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Outpatient Physical Therapy Management of Patient with Torn Right Anterior Collateral Ligament Prior to Surgical Repair: A Case Study

Isaac Scott
University of North Dakota

OUTPATIENT PHYSICAL THERAPY MANAGEMENT OF PATIENT WITH TORN RIGHT ANTERIOR COLLATERAL LIGAMENT PRIOR TO SURGICAL REPAIR: A CASE STUDY

by

Isaac Scott

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This Scholarly Project, submitted by Isaac Scott in partial fulfillment of the requirements for the Degree of Doctor of Physical Therapy from the University of North Dakota, has been read by the Advisor and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

DocuSigned by:
Emily Henneman 4/10/2023
0007E68EFC29428...

(Graduate School Advisor)

DocuSigned by:
Cindy Flom-Meland 4/10/2023
D0E1D60A5EE3422...

(Chairperson, Physical Therapy)

PERMISSION

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ABSTRACT

Background and Purpose: Anterior cruciate ligament injuries are one of the most common in sports medicine. This structure provides stability to the knee joint. Depending on the level of ligament injury, this injury can be treated conservatively or surgically. The purpose of this case study is to explore a preoperative treatment plan for a patient looking to have a future ACL surgical repair. **Case Description:** This case study describes the 13-week treatment plan for a 21-year-old patient that had plans for a future surgical repair. This was the second time this patient tore the ACL in that extremity within 3 years. He also presented 2 weeks post knee arthroscopy, bone grafting of femoral tunnel, debridement and medial meniscus repair and deflexion of the proximal tibial osteotomy to prepare the knee joint for ACL repair. **Intervention:** The physical therapy interventions for the patient included blood flow restriction, neuromuscular re-education, lower extremity strengthening, gait training and mobility activities.

Outcomes: The patient following the therapy episode discharged himself. He no longer had pain at rest, was functional and independent with all activities of daily living, no longer needed an assistive device, was able to tolerate full workdays while standing and felt comfortable continuing on with the home exercise program independently leading up to the ACL reconstruction. This case study demonstrated that physical therapy treatment can be sufficient for returning a younger patient to be functional and independent without repair.

CHAPTER I

BACKGROUND AND PURPOSE

The anterior cruciate ligament (ACL) is one of the two cruciate ligaments that stabilize the knee joint by preventing excessive forward movements of the tibia or limiting rotational knee movements. It is also one of the most injured structures in sports medicine, and yet it, unfortunately, does not heal when damaged.[1] On the femoral side, the ACL attaches to the posterior aspect of the medial surface of the lateral femoral condyle. From the femoral attachment, the ACL descends and attaches to the site anterior and lateral to the medial intercondylar tubercle. The anterior cruciate ligament is the narrowest near the femoral attachment and fans out and widens as it proceeds to the tibial attachment. The ACL is crucial for stabilizing the knee joint and primarily stabilizes anterior translation of the tibia and plays a small role in resisting internal rotation and prevents any excessive movements. The ACL is innervated by the posterior articular branches of the tibial nerve. Most of the nerve fibers have vasomotor function, but some smaller myelinated and unmyelinated nerve fibers run independently of the vessels.[1]

A biomechanical study of the cadaveric ACL displayed the maximum load at failure, stiffness and modulus of elasticity was lower in the ACLs from female cadavers than that of male cadavers. It is possible there is a potential variation in the composition of the ACL between males and females. Females are reported to suffer two to seven times the amount of ACL injuries to their male counterparts of the same age.[1] Excessive loads on the ACL per unit body weight are

expected in females due to the lesser stiffness of the knee muscles. There was a decade-long study performed by Hewett et al[1]., that found female players had four neuromuscular imbalances including ligament dominance, quadricep dominance, leg dominance and trunk dominance. The quadriceps to hamstring strength ratio is also relevant as females tend to have poor hamstring strength compared to men. The imbalances of strength between the hamstring and quadriceps muscles may increase the risk of an ACL injury. The narrow intercondylar notch and the tibial slope also play a significant role for increased risk of ACL ruptures.[1]

Another risk factor that has been increasingly recognized in recent years is the significance of posterior tibial slope (PTS) in the setting of ACL injury and reconstruction. It was found recent evidence suggests that increased PTS is a risk factor for failure following an ACL repair, which may be mitigated by a slope reducing high tibial osteotomy (HTO). However, further investigation is needed to explain abnormal PTS values to determine appropriate indications for a slope reducing HTO in primary ACL repair.[2]

There are three modes of ACL injuries including direct contact, indirect contact and non-contact. Approximately 30% of ACL injuries are contact injuries, 5% are from indirect contact and 70% are non-contact which can be caused by erroneous movements.[1] ACL tears are frequently associated with sudden directional or speed changes while the foot remains firmly planted. This would include instances such as rapid deceleration, jumping, pivoting and direct impact to the anterior aspect of the tibia. ACL injuries can be classified in three ways, grades I, II, or III sprain.[1]

Grade I: The ligamental fibers are stretched, with a tear that is less than one-third of the ligaments. Mild tenderness and swelling are present. The knee joint feels stable with a knee laxity of <5 mm.[1]

Grade II: A partial tear (one-third to two-thirds of ligamental fibers) is present. Mild tenderness and swelling with some loss of function are present. The joint may feel unstable with increased anterior translation (knee laxity of 5-10 mm). The patient feels pain, and the pain may become exacerbated with Lachman's and anterior drawer stress test.[1]

Grade III: The fibers have completely torn. Tenderness and limited pain (relative to the seriousness of the injury) are features. The degree of swelling may be variable. The knee feels unstable, with rotational instability. There will also be knee laxity greater than 10 mm and hemarthrosis (bleeding in the joints) is observable within 1 to 2 hours.[1]

If an ACL injury is suspected the most specific special test with the highest likelihood ratio is the lateral pivot shift test, however this test was also found to be the least sensitive. The anterior drawer, Lachman and pivot shift tests were analyzed, and the results can be found below.[3]

Table 1. Special Testing Sensitivity, Specificity and Likelihood Ratios

Special Test	Sensitivity	Specificity	Likelihood Ratio (+)	Likelihood Ratio (-)
Anterior Drawer[4]	0.725	0.927	6.79	0.29
Lachman Test[4]	0.871	0.970	7.68	0.17
Pivot Shift Test[4]	0.490	0.975	16.00	0.17

When it comes to treatment, the grade of ACL sprain contributes significantly to whether a surgical procedure would be indicated. According to Dr. Otis Drew[4], MD grade I and II sprains

may not need surgical intervention, but grade III ACL sprains almost always require surgery. He goes on to mention that the growth plates, lifestyle, pain and activities that will be returned to play a large role in the decision. For example, if someone is not returning to sharp movements, living a sedentary lifestyle, growth plates are open, the knee is stable, or if pain is minimal then surgical intervention may not be indicated. If a patient were wanting to return to higher level of activities, the knee was unstable, or there was severe pain, even if a grade II sprain, surgical intervention could be indicated. However, patients with an ACL tear should be advised that surgical repair is not the only option for continuing sporting activities; a conservative approach consisting of a strict and vigorous rehabilitation plan can suffice.[5] The main purpose of surgical intervention is to enhance knee stability, which can be improved with correct neuromuscular therapy.

When further analyzing a different research article looking at conservative vs. surgical treatment it was found that patients who underwent surgical treatment presented important clinical findings in terms of better objective knee function and lower rates of secondary meniscectomies compared to conservatively managed patients.[6] However, a different article comparing the same treatments reinforces that knee stability can be improved not only surgically but also with neuromuscular rehabilitation. Regardless of the treatment, fully normal knee kinematics are not restored, and the risk of further knee lesions remains high.[7] A similar finding in both of the articles was that surgical intervention does not reduce the risk for developing knee osteoarthritis.[6,7] Deciding whether to pursue a potential ACL repair varies for every patient and is a difficult decision that should be made with guidance from their doctor.

In a systematic review conducted by Carter et al[8]., it was found that there is currently limited, very low-quality evidence to support the use of preoperative rehabilitation (prehab) for

ACL reconstruction. However, the same study does go on to mention that future research could look to provide consensus on the approach to Prehab and evaluate holistic interventions that consider the physical and psychological state of individuals and how this may affect post-operative biopsychosocial outcomes. This study did display limitations as there were only 3 studies included and analyzed limb symmetry, functional outcome measures and hop testing but only at the 3- and 6-month marks.

There was also a cohort study performed that analyzed the effectiveness of Prehab on outcomes 2 years following ACL reconstruction. It was found that the cohort treated with preoperative rehabilitation had higher functional outcomes and return to sport rates compared to the benchmark cohort. Both cohorts were treated using a criterion-based postoperative rehabilitation program consisting of progressive strengthening and neuromuscular training for 2 years following the ACL reconstruction. The article reports that progressive preoperative rehabilitation before ACL reconstruction should be considered as an addition to the standard of care to maximize functional outcomes following repair.[9]

When analyzing the treatments used by both articles it was found that there were variations between the protocols and the amount or length of treatment sessions. In the systematic review, the number of sessions ranged from 10-24 and were completed over varying time frames. The time frames varied from 3 – 6 weeks and some groups avoided a timeline and just wanted 10 visits total prior to surgery.[8] When looking at the cohort study the patient receiving Prehab would attend 10 preoperative rehabilitation sessions including neuromuscular training. These articles did not specify or elaborate on the variations of treatments performed.

Blood flow restriction (BFR) training has gained increased attention in recent years due to its potential for individuals to achieve an increased degree of muscle burden and

physiologic change at lower levels of resistance.[10] BFR training involves using a cuff or tourniquet system positioned circumferentially around the proximal end of an extremity inflating it to a predetermined pressure in an attempt to maintain arterial flow while restricting venous return.[10] By occluding venous outflow from the extremity, the resulting anaerobic environment promotes muscle hypertrophy through cell signaling and hormonal changes similar to what is seen at higher-intensity training with more resistance.[10]

The incorporation of prehab was also found to be beneficial according to a systematic review analyzing blood flow restriction in training for athletes. Out of the studies that met the inclusion criteria and were analyzed there was a significant increase in strength found in 7 out of 9 articles with the incorporation of BFR vs. the control group and 3 out of 4 articles reported significant improvements in sports specific measurements in the groups that incorporated BFR training.[10]

In another article reviewed to support the use of BFR there was a study performed in 2017 comparing physical therapy with and without BFR following a knee arthroscopy. Subjects in the study performed the same postoperative protocol with the addition of 3 BFR exercises. There were 17 patients included in the study and 12 sessions of traditional therapy or traditional therapy with the addition of BFR exercises were initiated following the 2-week postoperative visit. It was found that the group that completed the additional BFR exercises had significant increase in thigh girth, timed stair ascent and displayed 2-fold greater improvements in flexion and extension strength compared with conventional therapy.[11] When performing BFR interventions the common and frequently used set and repetition scheme exists that involves 75 repetitions across 4 sets of exercises, with 30 repetitions in the first set and 15 repetitions for each subsequent set.[12] The patient between sets takes a rest break that ranges from 30-60

seconds. The same article goes on to report that performing BFR two to three sessions per week is ideal.

During analysis of a different critical review looking at hop testing for return to sport decision making, it was found that the hop tests display good reliability and are sensitive to change over time.[13] However, the use of more than two hop tests does not appear to be necessary due to high collinearity and no greater sensitivity to detect abnormality. The inclusion of other hop tests in different planes may give greater information about the current function of the knee, particularly when measured over time using both relative and absolute measures of performance. It is recommended that the contralateral limb be evaluated prior to surgery for a more relevant benchmark for performance, and clinicians are strongly advised to measure and document movement quality, as hop distance alone appears to overestimate the recovery of the knee.[13]

The incorporation of isokinetic or Cybex testing is also a beneficial tool as it was found that hop testing should be interpreted with caution as they provided significantly higher limb symmetry index values than the isokinetic testing.[14] When looking at a research article analyzing the likelihood of ACL graft rupture for professional athletes returning to sport, they determined that six clinical discharge criteria as well as decreased hamstring to quadricep ratio of the involved leg within a 10% difference were the most relevant factors for predicting future reinjury of the ACL. It was found that there is four times increased risk for sustaining an ACL graft rupture compared to those who met all six of the return to sport criteria. The six clinical discharge criteria and the criteria required to permit discharge are listed below.[15]

1. Isokinetic test at 60, 180 and 300°/s
    a. Quadriceps deficit <10% at 60°/s
2. Single Hop

    a. Limb symmetry index > 90%

3. Triple Hop
    a. Limb symmetry index > 90%
4. Triple Crossover Hop
    a. Limb symmetry index > 90%
5. On-Field Sports-Specific Rehabilitation
    a. Fully completed
6. Running t test
    a. < 11 seconds

Overall, when analyzing the research there is mixed evidence. The literature implicates a potential relationship between prehab and functional outcomes following surgical treatment. The limitations to this research are that there is no set protocol or prehab procedure that is consistent with timelines and progressions.

The purpose of this case study is to assess the effectiveness of prehab using blood flow restriction and standard physical therapy rehabilitation techniques for strengthening the lower extremity prior to upcoming anterior cruciate ligament repair. Due to time constraints the patient's presentation following the ACL repair was not gathered. However, the information obtained in this case study could be applied to future research studies analyzing a prehab program for a patient that has had an ACL tear looking to have future surgical intervention. This case study can also be used by clinicians as a potential guide for blood flow restriction and standard physical therapy progressions. The case study also gives data on the effectiveness of physical rehabilitation and functional gains that can be obtained conservatively without an ACL repair.

CHAPTER II

CASE DESCRIPTION

The patient presented as a 21-year-old male with an anterior cruciate ligament (ACL) tear of the right knee. This patient had initially torn his right ACL on the same knee playing basketball in October 2019. The patient then had a right ACL repair in January 2021 that was followed by an episode of physical therapy. The patient at the initial evaluation mentioned that the knee never felt the same as it did prior to the ACL injury. The patient eventually went on to tear his right ACL again in the summer of 2022 while ambulating into his apartment. The patient reported his doctor discussed the second tear was related to a genetic down sloping of the patient's tibial tuberosity that placed his ACL at an increased risk for rupture.

The patient initially presented to therapy 2 weeks post right knee arthroscopy, bone grafting of femoral tunnel, debridement and medial meniscus repair and deflexion of the right proximal tibial osteotomy that took place September 2022. The operation was performed with the intention of preparing the patient's involved knee for the future ACL repair scheduled near the end of December 2022. The hope was that by having the surgical procedure and rehabilitation following the right knee arthroscopy, and prehab for the anticipated ACL repair that the patient would have improved outcomes following the second surgical ACL repair.

As the patient was 2 weeks post-operative, some of the precautions from immediate post-op had been lifted. Knee active range of motion was allowed, but limited to 90 degrees of knee flexion until the patient had his follow up with the surgeon 6 weeks post-op. He was instructed to

be toe touch weight bearing with use of bilateral crutches and instructed to wear a knee brace locked in extension for all ambulation activities. The patient was allowed to remove the brace while sitting or during physical therapy sessions.

Past Medical History and Prior Level of Function

The patient's medical history included anxiety, asthma, attention deficit hyperactivity disorder, insomnia and juvenile osteochondrosis of the foot. At the time of initial PT evaluation, the patient was a full-time college student and worked part-time as a bank teller. The patient's occupation involved spending considerable time on his feet. Due to the surgical procedure performed his employer provided him with a stool to reduce time in standing. However, following all the implications with the involved knee, the patient decided to withdraw from school until the knee was taken care of as he felt it was limiting and overwhelming to manage everything at the same time. The patient did have plans to return to school following the ACL surgical repair and rehabilitation.

The patient lived in a split-level house with friends and lived in the basement, requiring the patient to navigate stairs multiple times daily. Following rehabilitation and repair, the patient had goals of returning to prior level of function, returning to high level recreational activities such as playing basketball and simply not having to worry about the right lower extremity throughout the day.

Examination

The examination consisted of a subjective portion which entailed background information on the history of his right knee injuries, the purpose of the recent procedure, pain levels, occupation, goals, home environment, as well as obtaining information on the post-surgical

precautions and guidelines. The patient did not mention anything specific that made the pain worse but reported using ice for management of pain and edema. On arrival, the patient's knee brace was locked in extension. Throughout the initial evaluation, the patient was observed to intermittently demonstrate toe touch weight bearing. However, the patient initially demonstrated increased time non-weight bearing for increased efficiency with ambulation. On arrival he had 2-3/10 pain on the analog scale and reported that it could reach up to 4/10 and mentioned feelings of calf tightness.

The subjective portion was followed by range of motion testing, strength testing, edema measurements, palpation, observation, and a gait assessment. During the initial evaluation range of motion and manual muscle testing were not formally evaluated on the right lower extremity due to acuity following surgery and to adhere to surgical protocol. The left lower extremity was not formally assessed either but was assumed to be within functional limits due to the patient's ability to ambulate with his assistive device as well as his ability to perform bed mobility independently.

For this case, special testing measures to assess ACL integrity (anterior drawer, Lachman test, pivot shift test,) were not performed. This was also due to the acuity of the involved lower extremity. However, if the special tests were performed at initial evaluation, it is likely that they would have all been positive. These same special testing measures if performed following the ACL repair and rehabilitation would likely all be found to be negative.

To examine the surgical site, the brace was removed and then the patient's Tubigrip over the involved knee was removed and Steri-strips were observed over the incision along the anterior portion of the knee. Following removal of the Tubigrip, the patient was found to have notable ecchymosis surrounding the right knee, thigh and calf with the most notable bruising at

the posterior knee. Atrophy of the right quadricep musculature was observed as compared to the left lower extremity. There was also moderate swelling noted at the mid patellar line on the right knee. Circumferential measurements taken at the mid patellar line were found to be 38.2 cm on the involved lower extremity while the uninvolved side was found to be 35.5 cm.

Evaluation

Following the initial examination, the physical therapy diagnoses determined for the patient was right knee pain, lack of strength, lack of range of motion, impaired balance, impaired functional mobility and swelling. The patient's problem list for the episode of care can be found on the table below.

Table 2. Patient Problem List
1. Right lower extremity weakness
2. Instability of right lower extremity
3. Right lower extremity pain
4. Right lower extremity decreased range of motion
5. Gait impairment due to altered weight-bearing status
6. Swelling of right lower extremity

Prognosis and Plan of Care

At the time of the initial evaluation, there was no specific date set for the second surgical repair of the patient's right ACL. The patient was scheduled to participate in therapy following the right knee procedure to prepare the extremity for future ACL repair. However, due to reinjuring the same knee following the initial ACL repair the patient wanted to work on gaining

strength prior to the second ACL reconstruction for optimal outcomes. The plan included prehab prior to ACL repair that was eventually scheduled near the end of December 2022. Interventions included in the plan were blood flow restriction (BFR), quadricep strengthening, hamstring strengthening, gluteus maximus strengthening, gluteus medius strengthening, gluteus minimus strengthening, gastrocnemius strengthening, adductor strengthening, gastrocnemius stretching, hamstring stretching, quadricep stretching, as well as static and dynamic balance exercises.

The patient's rehabilitation process following the ACL repair would be monitored through Cybex testing, single leg hop, single leg cross-over hop, and single leg triple jump testing. Cybex testing and the various hop tests allowed comparison of the patient's involved side with the uninvolved side. Ideally for patients to return to sport, they will be able to achieve 85-90% [15,16] when comparing hop and Cybex testing measures on the involved side to their uninvolved side.

The patient was expected to have good prognosis and outcomes as he was young and had a history of physical therapy treatment for his initial ACL repair and was motivated to return to his prior level of function. The plan was for the patient to continue on with physical therapy up to, as well as following his ACL repair in December of 2022. The patient's discharge from physical therapy following the future repair would be determined by results of limb symmetry testing and his doctor. The short- and long-term goals determined for the patient can be found below on tables 3 and 4.

Table 3. Short-Term Goals
1. Following PT intervention, the patient will demonstrate 0–90-degree right knee active and passive range of motion. To be met in 4 weeks.
2. Following PT intervention, the patient will be able to do a straight leg raise without extensor lag, with brace as needed. To be met in 4 weeks.
3. Following PT intervention, the patient will tolerate progression of gait with crutches up to 50% weight bearing per postsurgical precautions. To be met in 4 weeks.
4. Following PT intervention, the patient will report no pain at rest. To be met in 4 weeks.

Table 4. Long Term Goals
1. Following PT intervention, the patient will demonstrate functional right knee active and passive range of motion within post-surgical precautions. To be met in 12 weeks.
2. Following PT intervention, the patient will be able to complete activities of daily living with no pain worse than 1/10. To be met in 12 weeks.
3. Following PT intervention, the patient will demonstrate a normalized gait pattern on level surfaces and stairs with assistive device if needed, within weight bearing precautions of surgeon. To be met in 12 weeks.
4. Following PT intervention, the patient will demonstrate right lower extremity strength within functional limits to allow return to activities of daily living and sit to stand without hand support. To be met in 12 weeks.
5. Following PT intervention, the patient will be independent with home exercise program at discharge.

CHAPTER III

INTERVENTION

Throughout this episode of care, the patient performed a variety of gait, mobility, balance and strengthening interventions. Interventions were initially limited due to protected weight bearing (25-50%) and range of motion precautions during the initial 2 weeks of physical therapy. The precautions were less restrictive during therapy weeks 3-4, the patient continued with range of motion (ROM) limitations, but weight bearing was progressed to as tolerated with the knee brace locked in extension. During week 5 the patient was lifted from all surgical precautions and was able to be progressed as he was able to tolerate.

Initial treatment sessions focused on progressing weight bearing through the right lower extremity as the protocol allowed. A weight scale was incorporated throughout initial treatment sessions to help guide the patient in understanding the appropriate amount of weight to place through the right lower extremity for 25 and 50 percent weight bearing. On arrival, he was able to demonstrate an appropriate 3-point gait pattern using bilateral crutches. Initial therapy sessions were limited due to the weight bearing and range of motion precautions. As precautions were lifted treatment sessions included a variety of mobility, strengthening and balance interventions.

Treatment sessions included various intervention types, but time was mostly spent on strengthening of the involved lower extremity quadriceps, hamstrings and hips followed by balance with the least amount of time being spent on mobility. Mobility was focused on initially

with treatment sessions, but as surgical precautions were lifted, the patient's involved lower extremity range of motion was found to be within normal limits. Occasionally mobility exercises such as stretching and soft tissue mobilization (STM) were incorporated to relieve pain and stretch surrounding musculature. The interventions used were tailored to how the patient presented for that day's treatment session. For example, when the patient demonstrated tensor fascia latae (TFL) discomfort, soft tissue mobilization with a roller stick or hands-on myofascial release and stretching were incorporated to relieve discomfort. This intervention was followed by education on how the TFL is often recruited when there are weakened gluteal muscles. Studies have shown that resisted side stepping in a squat position minimizes TFL activation and increases activity of gluteal muscles.[17] The lateral side-stepping intervention with an exercise band at the knees was incorporated into treatment sessions and eventually added to the patient's home exercise program.

When performing BFR the appropriate limb occlusion pressure needs to be assessed on the individual patient based on the position the exercises will be performed. This pressure is calculated to determine a pressure that maintains arterial flow while restricting venous return.[10] The pressure was initially assessed and calculated for the patient in supine as that is the position initial BFR exercises were performed. For this case BFR was implemented at the beginning of the session following an initial warm up if there was time and traditional physical therapy interventions took place afterwards. However, in situations where the patient only had a 30-minute session scheduled or had to leave early for work, BFR interventions were not performed. The standard 75 repetitions (30,15,15,15) with 30 second rest breaks between sets were utilized.[12] The patient would typically perform 2-3 different exercises per session with the BFR cuff on.

The incorporation of BFR was due to the patient having difficulty getting appropriate quadricep contraction and strength, but it was not implemented until the 9th visit. In future situations when a patient is post-surgical, it would be beneficial to initiate BFR earlier on in treatment. However, the exercises were still challenging for the patient and were progressed as the patient was able to tolerate. When looking at when BFR could be implemented it is related to the current strength of the patient. If they are unable to lift 60-75% of their one repetition max, then incorporating BFR can be beneficial.[10] The limb occlusion pressure calculated for the patient by position are listed below.

-Right lower extremity limb occlusion pressure in supine 199, 60%, 119

-Right lower extremity limb occlusion pressure in seated 199, 60%, 119

-Right lower extremity limb occlusion pressure in standing 227, 60%, 136

Overall, with the incorporation of blood flow restriction (BFR), stretching, strengthening and balance interventions the patient demonstrated significant improvement. The plan for re-evaluation was assessing the functional strength of the patient by assessing his single leg squat. The assessment included observing the hip-knee-ankle relationship and identifying any knee valgus. The patient early on in therapy was unable to perform a single leg squat with appropriate mechanics but demonstrated significant improvement throughout treatment sessions. There was electronic communication with the surgeon that took place prior to the initial evaluation. There was no specific protocol to follow other than the range of motion and weight bearing restrictions provided following the procedure. However, other than this electronic communication there was no verbal communication between therapist and surgeon.

The patient's home exercise program was initiated following the first treatment session. The program was updated and progressions were given to the patient as he was able to tolerate and as the precautions mentioned were lifted. The total list of clinical interventions and home exercise program that were included are listed below. The exercises that had a direct progression are grouped together and discussed. For table 7, strengthening interventions are organized by muscle group. The list of interventions for weeks 5 through 13 are organized so that the initial interventions are higher on the list. The more challenging or later stage interventions completed by the patient are listed closer to the bottom of their respective category.

The patient was scheduled to attend physical therapy 1-2 times a week for 30-45 minutes up until the patient had his ACL repair. He attended most treatment sessions but did occasionally miss due to forgetting, sleeping in, or having time conflicts with work. The patient's last appointment prior to the surgical repair was on November 28th, 2022. The patient did not have an official discharge but felt comfortable carrying on independently for the month of December leading up to the surgical procedure. The patient demonstrated significant strength improvement in the clinic but was not as consistent performing exercises outside of the clinic based on his subjective reports.

Clinical Treatments and Progressions

Table 5. Interventions Weeks 1–2 (Initial Evaluation – Visit 3)
<u>Precautions Lifted at this Stage:</u> - Knee ROM on involved lower extremity limited to 0-90 degrees until the patient has follow up at 6 weeks post-op with surgeon.

Gait Interventions: -Worked on appropriate weight bearing through involved lower extremity and gait training with bilateral crutches
Mobility Interventions: -Heel slides to 90 degrees with brace on
Strengthening Interventions: -Supine quadriceps set with heel propped on towel roll (terminal knee extension) -Straight leg raise with brace, focusing on appropriate quadriceps contraction

Table 6. Interventions Weeks 3-4 (Visits 4-5)
Precautions Lifted at this Stage: - Patient may begin weight bearing as tolerated with knee brace locked in extension.
Gait Interventions: -Ambulating on treadmill with bilateral upper extremity support. Gave the patient cues for heel to toe pattern working towards a normalized gait pattern.
Mobility Interventions: -Heel slides to 90 degrees knee flexion -Prone knee extension avoiding pressure on the anterior portion of the knee, with gentle overpressure applied -Gastrocnemius stretching -Patellar mobilizations in all directions

-IASTM with cocoa butter to involved extremity on medial and lateral lower leg to patient's tolerance
Balance Interventions: **Static Balance:** -Standing tandem balance **Dynamic Balance:** -Standing weight shifts anterior/posterior and medial/lateral -Left toe taps to 8-inch stool while balancing on the right lower extremity -Split stance with right lower extremity weight bearing and left foot up on 6-inch stool with added upper extremity movements
Strengthening Interventions: -Quadricep and hamstring sets with a five second hold -Sidelying hip abduction and adduction -Straight leg raises -Prone hip extension -Bilateral calf raises

Table 7. Interventions Weeks 5–13 (Visits 6 – 17)
Precautions Lifted at this stage: - Patient no longer needs to wear brace and weight bearing as tolerated. Knee ROM no longer restricted to 90° flexion
Mobility Interventions: -Upright bicycle

-Prone quadriceps stretching

-Soft tissue mobilization to ITB and TFL with rolling stick

Balance Interventions:

Static Balance:

-Balancing with bilateral lower extremities and narrow base of support on foam balance pad with eyes closed. This was progressed to standing tandem balance with eyes open. Which was then progressed by incorporating a foam balance pad. The final progression was tandem on the foam pad and cueing the patient to close their eyes.

-Single leg stance on foam balance pad

-Single limb balance on dome side of BOSU ball

Dynamic Balance:

-Anterior/posterior and medial/lateral rocking with rocker board, working on controlled rocking

-Single limb stance on involved lower extremity kicking ball with uninvolved lower extremity

-Lower extremity active range of motion in all planes with uninvolved lower extremity while balancing on foam pad the involved lower extremity

-Single limb stance and catch with 1-pound ball toss. This intervention was progressed by adding a foam balance pad. The final progression of this activity was standing on foam balance pad with 2-pound ball toss.

-Cone taps balancing on involved lower extremity. This intervention was progressed by adding a foam balance pad. This intervention was progressed further by adding different colored

cones. Therapist calls out color of cone for the patient to tap with their uninvolved lower extremity.

-Dynamic Y-balance on involved lower extremity

-Single limb balance with uninvolved extremity on dome side of BOSU ball reaching with the uninvolved lower extremity anterior, posterior, medial and laterally

-Squats on foam balance pad. This intervention was progressed to performing squats on flat side of BOSU ball up toward the ceiling. The final progression was performing squats with the dome side of the BOSU ball facing the ceiling.

Strengthening Interventions:

Gross Lower Extremities:

-Mini squats

-Sit to stands with cues for appropriate biomechanics, avoiding quadriceps dominant posture

-Wall sit with isometric adductor ball squeeze. This was progressed by increasing the hold time as the patient was able to tolerate.

-Squatting on a foam balance pad. This intervention was progressed to squatting on a BOSU ball first balancing with the flat portion towards the ceiling, which was then progressed by having the patient balance on the BOSU with the dome portion towards the ceiling.

-Seated leg press using bilateral lower extremities. This was progressed to being performed with only the involved lower extremity. This intervention was then progressed and regressed by adding or removing weight to the patient's tolerance.

-Single leg sit to stand focusing on appropriate mechanics. This intervention was progressed by having the patient hold a 6 kg kettle bell at chest level.

Quadriceps:

-Seated long arc quad with exercise band and 5 second hold

-2-inch step up with involved lower extremity. This intervention was progressed by increasing the step height by 2 inches as the patient was able to tolerate.

-Seated knee extension machine with only involved lower extremity. This intervention was progressed and regressed by adding or removing weight to the patient's tolerance.

Hamstrings:

-Seated knee flexion with exercise band. This was progressed to prone knee flexion with a 5-pound ankle weight

Hip Abductor, Hip Adductors and Hip Extensors:

-Sidelying hip abduction and adduction

-Standing hip abduction and hip extension with an exercise band at the knees. This exercise was progressed by moving the exercise band down to the ankles.

-Lateral step downs initially with 4-inch step. This intervention was progressed by increasing the step height by 2 inches as the patient was able to tolerate.

-Forward, backwards, and lateral side stepping with an exercise band at the knees. This was progressed by moving the exercise band down to the ankles.

-Supine bridge with a 5 second hold. This intervention was progressed to a single leg bridge. The single leg bridge was progressed to a bridge with the lower extremities up on an exercise

ball. The final progression of bridging with this patient was with the lower extremities on the exercise ball while also incorporating a hamstring curl

-Seated hip abduction machine with bilateral lower extremities and gave the patient cues to focus on appropriate contraction on the involved side. This intervention was progressed and regressed by adding or removing weight to the patient's tolerance.

Gastrocnemius:

-Bilateral heel raises on 1 inch step. This intervention was progressed to using only the involved lower extremity with focus on eccentric control.

BFR Interventions:

BFR was initiated on the ninth session. All BFR interventions were performed in the same way. Each exercise was performed for one set of 30 repetitions followed by four sets of 15 repetitions, with a 30 second rest break between every set.

-Supine quadriceps set holding for 3 seconds

-Supine short arc quad with bolster beneath the knees

-2 inch step which was progressed to a 4 inch step as the patient was able to tolerate

-Seated long arc quad

Home Exercise Progressions

Table 8. Home Exercise Program and Progressions
Week 2: -Ankle pumps -Seated gentle gastrocnemius stretching with towel or belt assist -Supine heel slides 0-90 degrees -Quadriceps set without a towel under the knee with knee brace on -Supine straight leg raise with knee brace on
Week 3: -Sidelying hip abduction and adduction -Prone hip extension -Supine bridges
Week 7: -Supine straight leg raise without brace
Week 8: -Wall sits
Week 11: -Forwards, backwards, and lateral side stepping with exercise band at the knees. This was progressed by having the patient place the exercise band at the ankles.

Chapter IV

OUTCOMES

It is difficult to rigorously evaluate the outcomes of the case as the patient chose to discontinue physical therapy before discharge outcome measures could be assessed. Initial evaluation occurred 2 weeks post right knee arthroscopy, bone grafting of femoral tunnel, debridement and medial meniscus repair and deflexion of the right proximal tibial osteotomy, thus many objective measurements were deferred due to acuity. For these reasons there is limited objective data available for comparison. However, the patient demonstrated significant progress throughout the physical therapy treatment sessions and these interventions and progressions could be used to guide prehab before upcoming ACL repair.

The patient demonstrated progress in his mobility as he was initially partial weight bearing with bilateral crutches and progressed to ambulating on a treadmill with bilateral upper extremity support at 0.5 mph for 2 minutes with cues for heel to toe pattern and working towards normalized gait pattern. By the end of treatment, he was able to ambulate with appropriate gait mechanics without any cues and the brace removed. Progress can further be demonstrated as the patient was only able to perform 2-3 straight leg raise repetitions without extensor lag at the second visit and by the seventh visit was able to perform straight leg raises without extensor lag on the involved extremity with a 2-pound ankle weight for 2 sets of 15 repetitions. The patient was also able to progress from performing a 4-inch lateral step down to 8 inches by the end of the therapy sessions.

Initial interventions focused primarily on range of motion and effective mobility. Initial range of motion precautions were in place to protect the integrity of the procedure and as the surgical range of motion precautions were lifted, the patient's right knee range of motion was assessed and measured to be 3-0-128. Due to the patient's knee range of motion being within normal limits most mobility interventions were discontinued early on in treatment. Roughly 2/3 of treatment session time was spent on strengthening and 1/3 of treatment time focused on balance interventions. The patient, by the end of the physical therapy episode of care, met all his short-term goals and long-term goals. During final treatment sessions, the patient continued to demonstrate hip weakness during performance of single squat but was within functional limits.

Results

Initial Treatment Session: Initial treatment sessions were limited due to the precautions. However, at week 4 when the patient was on his third visit, he was able to begin weight bearing as tolerated. Knee range of motion was limited to 90 degrees until he had his follow up 6 weeks post op which was his 6th visit. He no longer had to wear his knee brace and his range of motion was found to be 3-0-128.

Midpoint of Treatment: The patient attended seventeen total visits. The halfway point of treatment was the 9th treatment session which was after all precautions from the surgical procedure were lifted. At this point in time the patient working on the strengthening the quadriceps and preparing for the upcoming procedure. The patient did have a continued "squeaking" in the knee at this point in time.

Final Treatment Session: For the final treatment session for the patient, treatment focused on strengthening and balance interventions. He was able to perform all exercises but did mention

"strange" feelings in the knee during knee extension performance with higher weights. During the last session the patient was able to tolerate and perform the following interventions:

-Bridge combined with hamstring curl and lower extremities up on an exercise ball for 2 sets of 10 repetitions

-Tripod sit<>stand (single leg sit<>stand using left lower extremity as needed for support) with a 6-kilogram kettlebell for 2 sets of 10 repetitions

-Lateral step downs from an 8" step for 2 sets of 10 repetitions

-Right single leg knee extension with 55 pounds of resistance but patient had reported a "strange feeling" in his knee during performance but was able to tolerate 55 pounds for one set of 10 repetitions but decreased to 50 pounds for second set of 10 repetitions. He continued to report this "strange feeling" in his knee following the weight decrease as well.

-Right lower extremity leg press with 80 pounds of resistance and was tolerated. He performed 20 repetitions and based on performance would have been progressed next session.

On initial evaluation the patient was toe touch weight bearing through the right lower extremity using bilateral crutches and reported up to a 4/10 pain at worst. On the final treatment session with this patient, he was ambulating without an assistive device, appropriate gait pattern and reported 0/10 pain at worst. The patient also reported no longer wearing his knee brace when at home but did continue to wear it when outside or ambulating in the community. The patient was able to perform a single leg sit to stand with minimal to no assistance from the left lower extremity during final treatment sessions. The patient did demonstrate hip weakness during performance of tripod sit<>stand but was able to complete 2 sets of 10 repetitions and had also performed bilateral squats on a BOSU ball previous treatment sessions. The patient reported

being able to navigate stairs in his home independently without difficulty. He also reported tolerating full time work weeks at the bank.

For tracking progress in future research, incorporating hop, isokinetic and/or dynamometer testing would be beneficial to track quadricep, hamstring and functional strength over time. These testing measures provide reliable objective measurements to track progress of specifically the quadriceps and hamstrings musculature. These measurements are taken bilaterally and can be used for goal setting and measuring when return to sport would be appropriate if applicable. Isokinetic testing is the most accurate testing measure as it prevents compensation with straps and pads. It also provides precise measurements of quadricep and hamstring strengths with the use of its software. Hop testing is also a good way to track progress as you can keep track of the hop distance over time bilaterally. However, it should be interpreted with caution as it was found that limb symmetry index (LSI) values for hop testing provided significantly higher LSI values than isokinetic testing.[13]

Dynamometer testing would also be appropriate option if an isokinetic device is not available as they costly and not available at all locations. It is important when using this testing measure to accurately document on the testing position and stabilization strategies used. A limitation to dynamometer testing can be if the clinician is unable to provide appropriate resistance to the quadriceps due to clinician and patient size difference or not having an appropriate set up. Also, the scale device being used to monitor the movement will need to have a maximum force reading greater than what the patient will provide to avoid an incorrect reading. Incorporating a strap to the bottom of a plinth table to stabilize the dynamometer and provide resistance to the patient can give more accurate measurements in quadricep strength as the patient will not be able to move the table. This is a challenging test for the handheld

dynamometer as it is the strongest major muscle group on average for all age groups in force produced.[18,19]

Chapter V

Discussion

The purpose of this case study was to assess the effectiveness of BFR and traditional physical therapy rehabilitation on a patient prior to an upcoming ACL reconstruction. This patient was a unique case as he was only 21 years old, and had two ACL tears in a 3 year span. This patient also presented following the surgical procedure to "clean up" around the knee and prepare the joint for optimal outcomes after the ACL reconstruction. The patient from the start of treatment to the end made significant functional mobility and strength gains. This case study demonstrated that BFR and traditional therapy were effective physical therapy interventions to assist the patient in return to a functional level he felt comfortable with. Following the 13 weeks of physical therapy, he felt confident continuing independently with the home exercise program up until the right ACL surgical repair. The patient did not have an official therapy discharge. However, he had met all his goals and would have been having his surgical procedure roughly 3 weeks following his final visit.

Overall, this study compares relatively similar to the research analyzed as the patient demonstrated significant improvement with the incorporation of a prehab program consisting of BFR and traditional therapy. The physical therapy treatment was based upon physician goals for an ACL injury rehab program. These goals included restoring knee ROM, managing pain, reducing swelling, allowing for early ambulation and muscle strengthening exercises.[5] Also whenever incorporating BFR interventions in this case, the standard 75 repetitions (30,15,15,15) with 30 second rest breaks in between sets[12] was utilized throughout the course of treatment.

This study also compares similarly to the pilot study analyzing BFR training for patients following a knee arthroscopy.[11] The pilot study found benefit with BFR when used as an adjunct to post-op physical therapy treatment following a knee arthroscopy. The patient in this case was found to make significant progress following the right knee procedure with the incorporation of BFR and traditional therapy techniques. Although there was no control group, the patient's progress with BFR was able to be documented through treatment progressions, subjective reports and improved functional mobility. This case also attests to conservative treatment of grade III ACL sprains as the patient was functional and did not have significant pain at the end of therapy. However, he was young and did wish to return to higher level recreational activities such as basketball, so surgical intervention was appropriate.

However, this case was unique to the other research reviewed due to the patient's initial presentation being post right knee arthroscopy, bone grafting of the femoral tunnel, debridement, medial meniscus repair and deflection of the proximal tibial osteotomy. It should also be noted that some of the other studies found were able to follow the patient throughout the prehab process as well as months following their surgical procedures to assess outcomes. This case study differed from other research studies as the patient was not able to be monitored following the surgical repair. This case does provide a potential progression for BFR and other prehab interventions. It is important to note that progressions are not linear, and the incorporation of the given exercises can be implemented as the patient is able to tolerate or as post-op precautions allow, if relevant. If a patient is following a similar path leading to their upcoming procedure, then this treatment plan and progression could be an appropriate guideline. It would be expected that if a patient is not post-op and working on a similar prehab program they would likely be able to progress more quickly and perform higher level exercises. Relevant factors would include

their age, lifestyle, personal factors such as their support network, access to transportation or time since initial injury.

Limitations

In assessing the limitations of this case study, there were numerous factors that created a challenge analyzing the results. It should be emphasized that the patient discontinued on his own behalf, and he was unable to be assessed for a final collection of objective measurements at the end of the prehab therapy sessions. This case is also different as the patient at initial evaluation was 2 weeks post-op preparing the lower extremity for the upcoming ACL repair as he had a genetic down sloping of his tibial tuberosity. This is significant as this is not necessarily the typical presentation for a patient looking to take part in prehab prior to an upcoming ACL repair.

Another limitation to the study is that the patient could not be followed after the ACL repair. Although it was not able to be formally assessed, it would be expected that a patient that performed prehab prior to an ACL repair would demonstrate improved outcomes following their surgery. For the patient, having familiarity with interventions that will be performed following repair is beneficial to their recovery and can accelerate the recovery process. It is also hypothesized that recovery would be perceived as an easier transition for the patient as the muscles damaged and implicated in the surgery will be stronger which would assist with the recovery process.

Reflective Practice

For this case study isokinetic and hop testing measurements were not gathered. If these measures were going to be incorporated following the repair, then measurements of the uninvolved extremity should be collected prior to their initial discharge and surgical procedure.

In future research it would be beneficial to include these measurements for detecting strength and confidence in the involved extremity. Collecting both measurements give an objective measurement of how the patient is performing on their involved compared to their uninvolved lower extremity. When assessing hop testing it is important to make appropriate comments comparing the quality of the movement between lower extremities. Having the combination of isokinetic and hop testing is ideal as that extra information can give the physical therapist confidence determining whether a patient is appropriate or not for discharge if they are planning a return to sport or higher level of activity.

Another area of the study that would be adjusted for future research is when the BFR interventions were initiated. Blood flow restriction was incorporated into the treatment plan early on when the writer was treating the patient. When reviewing the literature on BFR it could have been initiated sooner with this patient, potentially as soon as the second visit. This could potentially affect the initial BFR interventions incorporated as they may be limited or varied based on what the patient can tolerate. It was also discussed in the research to end the session with BFR as it has the ability to stimulate gains at submaximal loads.[10] However, it was performed with the patient at the beginning of the session following his warmup.

Following completion of this case study there are various pieces of information that I will incorporate into future physical therapy practice. For interventions this includes information such as BFR exercise prescription as well as initiating BFR earlier on in the treatment timeline and towards the end of the treatment sessions. For examination incorporating special testing clusters when suspecting an ACL tear is beneficial and for prognosis incorporating isokinetic and hop testing prior to surgical repair and throughout treatment bilaterally is also benneficial to assess outcomes. Since it was found that hop testing can provided significantly higher limb symmetry

index values than the isokinetic testing[14], I will be mindful to include both hop testing and isokinetic testing to guide patient's that have intentions of returning to higher levels of activity. I have learned that the management of patients pre- and post- ACL repair is not a cookie cutter approach and that not one single protocol or treatment will fit every patient. Intervention strategies and treatment options should be tailored to the patient. I will also remember that surgical treatment is not required for every patient and is based on the grade of the tear as well as the level of function the patient would like to return to. BFR and traditional physical therapy interventions should be progressed and regressed as the protocol allows and as the patient is able to tolerate.

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