Anterior Cruciate Ligament Reconstruction of a College Student with a Prosthetic Limb: A Disablement Model Case Study

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ABSTRACT

This case examines a 19-year-old male college student with a left anterior cruciate ligament reconstruction (ACLR) secondary to a motor vehicle accident (MVA). The accident caused numerous severe injuries to both lower limbs including untreatable right lower leg injuries, leading to a right below knee amputation, and a left ACL tear. Before the accident, the patient was a varsity cross country and track athlete expecting to continue in college. Six weeks following surgical reconstruction, the patient reported to the rehabilitation clinic for standard ACLR rehabilitation practices including lower leg and proximal hip strengthening, attaining full knee ROM, and balance exercises. Gait training was essential due to an antalgic gait and complicated by the presence of the right leg prosthesis. He progressed as expected with balance and strengthening exercises; but progress was inhibited by many factors including global left knee swelling, his inability to achieve or maintain full left knee extension ROM, intense end-range pain with left knee extension, and a leg length discrepancy (LLD) between his remaining limb and daily prosthesis. Psychological factors from rehabilitation fatigue may have hindered progress and contributed to higher pain sensations and frustration levels. Four months after surgery, the patient was showing improvement in pain reduction and extension ROM, but care was discontinued secondary to the COVID-19 global pandemic when the patient declined to continue formal rehabilitation in an online format. One year post ACLR the patient achieved normative scores for the LEFS and IKDC. This case exhibits the impact of a prosthetic limb on the overall healing time of a patient and highlights how factors that can be easily overlooked such as LLDs, psychological stressors, and kinetic chain disruptions can greatly impact a patient's rehabilitation. By looking holistically at our patients, we can make connections to improve the patient's rehabilitation and healing.
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INTRODUCTION

A male, collegiate, sophomore student presented to the clinic six weeks following a left anterior cruciate ligament reconstruction (ACLR) secondary to a motor vehicle accident (MVA) that occurred two years prior. The MVA caused numerous gross injuries to his lower limbs including a tear to the left ACL, but also a below-knee amputation (BKA) of his right leg. Throughout the rehabilitation process, the patient struggled with intense pain with knee extension, psychological fatigue from years of rehabilitation, and irritation of the right lower extremity stump, each contributing to a challenging rehabilitation progress. Additionally, the patient's daily use prosthesis presented a leg length discrepancy (LLD) making gait training difficult. Use of the running prosthetic diminished the LLD and the patient was able to ambulate without pain, with full knee extension, and less pronounced drop foot. The patient was then referred to his prosthetist who confirmed our suspicions of a LLD related to the prosthetic. The patient completed roughly four months of formal therapy before stopping due to the COVID-19 pandemic. While following up with the patient about a year later, he scored within published normative values for both the Lower Extremity Functional Scale (LEFS) and International Knee Documentation Committee (IKDC) Subjective Evaluation forms. He also reported being able to complete most activities that he previously enjoyed with more limitations caused by his prosthetic limb than his ACLR.

PATIENT INFORMATION

The patient was a Caucasian, 19-year-old male college student presenting with a left knee ACLR with a quadriceps tendon autograph. Three years prior, the patient and his family stopped on the side of the road to assist another motorist when a passing vehicle lost control striking the patient head-on. He sustained a multitude of injuries including untreatable right lower leg trauma, left femur fracture, left knee ACL and MCL tear, left ankle deltoid ligament tear, left hip greater trochanteric bursitis and heterotopic ossification, and left arm Triangular Fibrocartilage Complex (TFCC) tear. Immediately after the MVA, an emergency right BKA was performed with a left ankle deltoid ligament repair and left femur open reduction internal fixation (ORIF). As part of his initial BKA recovery, the patient was fit for a prosthetic leg and performed intensive rehabilitation to regain independent ambulation and restore normal activities of daily living (ADLs). A little over a year later, he underwent a left TFCC repair with loose body removal. Approximately three years following the MVA, after the resolution of other more severe injuries, the patient underwent a left knee ACLR with a quadriceps autograft. The patient decided to pursue the reconstruction based on a desire to continue his active lifestyle and fear of knee instability in the future with activities such as recreational basketball. The patient and surgeon's fear of potential knee instability increased due to the presence of the contralateral BKA. Both felt the ACLR gave him the highest chance of returning to future recreational activities. The patient was given a prescription for pain control medication (Oxycodone and Acetaminophen, 10mg/325mg) to be used during rehabilitation as needed. He had no diagnosed psychiatric history, but fatigue from years of therapy was evident clinically and may have contributed to increased frustration, higher pain sensations, and a longer recovery time.

Differential Diagnosis and Evaluation

Due to the high impact mechanism of the MVA, the patient was rushed to the hospital where several emergent diagnostic images were obtained including radiographs, a head computed tomography (CT) scan, and a full-body MRI. These scans were reviewed, and he was diagnosed with a left femur fracture, left knee ACL and MCL tear, left ankle deltoid ligament tear, and left wrist TFCC tear. He also had untreatable traumatic right lower extremity injuries, which resulted in a BKA. The differential diagnosis for his left knee included: PCL tear, meniscal tear, patella dislocation/subluxation, osteochondral fracture, and LCL sprain.

Body Structure and Function

The patient initially presented to the clinic six weeks post-operative from ACLR. The patient noted a sharp pain in his posterior left knee specifically during active knee extension. Mild left knee swelling and significant scarring on the global left tibial region from the MVA were observed. He had a bent-knee gait on the left lower extremity (LLE), drop foot, most likely caused by peroneal nerve damage from the accident, and gait alterations due to his prosthetic limb. The patient wore a hinged knee brace for support while walking. The brace allowed for a controlled range of motion (ROM) during ambulation, medial and lateral knee stability, and provided proprioceptive feedback to the patient. Without the brace he was guarded and cautious with his movement for fear of his knee giving way. Right knee active range of motion (AROM) was noted to grossly be within normal limits for both flexion and extension in the right side, with left knee flexion of 127° with no pain and knee extension 0° with pain. Strength testing of knee flexion and extension was 4+/5 on the right leg and 4/5 on the left. Hip abduction was 4/5 bilaterally. A 6-inch step test was performed, and the patient used his prosthetic to perform this test. Pain was present in the left leg when stepping onto the box, and the patient showed weakness with descending control for the right leg. This may have been due to not having proprioception between his prosthetic limb and the ground.

His quad set was fair. He was able to perform a good contraction but was unable to add movement to the hip without losing control. When asked to perform a Straight Leg Raise he had a 5 to 10° quadriceps lag. The patient experienced numbness on the anterior left shin where he had significant scarring, but no tingling or radiating pain.

Activity and Participation

Prior to the accident, the patient was a high school varsity track and cross-country runner with the expectation of continuing in college. He also lifted weights, played basketball, and swam recreationally after his accident, but before his ACLR. The ACLR procedure impacted his ability to perform all ambulatory activities including walking and going up and down stairs, participate in most of his extracurricular activities, and drive. He reported having disturbed sleep, and that he was taking melatonin supplements which helped. The patient reported his worst pain reached 8/10 on a 0 to 10 grading scale and occurred during active knee extension. He also completed the Lower Extremity Functional Scale (LEFS) on initial evaluation with a score of 36/80.

Environmental and Personal Factors

The patient expressed his rehabilitation goals were to return to playing recreational basketball, running, and weightlifting without restriction. Since the patient had spent the previous three years in rehabilitation, mental fatigue was evident upon the initial visit. The stressors of being a college student were also noted as a possible limitation to his rehabilitation progress as was his right BKA.

INTERVENTIONS

Treatment for the patient was structured around standard post ACLR rehabilitation practices including decreasing swelling, increasing ROM, strengthening of the hamstrings, quadriceps, gluteals, and calves, and improving balance. Gait training was also incorporated due to the presence of an antalgic gait on initial evaluation. The patient attended rehabilitation two days a week and was instructed to complete a home exercise program (HEP) daily (**Table 1**). Every week, the patient progressed as expected with balance and strengthening of the hamstrings, gluteals, and calves. The patient struggled continuously with global knee swelling for the first few months of rehabilitation. Swelling increased every week his activities of daily living (ADLs) included significant walking around campus or long car trips where his knee was held in a flexed position for hours at a time.

Table 1. Home Exercise Program Distributed to Patient during Initial Evaluation

	Sets	Repetitions
Side Stepping with Resistance Band	3	15
Sitting Knee Extension with Resistance Band	3	15
Glute Bridge with Arms at Sides and Feet on Swiss Ball	3	10
Long Sitting Calf Stretch with Strap	2	5 (10-second hold)
Lateral Step Down	3	10

*Each exercise was to be completed once per day, 7 times per week.

The patient struggled to maintain extension ROM throughout the treatment period due to swelling and intense pain. He responded well to passive stretching but increases of motion achieved in each session were often not sustained between sessions. Due to the severe level of posterior knee pain with knee extension, the

patient's surgeon was contacted who confirmed there was no remaining structural damage. The pain was present regardless of his knee extension ROM. To protect himself from the pain experienced during knee extension, he walked with a bent-knee gait likely contributing to the inability to maintain full knee extension. This limited knee extension from the quadriceps muscles but required overuse of his hamstrings. To walk functionally, he needed to compensate for his quadriceps weakness by also increasing the use of his glutes and calf musculature. The over-recruitment of the posterior chain muscles in the lower extremity dominated movement and contributed to his antalgic gait. These compensations led to slow strength progress of the quadriceps throughout the rehabilitation period. Step-down exercises continually demonstrated poor motor control and limited endurance of the quadriceps.

Six weeks into treatment and three months following the surgery, the patient attempted exercises on the agility ladder. On the first visit he attempted to climb the agility ladder, he did not have the correct sleeve for his running prosthesis. He was very excited to progress to the agility ladder so he attempted the exercise with his daily prosthesis. He was able to complete this exercise with good tolerance in the left knee, and no increased pain, discomfort, or feelings of weakness were reported. Unfortunately, the activity had to be discontinued early due to friction between his daily prosthesis and his right stump. Two weeks later, the patient presented with increased knee ROM, 2° of hyperextension and 138° of flexion, and decreased posterior knee pain. The patient reported he began committing time to his HEP and passive stretching. This likely contributed to his rapid progress as he had neglected his HEP previously. The agility ladder was attempted again during this time with his running prosthesis. The patient was able to complete the activity with greater ease than his first attempt and had good stability, speed, agility, and motor control of both legs. The patient used vasopneumatic compression after most sessions to help minimize swelling and decrease pain with good results.

The patient was last seen by the medical team one week prior to the university shut down due to the COVID-19 pandemic. He was struggling with pain due to ingrown hairs on his right extremity residual stump, causing him to be stationary or in his wheelchair for a week because wearing his prosthetic was too painful. He had improved extension ROM of his left leg after reportedly spending an increased amount of time every day stretching. Quadriceps weakness was still present. Once the patient returned home, he declined to continue with formal rehabilitation in an online format. He also had decreased compliance with his HEP because he had normal ambulation and did not think continuing rehabilitation was needed. He continued doing cardiovascular exercises such as playing basketball recreationally, but neglected strength training. This further impacted his progress and lengthened his recovery time. About a year later, his knee began bothering him again, specifically when he was active, so he began strength training on his own. **Table 2** highlights objective measurements of the patient throughout the rehabilitation process.

Table 2. Objective Measurements Throughout Rehabilitation

	Initial Evaluation	**4-month Progress**	**1 year Follow-up**
Knee Flexion AROM	R Leg: WNL L Leg: 127°	R Leg: WNL L Leg: 135°	R Leg: WNL L Leg: WNL
Knee Extension AROM	R Leg: WNL L Leg: 0° (with pain)	R Leg: WNL L Leg: -2° (no pain)	R Leg: WNL L Leg: WNL
Pain Level with Active Knee Extension (0-10)	8	7*	0**
Disturbed Sleep	Yes	No	No

* Pain occurred at end-range only

** no pain occurred with active knee extension, but pain was still present post activity

OUTCOMES

One year after stopping treatment, the medical team followed up with the patient. He reported that he was playing "a lot" of basketball which was one of his initial treatment goals. He reported no problems while playing, but stated afterward his left ACLR knee hurt. He used ice consistently to limit pain and swelling after playing. He completed a LEFS again and scored a 63/80 compared to 36/80 on the initial examination and a 55/80 on his last visit before campus closure (**Table 3**). This value matches the reported discharge outcomes of those undergoing ACLR and rehabilitation at four months.[1] However, it should be noted the patient population observed by Alcock and colleagues[1] did not have a lower extremity amputation on the contralateral limb, nor the extensive injuries and rehabilitation process the patient in this case did. The patient here also completed an IKDC Subjective Evaluation form and scored 67.8 for this left knee. The IKDC is a valid and reliable form that is used to assess function, symptoms, and sports activity in patients with a variety of knee conditions. Normative values have been reported for the IKDC previously and are based on gender, age, and if the patient was injured on the right, left, or both knees.[2] Those who had undergone surgery in their right knee only reported their IKDC score to be 56.6 $\pm$ 23.3, in the left knee only to be 58.3 $\pm$ 25.6.[2] Those reporting surgery in both knees, as was the case with this patient, reported their right knee IKDC score as 56.6 $\pm$ 25.3 and left knee as 51.4 $\pm$ 26.9.[2] Males in the study, aged 18-24 years, without a history of knee injuries or surgery reported a mean score of 89.1 $\pm$ 17.5.[2] The patient here still struggled with the fit of his prosthetic one year after discharge from rehabilitation, which has continued to limit his function. He was still unable to jump because of his prosthetic and reported that he felt that it was more limiting for him than his left knee.

Table 3. Patient-Reported Outcome Measure Scores

	Initial Evaluation	**4-month Progress**	**1 year Follow-up**
LEFS Score (out of 80)	36	55	63
IKDC Score (out of 100)	--	--	67.8

He had also followed up with his prosthetist and had the height of his prosthetic readjusted. Unfortunately, he then had problems with the socket requiring a new prosthetic. Since he attended school out of state, obtaining a new prosthetic was difficult.

DISCUSSION

The patient's complex musculoskeletal medical history limited multiple aspects of rehabilitation and contributed to his antalgic gait. While wearing his running prosthesis, he was able to achieve full knee extension on his right leg and his left leg drop foot was less pronounced than while using his daily prosthesis. The research team hypothesized a limb length discrepancy could be the root of these issues; so, he was referred back to his prosthetist who confirmed our theory. According to a study done by Friberg, only 15% of subjects had a prosthesis with equal leg length to their intact limb and shortening of the prosthetic between 5 and 10 millimeters was shown to lead to problems including knee or hip pain in the intact limb.[3] Both of these occurred in our patient. The patient's BKA also provided challenges with rehabilitation including pinching sensations from his prosthesis with certain exercises, and painful ingrown hairs that limited walking. According to a study done by Dillingham and colleagues on long-term (defined as those who have used a prosthetic for at least one year) prosthetic users who suffered lower-limb amputations due to trauma, only 43% reported satisfaction with prosthetic comfort. Skin wounds and sores caused by the prosthetic as with our patient were reported by 24% of the patients and general residual limb pain was reported in 17%. While not present in our case, Dillingham and colleagues noted phantom pain affected about 24% of the

patients. Furthermore, patients reported problems with their contralateral limb including problems with circulation (10%), joint pain (17%), muscle cramps (8.5%), sores or wounds (7%), and numbness or weakness (8.5%).[4] When working with patients with prosthetic limbs, it is crucial to understand these confounding conditions and how they can inhibit rehabilitation to other areas that are seemingly unaffected.

Another factor that lengthened recovery time was the patient's complaint of extreme pain with full knee extension and the inability to maintain knee extension between sessions. Typically, most patients no longer have extreme pain with extension four months after surgery and should visibly improve extension every few weeks. With full passive knee extension, this patient was able to identify two separate, distinguishable pains. One pain was a mild discomfort "stretching sensation" of the posterior knee which was felt during light passive stretching. The second pain was deep, sharp, and intense. This pain was elicited at the end range of knee extension and limited all aspects of rehab, most notably the patient's ability to achieve full knee extension. Due to the severity of the pain, the medical team contacted the patient's surgeon to confirm there was no remaining structural damage or mechanical limitation to impair motion. According to the surgeon's physician assistant, there was no structural damage to the knee, and she believed that there may have been a psychosomatic component as well as a Central Nervous System hypersensitivity contributing to the pain. She recommended continuing rehabilitation, and for the patient to use his prescribed medication as needed. Following the MVA, the patient had an Oxycodone and Acetaminophen (10mg/325mg) prescription to take as needed for pain. However, since he was a full-time student, he rarely took them because he felt that they interfered with his studies and his daily life.

Continued knee pain also contributed to quadriceps weakness, thus limiting the patient's ability to regain knee extension ROM and strength.[5] Limitation in full knee extension increased the dominance in the patient's posterior chain and further impacted his gait pattern. Regardless of the possibility of a leg length discrepancy, instead of equally distributing weight to both limbs, individuals with a BKA tend to put more weight and increase the stance time on their intact limb during ambulation.[6] Furthermore, a majority of them alter their gait to limit the forces on their prosthetic limb which has been shown to increase the forces acting on the joints of the intact limb.[6] With this in mind, our patient may have unconsciously put extra stress on his left leg while it was attempting to heal. The increase in pressure on his knee in combination with the amount of walking he did every day around campus may have contributed to our patient's struggle with global knee swelling and intense posterior knee pain.

The patient also struggled with psychological stressors slowing his overall rehabilitation and treatment. Since his MVA three years prior, he had been continuously in and out of rehabilitation following surgeries to his right leg, left ankle, and right wrist. Injuries overall have been shown to influence mental health and in turn the rehabilitation process.[7] Heijne and colleagues showed that all patients studied experienced frustration with the length of rehabilitation after an ACLR. This frustration negatively influenced their self-esteem and lead to decreased confidence in their rehabilitation process.[8] Looking at our patient, who had been in rehabilitation for over three years prior to his ACLR, he likely entered his ACLR rehabilitation with a similar frustration to those identified in the study by Heijne et al., the patient's mental fatigue with rehabilitation was evident early in the rehabilitation process. For a majority of the four months, he neglected his HEP, and would periodically cancel last minute or forget to come entirely. The medical team did not perform a formal screening of psychological wellness during the treatment period. Issuing a patient reported outcome measure, such as the Athletic Coping Skills Inventory-28 (ACSI)-28, early in rehabilitation or after the team noticed mental fatigue could have raised early awareness of this patient's psychological state. It may have also served as rationale for a referral for professional psychological counseling. The ACSI-28 form has been shown to significantly correlate with recovery time following an ACLR in an adolescent population.[9] Without

this outcome measure, the medical team found that changing his exercises consistently engaged the patient and he completed his rehabilitation with greater enthusiasm.

CLINICAL BOTTOM LINE

This case highlights how the presence of a prosthetic limb can complicate the rehabilitation plan and increase the recovery time of a patient with an injury otherwise unrelated to their amputation. In the case of this patient, while he was in rehabilitation for a left ACLR, his right BKA caused him to ambulate with increased pressure on his left leg. This imbalance of weight and increased pressure in the knee joint likely contributed to his struggle with global knee swelling and increased pain. When working with a patient with an amputated limb, it is crucial to routinely monitor the stump for any superficial injuries that could lead to infection. Even with continuous monitoring of the stump, problems arose in the patient such as friction in the prosthetic, worn-out sleeves causing pain, and ingrown hairs. These occasionally required the patient's ACLR rehabilitation to be modified or canceled for the day depending on the type of issues and the ability to work around them. When working with a patient with a BKA, Athletic Trainers must be aware of how the patient's prosthetic impacts the injured body part, how it can interfere with the overall healing time of the patient, and must be flexible with their rehabilitation plan if complications with the patient's residual limb occur.

This case also highlights the relationship between the healing of an injury and factors that may otherwise be overlooked. The patient's overall healing time and rehabilitation progress were impacted by kinetic chain disruptions, a LLD, and psychological stressors. In the case of this patient, the kinetic chain disruptions and LLD were due to an improper prosthetic fit, but these problems occur in patients without an amputation too. These types of complications can exacerbate symptoms that would otherwise be minimal or be the root cause of symptoms altogether. In this patient, his antalgic gait and posterior chain dominance were caused by his LLD. When using his running prosthesis, his LLD was less pronounced, and his gait became less antalgic as he was able to fully extend his left knee. Since his antalgic gait contributed to a posterior chain dominance, by correcting it we were able to see great improvement in overall function and pain sensations. In general, it is crucial for athletic trainers to practice patient-centered care and to look holistically at the patient, not just the injured body part, as there may be confounding conditions that can lead to a longer recovery time or inhibit recovery altogether.

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