Improvement of Gait Speed in Patients with Stroke Related Foot Drop by combined FESIA WALK system with conventional therapy

Suzana Dedijer Dujović, Jovana Malešević, Mirjana Popović and Ljubica Konstantinović

Abstract— **Foot drop is common gait impairment after stroke. Functional electrical stimulation (FES) of the ankle dorsiflexor muscles during the swing phase of gait can help correcting foot drop. The aim of this study was to determine whether FESIA WALK system combined with conventional therapy is an effective intervention for improving gait speed in both acute and chronic patients with stroke related drop foot. The results show that use of FESIA WALK combined with conventional treatment for 4 weeks may improve gait speed both in acute and chronic stroke patients with stroke related drop foot and provide shifting to a higher class of ambulation.**

Key words— **Stroke, Foot drop, FES.**

I. Introduction

Correcting the abnormalities of hemiplegic gait is the most important component of rehabilitation for independent and functional activities in daily living, community-dwelling, and social environments (1). Sustained distal weakness in the hemiparetic leg is manifested by an inability to adequately dorsiflex the foot during the swing phase of gait (2). This condition, known as drop foot occurs in up to 20% of persons who have had a stroke. Drop foot in combination with commonly seen low selectivity of hip and knee in this patient group results in an abnormal gait, consisting of hip hitching, circumduction, and toe catch (3). Walking speed is impaired and there is a higher chance of stumbling and falling.

A number of treatment strategies for drop foot may be used depending on the underlying cause. The most common treatment is an ankle-foot orthosis (AFO), which is a brace that holds the ankle in a neutral position and improves limb clearance during the swing phase of gait. AFOs have significant drawbacks including limitation of ankle mobility, which contributes to contracture development, possible undermining of motor recovery, difficulty in standing from a seated position, and poor acceptance by the wearer as a result of discomfort and the perception of undesirable aesthetics (4, 5).

An alternative to the more traditional AFO is the use of functional electric stimulation (6, 7). Foot drop stimulators (FDS) use functional electric stimulation to stimulate the common peroneal nerve, activating the muscles that dorsiflex the foot during the swing phase of gait. A systematic review by Kottink et al including pooled estimates from 3 studies demonstrated that FES was associated with a 38% increase in walking speed in persons with stroke (8). This review evaluated the impact of FES on gait speed with the stimulation on during testing (ie, FES was used as an orthotic device). On the other hand, Robbins et al conducted a meta-analysis evaluating the therapeutic effectiveness (carryover effect) of FES on gait speed in persons with stroke (9). The authors found that training with FES may have a sustained effect on gait speed. In addition, Merletti et al mentions that walking with FES implies a more energy efficient use of the hip and knee muscles by avoiding the need for compensatory movements (10). However, the FES system is more sensitive to disturbance and its application requires more preparatory time for the placement of surface electrodes. Technical limitations associated with the use of surface stimulators concern the lack of selectivity over recruited muscles and nerves, the sensitivity of muscle recruitment to electrode placement, and pain and tissue irritation associated with the passage of current through the skin (11).

Multi-pad electrodes containing individual, relatively small stimulation pads which can be activated individually or as a part of stimulation pattern (12, 13) may improve the selectivity upon stimulation responses. One such system based on multi-pad electrodes, FESIA WALK, has been developed by Tecnalia R&I, Spain (14). The use of this novel electrode may be a solution for decreasing muscle fatigue as well as for stimulus and placement discomfort because it is simple to attach to the limb and allows for more precise stimulation of affected areas.

The evaluation of recovery following a stroke is essential for both treatment and research. Traditionally, it has been accepted that neurological recovery peaks at around 3 months post stroke with little potential for further recovery in the chronic phase of stroke (15). However, a closer look at the literature has revealed that many studies in stroke rehabilitation include chronic stroke survivors and have demonstrated that functional recovery may occur years following a stroke (16).

The objective of this study was to determine whether FESIA WALK system combined with conventional therapy

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is an effective intervention for improving gait speed in both acute and chronic patients with stroke related drop foot.

II. Materials and Methods

Six hemiplegic patients with stroke related drop foot participated in this study. The study was performed in a post-acute rehabilitation medicine hospital, Clinic for Rehabilitation "Dr Miroslav Zotovic", Belgrade, Serbia. Our study followed the principles of the Declaration of Helsinki and all patients provided informed consent.

Inclusion criteria for study participation were: Hemiplegia or hemiparesis caused by first-time stroke; Independent walking before the stroke; Foot dorsiflexion inability during the swing phase of gait; Sufficient cognitive and language functions to reliably follow study related instructions and provide feedback; Ability to walk at least 10 m with or without the use of aids; Walk speed less than 0.4 m/s.

Gait speed, as a valid and reliable measure of walking recovery after stroke, was quantified using the 10m walk test (17). Patients walked at a self-selected pace using walking aids as needed but with no physical assistance. All patients were examined at the beginning of treatment and 4 weeks after treatment.

The participants received the conventional stroke rehabilitation program of physiotherapy and occupational therapy during the treatment for 60 min a day, 5 days a week, for 4 weeks. Conventional physiotherapy was based on the neurodevelopmental facilitation approach and task-specific exercise (walking on the ground, endurance training, sit-to-stand exercises, balance training, lower extremity strength training, stretching exercises, etc.). After completion of conventional therapy and rest for half an hour patients additionally received FES therapy using FESIA WALK system by Tecnalia for correcting drop foot. Stimulation began with 20 min sessions per day for the first week of the treatment and progressed to 30 min sessions daily for the rest of the 4 weeks treatment.

The FESIA WALK system consists of a stimulating unit, multiplexer, garment with integrated multi-pad electrode, wireless inertial sensors and tablet PC with application (Figure 1). The garment with integrated multi-pad electrode was placed on the skin around the patient's knee, close to the neck of the fibula in order to stimulate common peroneal and tibial nerves. The inertial sensor was placed on the patient's paretic foot so as to register the patient's foot position during calibration and gait cycle. Upon placing the garment in the envisaged position, by means of a tablet application, calibration process started – consisting of short-term stimulation of each electrode pad. The control unit attached on the garment received this trigger signal wirelessly and delivers a single pulse train comprising of pulses of various pulse widths and amplitudes to the multiplexer which routes it to different independent conductive pads within the multi-pad electrode. The automatic algorithm suggested the electrode pads that should be used for stimulation based on the sensor registered values. Once the parameters for stimulation were determined, the input was sent to the stimulator unit, which was either kept in patient's pocket or was strapped to the patient's waist, and the patient started walking. While walking, the system was independent from tablet PC. The stimulation frequency was set to 40 Hz and the pulse width to 400 μs.

Figure 1. FESIA WALK system

III. Results

Baseline demographics for the 6 participants are presented in Table 1. According to the post stroke duration patient were classified to the acute group (ID: 1, 2, 3) and chronic group (ID: 4, 5, 6) of patients.

For each patient involved in the study ischemic stroke etiology was confirmed by either computed tomography or

TABLE I
Demographic data of the participants

Subject ID	Gender Male/Female	Age (years)	Post stroke duration (months + category)	Etiology (Ischemic/Haemorrhage)	Paretic side (right/left)
1	F	61	3 (acute)	Ischemic	left
2	M	55	2 (acute)	Ischemic	right
3	F	59	2 (acute)	Ischemic	right
4	F	65	14 (chronic)	Ischemic	left
5	M	66	16 (chronic)	Ischemic	right
6	F	58	12 (chronic)	Ischemic	right
mean±SD	4F/2M	60,6 ± 4.22	3a/3c	6I/0H	4r/2l

magnetic resonance imaging.

In this study we utilized Perry ambulation categories to rank subjects by gait speed (18). According to the functional walking category, the walking ability of all subjects at the onset of trial was classified as the household ambulation with gait velocity of < 0.4 m/s.

With regards to the gait results of stroke patients, Figure 2, a noteworthy increase in mean walking speed between the beginning (0.28 ± 0.05 m/s) and the end (0.4 ± 0.06 m/s) of the trial was in the acute group of patients. Improvement in the gait mean speed was also noted in chronic patients, from 0.27 ± 0.04 m/s to 0.37± 0.06 m/s. Analysis of functional categories based on walking speed showed that two subjects from the acute group and also two subjects from the chronic group transitioned from household ambulation category (<0.4 m/s) to limited community ambulatory (≥0.4 and ≤0.8 m/s).

A number of limitations must be kept in mind when interpreting the results of this study. One limitation is that it examined stroke survivors with a mean walking speed of 0.27 m/s ± 0.04 at initial evaluation, so results cannot be generalized. After this proof of concept, further large-scale randomized control studies are required.

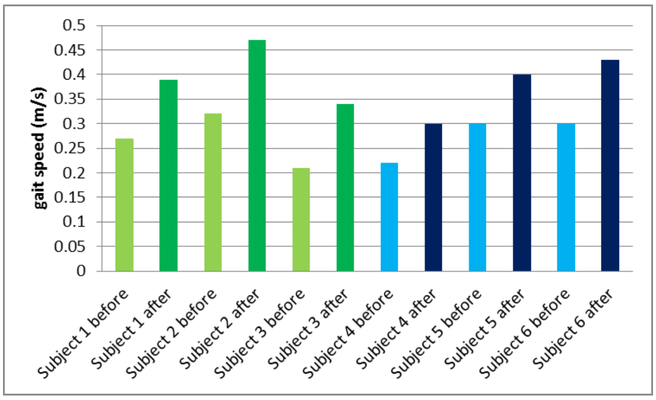

Fig. 2. Analysis of gait speed before and after 4 week treatment in participants; 1-3 acute patients, 4-6 chronic patients.

IV. Conclusion

The results of this study indicate that use of FESIA WALK system combined with conventional treatment for 4 weeks may improve gait speed both in acute and chronic stroke patients with stroke related drop foot. Shifting to a higher class of ambulation is associated with substantially better function and quality of life, especially with regard to mobility and community participation, in initial household ambulators.

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