research. It has been definitively reported that ACL injuries occur in females at a much higher rate than males. Many explanations have been proposed for the overwhelming number of females with ACL tears. Mary Lloyd Ireland describes the "position of no return" for many female athletes in which the athlete "is noted to be in a relatively upright position with less flexion of the hip and knee, relatively straight back, momentum forward, and then excessive valgus at the knee." She further notes that gender is a main factor due to differences in hormones, anatomy, femoral notch size, neuromuscular training, and core stability. Estrogen is believed to be involved in ligament laxity, as it has been reported that ACL injuries occur most frequently during the ovulatory phase when estradiol levels are highest. Anatomical differences that may contribute to ACL injuries include ratios of hip width to femoral length (females have a higher ratio) and Q-angle, the angle between the line of the quadriceps force and the patellar tendon (females have a slightly greater angle). A smaller femoral notch size has been linked to ACL injuries, regardless of gender. Shelbourne and Kerr found females had a "significantly narrower notches than men" of the same height. It is also reported that females have an increased laxity in the joint and take longer in sensing knee joint
motion (proprioception) while extending the knee. Neuromuscular differences seem to contribute most significantly to ACL injuries. Males have a better ability to stiffen their knees, a sign of maximum muscular contraction, which protects against anterior tibial translation. In addition, it has been found that females take considerably longer in generation of maximum hamstring force; a force that supports the ACL in its role. Also, females tend to activate their quadriceps instead of the hamstrings when preventing anterior tibial translation. Females when cutting, have, on average, less knee flexion, less hip flexion, more knee valgus, and less hamstring activation. In doing a simple step-down exercise, females tend to rotate the pelvis anteriorly, adduct and medially rotate the femur causing the tibia to laterally rotate and the foot to pronate. This position causes high valgus stress on the knee joint. Males tend to rotate the pelvis posteriorly and keep the knee over the ankle, decreasing valgus stress to the knee. Core stability is cited as a factor in protecting against ACL injuries by relying on the core (abdominal, back extensor, and hip musculature) to provide a stable base for the rest of the body. Males tend to have a stronger core compared to females.8

Reconstruction surgery

After finding remnants of old Osgood-Schlatter’s disease and a partial patellar tendon avulsion on the x-rays, the type of graft that could be used for surgery became limited. Normally an autograft (graft taken from the individual’s own body) is taken from the middle third of the patellar tendon to replace the ACL; however, due to Osgood-Schlatter’s disease and the prior partial patellar tendon avulsion, Dr. Mathien decided, with Jen’s consent, to use an allograft (graft taken from a human donor). During surgery,
a small 2.5-3cm incision was made over the anteromedial aspect of the proximal tibia. A guide pin was placed on the tibia based on the imprint of the remaining ACL stump. This placement was 7mm anterior to the PCL and posterior to the anterior horn attachment of the lateral meniscus. A tunnel 10mm in depth was created in the tibia upon pin placement. A “femoral isometric point” was determined by using the posterior articular margin of the inner wall of the lateral femoral condyle as a point of reference. A guide pin was placed, and a tunnel 30mm in depth and 10mm in diameter was created in the femur. After testing for any impingement that could occur, the knee was thoroughly irrigated. The ACL graft was then brought through the tibial tunnel and into the femoral tunnel. Femoral fixation was achieved using an 8 x 23mm bio-absorbable interference screw, while tibial fixation was attained using a 9 x 23mm bio-absorbable interference screw. The joint was checked for stability and range of motion. Deemed a success the knee was again irrigated before closing the incision.

**Biology**

In order for the allograft to be received by the body, many biological processes must occur. Graft necrosis, cellular repopulation, revascularization, and collagen remodeling are all involved. The donor cells in the graft must undergo necrosis before the cellular repopulation begins. Repopulation, most likely from synovial cells, occurs around 4 to 6 weeks after surgery. This process starts on the outer regions of the allograft and moves inward. Revascularization begins 3 weeks after surgery and is complete by week 8. The blood stems from the posterior synovial tissue and the infrapatellar fat pad. Original large diameter collagen fibrils are remodeled with small diameter fibrils, a process which takes around six months for completion\(^{24}\).


**Autograft vs Allograft**

In comparing allograft and autograft reconstructions, it has been shown in a study by Shelton et al. that there is no difference between the two with regard to pain and swelling, pivot shift test, range of motion, patellofemoral symptoms, or in Lachman's test 3 to 12 months after surgery. However, 24 months post-op, more patients with allografts had a glide on the pivot shift compared with patients with autografts. Autografts have a low risk of adverse inflammatory response and minimal risk for disease transmission. Yet, autograft reconstructions were linked to a higher incidence terminal knee extension loss (3° loss versus 1.2° loss). Allografts have several advantages, including no donor site morbidity, a lower incidence of postoperative knee stiffness, earlier rehabilitation due to quicker recovery of muscle strength, and no added risk of patellar fracture. However, it has been shown that the allografts remodel slower and less effectively than autografts. It has been estimated that allografts are completely repaired by 18 months post-op. In a study done by Jackson et al. it was revealed that at six months post-op, a statistically significant difference between allografts and autografts in regard to the amount anteroposterior translation in the joint, with the allografts shifting more. From the results of this study, it was recommended that people with allograft reconstructions should have a slower rehabilitation, releasing to run only after six months post-op.

**Type of Graft**

The type of graft used for this particular surgery varies among surgeons. Most advocate the frequently used bone-tendon-bone (BTB) graft (both allograft and autograft) due to its bone-to-bone healing in the femur and tibia. Soft tissue allografts also are used, and include posterior tibialis tendon, anterior tibialis tendon, and Achilles' tendon.
Autograph soft tissue replacements are quadrupled semitendonosus/gracilis tendons and quadriceps tendon.

In the BTB graft, the central third of the patella tendon with bone on each end is used as the replacement ACL. Miller et al. reports that the BTB graft is the only graft among semitendinosus, quadriceps, fascia lata, and iliotibial tract grafts whose strength is greater than that of an original ACL (~168% of ACL). In addition to this advantage, it is estimated that BTB healing is completed six to eight weeks post-op, while the soft tissue completes healing at around twelve weeks post-op (due to healing by developing scar tissue or fibrous tissue). However with a BTB graft, one risks the developing harvest site morbidity in autografts, which can lead to patellofemoral pain.

**Graft Placement**

Placing of the graft has been subject to discussion, with the prominent placement being the posterior portion of the ACL tibial insertion site. This arrangement decreases graft impingement with knee extension. Impingement will cause extension loss, anterior knee pain, and effusions. Lawhorn and Howell recommend either a PCL-referencing guide with a 10mm offset replacement or centering the tibial tunnel posterior 4-5-mm posterior and parallel to the intercondylar roof with the knee in extension. However, Strickland et al. advocates the PCL-referencing system with the 7-mm placement anterior of the PCL, the placement Dr. Mathien used. The appropriate placement of the tibial tunnel contributes to the correct placement of the femoral tunnel.

**Graft Fixation**

The bone-tendon-bone graft as used in Jen’s reconstruction allows for bone-to-bone fixation, which is thought to be similar to the healing of a fracture. Interference screws,
also used in Jen’s surgery, are the most popular fixation method.

**Meniscus**

Not to be ignored, Jen had significant meniscal repair done during her ACL surgery. Prior to the reconstruction of the ACL, Dr. Mathien debrided Jen’s lateral meniscus (partial meniscetomy) after identifying “some inner leading rim tearing” in the area and repaired her medial meniscus after finding a peripheral tear of the posterior horn. Meniscal injury occurs during severe anterior subluxation of the tibia, usually due to the tearing of the ACL, and the impact of the anterior aspect of the femur onto the posterior aspect of the tibia. Going beyond the meniscus, the bone itself can get bruised, increasing the likelihood that the articular cartilage covering the bone can be damaged.

In a study by Spindler et al. 54 patients underwent MRIs to determine if meniscus injury had occurred along with their ACL tears. Fifty of the 54 patients (93%) had meniscal damage: 56% percent of the patients had lateral meniscal tears and 37% had medial meniscal tears (either complete or incomplete tears). Six of the 20 medial meniscal tears were repaired compared to only three of the 30 lateral meniscal tears. Other options for recovery were partial menisectomy (42%) or no treatment (40%). Non-contact injuries were linked to medial meniscal tearing. In an additional study, Murrell et al documented 94 of 130 patients (72%) with meniscal damage after sustaining an ACL injury. Asahina reports a 70% healing rate of all damaged menisci associated with ACL tears 16 months post-op, although the overall clinical success rate after four years was only around 54%.

Jen’s lateral meniscus was “cleaned up” by removing the damaged parts. The medial
meniscus was repaired using a rasp technique, in which abrasion serves as a promoter of vascularization and healing in the area. Afterwards an arrow fixation was used to mend the tear in the posterior horn of the medial meniscus.

**Bone Bruise**

Bone bruises are thought to occur in approximately 80% of ACL tears. In Spindler et al.’s study, 43 of the 54 ACL-ruptured group had one or more bone bruises on the lateral femoral condyle, the medial femoral condyle, the lateral tibial plateau, or the medial tibial plateau for a total of 78 bone bruises in 43 knees. Eighty-five percent of the bruises were on the lateral side, with the lateral femoral condyle being involved in 86% (37 of 43) of knees with bruising.

**Rehabilitation**

As previously stated, Jen underwent months of rehabilitation with the Lady Vols Athletic Training Staff. Chris Hofmann, ATC was her main therapist. After surgery on March 17, 2000, Jen started rehab with minimal weight bearing exercises, due to the meniscus repair, and progressed rapidly within the first few weeks. She was released in early August 2000. A timeline of the exercises and treatments performed is included in the appendix.

**Retear of the Meniscus: Partial Meniscectomy (Spring 2001)**

**Mechanism and Surgery**

In April of 2001, Jen revisited the training room as she succumbed to “soreness...and...some sensation of giving way” in her left knee. An arthroscopic
assessment by Dr. Mathien pointed to another medial meniscal tear. The posterior horn had both a flap and vertical component tear. It was addressed by partial meniscectomy using basket forceps and a shaver.

**Linking of Injury #1: Retear Rate**

The retearing of menisci is not uncommon. DeHaven et al. sight an 11% re-tear rate after a meniscal repair. Shelbourne et al. found that after ACL reconstruction and upon partial or complete meniscectomy of the lateral meniscus, 18 out of 207 (8.7%) needed an additional meniscal repair on the medial meniscus later in their lives. Whenever any meniscectomy (partial or complete) is performed, there is greater likelihood of reports of subjective complaints, such as swelling and activity-related pain. Thirty-one percent (9 of 29) of the concomitant ACL reconstruction and partial meniscectomy group in a study by Wu et al. reported giving way of the knee with activity. Taking into account the number of retears of menisci after a successful ACL reconstruction, Asahina states, “even though an ACL reconstruction may make the Lachman test or pivot shift test [tests for ACL stability] negative, the meniscus may still be exposed to excessive stress, even in those knees that are seemingly satisfactorily stabilized.”

Asahina et al. researched the factors that could be involved in the retearing of the menisci. Age, medial or lateral meniscus tearing, peripheral or central tearing, residual instability, and post-operative activities where evaluated. With a sample group of 63 patients, 50 patients had meniscus that completely healed, while thirteen patients exhibited incomplete healing. Of the thirteen with incomplete healing, six (46%) had another meniscal surgery and two had continuing symptoms, such as locking. Of the fifty
patients with complete healing, five (10%) later on required surgeries, while nine had symptoms related to meniscal injury. Statistically, an increased retear rate was linked to the incomplete healing of the meniscus. Whenever symptoms recurred, reinjury to the meniscus was proven to be the cause. However, only eleven of the twenty-two opted for additional meniscal surgery. Symptoms were reported between 12 to 28 months post-meniscal repair.

Six of the eleven opting for additional surgery, had reinjured the meniscus during sports related activity, as in Jen's case. The other five could not specify a cause. Retear either occurred at the original site or stemmed out from it. The second surgery for all eleven included a partial meniscectomy.

Age did not appear to be a factor in reinjuring the meniscus. Eighteen percent of the medial meniscal repairs and 17% of lateral meniscal repairs required additional surgery; therefore, ruling out a single susceptible meniscus. Tear site, peripheral or central, was also a non-factor in susceptibility of reinjury (6 in the former and 5 in the later). This finding was somewhat surprising when taking into account that the peripheral third is more vascular than the central third, presumably encouraging healing. Additionally, there was no significant difference in residual instability between the asymptomatic, symptomatic, and the revised surgery groups. Post-operative activities seemed to provide the most causal effect on retears. The revised surgery group participated in more physical activity than the other groups. However, Asahina points out this upward trend in retearing among the physically active could be due to the fact that there is a higher opportunity for injury during sports participation, not because of it. He also sites a study by Sommerlath
and Hamberg that reveals a reduction in activity following surgery produces more successful meniscal repairs.

Another intriguing and pertinent hypothesis Asahina et al. offers, is the idea that difficulty in viewing the periphery of the posterior horn of the medial meniscus with an arthroscope may contribute to a high retear rate at this location. He believes this theory could explain why the periphery is reinjured as frequently as the central portion of the meniscus. Reiterating, Jen tore the posterior horn of the medial meniscus.

**Osteochondral Replacement (Fall 2002)**

**Mechanism and Evaluation**

Mid-way through her final season as a Lady Vol, Jen incurred another devastating injury. Jumping for the ball, Jen landed awkwardly and felt a “pop” as her left knee gave out. Jen returned to the operating table for yet another arthroscopic viewing of her knee. Prior to surgery Dr. Mathien suspected a further tear of her medial meniscus. However, once inside, he found that Jen had a Grade 4 articular cartilage damage of the lateral femoral condyle, denoting a complete lack of cartilage in the area. Jen desired to finish out her senior year, thus Dr. Mathien cleared out a loose body in the knee, but was unable to repair the primary defect at that time. Upon completion of the soccer season, Jen had yet another surgery, an osteochondral replacement.

**Articular Cartilage Injuries**

Articular cartilage is the covering and bearing over bones in synovial joints. Dr. J.A. Buckwalter states that “damage or degeneration of this remarkable tissue decreases mobility and frequently causes pain with movement, and in the most severe cases,
chronic pain.” These injuries, however, are not easy to detect. Due to this complication, injuries to the articular cartilage and subchondral bone probably occur more frequently than first thought.

Articular cartilage is made up of water, collagens, and proteoglycans. Collagen provides tensile strength, while the proteoglycans and water combine to give the tissue resilience, durability, and stiffness to compression. Injury to the articular cartilage is most commonly due to sudden impact or torsional joint loading on the joint. Because the rapidity of the movement does not allow for the fluid movement that normally occurs within the cartilage, the regular deformation of the tissue does not take place and a particular area of the cartilage suffers a majority of the loading. In this event, the articular cartilage is compromised and the subchondral bone is at risk for injury. In addition, with rapid movements, muscles are not prepared to contract fast enough to stabilize a joint and can only absorb a minute amount of the energy generated. In a study cited by Buckwalter, it was deduced that cartilage damage would only occur under a stress level greater than that needed to fracture the femur. The extent of damage to the cartilage was dependent on the amount of repetitive loading. Increasing the amount of load or the number of loading cycles increases the extent of damage.

Surgery

During the surgery, another loose body was removed using grasping forceps. The lateral femoral condyle lesion had expanded to 12mm in diameter. Necrotic flaps at the borders were removed with a shaver and basket forceps. The lateral and medial menisci were undamaged. Dr. Mathien proceeded to perform the chondroplasty and the defect
was sized. He then created another portal anterolaterally to the patellar tendon to allow space for the transplantation. The donor replacement was prepared and fashioned to be 13mm diameter and 14 to 15mm in depth. The transplant was matched in size to the excised area of Jen’s femur and was appropriately fitted into her socket. No internal fixation device was required due to the exceptional press-fit.

**Osteochondral Replacement Surgery**

Osteochondral replacement is an option of treatment when the articular cartilage defect is severe. This technique involves the removal of disease cartilage and bone down to a practical subchondral bone. The defect is then measured for size, shape, and location. The allograft is then sized to fit the measurements. Some surgeons, such as Dr. Mathien, size the allograft 1mm greater in thickness than the original to account for bone re-absorption. It has been proven to be an effective technique in replacing a focal region and decreasing joint pain. The osseous portion of the allograft mends with the patient’s bone and the cartilage serves as the articular surface.

After surgery, a patient is required to be non-weight bearing for up to twelve weeks. Normal activity usually occurs around sixteen weeks. Sports and physical labor are usually suspended for at least six months. Often, it is recommended to avoid return to any sports requiring jumping, due to the high-load, repetitive motions.

**Linking of Injury #2: Osteochondral Defect**

Resulting from Jen’s prior injuries, the structural damage inside her knee could have culminated to increase Jen’s susceptibility to the osteochondral defect. Stated earlier, Jen was found to have bruising on her lateral femoral condyle as a result of her ACL tear.
This bruising marks the impact of the lateral femoral condyle on the posterior portion of the lateral tibial condyle. Buckwalter notes that repetitive impact loading can affect the articular cartilage matrix on the femur even if there is no visible disruption to the area, causing progressive cartilage degeneration. In addition to this finding, Murrell, et al. noticed a three-fold increase in knee cartilage damage when meniscus damage is involved in an ACL tear.

In Spindler’s study, mentioned earlier in this report, articular damage (defined as any chondralalacia, fractures, impaction, creases, cracks, or shear injuries) was seen in 25 of the 54 ACL reconstructed knees (46%). The femoral condyles were the most frequently damaged: the lateral femoral condyle was injured in 15 of the knees (60% of the knees with cartilage damage and 28% overall) and the medial femoral condyle was injured in eleven of the knees (44% with cartilage damage; 20% overall). It was somewhat rare to find articular damage to both the femoral condyle and the corresponding tibial plateau.

It was determined by Spindler et al. that bruising the lateral femoral condyle was significantly related to the damaging of articular cartilage in the same location. It was also discovered that bruising of the lateral femoral condyle was often associated with jumping activities (such as Jen’s). Spindler et al.’s conclusion states, “a bone bruise, assuming that it represents a blunt injury to underlying articular cartilage and subchondral bone, may be a predictor of future cartilage degeneration, even in the absence of a visible articular cartilage injury.” Vallet et al. agree with this theory as their study showed 62% of patients with “hidden” bone bruises, at a one to two year follow-up after ACL reconstruction, had signs of osteochondral damage (including osteosclerosis, overt...
damaged group, 52 had the lateral meniscus removed, 64 had both menisci removed, and 68 had no meniscal damage. 17.

Additionally, in a study on concomitant meniscal and articular cartilage lesions (without ACL reconstruction) by Lewandrowski et al. medial meniscus damage was found to be associated with femoral and tibial articular cartilage degeneration. Longitudinal, bucket-handle, and complex tears of the medial meniscus were found much more frequently with articular cartilage damage than tears that were radial, horizontal, or flap. In the lateral compartment, the lateral meniscus tearing had no significant relationship with lateral femoral condyle articular cartilage damage, except when the medial meniscus was also torn 13.

**FINAL LINKING: SUMMARY**

Upon tearing her ACL, Jen opened the door to a number of additional knee problems. Tearing her meniscus (especially the medial meniscus) and bruising the lateral femoral condyle contributed greatly to her subsequent injuries. After injuring the meniscus and proceeding to participate in high-impact sports, Jen increased her risk for retearing the meniscus. With the bruising of her femoral condyle and the additional meniscal repair, combined with the added stress on the left knee due to Jen’s right hip surgery, Jen’s knee was susceptible to the degeneration of the cartilage covering the femur. The continuance in competitive, high-impact sports, contributed greatly to the amplified risk of reinjury. With the pounding, cutting, and jumping involved in Division I soccer, Jen’s left knee never had adequate time to fully recover from the ACL tear and its
concomitant injuries. Due to the prevalence and seriousness ACL injuries, Johnson et al. recommend that in an ACL tear such as Jen's, there should be a period of protected weight-bearing and avoidance of axial loading of the cartilage and the bone. However, given the nature of NCAA Division I sports, this ideal situation is not always feasible.

Given that the allograft and the bone bruise each require additional healing time, it would be advisable, under these conditions, to favor an increase in the amount of time non-weight bearing activities are performed post-op. Further studies should be conducted to conclude the adequate and most beneficial length of time that this restriction on weight-bearing activities should be enforced.
Bibliography


APPENDIX

ACL Rehabilitation Timeline

This timeline shows the treatment and rehabilitation of Jen Laughridge. The exercises beside the date are only the new exercises added for that day. It does not include a listing of every exercise Jen did on a particular day. This timeline is a representation of an aggressive ACL rehabilitation of a NCAA athlete.

Pre-Surgery

- **March 5:** Ankle pumps
  - Straight-leg raises (SLR) 3 sets of 10 reps (3*10)
  - DC stim with ice @ 100pps for 25min

- **March 6 and 7:** Quad sets 2*10
  - Ankle manuals 3*10
  - One-leg balancing with eyes open 5*15sec
  - Calf Raises 3*10
  - Terminal Knee Extensions (TKE) 2*10
  - Heel Sides 2*10
  - DC stim with ice @ 100pps * 20min

- **March 8:** One-leg balancing with eyes closed 3*15

- **March 9-11:** BAPS cw/ccw*25 each
  - Wall sits 1*30, 1*45, 2*60
  - Tubing: flex/ext, add/abd 3*10 each way

- **March 13:** Hamstring curls (manuals) 2*10

- **March 14:** Arm bike*15 min
  - Recumbent bike*15min

- **March 15 and 16:** Rockerboard (front/back and side/side) 3*30each
  - Compression with stim

**Surgery: March 17, 2000**

**Post-Op**

- **March 18:** Ankle pumps*100
  - Quad sets 3*10
  - SLR 4*10
  - DC stim with ice @ (+) polarity, 100pps*30min
  - Active Range-of-Motion (ROM)
• March 19: Interferential stim (INF)@ 1-10*25min
  INF @ 80-150*25 min

• March 21: Lymphatic Drainage
  SLR 3*10
  One-leg balancing with eyes open 4*30
  Manuals*fatigue

• March 22: Hi Volt stim + ice*20min

• March 23 and 24: Ball squeezes

• March 25: Bike ROM

• March 26-28: Wall sits 3*30
  Tubing (flex/ext) 2*15
  One-leg balancing with eyes closed 3*30
  Patellar Mobilization

• March 29-31: Russian stim with Quad set and SLR*10 min

• April 4: Stool scoots: 3*around rehab area
  Walk on treadmill (TM) with incline (forward and retro walking)*5min
  Bike*15min

• April 5: Hamstring curls (manual) 3*10
  BAPS Level #3 cw/ccw*30each
  Balance beam walking (front/back, side/side)*5 each
  Mini-tramp balancing with ball toss 3*45sec

• April 6: Step-ups 3*10
  Body squats 3*10

• April 7 and 8: Multi-Hip machine (flex/ext, add/abd) 1*20each @ 40lbs
  Eccentric hamstring curls 3*10 @ 5lbs

• April 9: Multi-Hip machine @ 50lbs

• April 11: Lunges 3*10

• April 12: Jump stops with both legs*10
  Balancing on balance beam (one-leg) with headers 3*fatigue
  Multi-Hip machine @ 55lbs
  Hamstring curls 2*12 @ 10lbs
- April 17: Leg press machine (no weight) 2*10

- April 18: Mini-tramp balancing (one-leg) with volleys 3*fatigue  
  Multi-Hip machine @ 80lbs  
  Hamstring curls 3*10 @ 12.5lbs

- April 19: Lunges 3*10 @ 10lbs  
  Calf raises 2*30 @ 80lbs  
  Multi-Hip machine @ 70lbs

- April 24: Mini-tramp balancing with volleys 3*45sec  
  Rockerboards 3*1min  
  Jump stops with both legs, then one leg 2*12  
  BAPS Level #4 cw/ccw *30each  
  SLR 3*10 @ 10lbs  
  Balancing on balance beam with headers front/back*5  
  One-leg calf raise 3*25  
  Wall sits 3*1min  
  Lunges 3*10 @ 10lbs  
  Body squats 3*10  
  Walking backward on TM*5min  
  Hamstring curls 2*10 @ 20lbs  
  Calf raises 3*15 @ 100lbs  
  Leg Press 3*12 @ 50lbs  
  Dead lifts 3*8 with bar

- April 28: BAPS Level #5 cw/ccw*25each

- May 16: Bike*45min  
  Elliptical*45min  
  Jog  
  Ball Workout