

Effect of Gait Training Using Electrical Stimulation Elicited Flexion Withdrawal Reflex on Gait Pattern and Endurance in Patients with Incomplete Spinal Cord Injury

Kim JR¹, Lee YH¹, Kim YH^{2,3}, Chung YJ¹, Choi HS³, Kwon SJ¹

¹ Wonju College of Medicine, Department of Rehabilitation Medicine, Republic of Korea

² Institute of Medical Engineering, Yonsei University, Republic of Korea

³ Department of Biomedical Engineering, Yonsei University, Republic of Korea

juliang76@hanmail.net

Abstract

The flexion reflex, also known as the flexion withdrawal reflex is a polysynaptic, multisegmental spinal in which a complex flexion synergy occurs in the stimulated limb. The result is a rapid withdrawal response, which occurs at the spinal cord to protect the limb from damage. The aim of this study was to examine changes in gait patterns in patients with spinal cord injury after gait training designed to elicit flexion reflex of the hip. The gait training was conducted for four weeks by stimulating the foot sole area with functional electrical stimulation(FES) regularly matching the patient's normal walking pace. Gait patterns were analyzed before and after training using the VICON® motion analysis system, and walking distance, average heart rate were also measured. The knee moment and power significant increased during the loading response, compared with baseline measurements. At the same time, the maximum and minimum ROM of the knee shifted to normal values demonstrating the normal gait pattern.

1. INTRODUCTION

The weakened muscle of the limb and consequent gait disturbance undermine the quality of life in patients with spinal cord injury. The FES is widely used to recover muscle function of the limb. Many investigators have provided evidence that FES had positive effects on gait patterns in patients with spinal cord injury. This study examined the effects of the FES-based gait training designed to elicit hip flexion on gait patterns and endurance in 2 incomplete SCI patients whose functional recovery was stayed at a plateau.

2. METHODS

2.1. Subjects

Two patients with an incomplete spinal cord injury at the cervical level participated in this study. The subject 1 was 30 year old male and had been injured 20 months ago. The subject 2 was 36 year old male and had the accident 84 months ago.

Table 1. Clinical characteristics of subjects

Subjects	Age	Sex	Time	Neurological level
			Since injury (month)	
1	30	M	20	C7
2	36	M	84	C6

2.2. Gait evaluation

While walking with a walker at their normal walking pace on flat ground, heart beats (per minute), walking distance (m) and walking speed (m/s) were measured and averaged. Walking continued until subjects gave up. In addition, subjects were instructed to walk with a walker following the walking path (5 m in length) three times, and the dynamic ROM, moment and power of their knees were measured using VICON® motion analysis system. Two pre-tests were conducted separately with 2 weeks interval before FES-based gait training which lasted four weeks. A post-test was conducted following training. FES was not used for tests.

2.3. Electricla stimulation

FES was applied using Myomed 932, and the electrode was attached to the patient's the heel pad area and the medial arch area where weakness was severe (Fig.1). The frequency of FES was set at 20Hz, the pulse width at 0.3µs and the pulse duration at 1 second. Each

training was carried out for 15 minutes at the intensity of 45 mA in the beginning, which then increased to up to 70 mA during training. Subject 1 performed the gait training for 15 minutes a day, five days a week and four weeks in total with FES applied to the sole of the right foot. Subject 2 performed the same training for three times a week and four weeks in total with FES applied to the sole of the left foot. While walking comfortably with a walker, flexion withdrawal reflex was induced on lower limb under FES by applying an electrical stimulation for 1 second just prior to the swing phase. The onset time and the rest time of FES were maintained steadily matching the subject's walking pace.



Figure 1. Electrode arrangement; heel and medial foot

2.4. Statistical Analysis

Gait parameters were analyzed before and after training using two-standard-deviation band method. Based on mean and standard deviation of pre-test measurements, 2SD band was calculated. When a post-test measurement falls outside the 2SD band, the change was considered significant. The maximum and minimum values of ROM, moment and power of the stimulated knee were calculated as gait parameters and analyzed.

3. RESULTS

This study aimed to identify effects of gait training designed to elicit flexion reflex of the hip on gait patterns and endurance in incomplete SCI patients. Mean walking distance and mean heart rate measured during pre-tests and post-test are presented in Fig 2. Walking distance significantly increased after training in both patients. The mean heart rate was reduced in subject 1 after training. Based on the comparison of pre-test parameters and post-test parameters using two-standard-deviation band method, ROM of the knee joint

and knee joint moment and power generated during the loading response significantly increased. Increased knee joint moment and power are interpreted as the improvement of muscle and joint forces as well as gait pattern. Subject 1 showed the decreased degree of knee hyperextension and increased flexion range after training.

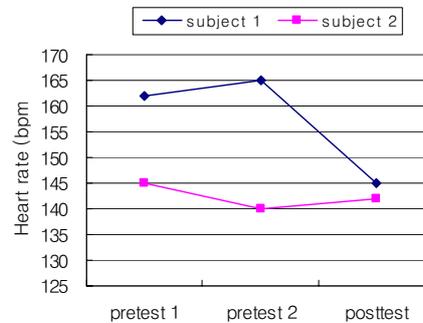


Figure 2 – Mean heart rate

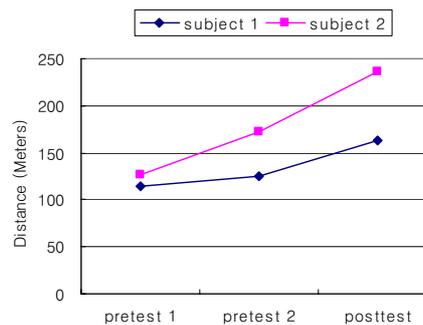


Figure 3 – Walking distance

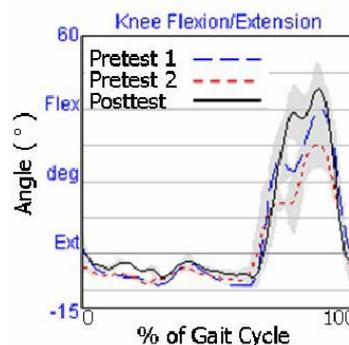


Figure 4 – Knee Angle (subject 1)

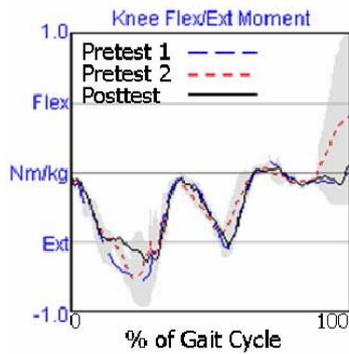


Figure 5 – Knee Moment (subject 1)

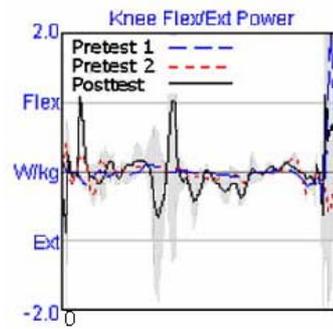


Figure 9 – Knee Power (subject 2)

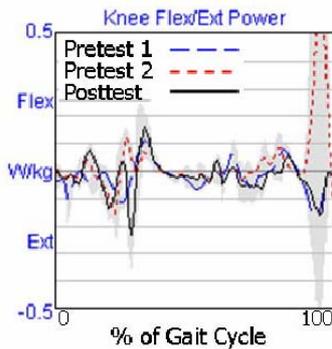


Figure 6 – Knee Power (subject 1)

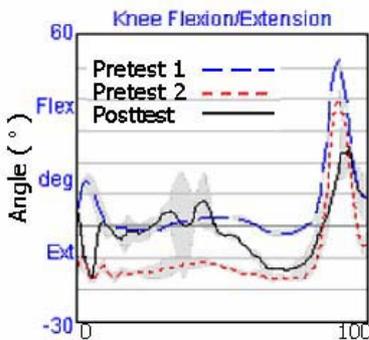


Figure 7 – Knee Angle (subject 2)

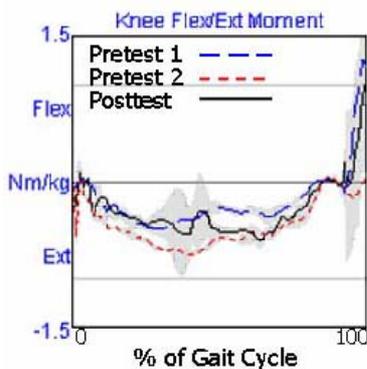


Figure 8 – Knee Moment (subject 2)

4. DISCUSSION AND CONCLUSIONS

This study was based on the assumption that flexion reflex of the hip induced during gait training would be effective for restoring neural conduction in the patient with chronic incomplete spinal cord injury after two years of injury. Flexion withdrawal reflex was elicited at the hip through the natural sensory input rather than the conventional FES approach that stimulates muscle directly. It was impossible to conclude that gait training designed to induce flexion reflex has rehabilitative effects. Still, the training proved to be ineffective to reduce muscle fatigue and control hip flexion but effective to improve gait patterns and endurance.

This study however has a few limitations. Only two subjects enrolled in the study, and the 4-week FES-based training period was not long enough to track changes in subjects. A further large-scale study is needed to ensure effects of gait training on incomplete SCI patients by extending the training period to several months or years and analyzing gait kinematics.

References

- [1] M Kinkou, BA Conway. Effects of electrically induced muscle contraction on flexion reflex in human spinal cord injury. *Spinal cord*, 43:640-648, 2005.

Acknowledgements

This study was supported by a grant (A05-0803-AG1101-06A2-00020B) of the Korea Health 21 R&D Project, Ministry of Health & Welfare, Republic of Korea, and partially by Regional Research Center Program which was conducted by the Ministry of Commerce, Industry and Energy of the Korean Government.