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Case Report

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Home-Based Functional Electrical Stimulation Across Different Levels of Mobility in Neurological Patients: A Case Series

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ABSTRACT

Background: In neurological conditions, achieving meaningful treatment effects often requires a high number of task-specific repetitions. For patients with impaired gait and mobility limitations, this can be difficult to accomplish within conventional outpatient rehabilitation due to time, financial, and logistical constraints. A home-based treatment program using functional electrical stimulation (FES) represents a real-world training approach that can be readily integrated into routine daily mobility.

Materials and methods: Three neurological patients with foot drop and differing levels of baseline mobility participated in an individualized, multi-month home-based FES program. Changes in functional mobility, ability to perform activities of daily living, and balance confidence were assessed using standardized questionnaires. In addition, patient-reported feedback was collected regarding integration of FES into daily routines, program intensity, perceived benefits and barriers, and overall satisfaction.

Results: Across all cases, FES was successfully integrated into routine mobility activities with varying stimulation doses, and improvements were observed in functional mobility, activities of daily living, and balance confidence. Distinct usage scenarios of home-based FES were identified, including intensive gait training, facilitation of safety and mobility during walking, and short-term support of recovery.

Conclusions: Home-based FES appears to be a feasible and adaptable intervention for neurological patients with different levels of mobility. The findings suggest that home-based FES may serve as a complementary extension of conventional rehabilitation, particularly for individuals facing transportation barriers or limited access to outpatient care.

Keywords: Home-based rehabilitation, functional electrical stimulation, neurological impairment, drop foot

Introduction

The inability or reduced ability to dorsiflex the forefoot due to weakness of the dorsiflexor muscles is commonly referred to as foot drop [1]. The neurological origin of this impairment may be central, as typically observed in patients with cerebral palsy or after stroke, intraspinal, for example, as a consequence of radiculopathy, or peripheral, most commonly following peroneal nerve injury [2]. This pathology can lead to an unsteady and compensatory gait pattern, an increased risk of falls, and may substantially affect patients' daily functioning and independence [1,3]. Walking speed is often markedly reduced, and in patients with peroneal mononeuropathy, up to 69% require assistance with mobility [4].

Treatment strategies largely depend on the underlying cause and the extent of neurological damage [3]. While complete recovery may be expected in some patients within several months, in others the impairment can persist, and therapeutic interventions are then primarily focused on support, compensation, and improvement of mobility [5,6]. One of the conventional approaches in the management of persistent foot drop is the use of an ankle-foot orthosis (AFO). The AFO maintains the foot in a neutral position, thereby supporting ankle dorsiflexion during the swing phase and improving knee stability during the early stance phase. However, this benefit comes at the expense of restricted ankle mobility, which may predispose patients to the development of joint contractures. In addition, individuals often experience difficulty rising from a chair, and report discomfort associated with prolonged orthosis use. From a practical standpoint, many users also perceive the bulky and unesthetic design of conventional AFOs [7].

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Several limitations of AFOs can be addressed by functional electrical stimulation (FES). Using a stimulator positioned on the lower leg, FES enables active ankle dorsiflexion during the swing phase of the gait cycle [8]. In addition to its immediate orthotic effect, which can be observed from the onset of stimulation, a training effect has been described, reflected by progressive improvements in gait performance during stimulated walking as a result of long-term use. Moreover, a therapeutic effect has been reported, indicated by improvements in gait that persist even after the stimulator is removed. These effects are thought to arise from changes in neural plasticity, peripheral muscle strength, and cardiorespiratory function [7].

Principles of motor learning required for activity-dependent plasticity of the central nervous system include the facilitation of near physiological movement patterns, active engagement of target muscles, focused attention, and task-specific practice with a high number of repetitions [9]. Unlike the use of an AFO or unstimulated voluntary movement, all of these principles can be addressed through the application of FES. A potential limitation, however, is achieving a sufficient frequency of task-specific practice. It is generally assumed that the induction of lasting neural changes and the optimization of motor learning require a high volume of repetitions, which standard rehabilitation programs, predominantly delivered in outpatient settings, are often unable to provide [10]. For this reason, some clinical centers have begun to offer individualized home-based FES training programs, in which the device is temporarily provided to the patient and used during routine mobility activities in the home and community environment [11].

This study aims to present three cases of patients with neurological impairments who underwent a several month home-based FES program. The study illustrates how patients with different baseline levels of mobility were able to integrate FES into their routine mobility-related activities, and describes their functional progression and overall patient-reported feedback.

Methods

Study design

This retrospective descriptive case series was conducted as part of standard rehabilitation care at the Center for Mental Balance (CEDR), Pardubice, Czechia, between February and October 2025. The aim of the study was not to evaluate overall treatment effectiveness, but to illustrate the potential role and effects of a home-based FES program across a heterogeneous group of patients with differing levels of neurological impairment. Patients were therefore intentionally selected based on their baseline level of mobility and functional limitation.

All participants were informed in advance about the study procedures, potential risks and benefits, and the possibility of publication of anonymized data. Written informed consent was obtained from all participants before inclusion. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Inclusion criteria

Inclusion criteria comprised patients with neurological impairments presenting with gait dysfunction in the form of foot drop, who were medically stable and without evidence of cognitive deficit.

Exclusion criteria included acute or systemic conditions such as febrile states, active bacterial infections, including tuberculosis, suspected malignancy, cachexia of any etiology, bleeding disorders, and inflammatory conditions in the treatment area. Patients were also excluded in the presence of cardiovascular disease, sensory disorders, lower limb fractures or dislocations, conditions adversely affected by movement, or unexplained pain treated with electroanalgesia without a confirmed etiology. Additional exclusion criteria comprised psychopathological syndromes, pregnancy-related conditions including menses, skin-related contraindications such as inflammation, trophic changes, irritation, or damaged skin at the electrode site, as well as the presence of electronic or metal implants.

Intervention

Before the initiation of the intervention, all patients completed a set of baseline questionnaires assessing fear of falls, limitations in activities of daily living, and mobility. The first therapy session was conducted at the rehabilitation center, where both patients and their family members received comprehensive instruction on device setup and use of the FES system (BTL Walk, BTL Industries Ltd.).

Patients were instructed and trained in a recommended procedure for FES setup and initiation. The stimulator was applied to the lower leg using a cuff while seated, with the hip, knee, and ankle positioned at approximately 90° flexion, or with the knee slightly flexed and the foot resting lightly on the heel (Figure 1). Stimulation intensity was gradually increased until visible ankle dorsiflexion was achieved. Electrode position and stimulation parameters were adjusted to maintain the foot in a neutral position and to avoid excessive inversion or eversion. Final adjustments were performed during walking, with parameters individualized according to patient comfort and functional response.

Following this initial session, the device was loaned to the patients for home-based rehabilitation, to be used according to their individual time availability and preferences. Subsequent visits to the rehabilitation center were limited to regular follow-up consultations and clinical checks. The therapeutic program, including its intensity and overall duration, was individually tailored to each patient's functional abilities, opportunities, and preferences.

During scheduled outpatient consultations, patient-reported feedback was systematically collected, focusing on the regularity of FES use, perceived benefits and challenges, overall satisfaction, and additional remarks related to home-based application, including transportation-related barriers. Upon completion of the home-based program, patients were asked to complete the same set of questionnaires as at baseline to allow evaluation of functional changes over time.

Outcome measures

Patient progress was assessed using several validated questionnaires, including the Activities-specific Balance Confidence (ABC) scale, the Patient Specific Functional Scale (PSFS), and the Rivermead Mobility Index (RMI).

The ABC scale is designed to evaluate patients' confidence in maintaining balance during various activities. It consists of 16 items, each rated on a scale from 0 (no confidence) to 10 (full confidence). The total score is expressed as a percentage of the maximum possible score, with values below 50% indicating low, 50–80% moderate, and above 80% a high level of functioning [12].

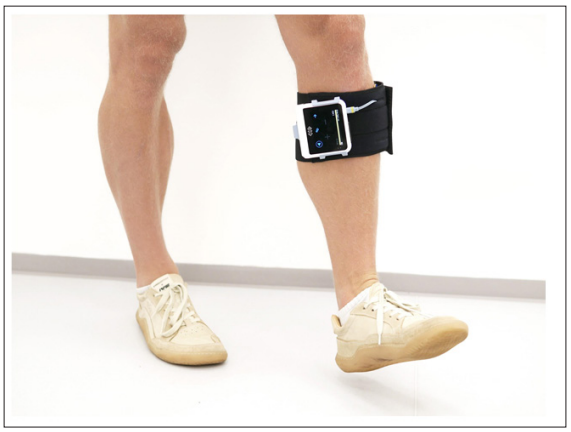

Figure 1: Example of FES stimulator placement during walking.

The PSFS allows assessment of patient progress in activities that were perceived as most limiting prior to the initiation of treatment. Patients are asked to identify up to five activities during which they experience significant limitations or are unable to perform the activity due to the treated condition. Each activity is rated on a numerical scale from 0 (unable to perform) to 10 (able to perform at the prior level of function) [13].

The RMI evaluates patient mobility using a 15-item questionnaire. Each item is scored dichotomously as 0 (unable to complete the task) or 1 (able to complete the task). The final score is calculated as the sum of all item scores, with higher values indicating greater mobility [14].

Data analysis

Given the descriptive nature of this case series and the small sample size, no statistical analyses were performed. Changes in outcome measures are presented as pre–post values at the individual level for each patient. Patient reported feedback and subjective evaluations are presented in a descriptive narrative form.

Case presentations

Case 1

A 51-year-old male patient with ischemic stroke participated in a seven-month home-based FES program. During outdoor ambulation, he routinely used one forearm crutch, while indoor walking was performed without an assistive device. At baseline, the RMI score was 13 points, indicating relatively preserved mobility. In contrast, the ABC score was low at 24%, reflecting reduced balance confidence. This was further supported by a low overall PSFS score of 1.0, indicating substantial limitations in patient-identified functional goals.

Following an initial training session at the rehabilitation center, the patient initially required assistance from his spouse with proper application of the stimulator. Over time, he became fully independent in donning the device, adjusting stimulation parameters, and initiating therapy according to personal comfort and functional needs. The patient used single-channel MEMS-triggered stimulation across a variety of mobility scenarios, including level walking, stair ascent and descent, uphill and downhill walking, treadmill walking, and travel using public transportation. With FES assistance, the patient was able to negotiate obstacles of approximately 15 cm in height, which enabled stepping onto the boarding step of most public transport vehicles.

During the first six months of the program, the patient used FES for approximately two hours daily. Subsequently, the regimen was modified to approximately two hours every other day, with increased incorporation of walking without stimulation and a greater focus on gait quality training. Based on self-reported usage, the total exposure was estimated at approximately 390-400 hours.

Subjective feedback was positive. The patient reported increased confidence during walking, a noticeable increase in walking speed, and expressed a desire to continue the intervention.

After seven months of training, the RMI score increased from 13 to 14 points, with one point still missing due to the inability to run. The ABC score improved to 54%, and the overall PSFS score increased to 4.75 points. A detailed breakdown of individual PSFS activities and pre–post comparisons is presented in Figure 2.

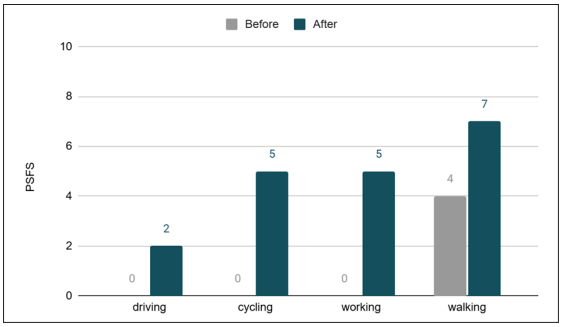

Figure 2: Detailed visualization of PSFS scores before and after completion of the home-based FES program in Case 1. Scores are presented at the individual level.

Case 2

A 56-year-old male patient with ischemic stroke and a history of right femoral neck fracture treated with subsequent total hip arthroplasty participated in a 4.5-month home-based FES program. The patient ambulated with two forearm crutches. At baseline, mobility assessed by the RMI was 7 points, indicating markedly reduced mobility. Balance confidence was very low, with an ABC score of 12%. This was consistent with a low PSFS score of 2.5, reflecting substantial limitations in daily activities.

During the initial training session at the rehabilitation center, the patient's partner was instructed in device application and setup and subsequently assisted with preparation of the stimulator prior to each use. The patient used single-channel MEMS-triggered stimulation. The training program was performed daily for approximately 30 minutes and included not only level walking

but also stair ascent and descent, uphill and downhill walking, and treadmill walking. As the use of public transportation represented a significant challenge, mobility training in the community environment was primarily limited to barrier-free public transport vehicles. The total exposure was estimated at approximately 65-70 hours.

The patient evaluated the intervention positively. According to his subjective feedback, the use of FES enabled faster walking and improved foot clearance. The patient expressed a desire to continue the intervention.

After 4.5 months of training, the RMI score increased from 7 to 10 points. The ABC score improved to 22%, and the overall PSFS score increased to 4 points. A detailed breakdown of individual PSFS activities and pre-post comparisons is presented in Figure 3

Figure 3: Detailed visualization of PSFS scores before and after completion of the home-based FES program in Case 2. Scores are presented at the individual level.

Case 3

A 44-year-old female patient recovering from traumatic brain injury participated in a 3-month home-based FES program. The patient was able to ambulate independently without any assistive devices, which was consistent with a high baseline RMI score of 14 points. Despite this, balance confidence assessed by the ABC scale was reduced, with a score of 51%. The PSFS score of 5 points reflected relatively preserved functional independence in daily activities, albeit with persisting limitations.

During the initial training session at the rehabilitation center, the patient's parents were instructed in device application and setup and subsequently assisted with preparation of the stimulator prior to each use. The patient used single-channel MEMS-triggered stimulation. The training program was performed daily for approximately one hour and included level walking, stair ascent and descent, uphill and downhill walking, and treadmill walking. The total exposure was estimated at approximately 85-95 hours.

The patient evaluated the intervention positively. According to her subjective feedback, the use of FES enabled noticeably faster walking, and she expressed a desire to continue the intervention.

After three months of training, the RMI score remained unchanged at 14 points, as the patient was still unable to run and therefore did not achieve the maximum score. Balance confidence improved, with the ABC score increasing to 72%. The overall PSFS score increased to 6.4 points. A detailed breakdown of individual PSFS activities and pre–post comparisons is presented in Figure 4.

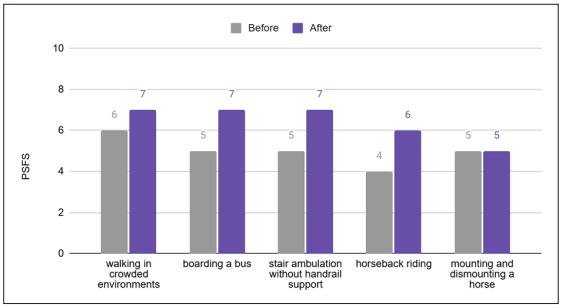

Figure 4: Detailed visualization of PSFS scores before and after completion of the home-based FES program in Case 3. Scores are presented at the individual level.

Visual comparison of individual patient progress in terms of RMI and ABC scores is presented in Figures 5 and 6, respectively.

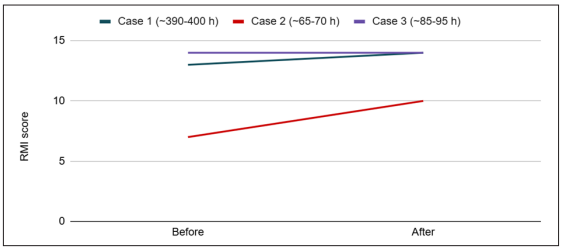

Figure 5: Individual pre-post changes in RMI score across the three cases. Estimated total exposure to home-based FES is indicated in the legend and is based on self-reported typical use.

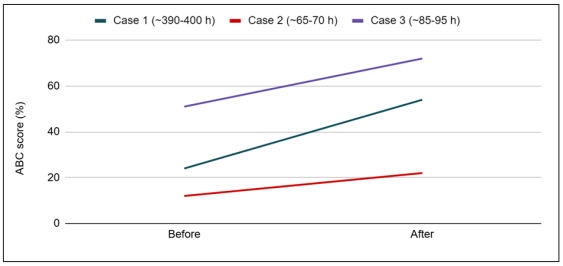

Figure 6: Individual pre-post changes in ABC score across the three cases. Estimated total exposure to home-based FES is indicated in the legend and is based on self-reported typical use.

Discussion

The present case series demonstrated the feasibility of a home-based FES program in patients with differing levels of baseline mobility. All three patients were able to integrate the intervention into their routine mobility activities and achieve relatively high cumulative exposure to stimulation, which would have been difficult to attain within a conventional outpatient rehabilitation setting. Across cases, this more intensive approach was associated with functional improvements and increased balance confidence.

The intentionally selected heterogeneity of cases, in terms of baseline mobility as well as program intensity and duration, allowed illustration of different use scenarios and potential roles of a home-based approach. Case 1 demonstrated a long-term and intensive protocol in a patient with marked functional limitations, primarily targeting improvement in gait quality both with and without stimulation and gradual progression toward greater independence in daily life. In contrast, the more severe functional impairment observed in Case 2 was associated with a

role of FES focused mainly on facilitating safety and improving mobility during active stimulation. Finally, recovery following traumatic brain injury in Case 3 suggested that a home-based FES program may also serve as a short-term facilitator of recovery, with the patient achieving substantial functional independence and increased balance confidence within three months.

Estimated training doses of FES varied substantially across the individual cases. While Case 1 involved an estimated exposure of approximately 400 hours, the cumulative dose in Case 2 likely did not exceed 70 hours. Nevertheless, even the lower end of exposure observed in this series represents a substantially higher training volume than would typically be achievable within standard outpatient rehabilitation practice. In addition, transportation was repeatedly identified in patient-reported feedback as a significant barrier, even during active stimulation. Daily travel to outpatient therapy would therefore likely represent a limitation not only in terms of time and financial burden, but also from a practical perspective, particularly for individuals with neurological impairments. High numbers of repetitions of desired movement patterns are considered a key prerequisite for motor learning and activity-dependent neural plasticity [9]. In this context, a home-based FES program may extend access to therapy for patients for whom regular outpatient rehabilitation would otherwise be inaccessible or impractical.

The observed improvements should be interpreted in the context of differing baseline functional levels, variability in program intensity and duration, as well as the type and chronicity of neurological impairment. The findings suggest that treatment effects are not uniform across similar indications, and that early and clear communication of realistic expectations regarding potential benefits and achievable progress may be critical for maintaining patient motivation.

In patients with higher baseline RMI scores, even a one-point change may represent a meaningful improvement in mobility. In contrast, ABC and PSFS scores appeared to be more sensitive to subjective changes in perceived safety and independence in daily activities within this cohort.

The primary limitation of this study is the small sample size inherent to a case series design. Evaluation of the effectiveness of home-based FES in neurological populations would require larger-scale research, ideally conducted in a more homogeneous patient cohort with a standardized intervention protocol and an appropriate control group. In the present study, it is not possible to fully disentangle the effects of the intervention from spontaneous recovery, particularly in Case 3, where a degree of natural functional improvement can be assumed.

In addition, the estimated stimulation dose was derived from patient-reported frequency and typical session duration rather than objective device logs. While this approach was sufficient for the descriptive and exploratory purpose of the current study, more precise dose quantification would be desirable in future research.

Overall, this case series highlights the potential role of home-based FES as a complementary approach to conventional rehabilitation, particularly for neurological patients with limited access to outpatient care or significant transportation barriers. The findings underscore the importance of individualized intervention planning tailored to patient-specific needs and capacities, as well as the critical role of adequate education of patients and, where appropriate, their relatives or caregivers. Although the individual cases differed substantially in terms of FES integration into daily activities and the magnitude of observed changes, all three patients reported subjective satisfaction with the intervention and expressed a desire to continue treatment.

Conclusions

The present case series demonstrated the feasibility of a home-based FES program in neurological patients with differing levels of baseline mobility. Through an individualized approach, FES was successfully integrated into routine daily mobility across all cases, with varying stimulation doses, and was associated with improvements in functional mobility, activities of daily living and balance confidence.

The findings suggest that home-based FES should be considered as a complementary extension of conventional rehabilitation, particularly for patients facing transportation barriers or limited access to outpatient care. Individualized program design, appropriate education of patients and caregivers, and early communication of realistic expectations appear to be key factors for successful implementation and sustained engagement. Further research in larger and more homogeneous cohorts is warranted to better define the effectiveness, optimal dosing, and long-term role of home-based FES in neurological rehabilitation.

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