Effects of Gait Training Using Functional Electrical Stimulation on Stroke Patients’ Balance and Gait Velocity

The purpose of this study is to examine the effects of gait training using functional electrical stimulation on the improvement of hemiplegic patients’ functions for balance and gait velocity. The subjects of the experiment were determined to be 10 each hemiplegic patients who had been diagnosed with stroke or brain damage six months or longer earlier assigned to an experimental group and a control group respectively. The subjects were evaluated before the experiment using Tetrax and 10M gait tests, received gait training five times a week for four weeks using functional electrical stimulation and were evaluated after the experiment in the same method as used in the evaluation before the experiment. In order to examine differences between the experimental group that received gait training using functional electrical stimulation and the control group that was treated by functional electrical stimulation and received gait training thereafter, differences between before and after the experiment were analyzed using paired sample t-tests and differences in changes after the experiment between the experimental group and the control group were analyzed using independent sample t-tests in order to compare the two groups with each other. Experimental results showed significant differences in weight bearing, balance and gait velocity between before and after the experiment in the experimental group(p<.05). In the control group, whereas weight bearing and gait velocity did not show any significant difference between before and after the experiment(p>.05), balance showed significant differences(p<.05). Weight bearing, balance and gait velocity change rates showed significant differences between the experimental group and the control group(p<.05). In conclusion, it was indicated that gait training using functional electrical stimulation is effective for enhancing stroke patients’ weight bearing rates, balance abilities and gait velocity.

Key words: Back pain; LLD; Muscle Power; Flexibility; Spinal Decompression Therapy

INTRODUCTION

Hemiplegia or hemiparesis that occur secondarily due to stroke causes motor disturbance. This motor disturbance becomes a cause of asymmetric postures, abnormal physical balance, lack of the ability to move weight and the loss of special motor elements that perform fine functions. In particular, asymmetric standing postures and weight bearing hinder the establishment of normal movement patterns and disturb hemiplegic patients in maintaining standing postures(1). Hemiplegic patients are also disturbed in abilities to sit down or get up, abilities to recover balance and abilities to safely maintain balance while making functional movements by themselves(2), and they typically move weight more severely toward the sound side than toward the affected side(3). These unstable postures are quite general damage to hemiplegic patients and the recovery of balance thereafter is an essential element in activities in daily life(ADL),...
Therefore, one of functional objectives in the rehabilitation of hemiplegic patients is inducing symmetric standing postures and important basic items in the evaluation of central nervous system damage patients are balance and postural stability(4). Functional electrical stimulation therapies applied to hemiplegic patients in order to improve these conditions are improving the gait of patients with foot drop in most cases. For stimulation, functional electrical stimulation devices consisting of surface electrodes are commercialized. However, because of displeasure due to stimulation and the problem of the necessity to replace the electrodes every day, completely implanted electrode type devices have been developed and used in the USA and functional electrical stimulation devices with transcutaneous electrodes inserted near the common peroneal nerve that can be controlled with foot switches are used and studied in Japan(9). However, functional electrical stimulation therapies generally used in clinics do not provide finely differentiated selective stimulation as simply patches are attached and choices of treatment methods are not diverse among different patients but are uniform due to many temporal and spatial restrictions. In addition, because of the electrical stimulation that is continued constantly with passive movements and that fact that programs are operated in a limited space of wheel chair, states where patient's concentration is low can be frequently seen.

The purpose of this study is to promote the development of new functional electrical stimulation devices and present the direction of treatment methods.

METHODS

Subjects

The subjects of this study were 20 subjects selected from those who were diagnosed with stroke or brain damage and were hospitalized or being treated as outpatients in J Hospital in Gyeonggi-do between March and June 2011 and agreed to the study after the intent of this study was explained to the patients and their protectors. In order to obtain reliable statistical significance, the patients were randomly assigned to make an experimental group of 10 patients and a control group of 10 patients.

Selection conditions of subject in the study are as follows. First, hemiplegic patients diagnosed with stroke or cerebral infarction that occurred at least 6 months earlier. Second, those who can understand instructions and show appropriate responses to instructions. Third, those who show satisfactory ankle dorsiflexion at heel strikes during gaits induced by electrical stimulation without intolerable pain. Fourth, those who have no problem in their visual system or auditory system and can communicate while tests are being conducted. Fifth, patients whose ankle joints are not plantar flexed during gaits due to their paralyzed dorsiflexor of affected side or those who can independently walk at least 45m using or without using a stick.

Measurement Instruments

FES(Functional Electrical Stimulation)

The functional electrical stimulation device used during gait training consists of a Microstim(Medel Gmbh, inc., Germany) that can adjust frequency, contraction time, relaxation time and on-time, a foot switch and disposable surface electrodes(0,5cm). The stimulation conditions used were biphasic rectangular waves at a pulse rate of 35 pps, a pulse width of 250μs and a short on-time of 0,3sec so that electrical stimulation can be given as soon as the heel gets off the ground(Fig. 1).

![Fig. 1. FES(Functional electrical stimulation)](image)

TETRAX

The TETRAX which is a system for balance diagnoses and biofeedback training developed by Sunlight Co, in Israel was used to test weight bearing and balance. This treatment device was developed to measure the degree of risk of falls or the balance states of the body that has force plates installed on the rear and front sides of the left and right side feet respectively so that weight bearing and balance of each region can be tested and has a monitor on the front side that can be used for biofeedback training. Out of the results of measurement, the weight bearing shows the degrees of weight
bearing by the left and right side lower extremities and its values closer to 50% which is the weight bearing of normal persons indicate further improvement. The balance shows the measurement of posture shaking on the four force plates that shows the overall stability of the patients by comprehensively measuring the areas, lengths and speeds of shaking and the shapes of movements of the center of gravity and smaller values indicate further improvement (Fig. 2).

Fig. 2. TETRAX

10m gait velocity
As a scale to evaluate gait performance, 10m gait tests of which the reliability and validity have been proved in many studies were used (10). Lines were marked at points that are 2m away from the two ends of a 14m long walking path to establish sections for acceleration and deceleration. Walking time for 10m out of the walking path was measured three times using a stopwatch and the average values were used as a measurement variable for walking abilities.

Procedure
In this study, the relationship between lower extremity balance and gaits was explained to the subjects and agreements to the purpose and method of the experiment were received from the patients and their protectors before the commencement of the actual experiment. The TETRAX and 10m gait tests were used for measurement in both the experimental group and the control group. Evaluation was conducted before the experiment and then 5 times a week for four weeks after the experiment. The experimental group conducted gait training for 30 min using functional electrical stimulation and the control group conducted training for a total of 30 min consisting of 15 min of functional electrical stimulation therapy and 15 min of general gait training. In TETRAX evaluation, to measure affected side weight bearing and balance, the patient places two feet on the force plates, look 15° upward toward the front side with eyes open and keep two hands comfortably on the sides of body. During the measurement, the patient should stand without holding anything with hands for at least 30 sec.

Data Analysis
To examine differences between the experimental group that conducted gait training using functional electrical stimulation and the control group that conducted gait training after functional electrical stimulation therapy from the results of this study using SPSS version 12.0, differences between before and after the experiment were analyzed with paired sample t-tests and differences in changes after the experiment between the experimental group and the control group were compared by analyzing the values with independent sample t-tests. The tests were conducted under a statistical significance level of 5% or lower.

RESULTS

General Characteristics of Subjects
The general characteristics of subjects follows as Table 1. The subjects of this study is 11 male and 9 female, and the right hemiplegia patients were 9 and left hemiplegia patients were 11.

<table>
<thead>
<tr>
<th></th>
<th>Experimental group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Female</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31~40</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>41~50</td>
<td>1</td>
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<tr>
<td>51~60</td>
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<td>3</td>
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<tr>
<td>61~70</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>71~80</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Paralyzed side</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Left</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

The pre-treatment results and the post-treatment results are shown in Table 2, 3, 4 respectively. In the
weight bearing, balance and velocity of experimental group, there were significant differences between pre-training and post-training(p<.05). But balance only increased significantly at control group.

Table 2. Comparison between before and after the experiment in the experimental group

<table>
<thead>
<tr>
<th></th>
<th>Before the experiment</th>
<th>After the experiment</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing rate</td>
<td>40.26±6.65</td>
<td>43.76±4.59</td>
<td>2.535</td>
<td>.032*</td>
</tr>
<tr>
<td>Balance</td>
<td>28.43±6.89</td>
<td>32.66±6.31</td>
<td>-3.104</td>
<td>.013*</td>
</tr>
<tr>
<td>Velocity</td>
<td>27.06±7.27</td>
<td>22.42±7.37</td>
<td>3.517</td>
<td>.007*</td>
</tr>
</tbody>
</table>

*p<.05

Table 3. Comparison between before and after the experiment in the control group

<table>
<thead>
<tr>
<th></th>
<th>Before the experiment</th>
<th>After the experiment</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing rate</td>
<td>37.23±10.37</td>
<td>37.86±9.73</td>
<td>.787</td>
<td>.451</td>
</tr>
<tr>
<td>Balance</td>
<td>28.55±8.37</td>
<td>27.66±8.29</td>
<td>2.508</td>
<td>.033*</td>
</tr>
<tr>
<td>Velocity</td>
<td>26.88±10.67</td>
<td>26.53±10.75</td>
<td>.575</td>
<td>.579</td>
</tr>
</tbody>
</table>

*p<.05

Comparison of experimental group and control group

After training, all of the result of the weight bearing rate, balance rate and velocity rate increased significantly(p<.05).

Table 4. Change rates of the experimental group and the control group

<table>
<thead>
<tr>
<th></th>
<th>Experimental group</th>
<th>Control group</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing change rate</td>
<td>4.56±3.09</td>
<td>.62±2.51</td>
<td>3.124</td>
<td>.006*</td>
</tr>
<tr>
<td>Balance change rate</td>
<td>4.22±4.30</td>
<td>-.88±1.12</td>
<td>3.637</td>
<td>.004*</td>
</tr>
<tr>
<td>Velocity change rate</td>
<td>-4.64±4.17</td>
<td>-1.15±1.80</td>
<td>-2.428</td>
<td>.031*</td>
</tr>
</tbody>
</table>

*p<.05

DISCUSSION

In treatment of hemiplegic patients, enhancing ambulatory abilities is very important because walking is an essential element in achieving functional independence in stroke patients’ daily life(10).

Keenan et al, found that ambulatory abilities are highly correlated with the sense of balance and in many other studies, it has been reported that standing balance is significantly correlated with ambulatory abilities(11). The unstable standing balance of hemiplegic patients appears from their impaired equilibrium reactions. Most hemiplegic patients show unstable standing postures and large part of their weight is supported by their sound side(12). This asymmetry is known to be highly correlated with walking which is an important objective of physical therapy of hemiplegic patients and affect the recovery of ambulatory abilities(12).

Efficient gait training reduces patients’ energy consumption resulting from their compensating action and enhances patients’ ability to control the lower extremity muscles that are necessary for walking to
accelerate motor relearning, enhance coordination between upper and lower extremities and affect patients feeling of self satisfaction and stability(13). Hemiplegic patients generally place larger weight loads on their lower extremity on the affected side during standing postures while they are walking, their gait velocity is low and the walking base of their gaits on their affected side are shorter and thus are asymmetric with their gaits on their sound side(12, 14, 15). Therefore, the stance phases of their affected lower extremity are shorter(16). In general, in order to recover normal gait patterns, assisting devices are used to assist the weakened or paralyzed muscles on the affected side and prevent plantar flexion of the ankle joint. In the results of this experiment too, it is thought that balancing abilities were enhanced in the experimental group as a result of the symmetry of weight bearing rates of the two extremities leading to the enhancement of gait velocity, Liberson reported that foot drop during swing phases was corrected by implementing functional electrical stimulation for hemiplegic patients’ gaits and the functions of the tibialis anterior were maintained even after the stimulation was removed although temporarily(17). Thereafter, after studies of hemiplegic patients gait training using functional electrical stimulation, Stanic et al, reported that ambulatory abilities were enhanced when multi-channel functional electrical stimulators had been applied for four weeks(18), and Bogata et al, reported that when multi-channel functional electrical stimulators had been applied for three weeks to patients who could not walk, the patients’ ambulatory abilities were improved and their lower extremity muscles were activated(19). The results of these studies are consistent with the results of the present study. When the group of hemiplegic patients applied with basic physical therapy only for three weeks and the group applied with functional electrical stimulation were compared with each other, it was indicated that the walking functions and abilities for independent activities of the functional electrical stimulation group were improved more(13). Water et al, reported that they could observe relief of foot drop by conducting functional electrical stimulation on hemiplegic patients peroneal nerve during swing phases of their gaits(20), and Granat et al, reported that stimulation on the peroneal nerve showed direct effects for ankle dorsiflexion and ankle eversion during swing phases(21). In the present study too, the experimental group’s weight bearing, balance and gait velocity were significantly improved when gait training using functional electrical stimulation was applied(p<.05) and thus it was identified that the results were consistent with the aforementioned results of previous studies, In addition, it was concluded that gait training using functional electrical stimulation is more effective than gait training after functional electrical stimulation therapy. It is considered that the fact that differences could be seen among application methods even when the same treatment method was used is an outcome of the present study. It is also considered that continuous studies of differences in the effects treating devices depending on application methods are necessary.

CONCLUSION

In the present study, the effects of gait training using functional electrical stimulation were examined. The subjects of the study were 20 patients diagnosed with stroke or brain damage who were receiving physical therapy in J Hospital in Gyeonggi-do and these patients were divided into 10 in an experimental group and 10 in a control group and were treated 5 times a week for four weeks.

Gait training using functional electrical stimulation was implemented and the patients weight bearing rates and balance were measured using Tetrax and 10M gait velocity was measured in order to measure the degree of improvement in weight bearing and balance between before and after the experiment. The experimental group and the control group were compared and analyzed before and after the experiment and based on the results, the weight bearing, balance and gait velocity of the experimental group before and after the experiment showed significant differences(p<.05), while the weight bearing and gait velocity of the control group before and after the experiment did not show any significant difference (p>.05), although balance showed significant differences(p<.05). The rates of changes in weight bearing, balance and gait velocity of the experimental group and the control group also showed significant differences(p<.05).

In conclusion, it was indicated that gait training using functional electrical stimulation are effective for improving the weight bearing rates, balancing abilities and gait velocity of chronic stroke patients. It is considered that studies of new treatment methods for enhancing the functions of chronic stroke patients should be continued.
REFERENCES