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Abstract

Background: Individuals who have suffered strokes benefit from physical therapy to maximize their function in everyday activities. Research has shown some success using cycling with functional electrical stimulation (FES) as an adjunct treatment in these individuals, but it is not widely used as a standard of care. The purpose of this case report is to describe an example of an individual who received this type of therapy and discuss his experience with the intervention. **Case Description:** The patient was a 36-year old male who suffered a left-sided stroke. Two weeks later, he was admitted into an inpatient rehabilitation facility. At this time, he required heavy assistance from 1-2 people for all functional mobility. **Intervention:** After one week of participation in rehabilitation, the patient was set up on a FES bike. This intervention was used 2x/week for 4 weeks in an effort to prime the muscles on his paretic limb. **Outcome Measures:** The Functional Independence Measure (FIM) was used as the main outcome in this case. The patient had improvements in each of his FIM scores for transfers, walking, and stairs. **Discussion:** This case report demonstrates that the use of FES cycling is feasible in the acute phase of hemiparesis stroke rehabilitation, even for a patient with significant functional impairments. The intervention was tolerated well, and provided an enjoyable experience for the patient.

Introduction

The American Heart Association has estimated that approximately 795,000 strokes occur in the United States each year [2]. Sensory and motor impairments on the contralateral side of the body are the most common deficits that present in individuals who have suffered a stroke [12]. In a high number of these people, impairments are long-lasting and have a direct effect on their quality of life and activities of daily living [10]. Individuals with hemiplegia in particular “had more problems with mobility, usual activity, and pain/discomfort” than those without hemiplegia [10]. A study in 2003 suggested that 43% of all elderly stroke survivors had moderate to severe neurological deficits, possibly indicating that stroke impairments do not resolve on their own [9].

Physical therapy can play an integral part in recovery of an individual post-stroke. Generally, early physical therapy interventions include task-specific training that targets mobility and balance required for transfers and gait training. These interventions are currently listed in the clinical practice guidelines for stroke rehabilitation and are often used as the standard of care [7]. However, in the acute stage of stroke recovery, specifically in an inpatient rehabilitation facility, individuals often receive 3 hours or more of therapy each day and may not be able to tolerate the intensity of interventions required for gait and transfer training. The use of a functional electrical stimulation (FES) bike may be able to serve as an intervention for these patients that is not as physically taxing, but still has a positive impact on their recovery. Some research has been done to evaluate the benefits of FES in stroke patients, but its use in acute stroke rehabilitation is not yet a standard of care. The purpose of this case report is to provide an example of the use of a FES bike in an inpatient rehabilitation setting as a physical therapy intervention for an individual who suffered a left-sided stroke.

Case Description

History

The patient is a 36-year-old male who was completely independent without an assistive device in all of his functional and daily activities prior to his stroke. He worked full-time remodeling bathrooms. He was able to drive and manage his own medications and finances. The patient is married and has two children under the age of 16. He has a history of alcohol and tobacco use. He also suffers from anxiety and depression. The rest of his past medical history up until the time of his stroke is unremarkable.

The patient initially presented to a rural hospital with a headache and vomiting. He was talking but became unresponsive and had a rapid deterioration in mental status. The medical diagnosis for this patient as revealed on imaging was a left basal ganglia intraparenchymal hemorrhage and subarachnoid hemorrhage. He was intubated and taken to a large hospital for immediate surgery. He required a decompressive craniectomy and placement of an external ventricular drain (EVD) due to the massive amount of swelling in his brain. He was on bed rest with the EVD, a feeding tube, IV, and chest monitors in place until 9 days after his stroke. At that time, he started physical therapy. The patient had significant expressive aphasia, so was unable to verbally express his concerns. He was able to use hand and facial gestures to communicate basic wants and needs. He had receptive aphasia as well, but appeared to understand demonstrations and commonly used social cues. A little over two weeks after his stroke, the patient was admitted into an inpatient rehabilitation facility where he received intensive physical therapy, occupational therapy, speech therapy, and recreational therapy.

Objective Evaluation

At the time of evaluation at the inpatient rehabilitation facility, he was unable to express complaints of pain due to expressive aphasia, but rubbed his head frequently during the session. It was interpreted that this was likely an indicator of discomfort for the patient. He had significant cranial swelling surrounding the craniectomy, which likely contributed to his head pain. A sensory screen was performed with the patient signaling when he felt light touch to his skin. Despite his aphasia, he was able to signal that he had sensation to light touch on the left side of his body, but he gave no signal to indicate the presence of light touch on his right arm or leg. His blood pressure was 129/85, assessed in a seated position. His passive range of motion was within functional limits throughout his lower extremities, but he had resistance to passive motion in his right lower extremity, indicating an increase in muscle tone. The patient exhibited extreme deficits in right lower extremity strength (0/5 manual muscle test in hip flexors/extensors and abductors/adductors, knee flexors/extensors, and ankle dorsiflexors/plantarflexors). Upper extremity strength and range of motion testing was deferred to occupational therapy, but there was no active movement of his right upper extremity noted during this session.

Several mobility and transfer tasks were assessed. For bed mobility, the patient required maximal assistance of two people to transfer from supine to sitting, and maximal assistance of one person at both his trunk and lower extremities to transfer from sitting to supine. Once sitting at the edge of the bed, the patient was able to maintain unsupported balance for ~15 seconds, but then required maximal assistance of one person after this time as he demonstrated moderate pushing behavior to the right. He performed a lateral scoot to his left with moderate assistance of one person and light contact assistance of a second person. When transferring from sitting to standing, the patient was unable to place his right foot in the appropriate position to complete the transfer, requiring both verbal cues and manual assistance to place it. He completed a sit to stand transfer with moderate assistance of one person and minimal assistance of another, with blocking of his right knee and verbal cues for hand placement. The patient was able to stand with moderate to maximal assistance of one person plus minimal assistance of another, again requiring blockage of his right knee and assistance with weight shifting to the left as he preferred to lean towards the right.

Clinical Impression

After completing the examination, the physical therapy diagnoses were determined to be the following: right-sided weakness, impaired balance, poor activity tolerance, impaired gait, and overall decreased functional mobility. He also had high tone in his right lower extremity. The patient was unable to state his own goals at the time of evaluation. His wife was hopeful that the patient would be able to return home with her help.

Intervention

The patient received several interventions while in inpatient rehabilitation such as: stretching, proprioceptive neuromuscular facilitation (PNF) strengthening, general strengthening, transfer training, ambulation, stair training, and FES cycling. The first session of FES cycling for this patient was six days after the patient was admitted to and evaluated at the inpatient rehabilitation facility. At this time, we determined that the patient was appropriate for this intervention because he was able to ambulate with assistance, but was struggling to fully engage muscle groups that are important in walking. His cognition was at a level that allowed him to understand instructions for the bike while also being able to tell us if the stimulation was hurting him. Since this patient had asymmetrical muscle strength, specifically in the hips and core, he presented with poor postural stability, which is common with this condition. The FES bike was used in this case to provide him with a safe option to exercise without risk of falling.

The FES bike also served as a way to prime his muscles for participation in functional activities such as walking. Research has shown that peripheral nerve electrical stimulation can alter spinal and supraspinal systems [4]. One study examined the effects of peripheral nerve stimulation two hours after the stimulation protocol in twelve subjects. The authors found that after nerve stimulation was applied, there was a larger TMS-elicited motor evoked potential than before the stimulation was provided. The increased excitability of the motor cortex persisted, even two hours post-stimulation [4]. This information supports the idea that electrical stimulation can prime muscles for participation in functional activities post-stimulation. For this reason, on each day FES cycling was performed, we chose to have the patient start with the FES bike, followed by other exercises such as ambulation, to take advantage of this priming mechanism. We noticed that the patient was able to ambulate with less assistance and often farther distances on the days he rode the FES bike prior to walking. Further, Stoykov recommends the use of peripheral nerve stimulation in patients with limited voluntary movement or endurance, as these individuals are unable to participate fully in extensive rehabilitation [15]. As our patient was not able to tolerate full therapy sessions consisting of walking, which would have been too fatiguing for him, the FES bike was used as an adjunct to provide meaningful exercise. This enabled the patient to tolerate full treatment sessions during inpatient rehabilitation.

The specific bike used in this case was the RT300 model from Restorative Therapies (see Figure 1). FES cycling is similar to recumbent biking as the patient remains seated in his wheelchair while cycling with his lower extremities. The wheelchair is attached to the FES cycling machine with heavy duty straps to prevent backward tipping or lateral movement of the patient.

Figure 1. An RT300 FES bike with electrodes hooked up to an individual [13].

Electrode pads were placed on different muscles on the paretic lower extremity. Two large electrodes were put on the quadriceps, one over the vastus medialis distally, and one on the vastus lateralis proximally, with the intent to activate all of the quadriceps muscles. Two large electrodes were also placed on the hamstrings, one placed three to four finger widths proximal to the popliteal crease, and one approximately four to five finger widths distal to the ischial tuberosity. Medium-sized electrodes were placed on the gluteal muscles, the lumbar paraspinals, and the gastrocnemius muscles. One electrode was put on the most lateral aspect of the gluteal muscles, and one toward the medial aspect of the gluteals. One electrode covered the lumbar paraspinals in a longitudinal fashion (in the direction of the muscle fibers). One electrode was placed three finger widths distal to the popliteal crease along the largest part of the gastrocnemius muscle, while another electrode was placed four finger widths distal to that electrode. Finally, two small electrodes were put on the anterior tibialis muscles, one approximately two to three finger widths distal to the fibular head, and another about four finger widths distal to the proximal electrode.

Once the electrodes were all in place during the first session, the maximal stimulation for each muscle group was tested based on the patient's tolerance. He was instructed that the goal was to produce a strong muscle contraction. One muscle group at a time, the stimulation was turned up until the patient signaled to stop. This ensured that the patient would not receive higher stimulation than was tolerable at any point during the FES cycling intervention. Even though the patient had aphasia, he was still able to indicate when the stimulation was too strong by pointing to that muscle group while it was being stimulated. As an additional safety precaution, the therapist palpated each muscle group as the stimulation was increased to assess for muscle activation and prevent excess stimulation.

The patient was then brought closer to the bike to determine the height of the bike (specifically the pedals) to fit the patient. These findings were noted so the therapist could set up the bike the exact same way at each subsequent session. At the beginning of each session with the FES bike, proper placement of the wheelchair was determined by having the patient pedal a few times while the therapist held the chair in place (before securing it). The chair was brought closer or farther away and moved side to side as necessary to find the best alignment. The patient's feet were strapped onto the pedals, and a lower leg pad was fastened to also help keep the patient's lower extremity in place. These steps ensured the cycling pattern was smooth and biomechanically appropriate.

The FES bike was used two times per week for approximately one hour. The FES bike was only used two times per week due to the amount of time required for set-up and takedown. The time used for each session included setup of the bike and the electrodes, take down of the electrodes, a warm-up and cool-down phase, and active cycling. The exact duration of cycling was based on the patient's tolerance for the treatment. During the warm-up and cool-down, the patient does not actively cycle the bike, but rather the bike passively moves the legs through the cycling pattern (no FES applied). The patient starts pedaling during the active transition phase, when the electrical stimulation begins. The resistance on the bike was varied throughout each session and between sessions based on the patient's tolerance to the activity, and how much electrical stimulation he required to keep up with a given resistance. The bike's stimulation parameters only allow the therapist to increase the resistance when the patient had consistently been able to meet the current resistance level with some active use of his lower extremities (the exact amount required is unknown). The more stimulation the electrodes are providing to the patient, the less work the patient does on his own. The desired revolutions per minute (RPM) is also set, which was kept between 35-40 revolutions per minute (RPMs) for this patient. The maximum speed the bike can perform is 55 RPMs, but the 35-40 RPM range was chosen for this patient because it challenged him and was tolerable.

The screen on the bike displays the resistance, the RPM, desired RPM, a power output, and a reading of how much of the workload is being performed by each lower extremity. The screen also displays a figure that shows how much electrical stimulation is being provided to the patient overall. The patient was asked to focus on 3 things when receiving visual feedback from the screen: the left/right asymmetry, the RPMs, and the amount of stimulation being provided. The patient was asked to stay within 5 RPMs of the target level. Throughout each session, the he was encouraged to cycle minimally with his strong lower extremity, and to focus on cycling as much as he could with his paretic lower extremity. He was told that the paretic limb should be doing at least 50% or more of the work throughout the activity, and to look for that number displayed on the screen. The patient indicated he understood these instructions by pointing at these areas on the screen.

As appropriate, we progressed our patient in this intervention over time by turning down the stimulation on his major muscle groups. This required the patient to do more of the work with less assistance from the stimulation. The patient showed improvement over time as evidenced by his ability to cycle 4.64 miles on the last day of this intervention compared to only 2.68 miles on the first day. Overall, the patient tolerated FES cycling well. He was able to participate in this activity, even on days he had increased headache pain.

Outcomes

After six weeks in inpatient rehabilitation, the patient was discharged home with his wife. At this time, he was independent with sitting balance, was able to get into and out of bed, roll around in bed, and stand from a seated position with standby assistance. His static standing balance was good, but he required standby assistance for safety. He was walking up to 175 feet with a custom-made AFO, a small-base quad cane, and standby assistance of one person. The patient transferred from chair to bed (and vice-versa) and to/from the toilet using a stand-pivot transfer with standby assistance and his quad cane. The patient was independent for wheelchair mobility on level surfaces (distances greater than 300 feet) and on ADA-approved ramps.

Functional Independence Measure (FIM) scores were used as the primary standardized outcome measure in this patient's case to track his improvement over time. FIM scores are used in the inpatient rehabilitation setting as an outcome measure to objectively assess patient progression [3]. There are 18 items total, 13 of which are motor tasks. The other 5 are communication/cognition tasks. In this specific inpatient rehabilitation facility, physical therapists often focus on and assess three of the 18 tasks including bed/chair/wheelchair transfers, locomotion, and stairs. Each item is scored on a scale from one (total assistance) to seven (complete independence), or zero if the item was not attempted (due to safety concerns or any other reason). The minimal clinically important differences (MCID) for the total FIM, motor FIM, and cognitive FIM are 22, 17, and 3 respectively [1]. The patient improved his FIM scores from time of admission to time of discharge by greater than the MCID in the motor subscale, the cognitive subscale, and the total FIM (see Table 1).

Table 1. Functional Independence Measure (FIM) scores at time of admission to inpatient rehabilitation and at time of discharge from that setting.

	Admission	**Discharge**
Eating	1	5
Grooming	1	6
Bathing	1	3
Dressing Upper Body	1	5
Dressing Lower Body	1	3
Toileting	1	4
Bladder Management	1	7
Bowel Management	1	7
Transfers (bed/chair/wheelchair)	2	5
Toilet Transfers	2	4
Tub/Shower Transfers	1	4
Locomotion (Walk/Wheelchair)	1/4	5/6
Stairs	0	2
TOTAL Motor Score	**14**	**60**
Comprehension	1	5
Expression	1	1
Social Interaction	1	6
Problem Solving	1	5
Memory	2	5
TOTAL Cognition Score	**6**	**22**
TOTAL FIM Score	**20**	**82**

Other items that were assessed during the initial evaluation such as manual muscle testing and muscle tone assessment were not performed on the day of discharge due to time constraints. It would have been beneficial to retest his lower extremity strength and tone to quantify the improvements he made during inpatient rehabilitation.

Discussion

Individuals who have experienced strokes often require intensive rehabilitation to progress toward independence in their daily activities. Research has shown that a variety of interventions can contribute to the recovery of these patients. The research is more limited on the effectiveness of FES cycling in the stroke population, but there are some studies that have shown positive outcomes. One study by Sabut et al observed the impact of FES to the tibialis anterior muscle on gait restoration and motor recovery in thirty stroke patients. They concluded that FES therapy in combination with conventional therapy allowed patients to ambulate with more efficiency than those who received conventional therapy only [14]. A topic that remains uncertain is the impact FES has on individuals long-term. Another research study attempted to observe the impact of FES on those with chronic strokes. They used the 6 minute walk test as their primary outcome measure, and found that FES increased functional mobility even six months after having a stroke [11]. A systematic review by Howlett et al concluded that FES seems to produce a moderate improvement in activity post-stroke compared to a placebo [8]. They also concluded that FES is more beneficial than standard care alone, but were not able to determine whether FES has a long-lasting effect on activity. These research studies overall either had small effect sizes and/or small sample sizes, so more research is needed to demonstrate the effects of FES therapy on motor recovery both acutely and chronically in stroke patients.

It is important to determine whether or not a patient is a good candidate for the FES bike. This intervention can be used in a wide variety of patients, however, one should be aware of the contraindications and precautions for this activity. Absolute contraindications to FES cycling include: presence of a pacemaker, pregnancy, an unhealed fracture in the area, placement over the carotid sinus, placement over areas of skin breakdown, near another stimulator, and near arterial/venous thrombus. Relative contraindications include: severe spasticity, heterotopic ossification, severe osteoporosis, dysaesthetic pain syndrome, open sores in the area of treatment, malignancy in the area of treatment, spastic response to electrical stimulation, uncontrolled autonomic dysreflexia, and obesity [5,6]. Once contraindications have been reviewed, the clinician should decide if the patient is cognitively aware of what the intervention is and what is expected of the patient. If he is unable to understand the task, he should not participate in it. He should also be functional enough to be able to cycle the bike with assistance from the stimulation. A general rule of thumb that can be used to decide if a patient is at the appropriate functional level is if the patient can participate in ambulation to some extent, with assistance. This would suggest the patient could benefit from this intervention and make progress in his ability to ambulate.

The patient in this case report tolerated the FES bike well. An example of his tolerance to this intervention was his ability to participate in full therapy sessions even during the second week of his inpatient rehabilitation stay when he was experiencing increased headaches. The patient may not have tolerated other interventions that were more strenuous during that week, which could have delayed his recovery overall. When asked about his experience with the bike, he felt that he got a decent workout from this activity but that it did not exhaust him completely. He saw the FES bike as something different than transferring or walking, which he enjoyed.

The results of this case report suggest that FES cycling may contribute to recovery in individuals post-stroke. However, since this was a case report of only one patient and multiple interventions were used, we cannot conclude that the FES cycling caused improvement in the patient's function. Future studies with large sample sizes are needed to determine the effects of FES cycling on rehabilitation compared to standard of care.

Conclusion

The purpose of this case report was to describe the adjunct use of FES cycling during the care of a patient who suffered a left-sided cerebrovascular accident. The use of FES during this time was used in an effort to prime muscles on his paretic limb for participation in functional activities such as bed mobility, transfers, and ambulation. While the patient received a variety of interventions throughout his stay in an inpatient rehabilitation facility that surely assisted in his recovery, FES cycling proved to be a safe form of exercise for him. This case report suggests that FES cycling as an adjunct treatment could have contributed to his ability to participate in functional activities with greater independence. Further research must be done in the stroke population to compare this intervention with other interventions and determine the effectiveness of FES as a treatment.

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