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Effect of Electric Stimulation Training on Walking Ability of Patients with Foot Drop after Stroke

Background: Foot drop is a common symptom after stroke and causes walking disorders. Therefore, its proper treatment is important for improving the walking ability of patients with foot drop.
Objective: This study aimed to investigate the effects of electrostimulation during walking on the walking ability of patients with foot drop after stroke.
Design: Quasi-experial study.
Methods: The study enrolled 18 patients with foot drop after stroke. All subjects were assigned to the experimental or control group. The experimental group underwent electric stimulation during walking, while the control group used ankle foot orthoses. Both groups received treatment 20 minutes a day 5 times a week for 4 weeks. Outcome measures were assessed for walking and balance ability using the 10-m walking test (10MWT), 6-min walking test (6MWT), and Timed Up and Go test (TUG)
Results: After the intervention, both groups showed significant improvements in 6MWT and TUG results. However, the experimental group showed significantly better improvement on all tests than the control group.
Conclusion: The foot drop stimulator effectively improved the walking and balance ability of patients with foot drop after stroke.

Key words: *Stroke, Foot drop, Gait, Balance*

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INTRODUCTION

Foot drop is a common symptom after stroke that causes walking impairments due to difficulty in proper dorsiflexion of the ankle during the swing phase of walking.[1] During walking, the foot drop symptom causes an inefficient walking pattern of the hip and knee joints, which results in unstable walking and reduces balance ability.[2] This creates potential for falling and negatively affects daily activities. Therefore, rehabilitation therapy is important for improving the walking ability of patients with foot drop after stroke.

Various methods have been reported for the purpose of improving walking ability by relieving foot drop symptoms. Ankle foot orthosis (AFO) are commonly used in the clinic to improve the walking and balance ability of patients with foot drop. This method relieves foot drop symptoms during walking by limiting the movement of the ankle joint.[3] As a result, the use of AFO improves walking ability and enables, more safer, energy efficient gait.[4,5] However, because AFO is a compensatory strategy and not a therapeutic method, foot drop symptoms are only temporarily controlled during walking. Therefore, a therapeutically applicable method for recovering foot drop symptoms is still needed.

A foot drop stimulator (FDS) was recently introduced as a method for improving the walking ability of patients with foot drop after stroke.[2,6] FDS provides electrical stimulation to the peroneal nerves during the swing phase while walking, causing contraction of the tibialis anterior muscles.[7] As a result, dorsiflexion of the ankle joint is generated, which has the advantage of making a more normal walking pattern.[8] In other words, this method has a similar

effect to AFO because it has the immediate effect of relaxing foot drop during walking. In addition, FDS continuously provides electrical stimulation to the peroneal nerves during walking, aiding in neuromuscular re-education, muscle strength, and circulation and prevention of muscle atrophy.[9,10] Because research on FDS is lacking, its effects remain unclear. Therefore, this study investigated the effect of FDS on the walking and balance ability of patients with foot drop after stroke.

SUBJECTS AND METHODS

Subjects

The study enrolled 20 patients with foot drop after stroke. The selection criteria were as follows: hemiplegic paralysis after stroke, more than 3 months since stroke, foot drop symptoms during walking, ability to indoor walk with minimal assistance, fair or better ankle strength, Modified Ashworth Scale score for ankle joint stiffness of <2, and a Mini-Mental Status Examination score of ≥ 20. Ethical approval was obtained from the institutional review board before conducting the experiment.

Methods

In this study, 20 patients with foot drop after stroke were assigned to the experimental or control groups based on hospitalization numbers. The experimental group applied FDS (Walkami, Seoul, Korea) for electric stimulation during walking (Figure 1). The FDS detects angular changes based on accelerometers and gyroscopes to provide electrical stimulation to the target nerve. In other words, electrical stimulation is provided when the angle of the knee joint changes for the swing phase of walking, resulting in dorsiflexion of the ankle joint. In this study, a pair of FDS electrodes was applied to the peroneal nerve of the lower extremity of patients (near the head of the fibula, directly over the motor nerve and proximal musculature). All patients walked indoors with an FDS with minimal assistance from a physiotherapist. In contrast, the control group used AFO for walking training for the same space and time as the experimental group. Both groups were trained five times a week for 4 minutes and 20 minutes a day using their respective equipment. Both groups received an additional 30 minutes of traditional physical therapy per day for 5 days for 4 weeks.

Outcome measurements

In this study, walking and balance ability was assessed using a 10-meter walking test (10MWT), a 6-minute walk test (6MWT), and a Timed Up and Go test (TUG) The 10 MWT measured the time required for the subject to walk 10 meter on a course that was a distance of 14 meter. Tape, at 2 m and 12 m, indicated the start and end point of the 10-meter walking distance. The first and last 2 meter of the course were not timed.[11]

The 6 MWT was performed only once because of its challenges to the subjects. Each subject went as far as he or she could go, and in cases where the patient gave up or had difficulties, the test was immediately stopped, and the distance walked in that time was measured and used for data analysis.[12]

Balance ability was assessed using a TUG. TUG is a simple test that can quickly measure mobility. TUG measured the time that the subject took to rise from a 46-cm height armchair, walk 3 m, turn around as fast as possible in the direction of the affected side, walk back to the chair, and sit down. [13]

Statistical analysis

The statistical analyses were performed using SPSS version 15.0 (IBM Corporation, Armonk, NY, USA). The normality of the variables was assessed using the Shapiro-Wilk test. Descriptive statistics are presented as means with standard deviations. To evaluate the intervention effects, the Wilcoxon signed-rank test was used to compare measures pre- and post-intervention in each group. The Mann-Whitney U test was used to compare the intergroup changes in outcome measures. Significance level was set at $p<0.05$.

RESULTS

General characteristics of the subject

The study included 18 subjects. However, two of them were dropped out (discharge) and a total of 18 data were analyzed (Table 1). There were no significant differences in the baseline characteristics between groups ($p>0.05$).

Effect on walking and balance

The experimental group showed statistically significant improvement in 10MWT, 6MWT and TUG evaluations ($p<0.05$). In addition, the control group also showed a significant improvement in the 10MWT,

Table 1. General characteristics of the subject

	Experimental group (n = 9)	Control group (n = 9)
Gender (man/woman)	5/4	4/5
Age (years)	61.5 ± 5.6	60.4 ± 7.0
Paratic limb (right/left)	4/5	6/3
Stroke onset (weeks)	18.2 ± 2.1	20.3 ± 3.3

Table 2. Comparison of 6MWT, 10MWT and TUG values between the experimental group and control group

Variables	Experimental group (n = 9)			Control group (n = 9)			Inter-groups P values
	Pre-test [mean (SD)]	Post-test [mean (SD)]	P	Pre-test [mean (SD)]	Post-test [mean (SD)]	P	
6MWT (m)	333.98 (10.63)	366.36 (11.03)	.012	333.03 (8.43)	352.16 (10.26)	.012	.026
10MWT (s)	13.98 (0.64)	11.02 (0.95)	.012	13.89 (0.59)	11.72 (0.95)	.012	.247
TUG (s)	14.27 (0.82)	10.55 (0.71)	.009	13.93 (0.63)	11.89 (1.02)	.012	.048

6MWT, 6-m walk test; 10MWT, 10-min walking test; TUG, timed up and go test.

6MWT and TUG evaluation ($p<0.05$). On the other hand, after the intervention, the two groups were compared and the experimental group showed a significant improvement in 6MWT and TUG than the control group ($p<0.05$).

DISCUSSION

This study investigated the effects of FDS on the walking and balance ability of patients with foot drop after stroke. After the intervention, participants in the two groups showed significant differences in their 6MWT, and TUG assessments, indicating that the FDS was more effective for walking and balancing than AFO.

FDS has a function similar to AFO because the electrical stimulation enables safer walking by causing dorsiflexion of the ankle joint during walking. Previous studies compared the effects of FDS and AFO in a gait analysis. FDS and AFO reportedly had similar effects on the walking ability of patients with foot drop,[8] but only their immediate effects were reported. Therefore, to investigate the therapeutic effect of these methods, it is important to confirm the therapeutic effects of each approach.

AFO and FDS differ in their rehabilitation strategies. AFO has an immediate effect of relieving foot drop symptoms during walking by restricting the movement of the ankle joint, but this is a compensatory strategy. This is because it guarantees immediate effects, but with the AFO removed, foot drop occurs again. In addition, AFO relaxes the foot drop simply by limiting the movement of the ankle joint, so there is little therapeutic effect on the walking ability.

In contrast, FDS involves a therapeutic and compensatory strategy that temporarily improves the walking ability by relieving foot drop symptoms using electric stimulation.[8,14] FDS can be expected to have therapeutic effects because it provides continuous electrical stimulation during the swing phase of walking. Previous studies have shown that electrical stimulation applied to the nerve roots is effective for re-education, muscle strength, and circulation through sensory input.[15-17] Therefore, electrical stimulation applied continuously to the peroneal nerve during walking may influence the retraining and strength of the tibialis anterior muscle, which may contribute to the improved walking ability. In addition, unlike AFO, FDS is fully open so that it can provide sufficient sensory input from the ground during walking. Sensory inputs entering the soles of the feet during walking with FDS are thought to be more effective than AFO as it can help maintain balance through proprioception.

The limitations of this study are as follows. First, the sample size was small, and the findings are difficult to generalize. Second, the absence of follow-up after the intervention did not permit the determination of long-term effects. Third, this findings do not

refiect a pure FDS effect because this trial performd the FDS together with conventional rehabilitation therapy.

CONCLUSION

This study demonstrated that FDS was a more effective method for treating walking and balance issues in patients with foot drop after stroke. Therefore, it is suggested as a therapeutic method to improve the walking and balance ability of patients with foot drop.

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