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Case Report

Functional Electrical Stimulation Therapy Applied to Intrinsic Muscles of the Foot and Tibialis Anterior for Treatment of Foot Drop: A Clinical Report

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Abstract

Many individuals who experience stroke are faced with permanent disability and significant mobility impairments. Limitation in walking capacity is a common outcome of stroke, and many patients are unable to actively dorsiflex the foot during the swing phase of gait, which is referred to as foot drop. This gait impairment can result in compensatory movement patterns, slowed gait, limited functional mobility and increased risk of falls. In this study we decided to use functional electrical stimulation therapy (FEST) to help improve voluntary control of the tibialis anterior muscle and the intrinsic muscles of the foot. To the best of our knowledge, this is the first study that used FEST to retrain the voluntary control of the intrinsic muscles of the foot. A single 65 year old female individual, who had stroke three years prior to joining the study, took part in this pilot trial. She presented with right foot drop, and ambulated with the use of an AFO and two canes. The pre-post differences in scores on all measures (eg. Berg Balance Scale, Timed Up and Go Test, 10-meter Walk Test, and Lower Extremity Manual Muscle Test) clearly demonstrated improvement in walking following only 10 one-hour FEST sessions. These results provide preliminary evidence that FEST for walking, which involves gait phase appropriate stimulation of the intrinsic muscles of the foot combined with stimulation of the tibialis anterior muscle, has a potential to considerably improve gait in patients with chronic stroke many years after the injury.

Keywords: Functional electrical stimulation; Therapy; Chronic stroke; Walking; Foot drop; Intrinsic foot muscles; Functional electrical stimulation therapy

Abbreviations

AFO: Ankle Foot Orthosis; FES: Functional Electrical Stimulation; BBS: Berg Balance Scale; MDC: Minimal Detectable Changes; MMT: Manual Muscle Testing; TUG: Timed Up & Go test; FEST: Functional Electrical Stimulation Therapy

Case Presentation

The recovery of walking capacity is central to regaining independent living, and gait training forms an essential part of the rehabilitation process [1,2]. Karsnia et al estimated that 20% of stroke patients have foot drop [3]. Treatment for foot drop includes physiotherapy, orthotic devices, electrical stimulation and surgery. First line treatment is usually physiotherapy or the use of an ankle foot orthosis (AFO). The AFO [4,5] is considered to be standard of care in the United States for dorsiflexion weakness. Use of an AFO restricts the natural passive range of motion and the flexibility of the ankle and foot. An AFO may limit walking ability on uneven terrains and it may be uncomfortable to use [1]. A study by Geboers et al [6] reported that an AFO does not improve walking performance as measured by a 10-meter Walk Test, and a recent study also showed that in the long run the effectiveness of an AFO is minimal [7].

An alternative to an AFO and the other interventions described above is functional electrical stimulation (FES) [8-13].

In this article we will present a new modality of using FES technology to improve gait following stroke. Study participant was 65-year-old female who had stroke three years prior to joining the study. She presented with right foot drop and ambulated with the use of AFO and two canes. The study began with an initial gait assessment to determine her walking capacity and which muscles and in which order should be stimulated to generate a gait that looks as natural as possible. A specific FES walking protocol was developed for the participant using fully programmable transcutaneous (surface) FES system, Compex Motion [14]. We have applied FES protocol for improving walking in hemiplegic individual. This FES protocol differs considerably from other FES protocols that were used in the past to improve locomotion in stroke patients. Namely, instead of stimulating only the common peroneal nerve, our system delivered electrical stimulation to tibialis anterior, extensor digitorum longus, peroneal longus, gastrocnemius, soleus and intrinsic muscles. Stimulation of extensor digitorum longus, peroneal longus muscles and intrinsic muscles represents a major deviation from the garden variety of FES systems used for improving walking in the stroke population. This is because extensor digitorum longus and peroneal longus muscles generate eversion of the ankle and contribute to unweighting for the swing leg, and intrinsic muscles help to maintain ankle stability during walking.

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Table 1: Lower Extremity Strength- Manual Muscle Testing (MMT) Scores.

Muscle Group	Left (Initial/Final)	Right (Initial/Final)
Hip Flexors	4/4	3-/4-
Hip Extensors	3/3+	2-/3-
Hip Abductors	4-/4	2+/3+
Knee Extensors	5/5	4-/4
Knee Flexors	3+/3+	3+/3+
Ankle Dorsiflexors	4/4+	2-/2+
Ankle Plantarflexors	5/5	3/3+

Table 2: Walking and Balance Assessments.

	Initial (used 2 canes)	Final (no aid)
Berg Balance Scale	48/56	55/56
Timed Up and Go	12.72 sec	11.56 sec
10 metre Walk Test (Comfortable/ Maximal speed)	14.91 sec/11.99 sec	15.13 sec/12.50 sec

The stimulation electrodes were placed on the participant's skin at the motor points above the nerves corresponding to the muscles that were targeted with FES. Following muscles were stimulated: tibialis anterior, extensor digitorum longus, peroneal longus, gastrocnemius, soleus and intrinsic muscles. The stimulation pulses used in the study were balanced, biphasic, asymmetric and current regulated pulses. The pulse amplitude was modulated from 8 to 50 mA, were the amplitude of the stimulation was muscle dependent. The pulse durations varied from 0 to 300 μs. The pulse frequency used in the study was 40Hz. The Compex Motion stimulator was used to deliver the protocol. The stimulation sequences were delivered/ timed using open-loop control strategy where each sequence of the stimulation was triggered using a push button. Walking exercises with the FES system were performed at the preferred/comfortable walking speed. Physiotherapists administered the therapy 45 minutes daily, 3 days per week. A total of 10 therapy sessions were delivered to the participant.

Results

Berg Balance Scale (BBS) [15] - As a part of initial assessment the physical therapist administered the BBS. Results before and after the FEST are presented in Table 2. The change score was 7 points. In addition, the participant walked without aids at the end of the therapy. Please note that at the admission to the study the participant used AFO and 2 canes to help her walk. Stevenson [16] has shown that the minimal detectable changes (MDC) for BBS for people with stroke after inpatient rehabilitation is 7 points. Manual Muscle Testing (MMT) [17] – Results on the selected muscles before and after the FEST are presented in Table 1. In summary, the participant improved the MMT scores on the affected (right) limb by 0.5 or 1 point.

Timed Up & Go test (TUG) [18,19]– Results before and after FEST are presented in Table 2**.** At discharge the participant improved and did not use AFO and 2 canes, which she needed for support during baseline tests. 10 Meter Walk Test [18]–Results before and after FEST are presented in Table 2. One reason that the times may have been slower at discharge was that the participant required AFO and two canes to complete the test at baseline test, and did not use the aids during the discharge assessment.

Spatiotemporal Gait Assessment [20,21]– The Zeno Walkway (ProtoKinetics, Havertown, USA) has been designed to measure the spatial and temporal parameters of gait in clinical settings. The mat used in this study measured 4.3 m long x 1.2m wide (14 feet long x 4 feet wide). Gait assessment consisted of collecting (i) gait cadence and velocity, (ii) means stance/swing percentages, (iii) step length and step length variance, and (iv) single and double support times. Results before and after FEST are presented in Table 3.

From the clinical decision-making stand point we have seen that the proposed FES intervention, which was aimed at improving her walking capacity, was effective. In particular, with respect to MMT, Berg Balance Scale, Cadence, Velocity and the fact that the participant did not need waking aids following 10 one-hour sessions of FEST. These findings suggest that the FEST has a potential to improve the locomotion capacity in this particular individual and that increasing the therapy dose and intensity may be further beneficial for this individual.

Discussion

This clinical report shows the efficacy of the multichannel Functional Electrical Stimulation Therapy (FEST) as a clinical intervention for the purpose of treating foot drop impairment in an individual with chronic stroke. Note that this FEST intervention is not a single channel peroneal nerve stimulation strategy that is commonly used as an orthotic system. Instead it is a multichannel FEST designed to provide neuromodulation therapy and by doing so enhance locomotion competency. We found that the participant experienced considerable improvements in voluntary walking ability, (i.e. in the ability to walk without the assistance of the FES device). The pre/post differences in scores on all measures clearly demonstrated improvement in walking. The fact that we were able

Table 3: Zeno Walkway Assessment.

	Initial (PS – no aid)	Final (PS – no aid)	Initial (FS – no aid)	Final (FS – no aid)
Cadence	86 steps/min	90 steps/min	98 steps/min	104 steps/min
Velocity	0.62 m/s	0.63 m/s	0.76 m/s	0.77 m/s
Mean Stance/Swing %	65.4/34.6	64.9/35.1	64.5/35.5	64.7/35.3
Step Length (L/R)	40/45	39/45	41/51	40/48
Step Length Variance (L/R)	6.3/7.1%	5.1/4.9%	4.7/4.3%	3.8/5.4%
Single Support (L/R)	41/28%	42/28%	43/29%	42/29%
Double Support	31%	30%	28%	28%

PS - preferred speed; FS - fast speed.
L/R-Left/Right.

to elicit significant changes in a chronic stroke patient with foot drop after only 10 one-hour sessions suggests that the multichannel FEST for lower limb may be a viable therapeutic intervention for this patient population and that it merits further investigation.

Conclusion

Although the results of this report are very encouraging, caution should be used since the study is a case report of only one chronic stroke patient with no control group. This makes it difficult to comment on comparative improvement that could have been achieved if the participant was administered a same dose of conventional physiotherapy alone. However, we have to acknowledge that the participant in the study decided to participate in the study because she already reached plateau in recovery following many sessions of conventional physiotherapy, and she joined our program because the conventional therapy was not helpful to her any longer. We believe that a study with a larger number of patients is warranted, where the effects of the multichannel FEST for foot drop after stroke, which is aimed at improving voluntary gait function, should be compared against current best practices for treating this patient population.

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