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Physical Therapy Management Involving Strength and Gait Training for a Non-Traumatic Pediatric Amputee: A Case Report

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Abstract

Background: Pediatric non-traumatic amputations are under-represented in the literature, especially secondary to various disease processes. Rehabilitation following a below-the-knee (BKA) amputation for a child involves prosthetic gait training as well as addressing other factors based on the patient's presentation. **Case Description:** This case study involves treatment for a fourteen-year-old patient with a BKA due to congenital tibia bowing as a result of neurofibromatosis. Both the patient and family's goal was to normalize the gait pattern of the child with the prosthesis. The treatment was spread across nine sessions for approximately one month. **Evidence Based Treatment:** Treatment involved gait training using a Biodex treadmill and aboveground walking techniques. Additionally, due to patient specific factors, strength training was also implemented in order to normalize the gait pattern with the prosthesis. There was a focus on quadriceps, hip, and core strengthening. **Outcomes:** The patient had a 51.89% increase in his six-minute walk test distance. Also, an increase in strength was evident based on a more normalized gait pattern at the end of the encounter. **Discussion:** Recently, prosthesis design and fitting has greatly improved, especially to make the pediatric patient normal functioning. Following the fitting of the prosthesis, physical therapy is vital in order to normalize gait impairments. Additionally, there is a need for individualized treatments, as well as patient-family centered approaches when treating pediatric patients. The disease state, its implications, and the goals of the family contribute to the emphasis in therapy.

Keywords: Amputation; non-traumatic; pediatrics; orthopedics; physical therapy; rehabilitation; gait; 6MWT

Background

Amputations

The Amputee Coalition states that there are about two million people living in the United States with an amputation, and about 185,000 amputations occur per year. For adults, the major causes of amputation are vascular-related followed by trauma. The statistics for children with limb loss are different. Acquired amputations most commonly occur from trauma or disease (neoplasm or infection). In a study that analyzed twelve years of amputations in an emergency room, there were over 110,000 children that were involved. The average age of the child receiving the amputation was six years old, the majority were males (65.5%), and finger amputations were 91.6% of all amputations (Le & Scott-Wyard, 2015).

The field of amputation, prosthetic design, and research has grown greatly over the past few years. There have been great improvements in the fitting of prostheses for all age groups. One study demonstrated that if a pediatric prosthesis is good fitting, there is not increased force across the joints of the amputated limb, which potentially reduces the risk for early arthritis (Lewallen et al., 1986). However, even though there is increased knowledge on the design and fitting of the prostheses for amputees of all ages, there are limited studies involving pediatric management following the amputation. Specifically, there is a lack of literature involving the rehabilitation for non-traumatic pediatric cases. According to Khan et al. (2016), there have been very few developments in the assessment and management of pediatric trauma compared to adults. Additionally, even though there is general lack of prevalence, pediatric traumatic amputations are more common and extensive when compared to adults (Khan et al., 2016). Pediatric care is significantly different than that of adults and needs to be individualized. This is even truer for non-traumatic pediatric amputations, which are even less well represented.

There has been some discussion on management following amputation for children, however, research is lacking in regards to physical therapy for these pediatric patients. Current research shows a child (or individual of any age) should attend therapy immediately following amputation to reduce risk of developing contractures. However, when the child receives his or her prosthesis, there are a number of other individual factors that also need to be considered with treatment. Gait deviations with prostheses have been investigated with adults, however children are functionally different. Additionally, it is usually accepted that when there is a gait deviation following amputation, the prosthesis is typically the cause. However, this becomes less clear in a child with a disease process that leads to the amputation, as there could be other neuromuscular causes for the gait deviation. Van Velzen et al. (2006) concluded that there should be a better evaluation of both walking ability and physical capacity following an amputation involving the lower extremity, as factors other than the amputation could be involved.

Eshraghi et al. (2018) reviewed rehabilitation protocols for amputees of various ages and suggested there is limited research regarding how to improve gait and balance treatments of all amputees, but especially of the pediatric lower limb population. Protocols that could improve long-term outcomes through adulthood based on the varying components of prosthetics and rehabilitation would be of benefit in the research and clinical settings.

Neurofibromatosis

Neurofibromatosis is a genetic disorder that can cause small tumors to form on nerve tissue throughout the body (Mayo Clinic). It is the most common single gene disorder in humans (Crawford, 1986). There are many different symptoms that can be associated with this disorder, including cafe au lait spots, optic gliomas, learning disabilities, and of greatest relevance, bone deformities. These deformities can range from abnormal bone growth to bone mineral deficiencies, resulting in scoliosis or bowing of the long bones (Mayo Clinic). Only about 2% of people with neurofibromatosis develop the bowing of the long bone, especially the tibia. For those with the disorder, fractures typically occur either spontaneously or after simple injuries requiring surgery, which in some cases leads to amputation (Ferner et al., 2007).

This case report describes a child with neurofibromatosis resulting in a below-the-knee amputation due to bowing of the tibia. The case report highlights treatments used for gait training with a pediatric prosthesis as well as individualized rehabilitation involving strength training to normalize the gait pattern. The purpose of this case report is to present the outpatient physical therapy plan of care and progression for a pediatric amputee based on individualized patient factors following the fitting of a prosthesis.

Case Description

The subject in this case report is a fourteen-year-old male high school student presenting to an outpatient physical therapy clinic following a below-the-knee amputation (BKA). The initial therapy evaluation occurred about two and a half months following the amputation and ten days after obtaining the prosthesis. The subject's BKA was secondary to congenital bowing of the tibia due to a neurofibromatosis diagnosis. The patient was examined with various functional outcome measures as well as gait analysis. His mother was present for the initial treatment as well as all subsequent sessions. As the patient was in high school, he functionally needed to be able to walk from one class to the next on time. There were stairs within the school, as well as an elevator that was accessible to the patient. The subject and family stated their primary goals were "to be able to walk without a limp and to roller skate again".

Objective Evaluation

With the initial evaluation, the prosthesis was removed and the residual limb was observed and palpated. It was well shaped with some red-colored markings from the prosthesis, but no wounds were noted. The subject was not having any pain in the residual limb and denied phantom pain, but stated he "could feel the phantom limb". The prosthesis was a total surface-bearing socket with pin suspension. Bed mobility and transfers were assessed, and he was able to complete these tasks independently without an assistive device. The subject ambulated into the therapy session without any assistive device. He reported using a front-wheeled walker for the first five days after being fitted for the prosthesis and then progressed to ambulating for the following five days without an assistive device. He navigated stairs with standby assistance, ascending four steps without a rail and a reciprocal gait pattern. When descending, however, he used two rails and a step-to gait pattern, taking one step at a time. The quality and quantity of gait was also evaluated at this initial visit. The six-minute walk test was utilized, and he ambulated 1056 feet without any rest breaks. In terms of ambulation quality, the subject had a noticeable gait impairment with limited heel strike on the amputated leg. He lacked quadriceps control for the transition from heel strike to the stance phase of gait, where there was a forward buckling motion and flexion of the knee. There were also occasional losses of balance secondary to a lack of prosthetic foot clearance during the swing phase of gait when ambulating over carpet, but he was able to catch himself to prevent a fall.

Gait Pattern

There are several components of a desired gait pattern. These include but are not limited to, foot flat in midstance, lateral stability of the knee, smooth movements, minimal lateral shifting of the trunk, and proportional step length. There can be deviations in the gait pattern that can lead to impairments with ambulation. One deviation that can take place with an amputee is excessive knee flexion between heel strike and midstance. This can be the result of placement of the socket in respect to the foot, excess plantarflexion of the shoe, or a flexion contracture of the knee. During heel strike with normal gait, the knee is approximately in full extension, and will then begin to flex until foot flat (Van Griethuysen, 1979). This patient, however, demonstrated at the initial evaluation with an inability to maintain knee extension during heel strike. Additionally abnormal motion at the pelvis was noted throughout the gait cycle, suggesting core and gluteal muscular weakness. Also, there was decreased step length for the amputated limb compared to the intact side also causing the gait impairment.

Evidence Based Treatment:

In existing literature, different methods have been found to be effective for post-amputee gait training. According to Highsmith et al. (2016), interventions are needed following lower extremity amputation due to gait asymmetries, altered biomechanics, and related secondary consequences. They found that overground training with auditory, manual, and psychological awareness treatments were successful with gait training. In addition to overground training, treadmill training could be effective when evaluating biomechanics and distance walked. Plantar pressure plates have been shown to help determine gait impairments and guide rehabilitation with amputees (Castro, 2014). However, within our clinic, this was not a feasible option. We needed a more practical option to be able to determine gait asymmetries, thus we used the Biodex treadmill to measure step length and stance time on each limb based on height, age, and gender. Also, the use of overground walking with verbal cueing to assist with gait training was more functional and a progression from the treadmill training.

A study in adults found that quadriceps tension and rate of tension development were very important factors for rehabilitation for below-the-knee amputees (Soderberg, 1978). Also, Esposito et al. (2017) found that people with amputations exhibit lower flexor and extensor moments and power generation. These factors were evident in our pediatric patient and were important components to be considered in the rehabilitation process. The initial focus of rehabilitation was quadriceps muscle strengthening to allow the patient to control terminal knee extension when initiating the gait cycle. Additionally, Hendershot & Wolf (2014) demonstrated that a person with a lower limb amputation could exhibit altered trunk motion and spinal loading leading to increased risk for low-back injury. Another study had similar conclusions, stating that correcting trunk motion and increasing hip abductor strength (force generating capacity) can be helpful for amputees. However, this study was done with a trans-femoral amputation (Darter & Wilken, 2011). Our subject had poor trunk control due to decreased neuromuscular core and hip strength. Initiating pelvic stability early in treatment was an important factor to normalize the gait pattern. We used hip and core strengthening to supplement the quadriceps strengthening so that the gait impairments could be normalized (see table 1 for complete rehabilitation progression and interventions).

Table 1. Subjective, Assessment & Interventions Used for Each Treatment Session

Days	Subjective/ Assessment	Interventions
Initial Evaluation (Day 1)	About 10 days after obtaining prosthesis, walked into session. Used FWW for the first 5 days and had been without it for the past 5 days. Obvious hip and quad weakness	Quadriceps (quad) set Straight leg raise (SLR) with quad set (noticeable extensor lag) Long arch quad (LAQ) Heel to toe weight shifting at counter to promote the correct movement with gait
Session 2 (3 days later/3 days total)	"Home exercise program (HEP) getting easy" Step length difference with steps with left lower extremity (LLE)	Standard exercise bike warm up x10 min SLR (added to HEP) SLR with ER (added to HEP) SLR abduction (added to HEP) challenging to keep leg in extension LAQ with 10 sec hold Wide stance mini squat on foam (heels tended to raise)

	longer than right lower extremity (RLE) and decreased heel strike on RLE	Balance/proprioception: Marching on foam with no UE support (decreased stance time on RLE), narrow base of support with modified tandem for 20 sec Biodex Treadmill Walking: 10 min with average speed of 0.74 m/sec using upper extremity for support; average step length: L: 64 R: 59; time on each foot 51% L and 49% R
Session 3 (6 days later/9 days total)	"Did more walking this weekend and went alright" Improved heel strike with cueing about 25% of the time with improved quad stability, no loss of balance or unsteadiness	Warm up on bike x10 min Bridge with 3 second hold (added to HEP) Standing band flexion red theraband (RTB) Standing band abduction (RTB) Hooklying hip abduction (RTB) (added to HEP) Forward step-ups (4-in step) Lateral step-up (4-in step) Wall squat with ball Standing terminal knee extension (TKE) with RTB Hamstring curls (2# weight) Seated marches on 55cm stability ball for 45 seconds
Session 4 (5 days later/14 days total)	"Ready to increase resistance bands, feels as though walking is getting easier"	Warm up on bike x10 min Lateral side stepping 2x 40ft with green theraband (GTB) (added to HEP) Monster walks with GTB 20ft (added to HEP) Standing TKE blue theraband (BTB) (added to HEP) Bridge with marching (added to HEP) Seated marches on stability ball with transverse abdominus (TA) activation; Seated on stability tossed/caught 2# ball Biodex Treadmill without UE support 4 min with step length L: 48 and R: 42, time on each foot L: 45% and R: 55% cueing for longer step length on R and heel strike
Session 5 (2 days later/16 days total)	"Has not tried the new HEP yet" Emphasis on doing HEP 1x/day, nothing added	Warm up on bike x10 min Lateral side stepping 2x 60 ft with GTB Monster walks 30 ft with GTB Wide stance mini-squats against stability ball Standing TKE BTB Marching on stability ball while tossing 2# medicine ball 12 min on Biodex treadmill, less cueing for heel strike, more for increased step length on R; more normalized gait pattern, able to tolerate increased time and faster speed
Session 6 (5 days later/21 days total)	"HEP is going well, feels like the limping is a lot better" Better mechanics with therapeutic exercise	Warm up on bike x10 min Ambulation on carpet for 1000 ft, normal pace with randomized speed changes with increasing gait speed and decreasing speed. No cues needed for heel strike with normal gait speed, but increased time on LLE with increased step length on L. Neglected heel strike with fast paced walking requiring cueing Lateral side stepping with BTB, better mechanics (less valgus and able to keep minisquat) for 50 ft

		Monster walks with BTB, more control 50 ft Wall squats without theraball, tending to have increased weight on LLE (added to HEP) Leg press level 26 with BLE; level 17 with RLE and 3 sec controlled eccentric descent, knee tending to move into valgus with SL Bridge with marching Sitting on theraball with LLE hip flexion and toss/catch of 2# medicine ball and TA activation. Some LOB
Session 7 (2 days later/23 days total)	"Doing well, no complaints" Focus more on shorter stride lengths to have less pelvic motion	Warm up on bike x10 min Ambulation on carpet with fast, slow normal walk with stops and turns per instructions of therapist; cues to decrease step length (very long strides creating increased pelvic shift/limp) light cues for heel/toe gait Gluteus medius kick outs Attempted hip hiking (unable to perform with proper technique) (added to HEP) Wall squats for 10 sec hold 10x Leg press at level 18 with RLE and focus on eccentric control (5 sec) Tandem stance x30 sec; single limb stance R x 5 sec Obstacle course in gym walking around cones/hurdles and reaching to promote weight shifting
Session 8 (5 days later/28 days total)	"Had to walk a lot with attending a football game and had to do stairs and it all went well." Parent and patient happy with how it went Harder time with balance with SLS	Warm up on bike x10 min Fast/slow pace walking on carpet, focus on shortening step length on L, normalizing gait pattern Taps anterior; anterior/lateral; lateral; posterior/lateral; posterior with RTB around ankles Gluteus medius kick with RTB Hip hiking attempted but struggled to get motion Wall squat with 10 sec hold and ball toss of 2# Leg press, level 20 with 5 sec eccentric control Single leg balance for about 5 sec; toe touch on L to increase balance to 15 sec (added to HEP)
Session 9 (7 days later/35 days total)	"Practiced some running and it went well" Mother and subject wanting independent HEP for 4 weeks	Warm up on bike x10 min Bridge with GTB (added to HEP) Hooklying clamshells with GTB (added to HEP) Hooklying hip adduction squeeze (added to HEP) Wall squat with 10 sec hold Prone hamstring curl with 5 sec eccentric lowering (added to HEP) Quadruped opposite upper extremity/lower extremity raises (added to HEP)

Outcomes:

The patient in this case study met one of his primary goals while in therapy, as his gait impairments appeared to be improved. According to both the patient and his mother, they were pleased with his progress in therapy. Not only did the quantity of the subject's gait increase, but the quality of it also improved. Even though it was a subjective measure, the patient did not feel his gait was impaired and wanted to establish a home exercise program. Additionally, the patient lived about 30 minutes from the outpatient clinic needing fewer treatment sessions. At the end of therapy, fewer cues were needed for step length or heel strike at the initiation of the gait cycle. He was also able to adjust his gait speed on command. While additional strengthening and time in therapy could have benefitted the patient, based upon personal factors, the patient and family chose to discharge from therapy after nine sessions.

The six-minute walk test was an outcome measure used to determine difference in gait speed at the beginning and last treatment sessions. From initial evaluation to the last treatment session, the patient had increased ambulation distance by 548 feet (from 1056 feet to 1604 feet), which is 51.89% increase in distance covered. Minimal clinical important differences (MCID) or minimal detectable change (MDC) for the six-minute walk test varies with different patient populations in the literature. For example, individuals with osteoarthritis need a value of 201.25 feet to have an MDC. Whereas a person who had a stoke needs an increased distance of 120 feet or 12% change for the MDC or a value of 112.86 feet for the MCID (Shirley Ryan Ability Lab). There is not a measurable distance for children with amputation with an MCD or MCID available currently in the literature.

Discussion:

This case study examined the outpatient physical therapy management of a pediatric below-the-knee amputee following his fitting for a prosthesis. Since the amputation was non-traumatic due to neurofibromatosis, there needed to be a variety of interventions involved in the treatments to normalize the gait pattern. Although the patient did not use any assistive device at the initial evaluation, there were very significant gait impairments that needed to be corrected so that the child would be able to accomplish daily tasks, such as walking the halls to get to classes in high school. Treatment focused on quadriceps, hip, and core strengthening, along with gait training with the prosthesis in order to normalize the gait pattern.

Normalizing Gait Pattern

Grade B evidence has been found in regards to strengthening to improve gait speed. The outcome measure used in this research was self-selected gait speed. Rehabilitation programs involving supervised walking, muscle strengthening, balance exercises, gait training, and functional training programs had varying degrees of improvements with gait for amputees. One aspect of this study that we did not attempt with our patient was resisted gait, even though it has been shown to be more effective than just supervised walking (Wonk et al., 2016). Further studies and cases should further incorporate this intervention with pediatric cases. However, our goal with this case study was not necessarily improving gait speed, but rather normalizing the gait pattern. A lot of research uses gait speed as a functional measure, and it is one outcome measure when using six-minute walk test. However, the more appropriate measure in this case would be the quality of gait. There needs to be additional research done in order to find a normalized, objective measure of gait to account for the quality of patterns and deviations, followed by the rehabilitation used to correct those particular patterns. The patient in this case study was at an advantage according to Fajardo-Martos et al. (2018). Their study, though it only included adults, showed that improved walking ability or merely successful rehabilitation was more likely in younger participants or adults lacking other comorbidities. Additionally, the subject was actively wearing his prosthesis throughout the entire day, which Ulger and Sener (2011) found to be effective in improving function, gait pattern, and amount of weight-bearing on the amputated limb.

In a study done by Lin et al. (2014), it was found that a person with a lower limb amputation is more likely to participate in a higher level of physical activity if possessing good functional capacity and lateral stability. Additionally, it was shown by Herbert et al. (1994) that children with below-the-knee amputations had higher energy needs for walking. Van Velzen et al. (2006) strongly encouraged balance training when improving walking ability and physical capacity for rehabilitation following lower limb amputation. These were a few of the key components of this case's rehabilitation program. The intention was to not only increase strength for trunk and lower extremity stability, but also to increase endurance and vital capacity based on the individual factors of the patient. We incorporated these by utilizing the exercise bike as well as challenging him with exercises to increase his functional capacity. We also emphasized gluteus medius and maximus strengthening to provide lateral stability during gait training.

Non-Traumatic Pediatric Amputations

There has been little research regarding gait training or physical therapy management following the fitting of a prosthesis for a pediatric patient with varying disease processes. Future studies could involve determining the beneficial amount of therapy sessions for adequate treatment of non-traumatic amputations. This, however, would be difficult due to various personal factors when dealing with pediatric patients. Additionally, though the literature well documents the description of neurofibromatosis-1 patients, the implications involving the osseous changes and problems associated are rarely discussed in the clinical topics concerning the disease (Karwacki & Wozniak, 2012). With this disease process, the focus is on gait training following amputation, though other factors need to be considered into the plan of care. For instance, this population has been found to have low concentrations of vitamin D, resulting in decreased overall bone density (Hirbe & Gutmann, 2015).

There has been one important study in the literature that targeted pediatric amputees. Feick et al. (2016) demonstrated that walking speed, distance, and functional balance are significantly decreased in lower limb amputees compared to able-bodied children. Also, better postural control and balance were correlated with increased walking speed. Some of these theories were implemented with our patient. However, the study stated that there is limited research with clinical outcome measures in pediatric amputations. Future research should be directed towards finding out more information on this population in regards to their gait and balance deficits, working towards establishing steps to improve outcome measures. Also, when looking at pediatric patients with a BKA, Engsberg et al. (1991) concluded that when compared to an able-bodied child, if there is a functional difference between the intact limb and the prosthetic limb, then there will be more difficulty walking. Thus, it is important to take all considerations into the rehabilitation of the child, such as type of prosthesis, the joints involved, and gait pattern, as well as the other personal factors and diseases processes.

Differences with Pediatrics

Pediatric patients need to be evaluated and treated differently in physical therapy than adult patients with limb loss. One study showed that high functioning people with amputations reported that having gait deviations were unimportant to the person. Rather, the self-reported functional ability and attitude toward the prosthesis were the greatest correlation with satisfaction following the amputation (Kark & Simmons, 2011). Unlike these results, the subject in this case report had the goal to normalize his gait pattern, as he wanted to walk like able-bodied children. These psychosocial factors need to be taken into consideration with all patients, especially children. Additionally, it was shown that people with lower limb amputations require increased cognitive control compared to able-bodied people, and understanding this idea needs to be taken into consideration when treating for balance and gait impairments (Morgan et al., 2018). This case involved the cognitive aspect during the rehab process, as verbal cues were frequently provided during ambulation to help the patient become mentally aware of his gait pattern.

Therapy in this encounter was the initial treatment sought following the fitting of the prosthesis and focused on the family and patient's goals. The family decided to discharge following a month of therapy due to his progress and meeting their individual goals. There could have been additional therapy to progress the gait to include running and higher-level activities. However, based on the availability within the clinic and the commute for the patient, this was not a priority at the time. An important concept with physical therapy is patient and family centered care that takes the goals of the family into consideration for therapy management.

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