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Original Article

The immediate effect of FES and TENS on gait parameters in patients after stroke

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Abstract. [Purpose] This study was conducted to compare the immediate effects of different electrotherapies on the gait parameters for stroke patients. [Subjects and Methods] Thirty patients with stroke were randomly assigned either to the functional electrical stimulation group or the transcutaneous electrical nerve stimulation group, with 15 patients in each group. Each electrotherapy was performed for 30 minutes simultaneously with the therapeutic exercise, and the changes in the spatial and temporal parameters of gait were measured. [Results] After the intervention, a significant, immediate improvement in cadence and speed was observed only in the functional electrical stimulation group. [Conclusion] Based on this study, functional electrical stimulation that stimulates motor nerves of the dorsiflexor muscles on the paretic side is recommended to achieve immediate improvement in the gait ability of stroke patients.

Key words: Functional electrical stimulation, Gait, Transcutaneous electrical nerve stimulation

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INTRODUCTION

Common pathological gait patterns appear in patients after stroke[1, 2)]. Such gait patterns are characterized by increased double support duration on the paretic side and reduced swing phase duration, cadence, speed, and stride length[1)]. In particular, the asymmetric gait patterns in these patients result from the weakness of dorsiflexors and the spasticity of plantarflexors[2)]. Therefore, it is necessary priorly to figure out whether an increase of the dorsiflexors strength or a decrease of the spasticity of plantarflexors is required for immediate improvement of the gait ability for stroke patients.

Among therapeutic modalities, electrical stimulation is an effective intervention method for stimulating motor and sensory nerves[3)]. Functional electrical stimulation (FES) stimulates motor nerves in patients with upper motor neuron lesions[3)], leading to an increase of the dorsiflexor strength on the paretic side[4)], a decrease of gastrocnemius (GCM) muscle tone and stiffness[5)], and improvement of gait ability[6)]. On the other hand, transcutaneous electrical nerve stimulation (TENS) stimulates sensory nerves, causing pain relief[7)], and it increases the presynaptic inhibition, reducing the muscle tone, stiffness, and spasticity[8, 9)].

However, there have been few studies on the immediate comparison of spatiotemporal gait parameters between different kinds of electrical stimulation on the paretic side in stroke patients. This study aimed to propose an effective electrotherapy, applied simultaneously with an exercise therapy, to improve gait of stroke patients by comparing the immediate effects of FES and TENS on their gait ability.

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SUBJECTS AND METHODS

This study included patients hospitalized in Gyeonggi-do, South Korea, who had been diagnosed with stroke for more than 6 months. The included criteria for the study subjects were as follows: 1) those with the modified Ashworth scale of 2 or below, 2) those with the Brunnstrom stage 3 or above, 3) those who were able to perform dorsiflexion and platarflexion in a lying position. Participation was excluded for those whose cognitive function was reduced and who scored 24 or lower on the Korean version of the mini-mental state examination. The informed consent form was obtained from the subjects after the investigator explained the study's purpose and intent. This study was conducted in accordance with the principles of the Helsinki Declaration.

The subjects were divided randomly into the FES group (mean ± SD: age, 64.2 ± 9.7 years; height, 168.0 ± 6.8 cm; body weight, 69.8 ± 2.9 kg; time since stroke, 13.6 ± 3.7 months) and the TENS group (mean ± SD: age, 63.5 ± 8.6 years; height, 169.1 ± 9.4 cm; body weight, 71.0 ± 9.4 kg; time since stroke, 13.8 ± 3.2 months), with 15 patients per group.

The spatiotemporal gait parameters of the stroke patients were measured using an accelerator (G-waker, BTS Inc., Italy). This instrument has a high correlation with the motion analysis system[10]. The investigator inserted a G-sensor in the pocket of the belt and fixed it on the lumbar 4–5 of the subject. After the stabilization phase in a static standing posture was completed, the investigator instructed the subject to walk 8 meters straight forward in the usual walking method. Among the collected data, the data of cadence, speed, stride length, swing phase duration, stance phase duration, and double support duration on the paretic side were used in this study.

During this study, the interventions were conducted on days without an exercise schedule to rule out the variables that could affect the evaluation. All subjects were treated with the respective electrotherapy along with the therapeutic exercise for 30 minutes, and all interventions were performed by 1 physical therapist. The exercise method consisted of arm-stretching to different directions in a standing position, sit-to-stand, stepping forward and backward onto blocks, and forward step-up onto blocks.

For the FES group, FES (Microstim, Model GmbH, Germany) was used to stimulate motor nerves. The electrodes were attached to the TA motor point and below the fibular head in the paretic limb to induce dorsiflexion and eversion of foot, respectively. The flow of current was arranged in such a way that the current was to be carried through the heel switch when the paralyzed foot was heel-off from the ground during the therapeutic exercise. The frequency of 35 Hz, the pulse of 280 µs, and the intensity of the tolerance level of each subject were applied[8]. For the TENS group, TENS (Novastim CU-FS1, CU Medical Systems, Korea) was used to stimulate sensory nerves. An electrode for stimulating the sural nerve of the paretic limb was attached to the lateral malleolus level on the paretic side, and the other electrode was attached 10 cm above the lateral malleolus. In the program mode of electrotherapy, TENS was set to adjust the ranges of the frequency within 0–100 Hz and the pulse within 20–700 µs. The intensity was adjusted to prevent visible muscle contractions in each subject[8].

The Windows version of SPSS 20.0 was used for data analysis. For general characteristics of the subjects, the homogeneity of variance was verified by independent t-test, and the test of normality was verified by the Kolmogorov-Smirnov test. The paired t-test was used to determine the difference in the intervention effects within groups, and the independent t-test was used to compare changes after intervention between groups. All statistical significance levels in this study were set at $\alpha=0.05$.

RESULTS

There was no significant difference in stride length, swing phase duration, stance phase duration, and double support duration in both groups ($p>0.05$). Cadence and speed significantly increased after intervention only in the FES group ($p<0.05$). However, there was no significant difference in all gait parameters between the two groups (Table 1).

Table 1. Changes of spatiotemporal gait parameters on each electrical stimulation group

Variable	Functional electrical stimulation group (n=15)		Transcutaneous electrical nerve stimulation group (n=15)	
	Before	After	Before	After
Cadence (steps/min)	67.6 ± 14.3	80.58 ± 15.5*	74.2 ± 13.2	77.4 ± 23.8
Speed (m/s)	0.6 ± 0.1	0.78 ± 0.1*	0.7 ± 0.9	0.7 ± 0.1
Stride length (m)	1.1 ± 0.1	1.17 ± 0.7	1.1 ± 0.1	1.1 ± 0.1
Swing phase duration (%)	37.0 ± 5.6	39.95 ± 9.7	34.4 ± 7.0	36.9 ± 8.1
Stance phase duration (%)	62.9 ± 5.6	60.05 ± 9.7	65.5 ± 7.0	63.0 ± 8.1
Double support duration (%)	16.7 ± 4.0	17.95 ± 4.8	17.2 ± 7.1	15.3 ± 4.7

Values are means ± standard deviation.
*Significant difference between before and after the electrical stimulation in each group ($p<0.05$).

DISCUSSION

Neurological deficits after stroke result in asymmetrical gait disturbance because of the weakness of dorsiflexors and the spasticity of plantarflexors[2]. The application of FES to the TA muscles on the paretic side has been shown to enhance the dorsiflexor strength[4] and decrease the medial GCM muscle tone and stiffness[5, 7]. Electrical stimulation (TA, soleus muscles) and hip joint passive movements immediately improved the gait speed of stroke patients[11]. In this study, the cadence and speed of gait were significantly improved only in the FES group. It seems that the intervention method, where both FES and the therapeutic exercise were applied together in the TA muscles on the paretic side, enhanced the gait speed immediately through the decrease of the GCM muscle tone stiffness and spasticity on the paretic side and the increase of the motor unit recruitment of TA muscles. The group receiving both electrical stimulation and a conventional physiotherapy showed a significant improvement in the timed up-and-go test compared to the group receiving TENS and a conventional physiotherapy[12]. Results of previous studies supports the results of this study.

In contrast, the TENS group of this study showed no significant difference in all gait parameters. It seems that the one-time application of TENS to the paretic limb of stroke patients has only a limited positive immediate impact on gait parameters.

This result suggests that the immediate intervention for a short period did not affect the gait parameters enough to generate differences between the two groups.

Although various gait parameters were examined in this study, this study has limitations in that it failed in evaluating the psychological effects on the subjects and the lower limb spasticity and dorsiflexor strength of the subjects. But, this study suggested that the simultaneous application of FES and a therapeutic exercise to the TA muscles on the paretic side improved the gait ability of the stroke patients immediately, which may be helpful for physical therapists to set short-term treatment goals for stroke patients.

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