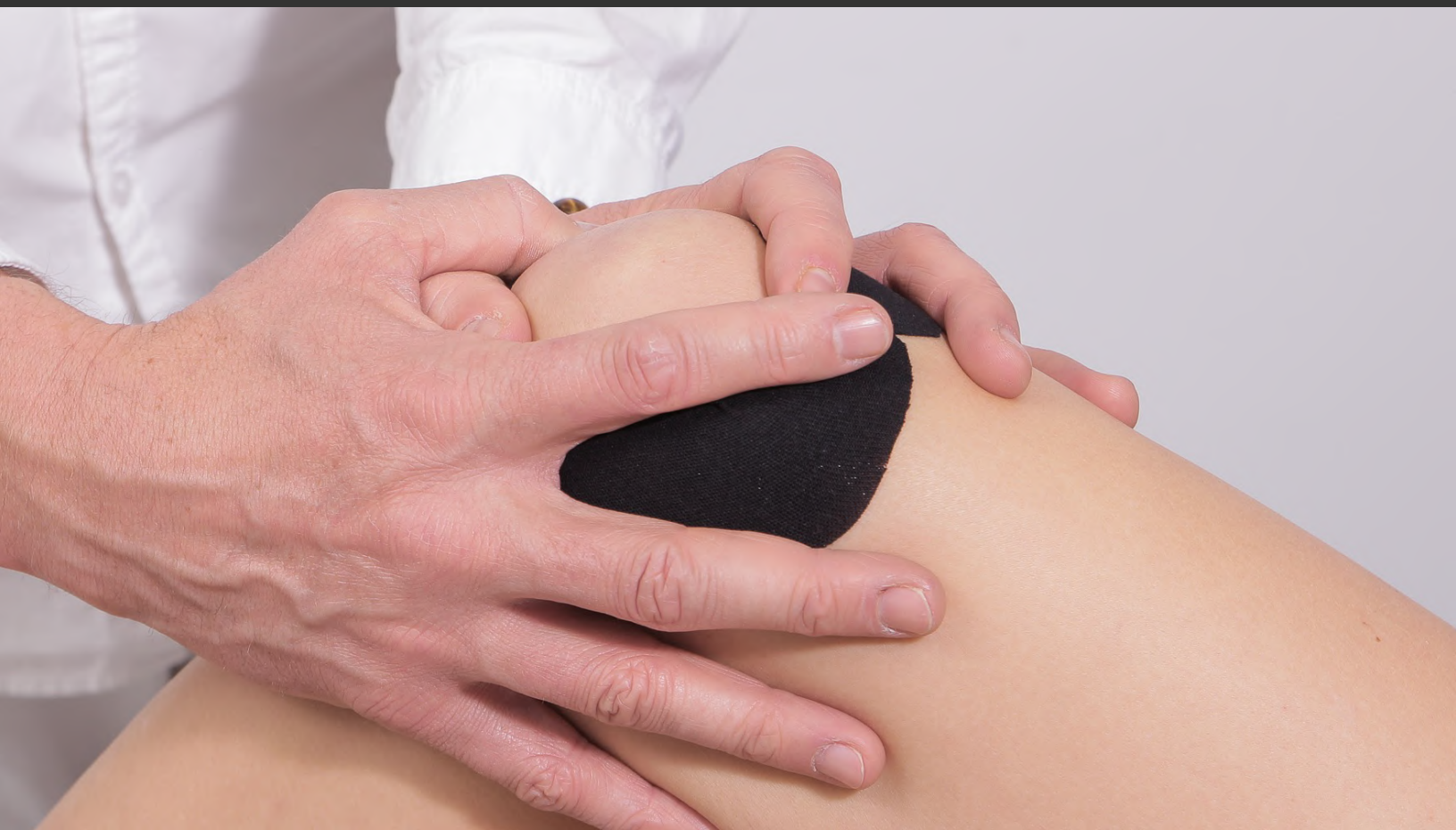
FLEX CEUs

Management of ACL Injuries in Children



Introduction

The anterior cruciate ligament (ACL) is one of the four major ligaments that provide support to stabilize the knee joint. When the knee is forcefully hyperextended or twisted, the force may be too much for the ligament to endure which results in a tear. This type of injury is extremely common in contact sports that involve forceful impacts, sudden stops, or changes in direction such as soccer and football, and will sideline a child athlete due to the extreme actions that must be taken to repair and rehabilitate the knee. When a child suffers from an ACL injury, there are unique obstacles to be taken into consideration given the child's current physical structure and the future physical growth and maturation. It is important to recognize risk factors and signs and symptoms of an ACL tear, as well as the tests required to diagnose an ACL injury and to assess the progression of healing. Physical rehabilitation is a vital component of the lengthy, difficult recovery process. Although physical therapy is an arduous, painful ordeal, it is necessary to return to full function after an injury.

Section 1: Understanding Knee Structure, Risk factors, and Signs and Symptoms of ACL Injury

Four main ligaments surround the knee for stabilization. Ligaments are strong bands of tissue that connect one bone to another. These ligaments in the knee are the **anterior cruciate ligament** (ACL), **posterior cruciate ligament** (PCL), **medial collateral ligament** (MCL), and the **lateral collateral ligament** (Mayo Clinic, 2019). The posterior cruciate ligament is located in the center of the knee and controls posterior movement of the tibia, or shinbone. The medial collateral ligament provides stability to the medial knee, while the lateral collateral ligament provides stability to the lateral knee. The anterior cruciate ligament is one of the two ligaments that provide stabilization to the mid-knee, connecting the femur to the tibia. The ACL prevents the tibia from subluxing anteriorly to the femur. These four ligaments together help to stabilize the knee joint and prevent subluxation, rotating, and hyperextension during running, jumping, and landing.

The PCL is commonly injured when the tibia is hit and forced posteriorly when the knee is flexed, or by falling onto a flexed knee. These types of injuries can be caused by tackles in football, or by other unexpected collisions. An impact from a varus stress on the knee would cause injury to the LCL. An impact creating varus stress can include injury to the ACL, MCL, or both of these and the meniscus. When the ACL, MCL, and meniscus are

injured, this is known as the “unhappy triad”. The unhappy triad is a knee injury that occurs when valgus stress is applied to the flexed knee while the lower leg is immobile and the foot planted on the ground. The femur and tibia twist in opposite directions, which results in the injury. This can happen to an athlete who is wearing cleats and is hit with great impact to the lateral knee, or to a skier if the ski does not release from the bindings during a fall. In the event of an unhappy triad, the ACL can be reconstructed while the meniscus is repaired by removing the damaged tissue or transplanting new tissue. The MCL does not usually require repair as it typically heals on its own. An unhappy triad injury is one of the most severe sports injuries, and most require surgery and extensive rehabilitation.

Of these four major ligaments, the ACL is the most commonly injured knee ligament. ACL injuries are common sports-related issues and occur during activities that put stress on the knee such as;

- A result of suddenly slowing down and changing direction, known as “cutting”
- When performing pivoting maneuvers, which is when a person plants a foot and suddenly shifts their direction.
- When someone leaps and lands awkwardly on one leg, such as when jumping in volleyball or basketball.
- During a sudden slowing or stopping from running during sports, which can cause the ligament to hyperextend.
- When a patient receives a sudden direct blow to the knee, such as a football tackle or accidental collision with another player.
- Extreme hyperextension of the knee, either from contact or jumping and landing. This can occur when the knee straightens more than it should and extends beyond the normal range of motion. This injury often occurs because of a missed dismount in gymnastics or an awkward landing from playing basketball.
- When the patient’s knee is hyperextended or twisted by suffering a fall or landing awkwardly from a jump.
- Repeated stress injury from stressful activity that can cause the ligament to lose its elasticity and stretch out.

While sports-related injuries are the most common type of way to tear or stretch the ACL, it can be injured from any trauma. This can include car accidents, falls, or something as simple as missing a step on a staircase.

Certain factors can put an individual at higher risk for an ACL tear (Mayo Clinic, 2019; Swan, 2019). These include;

- Female gender. Title IX was an amendment established in 1971 which prohibit the exclusion of people in sports based on sex, and mandates that males and females be provided the same opportunities in sports. Since this amendment, the number of females who play sports in schools has risen from 1 in 27 female participants to 1 in 5 (Women's Sports Foundation, 2016). The increase of female participants has shown a correlation with a rise in ACL injury. Females are 2 to 8 times more likely to suffer from an ACL injury than males (Mirabile, 2019). The exact reason for this is unknown but has been linked to multiple reasons;
    - The notch width index (NWI) is the ratio of the width of the intercondylar notch to the width of the distal femur at the level of the popliteal groove. A smaller notch width index is indicative of an increased chance to injure the ACL. Women have been shown to have a smaller notch width index than men, placing them more at risk for injury.
    - The quadriceps (Q) angle is the angle formed between the quadriceps and patella tendon which normally falls between 12 and 20 degrees (Abu-El-Rub et al, 2019). Males normally tend to fall on the lower end of this trend, while women have a larger Q angle at 3.4 to 4.9 degrees higher than males (Mirabile, 2019). The larger Q angle is due to females having wider hips than males. This leads to knee valgus, which increases the risk of ACL injury.
    - The ACL width is smaller in females, which could increase the likelihood of injury.
    - Women have a wider pelvis than men to facilitate childbirth. This results in the downward angle of the femur bones to be sharper, which causes women to bend their knees towards the midline of their body and places additional stress on the ACL.
    - Women have more elastic ligaments than men, which means that the ACL is more prone to being stretched and twisted.

    - Studies have shown that when jumping, women typically land on the soles of their feet instead of on the balls of their feet. By landing this way, the knee has to absorb most of the shock.
    - Women tend to run in a more upright position than men, which allows less control over how the knee rotates, especially during sudden movements.
    - Studies also show that females tend to have stronger quadriceps in relation to their hamstrings. This can cause a female athlete to rely more on their quadriceps for movement, resulting in the knee compensating for the lack of hamstring strength by placing additional stress on the ACL.
- Uneven surfaces. Hilly areas, rocky ground, sandy soil, and artificial turf can increase the risk of injury to the ACL due to the knee needing to compensate for balance.
- High BMI. Increased body mass index (BMI) has been associated with an increased risk of ACL injury or tear. The greater compressive axial force due to a high BMI increases the probability of ACL injury.
- Improper footwear. Approximately 36% of sports injuries are non-contact, with one of the major variables associated being the shoe-surface interaction and specifically footwear traction. Wearing shoes with the proper shock absorption and the implementation of cleats for activities such as football and soccer can significantly reduce the risk of injury not only to the knee but also to the ankle. It is also important to wear footwear that properly fits the foot, to avoid the foot sliding around inside the shoe and increasing the torque the knee has to compensate for.
- Poor conditioning. Patients should ensure they maintain a healthy knee environment. They should strengthen the hamstring and gluteal muscles as well as the quadriceps to help the hip joint control knee stability. Core strength should not be neglected, as a strong and stable core controls the body's center of mass, which creates the correct movement of the body.
- Use of poorly maintained sports equipment. Items such as cleats that are broken can cause instability, as well as skis that have broken straps.
- Familial disposition. There have been studies that suggest that patients who have suffered from ACL tears have family members who have also experienced an injury to the ACL, which indicates that there is some genetic predisposition to suffer from an ACL injury.

- Participation in sports. Sports make the patient more likely to injure their ACL based on the fact that the patient will be performing sudden stops and turns, jumping, and are at risk for collision injury from other players. Patients can avoid some danger by avoiding participating in multiple sports and teams in the same season, as this increases the risk of overuse stress injury and of course the probability of injury from more activity.

A study performed over 20 years on patients 6-18 years old (Beck, N., et al., 2017) suggests that the rate of ACL tears among children and teens has been increasing at a rate of about 2.3% per year over two decades. The study involved researchers reviewing insurance billing data from the years 1994-2013. This review found that on average, ACL tears occurred at a rate of 121 ± 19 per 100,000 people over the years. On average for males, the incident rate rose 2.2% annually, while for females it rose 2.5% per year. Children are more likely to injure their ACL because they are more active in general than adults. ACL injuries tend to peak in high school, as the frequency and intensity of practice and games tend to increase as children age. It should also be noted that more girls are playing sports, which of course affects the statistics due to females being more likely to suffer from an ACL injury than males. It should also be noted that reported injury could be increased because the medical community is getting better at diagnosing an ACL injury.

Children can suffer more than adults from an ACL injury largely due to their bones still developing well into their late teens. The growth plate is still developing new bone in children, while this area tends to harden as the child grows older. Knee ligament laxity is greater in children than in adults to account for the expected growth, which can result in overstretching of those ligaments and more tears or strain. As a child ages, it is the bones that increase in length. The ligaments, tendons, and muscles have to stretch to accommodate this length change. This is why the ligaments are laxer in children, to allow more room for growth.

The knee joint is the largest joint in the body. It is a **compound joint** that primarily serves as a hinge joint allowing flexion and extension. It joins the lower and upper leg and is an essential component of efficient bipedal movements such as walking, running, and jumping. The function and stability of the knee depend on muscles, bones, ligaments, cartilage, synovial tissue and fluids, and other connective tissues. Children often have genu varum (bowleg) or genu valgum (knock knee) which are considered normal during certain ages ranges. Genu varum and genu valgum are most often caused by this laxity in the supporting knee ligaments. These disorders

increase knee instability and risk of ACL injury and should be addressed if the patient does not progress beyond them after approximately the age of two years.

Babies have more cartilage in their skeletons than adults. Upon birth, the patella is cartilage, allowing for more flexibility. Between the ages of 2 and 6, most children's patellas begin to ossify, turning cartilage into bone. This is a slow process that takes many years throughout childhood. Typically, by age 10 or 12 the patella is fully developed into bone. If a child tears their ACL, the adjoining patella could be stressed or torn, placing more strain upon the patella itself and hindering the ossification and development process. The completely developed patella offers protection to the tendon and ligament structures of the knee joint, so any injury that hinders the development of the patella can result in the tendons and ligaments having less protection and therefore more likely to be injured.

Symptoms of an ACL tear are sudden and can almost always be traced back to a specific moment of incident or injury. Signs and symptoms of an ACL tear can include;

- Immediate sharp pain in the center of the knee.
- Swelling after the injury that can last up to a week. Swelling usually occurs immediately after injury, but may take 24 hours to develop.
- A sudden “popping” noise in the knee at the time of the injury.
- A decline in knee mobility and range of motion.
- The presence of deep aching pain in the knee, made worse when walking or climbing stairs.
- Instability of the knee, or a feeling of looseness in the knee. Pivoting and walking downstairs may increase the feeling that the knee is “giving out”.

There are many ways to diagnose an ACL injury or tear. X-rays may be used to rule out a bone fracture. Since x-rays do not show soft tissues such as tendons and ligaments, an MRI can be performed to show the extent of an ACL injury and determine the amount of damage to other tissues in the knee such as the cartilage. Ultrasound may be used to visualize internal structures and check for injuries in the tendons, ligaments, and muscles. Many ACL tears can be diagnosed by a simple physical exam (Khadavi and Frederics, 2019).

Initially, it is important to know the etiology of the injury, such as;

- When did the injury occur?
- How did the injury occur?
- Was the injury accompanied by a popping sound or the feeling of tearing?
- Has there been a previous injury to the knee?
- Is it swollen, and if so, where?
- Is the patient able to bear weight on the leg? Does the knee feel unstable?

The clinician will then perform a physical exam to determine tenderness, pain, and range of motion. They will ask the patient to move the injured knee themselves and will perform a passive range of motion to assess non-active limitations. There are some tests available to ascertain that an ACL injury is present. These include;

- The Lachman's Sign Test. For this test, the patient should be placed in supine on a flat surface. The affected knee should be placed in about 20-30 degrees' flexion and slight external rotation. The Therapist should place one hand behind the tibia and the other hand on the patient's thigh. The clinician's thumb must be placed on the tibial tuberosity, and the tibia should then be pulled forward gently but firmly. An intact ACL should prevent forward translational movement of the tibia on the femur, also known as a "firm end-feel". A soft or mushy end-feel indicates a positive result. More than 2 mm of anterior translation compared to the unaffected knee suggests a torn ACL, as does 10 mm of total anterior translation. A KT-1000 knee arthrometer, which is an objective instrument used to measure anterior tibial motion relative to the femur, can be utilized for more specific measurements. The Lachman's Sign Test is the most commonly used physical exam to test for ACL tears.
- Anterior Drawer Test. This test is usually used in conjunction with the Lachman's Sign Test and performed at the same time. It is performed to test the stability of the ACL. It is not as accurate in diagnosing ACL injury as the Lachman's Sign Test. This test is performed while the patient is lying in supine on a flat surface. The knee should be placed in flexion at 20-30 degrees. This test can also be performed with the patient seated with both feet flat on the floor. The Therapist should place their hands on either side of the lower knee joint. They should apply gentle pressure behind the knee and attempt to move the lower leg slightly forward while the foot stays in place on the table. The ACL is responsible for maintaining the stability of the tibia. If the tibia moves forward, this is an indication that the ACL is not functioning properly. The therapist will grade how severe the injury is by how far they can displace the ACL, on

a scale of one to three with three being the worst tear. With a grade I tear the tibia moves 5 mm, grade II results in a movement of 5-10 mm, and a grade III tear moves more than 10 mm.

- Pivot Shift Test. This test measures instability, which is important to determine how the knee will function (Wheeless, 2017), as instability places the meniscus at the future risk of damage. This test is also performed with the patient in supine on a flat surface, with the hip passively flexed to 30 degrees in abduction. The abduction relaxes the iliotibial tract and allows the tibia to rotate. The Therapist should stand beside the knee and grasp the lower leg and ankle while allowing the knee to sag into complete extension. The opposite hand grasps the lateral portion of the leg at the superior tibiofibular joint, increasing the force of internal rotation. While maintaining internal rotation, the Therapist should apply a valgus force to the knee while it is slowly flexed. If the tibia's position on the femur reduces as the knee is flexed at the range of 30-40 degrees, or if there is an anterior subluxation felt during extension, the test is positive for instability. Keep in mind that range of motion may be limited and muscle guarding due to pain may produce a false negative result.
- Reverse Pivot Shift Test. The Reverse Pivot Shift Test is much the same as the Pivot Shift Test, with the patient in supine and valgus stress applied, except that the hip is in external rotation. This test tests specifically for posterolateral instability of the knee.
- Clunk Test. The Clunk Test is performed with the knee in flexion while a valgus force and internal rotation force is applied. The Therapist should push the tibia forward, and the clunk of reduction is felt as the knee approaches full extension. What this means is that subluxation of the lateral femorotibial articulation becomes maximum at 30 degrees of flexion, then as the knee extends further, spontaneous relocation occurs in the form of a sudden jerk. If the knee joint adducts more than compared to the uninjured leg the test is positive.

It is important to properly diagnose a torn or stretched ACL. It is common for an ACL injury to be undiagnosed, resulting in ongoing symptoms of knee instability, knee buckling, pain, swelling, and interference in daily activities. Misdiagnosis can also result in the patient receiving unnecessary treatment that can cause more harm. An ACL injury can often be misdiagnosed as a medial collateral ligament knee strain. The symptoms are similar, including swelling, inflammation, extreme pain, knee buckling, and instability. The main difference between an ACL tear and MCL tear is that an ACL tear will have a distinctive popping sound, while an MCL tear will not. An MCL tear is also usually easier to recover from than an ACL tear. With an MCL tear, the recovery process may

take eight weeks or more with therapy. An ACL tear will most likely require surgery and at least six months of therapy.

There are other tests available to determine the extent of the injury. These include;

- X-ray. While soft tissue injuries do not appear on x-rays, the doctor may order an x-ray to rule out any broken bones.
- MRI. An MRI uses radio waves and a strong magnetic field to create images of both hard and soft tissues in the body. MRI's can be useful to show the extent of the injury to the ACL and other tissues in the knee, such as the cartilage.
- Ultrasound. An ultrasound can be used to visualize the internal structure and check for injury to other ligaments, tendons, and muscles.
- Arthroscopy. Arthroscopy is a procedure used to look inside the joint. During the exam, a surgeon makes a small cut in the skin and inserts a small tool that contains a light and lens into this incision. The camera projects an image of the joint onto a TV screen, allowing the doctor to see what type of injury is present.

These tests are usually performed to confirm the extent of the injury and to see if there are any more injuries to the surrounding tissues or structures.

Section 1 Summary

The ACL is one of the four main ligaments that provide stability to the knee joint. Of those ligaments, the ACL is the most commonly injured. An ACL injury can occur when stepping off a step or ladder awkwardly, in collision incidents, and most likely during sports activities. Jumping, pivoting, and cutting maneuvers are known to increase the risk of an ACL injury. Some factors can increase the risk of an ACL tear, including being of the female gender, genetic and familial disposition, poor conditioning, uneven surfaces, high BMI, improper footwear, the use of improperly maintained sports equipment, and participation in sports, especially multiple sports at once. ACL tears are trending upwards at an average of 2.3% among children per year. This is because children are playing more sports, and females are participating in sports more frequently than in previous years. Children are prone to ACL tears not only because of their participation in more physical activities, but because their ligaments are laxer than those of adults.

It is vital to ensure that an ACL tear is properly diagnosed. ACL tears are most likely to be diagnosed as an MCL tear, which is dangerous because MCL tears are less serious and

will result in patients not receiving the care they require to properly heal. There are several tests available to determine if the ACL is torn, including the Pivot Shift Test, Reverse Pivot Shift Test, Clunk Test, with the two most common tests being the Lachman's Sign Test and Anterior Drawer Test. An X-ray, MRI, ultrasound, or arthroscopy may be used to confirm the extent of the injury to the ACL and surrounding structure.

Section 1 Key Concepts

- Anterior Cruciate Ligament-one of the key ligaments that help to stabilize the knee joint. The ACL connects the femur to the tibia.
- Compound Joint-a joint composed of three or more skeletal elements, or in which two anatomically separate joints function as a unit.
- Lateral Collateral Ligament-a thin band of tissue along the outside of the knee. This ligament connects the femur to the fibula.
- Medial Collateral Ligament-located on the medial, or inner, aspect of the knee, this ligament helps to connect the top of the tibia to the bottom of the femur.
- Notch width index- the ratio of the width of the intercondylar notch to the width of the distal femur at the level of the popliteal groove.
- Popliteal groove-a groove on the lateral condyle of the femur between the epicondyle and the articular margin.
- Posterior Cruciate Ligament-Similar to the ACL, located in the middle of the knee. This ligament connects the femur to the tibia. It is stronger than the ACL, but still at risk of being torn.

Section 2: Surgical Options and Considerations

ACL injury does not always require surgical intervention. The injury can be classified by the amount of damage to the ligament, either as a partial or complete disruption. There are three classifications of sprains to the ACL (UC San Diego Health, 2020);

- Grade I Sprain - In this instance, there is some stretching and micro-tearing of the ligament, but the ligament is intact and the joint remains stable. These types of injury rarely require surgery, and the knee will remain stable for the most part. Symptoms of a Grade I sprain include tenderness, swelling, pain, and some limited mobility. The

method of POLICE (Protect, Optimal Load, Ice, Compress, Elevate) in conjunction with anti-inflammatory medications and the use of crutches can usually be of great help during the healing process.

- Grade II Sprain – This grade of sprain is characterized by partial disruption of the ACL. Some tearing and separation of the ligament fibers is present with the ligament partially disrupted. The joint is moderately unstable. Depending on the activity level of the patient and the degree of instability, these tears may or may not require surgery. However, in cases of instability, ACL reconstructive surgery is typically recommended.

- Grade III Sprain – A grade III sprain entails a complete disruption, and is the most common type of ACL injury among athletes. This injury involves a total rupture of the ligament fibers, meaning that the ligament itself is torn in two. The ligament is completely disrupted and the joint is unstable. Symptoms include severe pain, swelling, tenderness, limited mobility, and stiffness. Although rare, a complete ACL tear can occur without pain, swelling, or stiffness, but a complete tear almost always leaves the knee unstable. Surgery is usually recommended in young or extremely athletic people who are involved in sports that involve cutting or pivoting maneuvers, once full knee extension is achieved, and the swelling decreases.

Sprains, although the most common type of injury, are not the only types of injury to the ACL. Some other injuries include;

- ACL avulsion fracture - In an ACL avulsion fracture, an injury to the bone occurs near the attachment point where the bone attaches to the ACL. When the bone fractures, the ligament pulls away and takes a small piece of the bone with it. This type of fracture is uncommon in adults and is more likely to be seen in children (FIFA Medical, 2018). This is thought to be due to the weakness of bone that is not completely ossified or possible due to the laxity of the ACL in children. An ACL avulsion fracture is usually caused by some form of hyperextension. In one such case study, a 28-year-old football player suffered this type of injury. Normally, surgical intervention is recommended in a case such as this. In some instances, non-displaced fractures can be treated with non-surgical intervention. In this particular instance, the player was treated with non-surgical intervention. The patient was placed in an extension brace for two weeks, followed by an adjustable brace allowing 20-90 degrees of extension/ flexion for three more weeks. A five-month follow-up examination revealed that the patient had a normal Lachman's test result, and had returned to his prior level of recreational football.

- ACL Deficient knee - An ACL deficient knee is one in which the ACL is injured or deteriorated in some way. In rare circumstances, the ACL can be absent at birth. Only about 2 children in every 100,000 live births suffer from this congenital defect. Some people do not have an ACL due to injury. Those who do not have an ACL tend to develop a knee joint where the femur fits into the tibia like a shallow ball and socket joint. The meniscus undergoes deformation to compensate for the lack of an ACL. Some individuals prefer to live without a functioning ACL, and some choose to have surgery to replace the ligament.
- Complex and multi-ligament knee injury - This type of injury occurs when other ligaments are injured in conjunction with the ACL. Multi-ligament knee damage occurs from a severe traumatic event, such as a car accident. In this instance, a knee dislocation or fracture can be present. X-rays and MRIs are required for diagnosis. To correct the overlapping injuries, grafts may be required to fully repair the site.

The first stage of any treatment for an injury involves the POLICE method (Sears, 2020). POLICE refers to;

- Protect. Immediately after an ACL injury, it is important to rest the joint. However, many patients take this step too far, which can lead to joint immobility and a decline in muscle strength. For this reason, the RICE (Rest, Ice, Compression, Elevation) method is no longer the preferred course of action for injury recovery. After a few days of rest, it is important to regain motion and movement in the knee.
- Optimal Load. Optimal loading refers to the initial range of motion and activity that begins in the protection phase. Activity helps to manage swelling, as muscle contraction helps to push the swelling out of the tissues and back to the nodes to be redistributed throughout the body.
- Ice. Patients should be advised to try to ice the knee at least every two hours for 20 minutes at a time. The application of ice immediately after an injury helps reduce swelling by restricting blood flow to the area and slowing down cellular metabolism. The use of ice frequently helps to keep the swelling down and also helps with pain relief.
- Compression. Compression can be applied with the aid of static bandages, elastic bandages, or compression devices. This can help by reducing blood flow to the area of the injury and allowing for less swelling.

- Elevation. When elevating an injured limb, it is best to keep the injury above the level of the heart. This helps use gravity to assist the blood to return to the heart.

While POLICE is a valuable tool for any injury, it is especially important to follow with an ACL injury. An ACL injury generally results in swelling, which can be alleviated by following the POLICE method while maintaining mobility. The patient may be placed in a brace or immobilization device for short times to avoid further injury. Once stabilized and immediate care is underway, the doctor will discuss treatment options. Surgical rehabilitation is often prescribed or required, with conservative treatment as an alternative. Young people, and people who participate in sports or work-related activities that require a lot of pivoting, jumping, or cutting, may be recommended surgery. In the case of someone who is not so physically active, conservative treatment may be the best option in an ACL tear with no other ligament or cartilage involvement. If a non-surgical approach is chosen, it is important to maintain the strength, balance, and range of motion by the implementation of physical therapy. Some patients may elect to use a sports brace and limit participation in activities that require pivoting, cutting, or jumping. Non-operative treatment is preferred when the patient is older than 35 years of age, has none or minimal anterior tibial subluxation, and when the patient is not highly active.

For a patient who is chosen to undergo the non-operative route, physical therapy is a major part of recovery. Recent studies have shown that there are high second ACL injury rates, a lower return to sports rates, and an increased risk of osteoarthritis (OA) in those who elected to have surgery than was previously reported (Paterno, 2017). For these reasons, a patient may elect non-operative interventions. Although not as common in the USA, this may be a viable option for patients who have no additional injury to the surrounding knee structure.

A screening tool developed by the University of Delaware has been used to help identify patients likely to be able to successfully return to function without an ACL reconstruction. This tool consists of four one-legged hop tests;

- Single leg hops for distance-performed with proper close stand by assist to avoid falls, the patient is instructed to hop forward on one leg as far as possible.
- Single leg triple hop-performed with proper close stand by assist to avoid falls, the patient is instructed to hop forward three times on one leg as far as possible.

- Single leg triple crossover hop-again performed with close stand by assist to avoid falls, the patient is instructed to hop forward as far as possible three times, each time crossing over a line.
- 6-meter timed hop test-with proper stand by assist to avoid falls, the patient is instructed to hop forward as quickly as possible for a distance of six meters.

These tests are performed bilaterally to compare the affected knee and unaffected knee to determine the symmetry between the two.

In addition to the hop tests, scales known as KOS-ADLS (**Knee Outcome Survey Activities of Daily Living Scale**) and KOS-SAS (**Knee Outcome Survey Sports Activities Scale**) are utilized to determine how the symptoms affect the level of activity of each patient (Med Star Health, 2016). The surveys are as follows;

Knee Outcome Survey Activities of Daily Living Scale: To what degree does each of the following symptoms affect the level of activity?

	I do not have the symptom.	I have the symptom, but it does not affect my activity.	The symptom affects my activity slightly.	The symptom affects my activity moderately.	The symptom affects my activity severely.	The symptom prevents me from all daily activities
Pain						
Stiffness						
Swelling						
Giving way, buckling, or shifting of the knee.						
Weakness						
Limping						

Functional Limitations with Activities of Daily Living; How does the knee affect the ability to do each of the following?

	Activity is not difficult	Activity is minimally difficult	Activity is somewhat difficult	Activity is fairly difficult	Activity is very difficult	I am unable to
Walk						
Go upstairs						
Go downstairs						
Stand						
Kneel on front of the knee						
Squat						
Sit with the knee bent						
Rise from a chair						

The patient should be instructed to fill the survey out as well as they can, checking one answer each line. The first column in each is scored 5 points for each item, followed in each successive column with scores of 4,3,2,1, and 0 for the last column. The total points will be added, divided by 70, and multiplied by 100 for the total score as a percentage.

Knee Outcome Survey Sports Activities Scale; To what degree does each of the following symptoms affect the level of sports activities?

	Never Have	Have, but does not affect my sports activity	Affects my sports activity slightly	Affects my sports activity moderately	Affects my sports activity severely	Prevents me from all sports activity
Pain						
Grinding or grating						
Stiffness						

Swelling						
Slipping or partial giving way of the knee						
Buckling or full giving way of the knee						
Weakness						

Functional Limitations with Sports Activities: How does the knee affect the ability to do each of the following?

	Not difficult at all	Minimally difficult	Somewhat difficult	Fairly difficult	Very difficult	Unable to do
Run straight ahead						
Jump and land on the involved leg						
Stop and start quickly						
Cut and pivot on the involved leg						

The patient should be instructed to fill the survey out as well as they can, checking one answer each line. The first column in each is scored 5 points for each item, followed in each successive column with scores of 4,3,2,1, and 0 for the last column. The total points

will be added, divided by 70, and multiplied by 100 for the total score as a percentage. The lower the percentage of these scales, the higher the disability. If someone scores less than 80% on these scales, surgical intervention is required. If someone does elect to pursue non-operative intervention, they must be encouraged to commit to a lifetime of activity modification which can lead to a more sedentary lifestyle. For this reason, non-surgical interventions are not normally advisable for young people or children.

Surgical intervention is preferred when the patient is younger than 25 years of age, has a marked anterior tibial subluxation, has additional intra-articular damage, and is heavily active. Young patients are often very active and therefore require surgical intervention. There are different types of reconstruction, including **single-bundle** or **double-bundle** reconstructions. The ACL is formed of thousands of individual fibers. Some fibers of ligaments are organized into distinct bundles. The ACL itself has two primary bundles of fibers, which are the anteromedial bundle and the shorter posterolateral bundle. When an ACL is torn, it cannot be repaired by sewing it back together. A graft must be used to reconstruct the torn ligament. When the ACL is reconstructed in a single-bundle reconstruction, one large graft is placed in the position of the anteromedial bundle. The graft is held in place by making a hold in the bone called a tunnel. One tunnel is made into the femur and one in the tibia. The graft is then held in place with some sort of fixation device, often a screw.

It has been shown that conventional single-bundle ACL reconstruction fails to restore normal knee kinematics which leads to altered joint loading patterns. For this reason, double-bundle reconstruction is becoming more popular. In the double-bundle reconstruction, two small grafts are implanted, one each for the anteromedial bundle and the posterolateral bundle. The double-bundle procedure requires two additional bone tunnels to accommodate a second graft, as well as an additional incision. This surgical procedure may take a bit longer to complete than a single-bundle reconstruction.

Studies have shown that there is a more normal function of the reconstructed ligament after a double-bundle ACL reconstruction when compared to single-bundle reconstruction. However, studies do not show any advantage for either reconstructive surgery five years post-operation in a study performed with a total of 53 patients (Bruder, 2018). In this study, there were 28 patients in the double-bundle reconstruction group and 25 patients in the single-bundle reconstruction group.!**A Laxitester device** was used to measure medial instability in combination with ACL injuries. At the five-year

follow-up, no advantage was observed for either the single-bundle or double-bundle reconstruction.

There are four types of grafts for reconstruction surgery;

- **Autografts.** Grafts are taken from the patient's own body, which includes portions of the extensor mechanism. The most common tendon harvested for younger athletes is the semitendinosus tendon with or without the gracilis tendon of the hamstring.
- **Allografts.** A type of graft taken from cadavers, preferred for older patients.
- **Xenografts.** These grafts are taken from animals, such as pigs.
- **Synthetic grafts.** These types of grafts are man-made. They include biodegradable (carbon fibers), a permanent prosthesis (Gore-Tex and Dacron), and ligament augmentation devices.

During a reconstruction surgery, the surgeon will place the patient under general anesthesia. They will then remove the damaged ligament and replace it with whatever graft is chosen. The surgeon will drill sockets, or tunnels, into the thigh-bone and shinbone to accurately position the graft in the approximate place that the original ACL was located. The graft is secured to the bones with screws or some other type of fixation device. This will then serve as a type of scaffolding on which new ligament tissue can grow. The surgery is usually performed on an outpatient basis and lasts for around 2 ½ hours, with the patient being released to go home later that same day. Before being released, physical therapy will be called in to educate and observe the patient walking with crutches or a walker and ensure the patient's safety. The patient may be asked to wear a knee brace or splint to temporarily help protect the graft. A continuous cold therapy device may be prescribed to help control swelling of the knee.

There are additional considerations for ACL reconstruction where children are concerned because children are still growing. There are multiple factors that surgeons must take into account when considering the surgical reconstruction of a child's ACL, as there is a potential risk of growth disturbance (Pandya, 2016).

During the surgery, when the surgeon drills tunnels in the femur and tibia bones to fix the new ACL grafts into place, there is a possibility that the tunnels may intersect the growth plates of the bone. The growth plate, also known as the epiphyseal plate, or physis, is the area in a child or adolescent bone where growth occurs. Each long bone has at least two growth plates, one at each end. The femur, tibia, and fibula are amongst

the long bones of the body. The growth plate determines the length and shape of the future mature bone. These plates usually close near the end of puberty. For girls, this is usually when they are 13-15 years of age, while for boys they are normally 15-17 years of age. By drilling a hole through an open growth plate, the body may close the growth plate early, causing irregularities.

Any damage to the growth plate can suppress the growth of bones, distort the joint, and can cause long-lasting damage such as arthritis. Damage can cause the legs to suffer leg length discrepancies or issues with an angular deformity such as genu valgus or genu varus.

Surgeons who treat pediatric patients will not only utilize x-ray's, MRI's, and puberty signs to gauge the amount of growth remaining in the young patient, they will assess parental height, chart the growth pattern, and take into account recent growth spurts. Due to the risk of growth disturbance, some ACL reconstructions in the youth may be delayed until the patients are done growing. These patients will have to impose restrictions upon their physical activity and wear specialized braces on the affected knee until they are done growing. Many young people, especially young athletes, find it extremely difficult to follow restrictions and slow their activity.

There have also been many studies that have shown that delaying ACL surgery in young patients to allow for continued growth can result in an increase of articular cartilage damage and increased risk of meniscus tears due to activity without ACL subjects the knee to instability and damage. Some accommodations can be made to spare the growth plate.

For example, reconstruction surgery can be modified by drilling smaller tunnels in for smaller ACL grafts, or by avoiding holes altogether and wrapping the grafts around the bone. This does allow for a higher instance of reconstruction tear or failure to completely stabilize the knee. One such procedure is known as an "**all-inside ACL reconstruction**" (Connaughton, 2017). This procedure has shown promise in recent years. This surgical technique includes closed-socket tunnels with less bone removal, dual femoral and tibial suspensory fixation, specialized graft choice, and smaller skin incisions. The graft typically used in this type of surgery is a semitendinosus tendon autograft in comparison to the semitendinosus gracilis tendon autograft. Since the smaller sockets are drilled instead of full tunnels, the required length of the graft is smaller than necessary for a normal ACL repair. For this reason, a single hamstring tendon harvest will suffice to serve as the autograft after it is tripled or quadrupled. Suspensory fixation refers to a type of fixation where a button rests on the cortex of the

femur with a loop that holds the folded soft tissue ACL graft in position to facilitate healing. This type of fixation does not require the deep tunnels a normal ACL reconstruction does, which bypasses the damage potential to the growth plate. A **suspensory fixation** can be fitted with a fixed loop or adjustable loop, which are equally effective methods. The all-inside ACL reconstruction is fast becoming a viable option to avoid damaging the growth plate while providing the necessary stability and reconstruction to eventually return to activities. Studies show that a comparison of these surgeries shows no significant difference in patients regarding pain, activity levels, and test scoring at two years of follow-up visits.

Section 2 Summary

There are many types of injuries to the ACL, such as ACL avulsion fractures, complex and multi-ligament knee injuries, an ACL deficient knee, and sprains to the ACL. There are three types of ACL sprain, including Grade I, II, and III sprains. A Grade I sprain often includes very small microtears to the ligament, a Grade II involves partial disruption of the ligament, while a Grade III sprain entails the complete tear of the ligament. When injured, immediate care for any injury requires the application of the POLICE (Protect, Optimal Load, Ice, Compress, Elevate) method. This method is extremely important for an ACL injury due to the amount of swelling that is usually a result of the injury, as POLICE can help to alleviate the swelling and pain while keeping the joint mobile for a short time. The patient may be placed in a brace or immobilization device to avoid further injury. After stabilization, doctors and surgeons will discuss treatment options. These options may include conservative non-surgical rehabilitation or surgical intervention.

Surgical intervention is usually recommended for those who are very active, and for those who are younger than 25 years of age. Tests including hop tests such as the 6-meter hop timed hop test, single-leg triple crossover hop test, single-leg triple hop test, and the single-leg hop test will be used to help identify those patients who are likely to be able to successfully return to function without an ACL reconstruction. The hop tests should be performed bilaterally to compare the affected and unaffected knee to determine the symmetry between the two. In addition to the hop tests, scales such a the KOS-ADLS (Knee Outcome Survey Activities of Daily Living Scale) and KOS-SAS (Knee Outcome Survey Sports Activities Scale) are used to determine how the symptoms of the injured knee affect the level of patient's daily activity, and to determine how the injury affects participation in sports activities.

There are many variations for the surgery itself. Autographs, allografts, xenografts, and synthetic grafts are the types of grafts that can be chosen from for the repair. Using one of these grafts, the surgeon decides on a single-bundle or double-bundle reconstruction. The single-bundle reconstruction is falling out of favor since it often fails to restore normal knee kinematics which leads to altered joint loading patterns, while a double-bundle restoration results in the more normal function of the reconstructed ligament. During a reconstruction surgery, the patient is placed under general anesthesia. The damaged ligament is removed and replaced with the chosen graft, which is affixed to the bone using sockets or tunnels. This is usually an outpatient surgery, with the patient being released to home the same day with a gait assistive device and possibly a cold therapy machine.

Considerations must be allowed for children who are still growing, as the typical surgery damages the growth plate. Damage to the growth plate can result in growth suppression of the affected limb and angular deformity, among other concerns. Surgeons may recommend delaying surgery until the child is done growing or almost grown. This can cause issues because the knee is unstable which can result in extraneous injury to the knee, and the patient may find it difficult to follow restrictions for a long period. There is also evidence that delaying ACL surgery can increase articular cartilage damage and increased risk of meniscus tears. A novel procedure that is gaining popularity is known as an all-inside ACL reconstruction, which includes closed-socket tunnels with less bone removal, dual femoral and tibial suspensory fixation, specialized graft choice, and smaller skin incisions. The all-inside ACL reconstruction is a viable option when concerned about growth plate damage due to the small sockets that are drilled to affix the buttons that allow for the fixation of the graft. Studies have shown that this is comparable to a normal ACL reconstruction in terms of pain, activity levels, and test scoring at two years follow-up visits.

Section 2 Key Concepts

- All-inside ACL Reconstruction-an alternative ACL reconstruction surgery that utilizes closed-socket tunnels with less bone removal, dual femoral and tibial suspensory fixation, specialized graft choice, and smaller skin incisions.
- Allograft-a tissue graft from a donor of the same species as the recipient but not genetically identical, typically a cadaver donor.
- Autograft-a graft of tissue from one point to another of the same individual's body.

- Double-bundle reconstruction-an ACL reconstruction involving the replacement of the anteromedial and posterolateral bundles in the ACL.
- Growth plates-The growth plate, also known as the epiphyseal plate or physis, is the area of growing tissue near the ends of the long bones in children and adolescents. Each long bone has at least two growth plates; one at each end. The growth plate determines the future length and shape of the mature bone.
- Knee Outcome Survey Activities of Daily Living Scale-a questionnaire utilized to determine how knee injury symptoms affect the daily life of the patient.
- Knee Outcome Survey Sports Activities Scale-a scale utilized in athletes to determine how an injury affects sports activities.
- Laxitester device-allows objectification of medial instability in combination with ACL injuries and provides a reference regarding the need for additional medial stabilization.
- Single-bundle reconstruction-a reconstruction where on the anteromedial bundle of the ACL is replaced.
- Suspensory fixation-Suspensory devices commonly feature a button that rests on the cortex of the femur and a loop that holds the folded soft tissue ACL graft in position until healing can occur.
- Xenograft-a tissue graft or organ transplant from a donor of a different species from the recipient.
- Synthetic graft-a man-made graft that can be either biodegradable, a permanent prosthesis, or a ligament augmentation device.

Section 3: Rehabilitation for Conservative and Post-Surgical ACL Injury

Therapy post ACL injury is vital to recovery whether a conservative or surgical approach is chosen. Physical therapy can help reduce pain and swelling, restore muscle strength, agility, and balance, and help the patient to return to as close to normal activity as possible. The Physical Therapist can construct a plan to help the patient to modify their activities to put less stress on the knee. If surgery is performed, the Therapist can help to

rehabilitate the knee before and after the procedure. The patient must be committed to exercise and their Therapy program no matter the venue that is chosen.

There are four stages of an injury (South Shore Hospital, 2016). They are as follows;

- Acute stage. An injury is acute from the initial stage of injury and while the symptoms are at the worst. At this point, it is vital to reduce pain, swelling, and to protect the joint from further injury. This can last up to four days post-injury but may be exacerbated depending on how the patient protects the injury.
- Sub-acute stage. The injury is termed as sub-acute when the body begins to make a transition to repairing the injured area. This stage can last up to six weeks while the body begins to build new tissue and repair the issues. Swelling is still an issue in this stage.
- Late-stage. Commonly referred to as the remodeling phase due to the continued stimulation of new tissue to help strengthen and support the healing injury site. During this stage, the patient may begin to return to some prior activities. This stage can last between six weeks to three months.
- Final stage. Also known as the return to activity/sport phase. This period can last from 3 months to 12 months. This stage focuses on improving the quality of the new tissue and preventing re-injury. Treatment should be sport and activity specific to prepare the knee for specific demands.

During the first stage with non-operative care, there are multiple considerations. Primarily, pain and swelling must be kept under control to allow the patient to return to limited mobility. Safety is an issue, as the patient will not be able to bear full weight upon the affected extremity. For young people, they will most likely be provided with crutches with a WBAT (weight-bearing as tolerated) recommendation. The patient should be instructed on proper gait pattern, safety, and sequencing with the crutches in a step-through method. The crutches are to be utilized to help support the patient's knee and provide proper balance assistance. The therapist should encourage range of motion (ROM) exercises to restore and improve post-injury function. Goals at this time are to improve pain and swelling, restore ROM, improve flexibility, assist with gait mechanics with assistive devices, and improve quadriceps activation. Some exercises to improve ROM and strength at this time can include;

- ROM

- Patellar mobilization. This exercise is performed in long sitting and can be performed by the patient, Therapist, or a caregiver. Movement of the patella is essential when restoring ROM during ACL reconstruction, as if the patella cannot move within the femoral groove the knee cannot flex and extend. Patellar mobilization is performed by pushing the patella up and down and side to side and holding each position if so desired.

- Knee extension stretch. Can be performed in long sitting, seated, or lying. The patient should utilize a belt or strap to assist in the stretching. The leg should be extended as straight as the patient is able. With the belt around the toe of the foot, the patient should gently but firmly pull the belt back while using the quadriceps to push the knee down into the table.

- Heel slides. While seated or supine with the foot flat on a mat, the patient should be encouraged to pull the foot back towards the buttocks, bending the knee. When the patient reaches the maximum flexion, the Therapist may encourage them to hold the flexion for 10-15 seconds to stretch the quadriceps muscle.

- Static cycling. Set with no resistance, as this exercise is for ROM and not strengthening, the patient should perform on a static bicycle for 10-15 minutes per day. This will help to normalize the ROM and "loosen up" the knee.

- Ankle pumps. It is not only important to maintain knee ROM, ankle ROM can suffer as well. This exercise can be performed in any position. Instruct the patient to tap the toes up and down.

- Strengthening

  - Quad sets. It is important to strengthen the quads as they will begin to weaken quickly. In long sitting or supine with the leg straight out, the patient should focus on contracting the quadriceps while pushing the knee into the table. A rolled-up towel can be placed under the knee to add some resistance.

  - Hip abduction/adduction. This can be performed with or without a band, although for young people resistance exercise is recommended as they are usually already strong. This can also be performed in standing. The patient should be instructed to keep the knee as straight as possible and slide or swing the foot away from the body and back towards the body in a slow, controlled movement.

  - Hip flexion. While in supine, straight leg raises (SLR) can be performed. The patient should be instructed to keep the knee straight as possible and raise the leg off the

table approximately 12 inches. For increased difficulty, the leg can be held above the table for 5 seconds. This can also be performed in seated marching, although standing marching is not recommended at this stage.

- Partial squats. With the patient standing with support and feet shoulder-width apart, the patient should bend the hips and knees and squat to lower their body slightly, until the thighs are about 45 degrees from parallel to the ground.
- Hamstring curls. In prone or standing, the patient should bend the knee and pull the foot towards the buttock, then extend to normal.
- Standing total knee extension (TKE) with theraband resistance. Facing the support structure that the band is tied to, the band should be placed around the back of the knee while in standing. The band should be snug with the knee slightly bent so that as the patient straightens the knee, pulling back against the band causes resistance.
- Standing heel/toe raises. Standing at a support counter, the patient should rise up on the toes, then rock back onto the heels. It is important to strengthen the ankles as well to provide the support the knee will be lacking.

This stage should focus primarily on improving ROM, swelling reduction, and pain reduction than strengthening. Strengthening can be performed 2-3 times per day if tolerable. Stretching should be performed 3-5 times per day to assist in returning normal ROM to move on to the next stage. Modalities should be implemented such as cold therapy to reduce swelling and pain in this stage. The patient should be encouraged to follow the POLICE method to alleviate pain and swelling as well. The Therapist should report any episodes of knee-buckling to the physician.

The sub-acute stage focuses more on strengthening. Goals are to maintain and improve ROM and flexibility, begin restoration of strength, and improve control. During this phase, the assistive device will normally be discharged. The ROM and stretching exercises will continue during this time, as well as the static cycle exercise. Light resistance on the cycle should be added and increased upon as tolerated to improve strength. The above-mentioned exercises should be continued adding weights and bands to improve strength as well. The following exercises should be added to promote increased strength;

- Hamstring curls should be continued, increasing resistance or adding weights. Implementation of a leg curl machine is advised.

- Leg presses should be implemented. This exercise can start as a double limb exercise, and increase to a single limb exercise as the patient is able. Resistance can be increased over time.
- Squats can progress from partial to full squats, with a limit of 90-degree knee flexion.
- Planks and side planks can be included at this time. Planks develop strength in the core, shoulders, arms, legs, and glutes. A forearm plank is performed by getting into a position on the floor like the patient is about to do a pushup, but with the body supported on the forearms. The elbows should be aligned below the shoulders with the arms parallel to the body at shoulder width. The toes should be pushed into the floor and glutes squeezed to stabilize the body. Remind the patient not to lock or hyperextend the knees. The head should be in line with the body. This plank can be made more difficult by progressing to the straight arm version. A side plank is performed by lying on the side with one leg stacked on top of the other. Next, the patient should be instructed to prop the body upon the hands (straight arm) or on the elbow. The plank can be made more difficult by raising the opposing arm or leg, or both, into the air. The side plank can be made easier by crossing the leg in front of the body for additional support.
- Bridges can be added. By lying supine with the knees bent and shoulder-width apart, the patient should raise the bottom into the air. This exercise can be performed by holding at the top of the bridge as well as repetitions. Bridges can be made more difficult by progressing to single-limb bridges, which is accomplished by the patient in the same position but with one leg raised and extended straight out, using the opposite leg as the support for the bridge. This exercise increases core and lower extremity strength.
- Single leg balance exercises can begin at this time. With support available, the patient should bend one knee and lift a foot off the ground. The patient should progress from eyes open to eyes closed, then on to unstable surfaces such as a pillow, foam, or BOSU ball. This not only works on strengthening the leg but strengthens the knee structure and improves balance.

All ROM and flexibility exercises should continue during this stage once a day. Strengthening should begin 3-5 times a week, and progress in difficulty and resistance as the patient is able at the discretion of the Therapist. If possible, the static cycle should be performed once per day to facilitate ROM and flexibility.

The late-stage includes a limited return to activity. During this stage, ROM and flexibility exercises will continue with resistance increasing. Single leg strengthening should increase to maximize strength and challenge proprioception. Light jogging should begin to reintroduce activity. Dynamic balance exercises are required to maximize neuromuscular control. Some advanced dynamic proprioception exercises can include;

- Single leg squats. These are great for strengthening and engaging knee and ankle proprioceptors. In standing with both arms extended in front of the body, the patient should balance on one leg with the opposite leg extended forward and the foot off the ground as high as comfortable. The patient should squat as far as comfortable, then raise themselves back up. For less difficulty, the patient can hold onto a counter or rail, or rest the non-weight-bearing leg on the floor instead of holding it up.
- Cone pickups. Beginning in a standing upright position with a cone or other object on the floor, the patient should bend forward at the hips while letting one leg extend backward. The patient should pick up the object and return to the starting position. The object should be placed back on the floor in the same way. Single leg squats can be incorporated into this exercise to increase the difficulty.
- Crossover walk. This is a good exercise for the ACL as it focuses on knee proprioception. Beginning with feet a little more than shoulder-width apart, the knees should be bent to a 45-degree angle. Crossing one leg over the other, a large step should be taken to the side. Then, the patient should step out so that feet are returned to the original position. This exercise should be performed slowly to concentrate on the movements required.

Plyometric exercise should be started at this time to increase speed, endurance, and strength. Plyometrics is also known as jump training. These types of exercises are beneficial for athletes, especially those young athletes or children who wish to return to full function. Be cautioned that plyometric exercises can cause stress to the tendons, ligaments, and lower extremity joints, so they should be limited and closely monitored for adverse pain and swelling reactions. These should be added gradually, slowly increasing the duration, difficulty, and intensity. Plyometrics that can be added include;

- Simple double limb exercises. This exercise can include double leg hops forward and backward over a line, or box jumping, which is jumping 6-8 inches max forward or backward.

- Complex double limb exercises. This can include double leg jumps for distance or height, or a jump with 90-180 degree turns. These are more advanced than the simple double limb and should only be implemented later in the therapy process.

Exercises such as step-ups, increasing the height of the steps, can be implemented at this time. Lateral movement is to be cautioned. Cardio exercise is recommended 3-5 times per week. The therapist should monitor swelling and decrease intensity if swelling persists or worsens. Sprinting exercises should begin at the end of the late-stage and beginning of the final stage. The patient should begin a gradual return to sports activities with the permission of the physician.

The final stage involves a return to sports or activities. Stretching, cardio and strengthening should continue while advancing exercises from static to dynamic. Plyometrics should continue while emphasizing control and avoiding increased trunk flexion, dynamic genu valgum, and femoral internal rotation. Sports specific drills can begin, as well as the implementation of a speed and agility program. Sprinting should continue while adding a change of direction and backpedal drills.

Post-surgery rehabilitation is very similar to non-surgical rehabilitation. The recovery process is strenuous and time-consuming. It is estimated that it will take at least six months for the patient to feel as though they have completely returned to a pre-injury level of activity (South Shore Hospital, 2016b). Children can return to school typically after a few weeks with crutches and possibly a brace. It is important to educate the patient on the use of crutches post-surgical intervention as their gait dynamics may have changed with the surgery. For patellar tendon grafts, the patient will be WBAT immediately after surgery with the aid of crutches, while with hamstring and allograft surgeries the patient will be under partial weight bearing (PWB) for approximately 4 weeks post-surgery. For those with patellar tendon grafts, the patient should begin to wean from the crutches at approximately 2 weeks post-op, while those with hamstring and allograft surgeries must wean to WBAT after four weeks and then wean from the crutches at approximately six weeks post-op. The physical therapist must continue to provide encouragement and education to enforce the weight-bearing status while reminding the patient that any deviation can reinjure the ACL graft and set back healing or require further surgery.

After surgery, the doctor may recommend a large knee brace. Generally, it is recommended that the brace is locked in extension for walking and when sleeping for the first two weeks after the operation. The brace should be unlocked when sitting to allow the knee to move and bend. The brace can be unlocked while walking depending

on how well the patient recovers lost muscle tone in the leg. The knee brace may be necessary for 4-6 weeks after the operation.

Open chain exercises versus closed chain exercises specifically for knee extension are a debated topic among therapists and researchers (Miller, 2020). During kinetic exercise, the joint undergoes shear or compression forces. Shear force occurs when the quadriceps muscle contracts strongly, resulting in the tibia shifting anteriorly while the femur moves posteriorly. Shear force is typical of open chain exercises. Compression force occurs when a strong external force is applied on the knee, resulting in the heads of the femur and tibia pushing together. This is seen in closed chain exercises, and causes stability in the knee while reducing shear force. Shear force places increased strain upon the ACL when compared to compression force. Due to the decrease in the harmful shear force with closed chain exercises, there is a related decrease in anterior tibial displacement. When performing closed chain exercises, the hamstring co-contracts which in turn also decreases anterior tibial displacement. A decrease in anterior tibial displacement results in less strain to the ACL. While most practitioners believe that there is a room in rehabilitation for both closed chain and open chain exercises, there needs to be more studies performed to assess the true difference. Until that time, open chain exercises can be implemented with care for the strain that the ACL will undergo with exercises such as seated knee extension and straight leg raises.

The patient should always be monitored and the treatment plan changed as needed to fit the specific patient. Upon the surgeon's approval, the patient can begin to transition to a full return to sports after 24 weeks. There are several protocols that the therapist can refer to as a guideline for ACL rehabilitation, including the Mass General Protocol and the Wilks Protocol (Massachusetts General Hospital, 2018). The Wilks Protocol is the most commonly used protocol, as it recommends an accelerated exercise program that has shown great success in ACL recovery. However, it is important not to follow a cut and paste type exercise program, and instead to use protocols as a guideline while taking into account each patient's personalized circumstances and recovery process.

Although a time-based protocol is a useful guideline, therapists are beginning to rely on a more **criterion-based** rehabilitation protocol since every patient progresses in their own way at their own time. In a criterion-based rehabilitation protocol, there are several factors to consider (Filbay and Grindem, 2019);

- Crutches can be discontinued when there is an absence of antalgic gait and no extension lag with a straight leg raise, and full extension is reached.

- When flexion of greater than 110 degrees is achieved, the patient is able to progress to full stationary cycling to assist with edema.
- The patient may begin active exercise in closed and open chain with the possible addition of neuromuscular electrical stimulation (NMES) to assist in the improvement of quadriceps strength when they present with full and active ROM, no knee joint effusion, and can perform a straight leg raise without lag.
- Squats, lunges, leg press, and stepping down may be introduced when ROM improves to 0-125 degrees and there is good patellar mobility present (Cavanaugh and Powers, 2017). A KT1000 should be performed at around 3 months post-surgery.
- When the patient has control of terminal knee extension in weight-bearing positions, 80% of the **quadriceps index**, and 80% symmetry on the hop test with good movement quality, they can begin on plyometrics, agility drills, and more extensive standing balance activities. Focus should be on achieving sound movement patterns while characteristics such as speed, distance, duration, and repetition should be changed to increase the difficulty of the exercise. At this time, unstable surfaces and other external factors should be added to also increase difficulty. Exercises should begin with light loads and high repetitions and gradually progress to lower repetitions and heavier loads.
- The patient may begin jogging and running when the quadriceps index reaches 90%, slowly increasing the distance and speed as the patient tolerates. With a 90% hop test symmetry in addition to the 90% quadriceps index, the patient can be subjected to performance-based tests to determine the appropriateness of a return to sports activities. The patient, if returning to sports, should progress from non-contact, to unrestricted sports, and finally to unrestricted participation in competition.

Section 3 Summary

Non-surgical and surgical post-operative care follow similar avenues concerning exercise and protocols. Surgical reconstruction is the normal decision chosen for young people and children, especially athletes. It is important to follow the surgeon's recommendations concerning weight-bearing, assistive devices, and general therapy progression. It normally takes at least six months for a patient to begin to return to full function and consider a total return to sports activities. Exercise should progress from open to closed chain, with no resistance to resistance. Exercises should also progress from double leg to single leg, and static to dynamic exercises. Gym equipment should be added gradually to increase strength and improve ROM. Therapy should not only focus

on strength, but on gait quality and safety, flexibility and ROM, proprioception, agility, and speed. Protocols such as the commonly used Wilks Protocol can be used as a basis for rehabilitation, however it is important to create an individualized and criterion-based plan for each patient.

Section 3 Key Concepts

- Criterion based-a type of guideline that relies upon the evidence gathered from the patient's progress to maximize the patient's response to exercise at the current level of function, while minimizing the risk of injury to the healing tissue.
- Plyometric exercise-exercises also known as jump training, are used to increase strength. They involve changing directions quickly and jumping.
- Quadriceps index-a measure of the relative strength of the involved quadriceps compared to the uninvolved quadriceps.

Summary

The ACL is one of the four major ligaments that stabilize the knee. Although ACL injury is more common in adults, this injury is becoming more common in children due to an increase in sports related activities. Symptoms of ACL injury include an immediate sharp pain in the center of the knee, swelling, a sudden popping noise in the knee at the time of injury, a decline in knee ROM and mobility, a deep aching pain, and knee instability. Physicians may use tests such as the Lachman's Sign Test, Anterior Drawer Test, Pivot Shift Test, Reverse Pivot Shift Test, and the Clunk Test to ascertain the presence of ACL injury. An x-ray, MRI, ultrasound, or arthroscopy may be used to determine the severity of the injury to the ACL and surrounding structures. Treatment includes immediate utilization of the POLICE method, while continuing ice, compression, and elevation throughout the treatment period to decrease swelling and pain. Patients and physicians will collaborate to determine the best treatment option, which will either be a conservative non-operative treatment or surgical reconstruction. For people under 25 who are active, including children in sports, a surgical reconstruction is recommended to return to full function. There are many grafts and types of surgeries available. Considerations must be allowed for children who are still growing as a reconstruction surgery may intersect the growth plate, resulting in damage that can result in leg length discrepancies or angular deformities. For this reason, the surgeon will most likely choose to drill sockets instead of tunnels to minimize the risk. Surgery is typically performed on

an outpatient basis, and the patient will be released with an assistive device and possibly a cold compression device. Physical therapy plays a vital role in recovery whether a conservative or reconstruction option is chosen. Therapy will help to restore muscle strength, agility, speed, and balance, and will help the patient to return to a prior level of activity.

The Therapist will include open chain exercises progressing to closed chain, and free activities that will progress to resistance. Gym equipment will be utilized to restore ROM and eventually to strengthen the extremity. As the rehabilitation continues, the patient will begin sports specific drills to assist in returning to the prior level of activity. A full return to sports and regular activities could take 6-12 months, depending on the patient and level of injury. During this time, the physical therapist will be a vital team member to monitor and progress the plan of care as the recovery process is a time-consuming and difficult journey.

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