THE INFLUENCE OF GENDER AND ATHLETICISM ON REHABILITATION FROM ANTERIOR CRUCIATE LIGAMENT SURGERY

A Report of a Senior Thesis

by

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ABSTRACT

The anterior cruciate ligament (ACL) is a frequently injured ligament, especially by active individuals (250,000/year in U.S.). Following injury, the surgery type and rehabilitation methods have a profound effect on the individual’s recovery. The current study focuses on gender and athletic involvement’s influence on rehabilitation from bone-patellar tendon-bone autograft ACL surgery. It was hypothesized that both gender and athleticism would have a significant difference on recovery rate, with males and athletes recovering more quickly. Patient files were obtained from Appalachian Therapy Center. All patients remained anonymous, and the data was reported in aggregate. Variables collected for each individual included: gender, athletic involvement, age, weight, time spent in clinic weekly, range of motion (weekly), and results from biodex tests (starting no earlier than ten weeks post operation). Tables were generated using Microsoft Excel, and the data was analyzed in StatView using analysis of covariance with gender and athleticism as the variables. The study concluded that gender had

absolutely no effect on any variable; thus, gender does not influence rehabilitation rate. On some endpoints, however, athletic involvement is significantly different with athletes having greater values. It is anticipated that these differences are due to a more rigorous recuperation regime to which athletes were exposed. Similar programs for non-athletes could accelerate the rehabilitation process.

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CHAPTER I

A DISCUSSION OF ACL INJURY, SURGERY AND REHABILITATION

Introduction

Within the human body there are numerous different structures that jointly form a well-organized unit that maintains life. The construction and anatomy of the structure plays a key role in its function (Shier, Butler, & Lewis, 1999). The lack of one of the structures can have drastic effects on many of the other structures and in turn cause debility. Thus, there are many checks and balances systems within the body that aim to keep all of the parts in working order. Ultimately, without the many systems of the body working together, like a machine, the ability of the body to move, support itself, and survive would be impossible. Joints are a very important part of the unit because they form a union between different parts of the body.

The Joint

A joint, as defined in Webster's Dictionary is "a place where bones come together, allowing movement" (Collin, 1992, p. 257). Joints allow body movement by skeletal muscle contractions and make bone growth possible. There are three general types of joints, fibrous joints, cartilaginous joints, and synovial joints, and they vary drastically in function and structure (Shier et al., 1999). Although fibrous and cartilaginous joints are noteworthy, the most common types of joints are the synovial joints.

Synovial joints are diarthrotic because they allow free movement and are more complex structurally than any other type of joint. The six different types of synovial joints that allow for various types of movement have been thoroughly examined by Shier et al. (1999). These six types of synovial joints include: ball-and-socket joint, condyloid joint, gliding joint, hinge joint, pivot joint, and saddle joint (see Table 1.1). The ball-and-socket joint is an articulation between a cup-shaped cavity in one bone and an egg-shaped head of another. It allows for the widest range of motion such as the shoulder and hip. The condyloid joint is the union between the elliptical cavity of one bone and the ovoid condyle of another and includes the articulation between the metacarpals and phalanges. The gliding joint is the union of two almost flat bones, allowing for sliding and twisting motion. Gliding joints are found in the wrist and ankle. The hinge joint is the union between the concave and convex surfaces of two bones such as the phalanges. The pivot joint is fairly uncommon, and it allows for rotation only around a central axis. It is

found in the neck. Lastly, the saddle joint is formed when the concave and convex surfaces of two bones are complementary to each other.

Shier et al. (1999) describe the components of the synovial joint. Every synovial joint has a joint capsule, consisting of dense connective tissue, that completely encases the bone ends, cartilage, ligaments, cavities, membranes and sometimes menisci and bursae that collectively make up the entire joint space. The cartilage within the joint capsule tends to cover the articulating ends of the bones to minimize friction and decrease the level of stress put on the joint as a result of movement. Menisci, when present, are located between the articulating surfaces and function to distribute the body weight evenly. The meniscus is very important in the knee because it supports so much weight. Bursae sacs are filled with fluid and function to cushion and aid in movement of tendons over bony parts. Lastly, ligaments are composed of strong, inelastic collagenous fibers that reinforce the joint capsule and help prevent excessive movement at the joint.

The Knee Joint

The complexity of the knee, shown in Figure 1.1, places it among the most intricate joints in the human body. Although it is commonly considered a hinge joint, it is not a “true” hinge joint because while

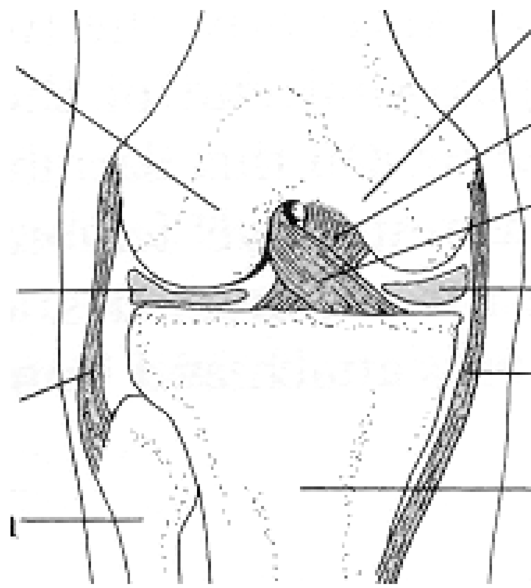

Figure 1.1. Anterior View of the Knee Showing the Ligamentous Arrangement, as Well as the Associated Bones (Arnheim & Prentice, 2000, p. 515).

its principal movements are flexion and extension, some rotation can occur (Arnheim & Prentice, 2000). In fact, the articulation between the patella and femur is a gliding joint, and the union of the femur and tibia is condyloid (Shier et al., 1999). The knee is designed to provide mobility in locomotion and to bear one’s weight, which is one reason for its complexity (Arnheim & Prentice). The knee joint consists of four bones, the femur, the tibia, the fibula, and the patella, which make up several articulations. As discussed earlier, the knee also consists of two menisci, the medial and lateral. Both menisci attach to the lateral and medial articular facets of the tibia, respectively, and serve to separate the articulating surfaces (Arnheim & Prentice).

The joint capsule of the knee is thin, but tendons and ligaments add strength and support (Shier et al., 1999). A ligament is nothing more than a band of soft connective tissue that is composed of collagen fiber bundles. They thoroughly explain the different ligaments and their significance in strengthening the joint. The patellar ligament, oblique popliteal ligament, arcuate popliteal ligament, tibial collateral ligament, and fibular collateral ligament, all shown in Figure 1.2, cooperatively strengthen the joint capsule. In addition, there are two ligaments within the joint, the anterior and posterior cruciate ligaments, which are very strong bands of fibrous tissue that assist in the prevention of displacement of the articulating surfaces.

Ligaments function primarily to transmit tensile loads; however, ligaments from the same joint sometimes have different properties and healing responses so it is difficult to group all ligaments into one category (Woo et al., 2000). For example, the healing responses of anterior cruciate ligaments (ACLs) and medial collateral ligaments (MCLs) are very different; the ACL takes much longer to heal and cannot heal on its own, which is why ACL injuries seem so much more abundant (Woo et al.).

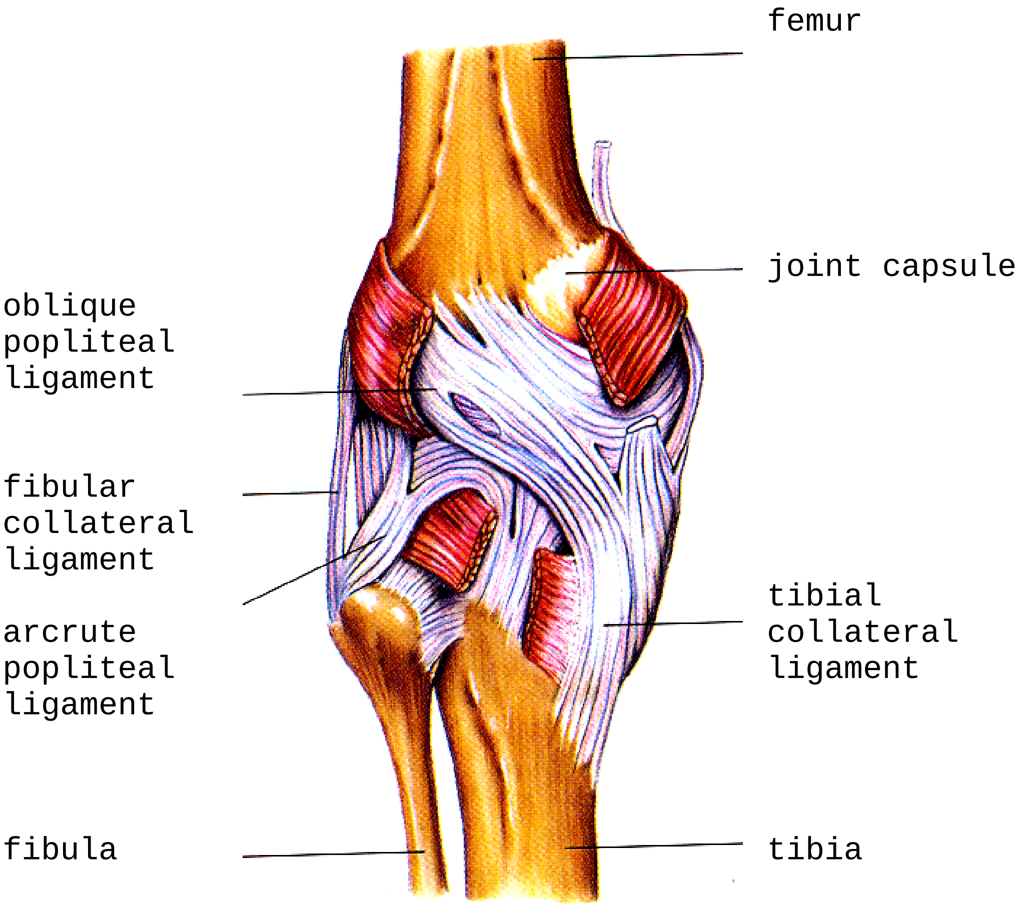

Figure 1.2. Posterior View of the Left Knee (showing all the joints that help to strengthen the joint capsule, except for the patellar ligament, which is on the anterior side) (Shier et al., 1999, p. 274).

Anterior Cruciate Ligament

The anterior cruciate ligament crosses the posterior cruciate ligament (PCL) between the tibia and femur and attaches to the anterior intercondylar area of the tibia (Shier et al., 1999). Arnheim and Prentice (2000) have comprehensively explained the ACL, and its functional and structural components.

The ACL is comprised of three twisted bands: the anteromedial, intermediate, and posterolateral bands. It primarily functions to prevent posterior movement of the femur during weight bearing. In juxtaposition with the hamstring muscles, the ACL is the main knee joint stabilizer. Furthermore, the ACL keeps the tibia from experiencing excessive internal rotation.

Injury to the ACL

Although the ACL is a strong ligament, it is frequently injured, especially in active individuals who participate in sports activities. In fact, there are about 250,000 ACL injuries in the United States each year, accounting for $1.5 billion going to ACL reconstruction annually (Boden, Griffin, & Garrett, 2000). Injuries to the ACL and medial collateral ligament account for as much as 90% of all ligament injuries at the knee, with ACL injuries comprising over half (Woo et al., 2000). The mechanisms for ACL injuries are typically non-contact and include planting and cutting, straight-knee landing, and landing on a hyperextended knee with a one-step stop (Moeller & Lamb, 1997). Furthermore, intensity of play has a great impact on the chance of ACL injury. Athletes, male and female, are seven times more likely to injure their ACLs in a game than in practice, because the intensity tends to be elevated during competition (Physical Therapy Corner, 2000).

ACL injuries tend to be much more common in female athletes. Boden et al. (2000) explain several reasons why females are more susceptible to ACL injuries. Several anatomical reasons are an increased Q angle, increased ligamentous laxity, and inadequate strength of the quadriceps and hamstring muscles. The Q angle is the line created when a line is drawn from the middle of the patella to the anterosuperior spine of the ilium and from the tubercle of the tibia to the center of the patella. The normal Q angle is, on average, 5 degrees larger in females. The larger the Q angle is, the more pronated the foot becomes and, consequently, increased stress is put on the knee. In addition to the increased Q angle, the estrogen in a woman's body can predispose females to ACL tears by relaxing soft tissue and diminishing tensile strength. Such diminished tensile strength results in ACL laxity. Lastly, females have less overall muscle strength than males. The decreased strength of the muscles that assist in knee stability makes the knee rely more on the ACL for stability and in turn also puts stress on the ligament. Statistics that were gathered by the National Collegiate Athletic Association (NCAA) show that women suffer from ACL injuries four times more often than men in basketball, two and a half times more often in soccer, and three times as often in gymnastics (Physical Therapy Corner, 2000). Today, coaches and doctors are working together to design strength programs for women that will increase strength in an effort to reduce the risk of ACL injury (Boden et al.).

There are four tests that are currently being used to test for ACL laxity. Laxity is defined in Webster's Dictionary, as simply "being loose" (Collin, 1992, p. 268). If the ligaments of the knee are loose, they are less likely going to be able to support one's body weight, which predisposes the individual to injury. The four types of tests for ACL laxity are defined by Arnheim and Prentice (2000) and are presented in Table 1.2. They include: drawer test, Lachman drawer test, pivot shift test and jerk test. The drawer test is designed to determine if the tibia easily slides forward from under the femur,

Table 1.2.

Comparison of Four Different ACL Laxity Tests.

Laxity Test	Knee's Angle	Indication of Damage
Drawer	90 degrees	tibia sliding forward from under femur
Lachman drawer	20-30 degrees	anterior movement of tibia
Pivot shift	extension to 30 degrees	palpable clunk at 20-40 degrees
Jerk	extension to 20 degrees	palpable clunk at degrees

Source: (Arnheim & Prentice, 2000, pp. 229-231).

which is a sign of ACL laxity. The Lachman drawer test is one of the most popular tests, especially for immediately after injury. By holding the distal end of the thigh with one hand and the proximal end of the tibia with the other, it is possible to attempt to move the tibia forward, which indicates ACL damage. Next is the pivot-shift test. It is used to determine anterolateral rotation instability, and if damage has occurred, the rotating movement of the test will cause subluxation of the lateral tibial plateau that will upon flexion of the knee cause a palpable clunk. Lastly, the jerk test is the reverse of the pivot shift test; however, it does, upon flexion of the knee, produce a palpable clunk. All of these tests have been proven to accurately test ACL laxity.

Humans are not the only animals affected by anterior cruciate ligament injuries. Many other mammalian species suffer from ligament injuries too; however, it is seldom detected unless it is in animals such as racehorses and dogs that are very dependant on joint mobility. Beale (1999) discusses the techniques that are used today in ACL ligament repair in both small and large dogs. In dogs, the type of surgery is influenced greatly by age and weight. With small dogs, generally under thirty-five pounds, a modified retinacular imbrication technique (MRIT) is employed. With larger dogs, an intracapsular procedure using an autograft is usually used. However, the MRIT can be used for both, and a new technique, tibial plateau leveling, is also emerging in larger dog ACL repair. These techniques are exceptionally different from those used in human ACL reconstruction.

Surgical Options

Not all patients with unstable or ruptured ACLs require surgery. In fact, some patients who are not very active are often encouraged to avoid surgery. It is a rather complex surgery with an extensive amount of rehabilitation and therefore is recommended only for patients who are active, young, athletic, participate in more than five hours of sports per week, or experience several instability episodes within a year (Bach & Boonos, 2001). In the majority of cases, however, surgery is administered as an outpatient procedure and requires no extended hospital stay. Patients who injure the ACL and do not have surgery generally still undergo rehabilitation in order to strengthen what portion of the ligament (if any) is left.

There are many surgical options for treatment of a ruptured ACL. The options include prosthetic replacement, augmented primary repair, primary repair, and ACL reconstruction, all of which are reviewed by Fu, Bennett, Ma, Menetrey, and Lattermann (2000). Prosthetic ligaments, although they have been found fairly successful in the past, are no longer recommended because at least 40% fail. Primary and augmented primary repair are both also considered out of date and prove functionally inadequate after a period of time in a relatively high proportion of patients. Therefore, the current trend in ACL surgery is the reconstruction via a biological tissue graft.

The goals of ACL reconstructive surgery are to eliminate of the pivot shift phenomenon, the reestablishment of normal joint stability, and the ability to maintain the stability with activity (Bach & Boonos, 2001). The two types of tissue graft surgeries that tend to meet these goals the best, and are most preferred by surgeons, are the bone-patellar tendon-bone and the quadrupled hamstring tendon (semi-tendinosis and gracilis) grafts (Brand, Weiler, Caborn, Brown, & Johnson, 2000). Both have been proven very successful; however, there is a chance for failure with any type of surgery.

Athletes generally undergo the bone-patellar tendon-bone graft because of the graft's durability, load to failure, stiffness, quality of fixation, success at long-term follow-up, and its allowance for the earliest return to activity and competition (Fu et al., 2000). It is typical for an athlete to be back to full load by four months post-surgery using this technique. On the other hand, the hamstring tendon graft also has its advantages. It generally inflicts less anterior knee pain on the patient and it provides for a smaller incision. However, the donor-site scar is typically much larger and obvious. Another area for debate is the issue over a single-incision versus two-incision approach to the surgery. Typically, the single-incision technique improves cosmesis and allows for faster rehabilitation, but there is still much debate over the pros and cons of both types (Fu et al.).

The major effort of all reconstructive grafts is to replace the ligament with material and in a fashion that it will provide as much strength as the original ACL (Brand et al. 2000). Therefore, different substitutes require different fixation techniques. Furthermore, it is important to ensure that the substitute material is able to withstand forces that will be put on the ligament. Table 1.3 gives estimations of forces (in Newtons) that are put on the

Table 1.3.
The Estimation of Forces That Are
Put on the ACL During Daily Activity.

Activities	Force (Newtons)
Level Walking	169
Ascending stairs	67
Descending stairs	445
Descending ramp	93
Ascending ramp	27

Source: (Brand et al., 2000, p. 762)

ACL during daily activity. Both patellar tendon and hamstring grafts are able to withstand the forces of daily activity.

The idea of graft fixation is to restore the original anatomy of the knee as precisely as possible. Fu et al. (2000) reviews the bone-patellar tendon-bone graft and the hamstring tendon graft fixation techniques discussing their criteria. When using a single incision method, tibial fixation is distant to the joint line and femoral fixaiton is at the joint line. When using the two-incision method, the femoral bone plug is away from the joint line and the tibial bone plug is at the joint line. Three different types of screws are used, including metallic, titanium, and biodegradable interference screws, in bone-patellar tendon-bone fixation currently, all producing the same clinical outcome of reconstruction. Furthermore, the use of bioabsorbable, soft tissue screws is the most recent trend in hamstring tendon graft fixation. They allow for tibial and femoral joint line graft fixation.

The steps of the surgical process are very precise and extensive. Bach and Boonos (2001) categorize the surgical process into several major steps: graft harvest and preparation, notch preparation and notchplasty, tibial tunnel placement, femoral tunnel placement, graft placement and fixation, and closure. There are many different instruments used during ACL reconstruction, which are listed in Appendix A.

When performing an autograft surgery, the surgeon must take the graft material from some other part of the body, and in these cases the patellar tendon or hamstring tendon is used. After the harvest of the graft, the surgery is quite similar for bone-patellar tendon-bone and hamstring tendon autografts. According to Bach and Boonos (2001), the surgeon carefully extracts a measured portion of the respective tendon through an incision that measures about 8mm. The extraction is done with a great deal of precision, so the tendon is disturbed as little as possible and the risk of intraoperative patellar fracture is minimal. A notchplasty is usually needed to stretch the lateral wall of the notch so that the graft is protected during the healing phase. Furthermore, it usually allows the surgeon a better view. Next is the tibial tunnel placement. The goal of the tibial tunnel placement is to imitate the previous mid-third ACL insertion region by having an intra-articular entrance. The femoral tunnel placement is the next step in the surgical process, and it aims to place the tunnel as far back as possible. Finally, the graft placement and fixation occurs. Bone plugs and interference screws are used to secure the graft in place. Before the knee is closed up, it is tested for stability with a series of tests. The tests used for stability testing include Lachman test, anterior drawer test, and pivot shift test. If acceptable results are found, the incision is closed, and the subcuticular tissue is sutured.

The main variation that occurs between these two types of reconstructive ACL grafts is found in the donor-site morbidity. Fu et al. (2000) compare the donor-site morbidity of these two techniques. The bone-patellar tendon-bone autograft has been found to cause anterior knee pain in 4-40% of patients; however, aggressive rehabilitation tends to decrease the amount of pain felt. Many techniques are being used to reduce the anterior knee pain after surgery (Tsuda, Okamura, Ishibashi, Otsuka, & Toh 2001). Furthermore, Fu et al. continue to compare the donor site morbidity of the two surgical techniques. While the closure technique may have some influence on the degree of anterior knee pain, the regaining of range of motion and intense rehabilitation tend to influence the amount of pain more directly. On the other hand, the hamstring tendon graft causes firm scar formation in the region of the harvest. However, there has been minimal donor-site pain reported, and there has been no major functional impairment found.

Post-ACL Surgery Rehabilitation

While the actual surgical procedure is very important, the therapy and rehabilitation techniques after the surgery are equally important. The main rehabilitation goal is to restore the normal knee function. However, other rehabilitation goals differ from person to person depending on the level of activity the person wishes to obtain (Prentice, 1990a). For example, an athlete would undergo a much more intense rehabilitation program than a middle-aged person who participates in athletic activities only occasionally.

The goal of any rehabilitation program is to minimize swelling, control pain, and restore full range of motion and function (Arnheim & Prentice, 2000). There are many different types of therapy and rehabilitation techniques used in post-surgery rehabilitation, and Arnheim and Prentice (2000) summarize them. Post surgery therapy includes, but is not limited to: RICE (Rest, Ice, Compression, Elevation), electrical muscle stimulation, ultrasound, massage, and mobilization techniques. Furthermore, the exercise rehabilitation includes: neuromuscular training, endurance exercises, hamstring and quadriceps strengthening exercises, open and closed kinetic chain exercises, patellar mobilization exercises, and sport-specific activities. All of these rehabilitation techniques are shown in Table 1.4.

Electrical muscle stimulation (EMS) is thoroughly covered by Arnheim and Prentice (2000). It is the use

of electricity as energy to transmit magnetic, chemical, mechanical, and thermal effects on soft tissue.   EMS is used primarily to reeducate the muscles surrounding the knee after they have experienced atrophy due to muscular inhibition after surgery. EMS also plays a minor role in increasing the range of motion of the knee (Prentice, 1990b). Ultrasound is a deep-heating modality and is primarily used to increase blood flow (Arnheim & Prentice). However, there are many other advantages to using ultrasound, which include a decrease in joint stiffness, increase in local metabolism, increase of pain threshold, and increase in extensibility of collagen tissue (Prentice, 1990b). Massage is defined as “the systematic manipulation of the soft tissues of the body” (Arnheim & Prentice, p. 367). Friction massage is used after surgery to prevent stagnation of circulation and to prevent scar formation rigidity (Arnheim & Prentice). There are many mobilization techniques which incorporate repetitive movement of the joint, all of which aim to restore the range of motion (Prentice, 1990b).

Neuromuscular training is the attempt to retrain the muscles to successfully complete repetitions of a patterned movement, thus reestablishing neuromuscular control (Arnheim & Prentice, 2000). Endurance exercises and strength exercises are often administered together. These types of exercises are usually done using exercise machines, manual resistance, free weights, or rubber tubing (Prentice, 1990a). However, strength training can be broken down into three categories, isometric training, isotonic training, and isokinetic training, all of which are briefed by Prentice (1990a). Isometric exercises are more common in early post-operative rehabilitation. They increase static strength and decrease atrophy, yet no functional force is developed. Isotonic exercises are important in improving muscular strength. The contractions are of two types: concentric and eccentric. The athlete generally focuses on the concentric contraction, which is the shortening of the muscle; however, in rehabilitation there is emphasis put on eccentric contraction, a contraction where force is being applied as the muscle is lengthening. Lastly, isokinetic exercises are most commonly used in the later phases of the rehabilitative process. With this type of exercise, it is possible to get maximal resistance throughout the range of motion because the resistance moves at a preset speed. There are many commercial isokinetic exercise devices that are sold to therapy clinics to be used for rehabilitation purposes. Furthermore, other types of exercises like bicycling, swimming, and jogging are also supplementary to the strength and endurance programs.

Hooper, Morrissey, Drechsler, Morrissey, and King (2001) compare the open and closed kinetic chain exercises when used after ACL reconstruction. There has been, in the past ten years, a shift from the use of open kinetic chain exercises to closed kinetic chain exercises for various reasons. Closed kinetic chain exercises tend to better replicate functional tasks, put less strain on the ACL, and put less stress on the patellofemoral joint.

With patellar mobilization exercises, the therapist addresses a specific limiting structure and focuses on the soft tissue contracture, trying to get it to release (Prentice, 1990a). This works to improve accessory motion as well as total motion of the knee. Lastly, sport-specific activities are an essential part of the rehabilitation process because it gets the patient ready to return to play. The skills are broken down into component parts and gradually introduced throughout the rehabilitation process (Arnheim & Prentice, 2000). By the time the athlete is in the third-fourth month post-surgery, he or she should be performing many of the sport-specific skills without pain (Prentice, 1990a).

Hypothesis

The knee is a very complex structure that incorporates many different ligaments, tendons, bones, and muscles into one functional unit that supports body weight, allows for mobility, and provides cushioning. Because of its many functions, the knee joint is predisposed to injury, causing 250,000 people in the United States to suffer from knee injuries yearly (Boden et al., 2000). Knowing the knee’s response to various types of treatment after anterior cruciate ligament reconstructive surgery is very important in today’s society, considering the elevated number of knee injuries. There are many studies that have researched the various types of reconstructive surgery options. The results from such studies are influential on the patient’s choice of surgery type to undergo. In fact, the best surgery type under particular circumstances is easily decided because of all of the research in the area.

It is the goal of my research to take patients who underwent bone-patellar tendon-bone autograft surgery and compare the post-operative progress of various subgroups (i.e., male and female, athlete and non-athlete). I hypothesize that the patients who are male will recover faster than those who are female. Furthermore, I hypothesize that the athletes will have a quicker recovery than the non-athletes because they typically have more desire and work harder than non-athletes. Further, the efficacy of post-operative therapies will be examined.

CHAPTER II

MATERIALS AND METHODS

Data Collection

Patients

Data was collected on patients who underwent their entire post-ACL surgery rehabilitation at Appalachian Therapy Center (ATC) in Maryville, Tennessee. Permission was obtained from Joe Black, PT, ATC, and CSCS, to use information obtained from charts that are on file. A list of past ACL surgery patients was generated by several of the physical therapists, physical therapist assistants, and athletic trainers that work at Appalachian Therapy Center. The list of names was then taken to the ATC business office where the charts are kept on file, and each person's file was obtained. Each patient was given a number, as his or her file was obtained, by which that patient was referred to throughout the experiment to ensure confidentiality. Thirty-six patient's files were obtained, including 20 males and 16 females.

File information

Initially, each file was reviewed to assure that the patient did undergo bone-patellar tendon-bone autograft surgery and furthermore completed his or her entire rehabilitation at ATC. Each patient's file included daily progress information, a weekly exercise sheet, a general protocol sheet, results from biodex test(s), and progress notes.

Each file was carefully analyzed to record any variable that may have an influence on the overall outcome of the rehabilitation. Factors taken into consideration included: gender, weight, age, involved knee, average time spent doing rehabilitation in the clinic each week, and whether the subject was an athlete or not. Athleticism was determined by participation in organized sporting function. The date of surgery was also recorded. Then, the range of motion (ROM) was recorded for each patient on a weekly basis until the patient reached full ROM. Beginning no earlier than ten weeks post-operation, biodex tests were performed every two to four weeks until the patient was released. Results from these tests were also recorded.

Data Recording

Range of Motion

Range of Motion is charted using a goniometer, which is shown in Figure 2.1. The patient is generally laying flat on his or her back and asked to

Figure 2.1. Use of the Goniometer to Measure ROM (Flexion) of the Knee (Pedersen, 2001).

flex at the hip first, then to flex at the knee as much as possible. Full ROM does vary slightly from patient to patient, but it is between 135^o and 150^o for flexion and around 0^o for extension (Pedersen, 2001). To take the measurement, the stationary arm of the goniometer should be midline on the femur and in line with the greater trochanter, and the moving arm should be aligned with the midline of the fibula. As the knee flexes, the angle becomes larger, and when the patient is at maximum flexion, the degree of the angle is recorded.

Biodex Test

The test used to chart progress of ACL rehabilitation patients at ATC is the biodex test. Other functional activities are also utilized, but they differ from patient to patient. Biodex tests are consistently administered to ACL rehabilitation patients and therefore are comparable. The biodex machine is shown in Figure 2.2. The biodex machine is connected to a computer that takes in the information and converts it to quantitative data that can then be analyzed by the physical therapist and orthopedic doctor. It charts progress in several areas through a series of essentially three tests. The patient sits in the chair attached to the machine (as shown in Figure 2.2). Then special settings are chosen on the machine to specify that a test is to be administered to the knee. At the time of the test the flexion and extension should be full and no limits will have to be set.

Figure 2.2. View of Patient Using the Biodex Machine, for Knee Rehabilitation (DB Equipment Consulting, 2002).

The non-injured leg is always tested first so a comparison can be made. The machine is set to do 3 of the same tests but at different speeds (60 degrees per second, 120 degrees per second, and 180 degrees per second). The two slower speeds test strength, whereas the third speed is a test of endurance. Both strength and endurance are vital to a full recovery, and without acceptable results on both, the patient will generally not be released. The patient is asked to extend and flex with as much power and strength as possible for five repetitions of each, with a rest between the two sets. The last set is much quicker, and, therefore, the patient is asked to perform fifteen repetitions during which endurance is charted. After the test is performed on both knees, the computer will generate a printout of quantitative data that is used to determine progress.

Peak torque, total work, and average power are three results generated by the biodex test that will be used in the current project. Peak torque is indicative of the muscle’s strength. It is the highest amount of force exerted at any time during the repetition. Total work is the muscle’s ability to produce force throughout the range of motion consistently. Lastly, average power is representative of the efficiency with which the muscle produces force and therefore it is the total work divided by the time.

After these results are generated they are recorded on a printout as seen in Appendix B. The printout includes the patient's weight and injury protocol as well as all of the results from the biodex test. All of the data was taken and the quantitative data was recorded for peak torque, average power, and total work. All information was recorded on a patient information form (Appendix C). A form was filled out for each individual patient, and then the information was transferred to a spreadsheet in Microsoft excel where the information for every patient could be compared.

Statistical Analysis

Averages for all factors were generated and the resulting averages were used to make figures in Microsoft Excel for the data. The figures were used to compare males vs. females and athletes vs. non-athletes. Furthermore, a figure was generated to compare the patient's ROM over time.

In StatView, an analysis of variance test (ANOVA) was conducted in order to analyze the data for week of release in regards to gender and athleticism. Furthermore, all other data sets were analyzed in StatView using an analysis of covariance test (ANCOVA). The raw data was used for the statistical tests as opposed to the mean value that was used in the figures. By imputing gender and the individuals' athletic involvement as the covariables, I was able to generate p-values for both. The ANCOVA test allowed for analysis of the correlation between gender and time, athleticism and time, and all three collectively.

CHAPTER III

RESULTS

The one variable that was measured from time of operation through the time of the first biodex test was range of motion (see Figures 3.1 and 3.2). The ROM showed no significant difference for athlete or gender. The week of release was not significantly different ($p = 0.747$) among gender and athlete either (see Figure 3.3).

The variables used to determine the strength of the knee (peak torque, average power, and total work) during extension and flexion at the three speeds were each analyzed separately. Furthermore, they were each analyzed to determine the relationship between gender and/or athlete as it correlated with the week of the test. Each figure represents the percent of the non-injured knee's performance for the appropriate test. All three speeds are represented in each figure and results are reported from ten weeks post-operation, continuing through twenty weeks post-operation, with the sample size for each week noted above the bar.

Peak torque was not significantly different at extension (see Figures 3.4 and 3.5) or flexion (see figures 3.6 and 3.7) at any speed except for flexion at 180°/second when athlete and gender were both considered ($p = 0.006$). Average power showed no significant difference for gender as it varied with week; however, extension (see Figures 3.8 and 3.9) at 120°/second and flexion (see Figures 3.10 and 3.11) at 120°/second and 180°/second did show significant differences ($p = 0.041$, 0.045, and 0.037 respectively) for athlete as it varied with week, with athletes having greater extension and flexion than non-athletes. When considering both athlete and gender as they varied with week, extension and flexion were both different at 120°/second ($p = 0.042$ and $p = 0.049$, respectively). Lastly, total work showed no significant difference for gender as it varied with week or for both gender and athlete as they varied with week. Total work was only significantly different when athlete varied with week during extension (see Figures 3.12 and 3.13) and flexion (see Figures 3.14 and 3.15) at 120°/second and extension and flexion at 180°/second ($p = 0.010$, $p = 0.007$, $p = 0.010$, and $p = 0.013$, respectively), with athletes having greater overall extension and flexion than non-athletes. See Table 3.1 for all of the p-values for ROM, peak torque, average power, and total work.

CHAPTER IV

DISCUSSION

The analyses of the data indicated that gender had absolutely no significant effect on rehabilitation from bone-patellar tendon-bone autograft surgery. Therefore, although females are at a greater risk of tearing their ACL, there is no reason to believe that they will experience a less successful rehabilitation compared to men. Similar results were found by Ferrari, Bach, Bush-Joseph, Wang, and Bojchuk (2001) analyzing the outcome of ACL ligament reconstruction with regard to gender. Ferrari et al. included 200 (137 men and 63 women) bone-patellar tendon-bone reconstructions in their study, all of whom underwent surgery by a single surgeon's practice. As opposed to using the biodex test results as the primary indicator of recovery, Ferrari et al. assessed the knee with Tegner, Lysholm, modified HSS, Cincinnati Knee rating scales, and a questionnaire. However, regardless of the method of determining rehabilitation success, comparable figures were generated statistically and no significant difference was found in either study.

The influence of athleticism on rehabilitation rate was also considered in the study. Significant differences were found at some endpoints, with athletes experiencing a more successful rehabilitation than non-athletes. Neither flexion nor extension at 60 degrees yielded a significant difference. The slower speed (60 degrees/second) is indicative of pure strength whereas the faster speeds (120 degrees/second and 180 degrees/second) are more indicative of endurance of the muscle. Therefore, in regard to strength the athletes and non-athletes were not different. However, a significant difference was found at several endpoints at 120 degrees/second and 180 degrees/second, which indicates that athletes regain endurance quicker and more efficiently than do non-athletes. Peak torque, the muscle’s strength capabilities, showed no significant difference at any point with neither flexion nor extension. Average power, speed by which a muscle can produce force, did show significant differences at 120 degrees/second and 180 degrees/second. This means that athletes typically have a significantly better endurance, with regard to average power. Lastly, significant differences were also found at 120 degrees/second and 180 degrees/second when considering total work, capability of the muscle to work throughout the entire range of motion for the entire time. This difference indicates that athletes regained their total muscular force quicker than non-athletes did. In summary, the overall rehabilitation of athletes progressed at a faster rate when compared to non-athletes.

The athletes all underwent an accelerated rehabilitation protocol whereas the non-athletes typically went by a more conservative, non-accelerated protocol. Several studies have compared accelerated and conservative rehabilitation protocols. The accelerated protocol does implement an increased use of closed kinetic chain exercises when compared to the traditional protocol (Shelbourne & Nitz, 1990). However, the primary difference in the two rehabilitation regimes is the rate at which the rehabilitation is administered. Each protocol consists of particular phases through which certain criteria must be met before advancement to the next phase. The accelerated protocol is much more intense, resulting in a quicker advancement through the phases of rehabilitation. A study by De Carlo, Shlebourne, McCarroll, and Rettig (1992) found that patients who underwent the accelerated protocol had more functional and stronger knees at the end of rehabilitation. In fact, they found that using the accelerated protocol could almost cut the rehabilitation time in half. Based on these results, most rehabilitation regimes have been somewhat accelerated in the past 10 years, but typically athletes still undergo a much more strenuous rehabilitation regime, which is what contributes to their quicker more efficient rehabilitation and recovery.

In addition to the De Carlo et al. (1992) study, several other studies have concluded that the accelerated protocol does in fact speed-up the rehabilitation process, without putting the graft at risk or compromising the stability of the joint. Shelbourne and Nitz (1990) found that quadriceps strength came back much faster with the accelerated protocol. Several factors were found to be important in the recovery of quadriceps strength and they include pain tolerance, motivation (whether it be personal or from someone else), and edema control (Shelbourne & Nitz).

It is important to keep in mind when analyzing the data that it came from a fairly small experimental group (36 total patients), and therefore could yield inaccurate results. Plus, the study included any patient who underwent therapy at Appalachian Therapy Center; however, it was not restricted to a single surgeon. Therefore, it is possible that there may be small differences in the method by which each surgeon administered the bone-patellar tendon-bone autograft surgery that could possibly contribute to variation in rehabilitation rate. Furthermore, another factor that must be considered, and could contribute to error, is that when a patient had recovered to the point at which he or she was released from therapy he or she then dropped out of the study. Therefore, the only patients included in the eighteen-to twenty-week tests were those who were experiencing slower recovery.

It is concluded that athleticism does have an impact on rehabilitation rate primarily due to the accelerated rehabilitation protocol that athletes are exposed to. However, other factors such as motivation, the will to return to active participation in a sport, and the understanding of exercise and endurance could also contribute to the quicker recovery of athletes. Furthermore, it is also concluded that rehabilitation rate is not dependant on gender.

Based on the results of the current study, it is anticipated that a quicker rate of recovery could be achieved for non-athletes if the accelerated rehabilitation protocol was implemented. It is understood that not all patients would be able to accommodate an accelerated protocol, but if possible it would contribute to a quicker recovery. However, only the patient can control factors such as motivation, desire, and mental attitude toward the rehabilitation, and without such things, a slower recovery will be the result. In order to obtain the optimal recovery rate for every individual, the accelerated rehabilitation protocol should be implemented for everyone. If the accelerated protocol was implemented, further research could be done to then compare the recovery rates. If a difference was still found, further study would be necessary to determine other factors underlying that difference. Furthermore, studies to determine the significance of other factors could also be done with regards to the idea of athleticism. By elucidating physiological and motivational factors, it would be possible to analyze the “athlete” and determine what underlying factors of athleticism have the greatest impact on injury recovery.

APPENDICES

APPENDIX A

Arthroscopic evaluation

- 4.5 mm, 30-degree arthroscope
- Inflow cannulas
- Arthroscopic probe and instrument

Graft harvest

- Scalpel
- Senn retractors
- Army-navy retractor
- Oscillating saw
- 10 mm wide oscillating saw blade
- Electrosurgery unit pencil
- Curved osteotomes (1/4-inch, 3/8-inch)
- Mallet
- Tissue forceps
- Metzanbaum scissors
- Measured ruler

Graft preparation

- Sizing tubes (10/11mm)
- 0.062 inch smooth K-wire
- Power drill
- Pituitary rongeur
- Sterile marking pen
- # 5 braided nonabsorbable polyester sutures

Notch preparation and notchplasty

- Adhroscopic scissors
- Arthroscopic osteotome
- Adhroscopic electrosurgery tool
- Motorized arthroscopic shaver (5.0mm)
- Arthroscoopic spherical burr (5.5mm)
- Curved 1/4 inch osteotome
- Mallet
- Large arthroscopic grasper

Tibial tunnel placement

- 1/2 inch Cobb elevator
- Electrosurgery unit pencil
- Tibial aiming guide
- 3/32 inch smooth Steinman pin
- Drill
- 10mm or 11 inch cannulated reamer
- Motorized shaver
- Chamfer reamer
- Arthroscopic rasp

- Large adroscopic grasper
- Finely woven gauze

Femoral tunnel placement

- 7mm femoral aiming offset guide
- 3/32 inch smooth Steinman pin
- Drill
- 10mm cannulated reamer
- Adhroscopic probe
- Motorized shaver/burr

Graft placement and fixation

- Capener gouge
- Senn retractor
- 2-pronged pusher
- Curved hemostat
- Flexible 14 inch hyperflex titanium pin
- Cannulated interference screw for femoral fixation (7mm x 25mm)
- Cannulated interference screw for tibial fixation (9mm x 20mm)
- Tibial plug

Special instrumentation

- Tissue protector
- Bone graft chip collector
- Meniscal repair cannulas, retractor, and sutures

Closure

- 2-0 braided absorbable suture
- 3-0 monofilament polypropylene suture
- Bupivicaine hydrochloride

Source: (Bach & Boonos, 2001, pp. 158-159).

APPENDIX B

APPENDIX C

APPENDIX D

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