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Case Report

The effects of FES-ambulation training on locomotor function and psychological well-being after a stroke: A case report

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ABSTRACT

The purpose of this case study was to investigate the effects of 8 weeks of functional electrically stimulated (FES)-ambulation training on locomotor function and psychological well-being in a 50 year-old women, 8 months post-stroke. The (FES)-ambulation training was performed at a frequency of 3 times per week for 8 weeks. Outcome measures for locomotor function included the 6-minute walk test, the 10 meter walk test and the timed get-up-and-go test. Measures of psychological well-being included the Perceived Stress Scale (PSS), the Center of Epidemiological Studies for Depression Scale (CES-D), the Perceived Quality of Life Scale (PQOL) and an internally developed 8-item questionnaire regarding task self-efficacy for walking. Following training, the participant made improvements in the 6-minute walk test (165.2 m to 242 m), the 10 meter walk test (0.35 m/s to 0.69 m/s) and the timed get-up-and-go test (32.7 s to 14.9 s), and these outcomes continued to improve though 8 weeks of follow-up. The participant also showed decreased stress and depression and increased task self-efficacy and quality of life, however, only the latter two outcomes remained improved after follow-up. In conclusion, FES-ambulation training may be a promising means to improve locomotor function and psychological well-being in individuals who have suffered a stroke.

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KEYWORDS: functional electrical stimulation, ambulation training, stroke, psychological well-being

INTRODUCTION

Following an ischemic stroke, individuals commonly have deficits in motor function that affect their ability to walk independently. This inability to walk, in turn, can have many negative effects on an individual's quality of life as it may compromise his or her ability to fulfill social roles and successfully complete activities of daily living [1]. Thus, rehabilitative strategies that target walking are highly valued after stroke.

The effects of body-weight support treadmill training (BWSTT) on locomotor function after stroke are equivocal. There is some evidence that this form of therapy improves both walking speed and endurance. For example, older adults and those with severe impairments have been shown to fair better with BWSTT than with over-ground walking training [2]. However, a recent Cochrane review (including 44 studies with over 2600 total participants), concluded that people who receive treadmill training after stroke, with or without body weight support, are not more likely to improve their ability to walk independently compared with people not receiving treadmill training after stroke [3].

The limitations of BWSTT as a means to improve ambulation after stroke are unclear. However, it is possible that the partially passive nature of the exercise (especially in more impaired individuals who require greater assistance) does not allow for optimal engagement of lower limb musculature, and training effects are thus compromised.

Recently, functional electrically stimulated (FES)-ambulation training has become available and recent work from our laboratory has shown this form of therapy to improve locomotor function and psychological well-being in individuals with an incomplete spinal cord injury [4]. This mode of exercise rehabilitation is gait-specific, and focuses on enhancing lower limb muscle contractions through patterned electrically stimulated muscle contractions. The lower limbs are guided through a gait pattern using a motorized stepper that is similar to an elliptical movement; however this stepper has an additional footplate allowing for control of plantar flexion and dorsiflexion to add to specificity of the gait movement. Due to its combination of gait-specific exercise and FES, it may be possible that this form of exercise may also be ideally suited to enhance ambulation in individuals who have suffered a stroke. However, the effects of FES-ambulation training after stroke have never been examined.

The purpose of this case study was to investigate the effects of an 8-week thrice-weekly FES-ambulation exercise program on over-ground walking outcomes and measures of psychological well being in an individual 8 months post-stroke.

MATERIALS AND METHODS

Pre-intervention clinical course

The participant in this case study is a 50 year-old women who suffered an ischemic stroke 8 months prior to the inclusion of this exercise trial. The stroke occurred during an angioplasty procedure, and therefore immediate medical care was delivered, followed by admission into the hospital for 2 weeks where she was stabilized and observed. At the completion of this hospital stay, the participant presented with difficulties in forming speech and she had full paralysis in the right arm and right leg, although there were no deficits to sensory function on either side of her body.

Following stabilization, the participant underwent 8 weeks of in-patient physiotherapy that occurred 5 times per week for 90-120 minutes per session (in 30 minute blocks). This in-patient therapy included lower limb strength training, stationary cycling, standing with a walker and balance training with the Nintendo Wii. No FES therapy was delivered to the lower extremities, although it was used periodically on the right arm. Following this 8 weeks of in-patient therapy the participant could stand independently, and walk with a cane for approximately ten minutes in her home, but she still relied on a wheelchair for mobility in the community. The participant then began an 8-week out-patient therapy program which involved 1 hour of rehabilitation, 3 days per week, and included general exercise training (resistance training for the lower limbs and stationary cycling), as well as locomotor training such as supervised walking with a cane, standing with the use of parallel bars and range of motion exercises with the lower limbs. Following this out-patient therapy the participant was able to walk independently with a cane at home, although she relied on a wheelchair when out in the community, and she still complained of stiffness in the right ankle and right knee as well as a drop foot on the right side. As well, the right upper limb still presented with no movement. Physiotherapy was discontinued when the case no longer improved on locomotor milestones at assessments. There were no drug therapies administered during the physiotherapy period.

Upon the conclusion of out-patient therapy, there was a 2-month period of time during which the participant was not involved in a supervised, structured rehabilitation program, and she only performed upper and lower limb stretching at home twice per week, and balance training with the Nintendo Wii once per week. The current trial with FES-ambulation training, thus began 8-months post-stroke, and 2-months post rehabilitation. The participant gave her informed consent, and received medical approval, before engaging in any testing or FES-ambulation exercise. Ethical approval for this study was granted by the Brock University Research Ethics Board.

Assessments

Outcome measures were assessed 24-48 hours before the first exercise session (baseline testing) and again 48-72 hours after the last exercise session (post-testing). Post-testing occurred 48-72 hours after the last exercise session in order to ensure that any observed improvements were due to chronic adaptations rather than the acute effects of the last exercise session. In addition, outcome measures were taken at baseline, after 4 weeks of training, at the conclusion of the 8-week training program, and after an 8-week follow-up during which time the participant did not engage in any FES-exercise or other structured exercise program.

Measures of locomotor function

The 6-minute walk test was used to measure walking endurance [5]. The participant was informed prior to testing that if she was unable to walk continuously for 6 minutes, she was allowed to take breaks by either standing in place or sitting on a chair without stopping the timer. However, at both pre and post-testing the participant could walk continuously for 6 minutes. The 10 meter walk test was used to measure maximum walking velocity [5]. The participant was asked to walk as fast as she could, while maintaining balance and safety, for 10 meters. From this test, the average walking velocity over 10 meters was calculated. The 6-minute walk test and the 10 meter walk test both start with the participant standing, and a researcher was always present during these walking tests to ensure safety and provide verbal encouragement. The timed get-up-and-go test was used as a measure of overall locomotor function [6]. In this test, the participant began seated in a chair, and was then asked to stand up, walk 3 meters, stop, turn around, walk back to the chair and sit down. Timing started when the researcher said "go" which signaled the participant to get up from the chair, and the timer was stopped when the participant had returned to the chair and sat down.

The order of these tests was kept consistent from pre-testing to post-testing (the 6-minute walk test, followed by the 10 meter walk test, followed by the timed get-up-and-go), and there was 30 minutes between each test to ensure a full recovery before the subsequent test.

Measures of psychological well-being

The Perceived Stress Scale (PSS) was used to measure changes in perceived stress levels. The PSS is a self-administered, 10-item questionnaire that measures the amount of stressful situations experienced during the previous month [7]. The PSS uses a 5-point scale where a score of 0 indicates that no stressful situations were experienced in the previous month and a score of 4 indicates that stressful situations were experienced "very often". Thus, the higher the score the more often stress was perceived.

The Center of Epidemiological Studies for Depression Scale (CES-D) was used to measure depressive symptoms. The CES-D is a self-administered, 20-item questionnaire that assesses feeling states in the previous week [8]. The CES-D uses a 4-point scale where a score of 0 indicates that depressive symptoms were "rarely experienced" and a score of 3 denotes that depressive symptoms were experienced "most of the time". Thus, the higher the score, the more often depressive symptoms were experienced.

Perceived health-related quality of life was measured with the 15-item Perceived Quality of Life Scale (PQOL). This tool uses a 7-point scale where a score of 0 indicates "very dissatisfied" and a score of 6 indicates "very satisfied" [9].

Finally, task self-efficacy for walking was measured with an internally developed 8-item questionnaire. For each item, the participant rated her level of confidence, on a scale from 0-100, regarding a locomotor task. For example, questions included "How confident are you that you can walk 100 m continuously", "How confident are you that you can walk up a staircase consisting of 5 steps unassisted" and "How confident are you that you can walk down a staircase consisting of 5 steps unassisted". The average score from all 8 items was taken for the final score.

Intervention

The exercise protocol consisted of 8 weeks of FES-ambulation, with the RT600 (Restorative Therapies; Baltimore, MD), at a frequency of 3 times per week. Before the start of each exercise session, bi-polar gel electrodes were placed on the right lower limb only, over the quadriceps, hamstrings, gluteus maximus, tibialis anterior and both heads of the gastrocnemius. The electrodes were then connected to a stimulation cable that was, in turn, connected to a Sage box, which provided the electrical stimulation. The RT600 allows for individualized stimulation parameters to be sent to each muscle. For this study, the stimulation amplitude ranged between 35-45 mA (depending on the muscle and the amount of sensation at the corresponding dermatome), the pulse duration was consistently set at 250 µsec and the frequency was consistently set at 40 Hz. A harness was placed around the participant's waist and was connected, with hook clips, to a motor generated hoist. The participant was then lifted off the ground with the hoist and then lowered onto the foot plates of the RT600, where her feet were strapped in with Velcro straps. The hoist also provides variable body-weight support depending on the individual needs of the exerciser. Thus, the exerciser receives both FES and partial body-weight support during the exercise, and in a closed-loop fashion, such that when the exerciser begins to fatigue and needs more support, the intensity of the stimulation is increased so that the proper upright position is maintained. During the exercise, the RT600 ergometer moves the legs in an elliptical-like manner while the foot plates alternate the ankles between dorsiflexion and plantar flexion, providing a walking-like pattern. Therefore, this form of gait training is not as gait-specific as treadmill training, but rather, it is a combination of both elliptical and walking exercise.

Each exercise session began with a 5-minute passive warm-up, followed by up to 60 minutes of stimulated FES-ambulation. The exercise was progressed mainly by extending the duration of the exercise per session, as tolerated. Specifically, the participant completed 30 minutes of stimulated exercise on day 1, and quickly progressed to 40-60 minutes of stimulated exercise on days 5-24. The speed of ambulation (40 steps/min) and the required body weight support (0-5%) remained consistent throughout the 8-week training program.

RESULTS

The participant made large improvements in all three measures of locomotor function (Table 1). These improvements were apparent even at the 4-week testing session (mid-testing), and further improvements were experienced at the conclusion of the 8-week training program (post-testing). Importantly, all 3 measures of locomotor function continued to improve throughout the 8-week follow-up period.

The participant experienced decreases in depression and stress as well as increases in task self-efficacy and perceived quality of life (Table 2). These

Table 1. Measures of locomotor function.

Outcome	Pre-testing	Mid-testing	Post-testing	8-week follow-up
10 meter walk test (m/s)	0.35	0.46	0.69	0.74
6-minute walk test (m)	165.2	190.4	242.0	261.5
Get up and go (sec)	32.7	22.3	14.9	12.4

Table 2. Measures of psychological well-being.

Outcome	Pre-testing	Mid-testing	Post-testing	8-week follow-up
CES-D	25	31	15	26
PSS	22	25	17	23
Task self-efficacy (%)	62.5	87.5	98.75	98.75
PQOL	29	32	46	36

CES-D: Center of Epidemiological Studies for Depression Scale; PSS: Perceived Stress Scale; PQOL: Perceived Quality of Life Scale.

improvements were apparent even at the 4-week testing session (mid-testing), and further improvements were experienced at the conclusion of the 8-week training program (post-testing). Depression and stress returned to baseline values by the conclusion of the 8-week follow-up; however, the improvement in task self-efficacy was maintained. Perceived quality of life decreased somewhat during the 8-week follow-up, although it still remained higher than baseline values.

DISCUSSION

The purpose of this case study was to examine the effects of an 8-week, thrice weekly FES-ambulation training protocol on over-ground walking and psychological well-being on a 50-year old woman who had suffered a stroke 8 months prior. In this case, FES-ambulation training improved walking endurance, walking speed and overall locomotor function, and these measures continued to improve throughout the 8-week follow-up period. The fact that the participant's locomotor function continued to improve throughout the follow-up period suggests that she reached a level of independent walking ability by the conclusion of the training program, that allowed her to practice during follow-up and realize further gains. This is also consistent with several comments that the participant made during the training program (see below). Further, the FES-ambulation may have caused adaptations to both the peripheral and central nervous systems that persisted after the training program and prompted further improvements in ambulation [10]. It is unlikely that these locomotor improvements were the result of spontaneous recovery considering this intervention began after the case completed physiotherapy, and showed no further improvements with training on locomotor milestones. Regardless, the present case study suggests that FES-ambulation may be an effective gait training therapy for individuals after stroke. This is particularly encouraging considering the recent Cochrane review that concluded that people who receive treadmill training after stroke, with or without body weight support, are not more likely to improve their independent walking ability compared to people not receiving treadmill training after stroke [3].

Stress and depression also decreased during the 8-week training program, but then returned to baseline values after 8 weeks of follow-up. However, task self-efficacy and perceived quality of life also made improvements during training, and these measures remained higher than baseline after 8-weeks of follow-up. Improvements in perceived quality of life are obviously a desirable adaptation to exercise training. Improvements in task self-efficacy for walking may be less commonly appreciated, but still very important. When individuals lose confidence in their ability to walk independently, they are less likely to venture out of the house, and as a result they are more prone to social isolation and continued declines in health.

The locomotor improvements that were made by our participant are encouraging, and it is essential to put them into context regarding their clinical importance. In this regard there are well-established thresholds set for locomotor improvements that denote a clinically important difference in function for individuals who have suffered a stroke. For the 6-minute walk test, it has been established that an improvement of 50 metres is required for the change to be considered clinically important [11]. As a comparison, our participant improved by 76.8 metres at the conclusion of the 8-week training program, and by 96.3 metres when comparing her baseline test to her test following the 8-week follow-up period. Similarly, for the 10 metre walk test an improvement of 0.06 m/s has been established as a small meaningful change, while an improvement of 0.14 m/s has been established as a substantial meaningful change [11]. As a comparison, our participant improved by 0.34 m/s after the 8-week training program, and by 0.39 m/s when comparing her baseline test to her test following the 8-week follow-up period. Thus, after follow-up our participant had made improvements in her walking speed that almost tripled what is considered a substantial meaningful change. Regarding the get-up-and-go test, there are also threshold times that correspond to various levels of functional independence. Specifically, times greater than or equal to 30 seconds indicate functional dependence, while times between 20 and 30 seconds indicate that the individual has mobility problems, cannot go outside alone and requires a gait aid. Times between 10 and 20 seconds indicate that the individual has good mobility, can go outside alone and is mobile without a gait aid.

Lastly, times less than 10 seconds indicate normal mobility [12, 13]. Further, a score of fourteen seconds or more has been shown to indicate a high risk of falls [12, 14].

Thus, prior to training our participant's get-up-and-go scores reflected functional dependence, however, at the end of the 8-week training program and lasting through follow-up, our participant's score reflected good mobility with the ability to go outside alone as well as mobility without a gait aid. Further, in contrast to her pre-testing scores, her post-testing and follow-up scores indicated that she was no longer at a high risk of falls. These test scores and reference values are also in agreement with the actual functional changes that we observed in our participant. For example, prior to training, our participant had plateaued in her recovery and was dependent on a cane at home and a wheelchair in the community. After 8 weeks of training, and lasting through follow-up, our participant no longer needed a cane at home and, no longer used a wheelchair in the community. In fact, after the follow-up period, our participant reported that she will sometimes bring a cane on community outings, but only if she is unfamiliar with her surroundings, and often times she does not actually use it.

Limitations

Although the findings from this case study are encouraging, larger scale randomized control trials are still necessary before firm conclusions can be drawn regarding the use of FES-ambulation training following stroke. Likewise, although 8 weeks of training did confer locomotor benefits in our case study, our participant's gains had not yet plateaued at the conclusion of the 8-week training program, and thus, longer training protocols, possibly with more sessions per week, may have yielded better results. Further research is required to determine these dose response issues. In addition, our participant began her FES-ambulation training 8 months post-stroke, and it is unknown if her improvements would have been more impressive if she had started her training sooner after her event. Again, further research is required to determine the optimal time post-stroke for FES-ambulation training.

CONCLUSION

This case study suggests that FES-ambulation training may be a safe, feasible and promising means to improve locomotor function and psychological well-being in individuals who have suffered a stroke. The gains in locomotor function were well beyond what is required for a clinically meaningful difference, and improvements continued through the 8-week follow-up period. The improvements that were made in depression, stress and quality of life seemed to regress during the follow-up period and thus, these psychological adaptations may need continued exercise to persist. The gains in task self-efficacy for walking, however, were substantial and persisted through follow-up. Further research with larger samples is warranted to determine the place for FES-ambulation in the rehabilitative process following a stroke.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest to declare.

ABBREVIATIONS

BWSTT	:	Body-weight supported treadmill training
CES-D	:	Center of Epidemiological Studies for Depression Scale
FES	:	Functional electrical stimulation
PQOL	:	Perceived Quality of Life Scale
PSS	:	Perceived Stress Scale

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