

# A Pilot Study on the Effect of Functional Electrical Stimulation of Stroke Patients in a Sitting Position on Balance and Activities of Daily Living

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**Abstract.** [Purpose] This study investigated the effect of functional electrical stimulation (FES) of stroke patients in a sitting position on balance and activities of daily living. [Methods] FES was applied to stroke patients (six male, three female) while in a sitting and supine position. FES was applied six times for 30 minutes each for a total of six weeks. [Results] The timed up and go (TUG) values at weeks 2, 4, and 6 after FES treatment in a sitting position were noticeably decreased in a time-dependent manner, compared with controls. In the sitting, the functional reach test (FRT) values were significantly increased in a time-dependent manner. The same values in the supine position weakly showed a similar pattern to those in the sitting position. Furthermore, the functional independent measurement (FIM) values in the sitting position were markedly increased in a time-dependent manner. In the sitting position, the intensity of FES was markedly decreased in a time-dependent manner. The same values in the supine position weakly showed a similar pattern to those in the sitting position. [Conclusion] These results suggest that the conditions of stroke patients in both the sitting and supine positions after FES treatment were improved and that FES had a greater effect in the sitting position.

**Key words:** Functional electrical stimulation, Sitting position, Stroke patients

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## INTRODUCTION

A stroke is a type of cerebrovascular disease caused by blockage and tearing of blood vessels in the brain and results in brain damage and disability<sup>1)</sup>. The origin of the damage and its location and range determine the symptoms and prognosis<sup>2)</sup>. Generally, a stroke leads to functional disability and problems with movement, as well as problems with sensory, language, and visual processing<sup>3)</sup>. Many stroke patients experience hemiplegia<sup>4)</sup>, and 69% of patients with hemiplegia have a functional disability of movement of the upper limb<sup>5)</sup>. The disability is caused by muscle weakness, abnormal muscle tone, abnormal movement, lack of flexibility, and lack of coordination of voluntary motion<sup>6)</sup>. According to Duncan et al.<sup>7)</sup>, 40% of stroke patients have moderate functional damage, and 15–30% have severe damage problems affecting movement that limit their functional independence and quality of life by inhibiting their ability to

control and use their arms in activities of daily living<sup>8)</sup>. In some patients, the decrease in the use of the affected upper limb causes it to become weaker due poor muscle power and a lack of sensory ability<sup>9–11)</sup>. Stroke patients experience many problems with daily activities such as eating, washing, discharging, and dressing themselves. Therapy has to focus on improving independent movement to aid daily activities<sup>12)</sup>. The trunk plays an important role in maintaining a stable posture against gravity, that is, arrangement of the center of the body and maintenance of an independent posture for functional movement<sup>13)</sup>. It is important that trunk muscles maintain stability during antigravity postures such as sitting and standing and that they provide stability to the proximal region of the limbs<sup>14)</sup>. Posture in which the center of the body is high are very important for daily activity, functional movement, and aspects of physical therapy<sup>15)</sup>. Any change in the center of gravity in the body that decreases the base of support (BOS) causes an increase in muscle participation and activity. When the body moves with an unstable posture, that center is high. Thus, controlling the posture is more complex, and more muscles are

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used, thereby increasing the level of activity of the muscles. In physical therapy, a standing position with a narrow BOS and high muscle activity are more effective than a supine position with a wide BOS and low muscle activity<sup>16</sup>. FES is generally used in treatments because it has positive effects in terms of strengthening the muscles, preventing muscle weakness, improving the range of motion, and reeducating the muscles without damaging the peripheral nerves<sup>17, 18</sup>. In previous studies, exercise and electrical stimulus therapy were used to improve movement. However, there are concerns about the risks to stroke patients during physical therapy. The present study applied functional electrical stimulation (FES) to improve the efficiency of daily activities. FES poses less of a risk to the patients and requires less work, making it convenient and efficient for the therapist<sup>19</sup>. The standing position is commonly used in many daily activities, and a positive effect of therapy in this position has been demonstrated more often than in a supine position<sup>18</sup>. None of the patients could maintain a standing position for treatment. Thus, FES was applied to the patients in a sitting position. Some previous studies have applied FES in supine and sitting positions. The present study investigated the effect of FES applied in a sitting position and a supine position to the affected upper limb on daily activities of living.

## SUBJECTS AND METHODS

This study was conducted with nine patients (six male, three female) who had been diagnosed with stroke and hospitalized in G hospital located in Korea. The study was performed from December 2010 to December 2011. The inclusion criteria were as follows:

- The patient voluntarily consented to participate in this study.

- The patient acquired a score of over 24 on the Korean Mini-Mental State Examination.

- The patient could maintain a sitting position.

- The patient had no allergy to electrical stimuli.

A Microstim (MED-EL Deutschland GmbH, Starnberg, Germany) device was used to treat the patients. With this device, the frequency, contraction time, relaxation time, and current time can be controlled. It utilizes biphasic rectangular waves. The pulse rate was 35 pps, the pulse width was 250  $\mu$ V, the current time was 8 seconds, and the no current time was 11 seconds. The FES electrodes had a carbon-rubber surface. This surface is characteristically noninvasive, cheap, and easy to apply<sup>20</sup>. The intensity of the stimulus was gradually increased to maximum contraction based on a visual assessment of the level of the stimulus needed to elevate the scapula<sup>21</sup>. The time up and go (TUG) is a simple test that measures functional mobility, movement, and balance ability. The patient initially sat on a chair, walked forward 3 meters, and then returned to the chair. The TUG test was repeated three times. The functional reaching test (FRT) applied in a previous study was performed to confirm the patients' kinetic postural control ability<sup>22</sup>. The patients' functional reach was tested by placing a yardstick or a tape measure on the wall, parallel to the floor, at the height of the acromion of the subject's dominant

arm. The patient was first required to stand at a comfortable distance, make a fist, and then flex the unaffected arm to 90 degrees. The patient was then asked to reach forward as far as possible without touching the wall. The distance between the initial and final location was then measured using the top of the metacarpal of the third finger. All the measurements were performed twice, and the mean value was calculated. The functional independent measurement (FIM) designed by Granger et al. was used to examine the performance of the patients in daily activities<sup>23</sup>. The FIM comprised 18 parts, which were divided into exercise and recognition items, making it possible to assess the total disability. The exercise items consisted of four parts (self-help activities, urine and feces control, movement, and work), and the recognition items consisted of two parts (communication and social recognition). Unlike other tools, the FIM includes an assessment of social recognition. It uses a score sum of 1 to 7 according to the degree of help. The minimum score is 18, and the maximum is 126 score<sup>24</sup>. In stroke patients, a higher level of stimulus is needed on the affected side than the unaffected side because type I and IIa muscle fibers and muscle fiber capillaries are damaged, and the activities of contractile proteins such as myofibrillar ATPase and succinate dehydrogenase are decreased. Patients also exhibit a decrease in muscle power, a decrease in the speed of muscle contraction, and increasing muscle fatigue. The intensity of the FES stimulus needed to achieve maximum dorsiflexion was measured at intervals of two weeks. Data were expressed as the mean  $\pm$  standard error (SE). The statistical significance level using SPSS 12.0 was set to  $\alpha = 0.05$ . The frequency test was performed to analyze the general characteristics of the participants, and the independent t-test was used to confirm differences in the measured parameters between the patients before and after the FES. The protocol for the study was approved by the Committee of Ethics in Research of the University of Yongin, in accordance with the terms of Resolution 5-1-20, December 2006. Furthermore, all stroke patients provided informed consent for participation in the study.

## RESULTS

Table 1 summarizes the clinical characteristics of the participants in this study. The TUG values at weeks 2, 4, and 6 after FES treatment in a sitting position were markedly decreased in a time-dependent manner compared with non-stimulated (0 weeks) controls (Table 2). The TUG values in the supine position weakly showed a similar pattern to those in the sitting position (Table 2). Table 3 shows the results of the FRT both in the sitting and supine positions. In the sitting position, the FRT values at weeks 2, 4, and 6 after FES treatment were significantly increased in a time-dependent manner compared with non-stimulated controls (Table 3). The same values in the supine position showed a similar pattern to those in the sitting position (Table 3). Furthermore, the FIM values at weeks 2, 4, and 6 after FES treatment in a sitting position were markedly increased in a time-dependent manner compared with non-stimulated controls (Table 4). The same values in the supine position

**Table 1.** Clinical characteristics of hemiplegic stroke patients

Patient Characteristics	Test Position of Stroke Patients		Total
	Sitting	Supine	
Ages (yr)	56.6±5.1	63.0±3.7	59.4±3.3
Gender (M/F)	4/1	2/2	6/3
Height (cm)	167.6±4.0	163.8±3.3	165.9±2.6
Weight (kg)	67.0±5.4	69.8±3.5	68.2±3.2
BMI (kg/m <sup>2</sup> )	23.8±1.5	25.9±0.9	24.7±1.0
Etiology (CH/CI)	3/2	2/2	5/4
Time Post-stroke (mo)	4.6±0.7	5.0±0.6	4.8±0.4
Paretic Side (L/R)	2/3	2/2	4/5

Mean ± SE. BMI, body mass index; CH, cerebral hemorrhage; CI, cerebral infarction; M, male; F, female; L, left side; R, right side.

**Table 2.** TUG test in hemiplegic stroke patients in sitting and supine positions

Test Position of Stroke Patients	Functional Electrical Stimulation (BRW)			
	0 weeks	2 weeks	4 weeks	6 weeks
Sitting (Sc)	30.3±2.2	27.5±2.0	25.8±2.6	22.8±2.3*
Supine (Sc)	32.0±1.8	30.3±2.4	28.8±2.3	26.4±1.8

Mean ± SE. TUG, time up and go; Sc, score of TUG; BRW, biphasic rectangular waves. \*Significantly different from 0 weeks with  $p < 0.05$ .

**Table 3.** FRT in hemiplegic stroke patients in sitting and supine positions

Test Position of Stroke Patients	Functional Electrical Stimulation (BRW)			
	0 weeks	2 weeks	4 weeks	6 weeks
Sitting (cm)	14.7±1.0	18.6±1.3	22.3±1.8*	23.9±1.6*
Supine (cm)	15.9±1.1	15.8±0.8	18.2±1.5	20.0±1.5

Mean ± SE. FRT, functional reaching test; BRW, biphasic rectangular waves. \*Significantly different from 0 weeks with  $p < 0.05$ .

**Table 4.** FIM in hemiplegic stroke patients in sitting and supine positions

Test Position of Stroke Patients	Functional Electrical Stimulation (BRW)			
	0 weeks	2 weeks	4 weeks	6 weeks
Sitting (Sc)	86.4±4.2	96.0±3.8	99.0±4.0	103.2±2.6*
Supine (Sc)	93.8±2.4	96.0±2.3	98.8±2.5	101.0±2.0

Mean ± SE. FIM, functional independent measurement; Sc, score of FIM; BRW, biphasic rectangular waves. \*Significantly different from 0 weeks with  $p < 0.05$ .

**Table 5.** Comparison of the intensity of FES in hemiplegic stroke patients in sitting and supine positions

Test Position of Stroke Patients	Functional Electrical Stimulation (BRW)			
	0 weeks	2 weeks	4 weeks	6 weeks
Sitting (mA)	48.4±5.5	46.6±5.9	35.8±5.8	27.6±3.1*
Supine (mA)	48.8±6.7	39.8±3.9	39.3±5.5	32.0±3.4

Mean ± SE. FES, functional electrical stimulation; BRW, biphasic rectangular waves. \*Significantly different from 0 weeks with  $p < 0.05$ .

weakly showed a similar pattern to those in the sitting position (Table 4). Table 5 shows a comparison of the intensity of FES both in the sitting and supine positions. In the sitting position, the intensities of FES at weeks 2, 4, and 6 were no-

ticeably decreased in a time-dependent manner compared with non-stimulated controls (Table 5). But the same values in the supine position weakly showed a similar pattern to those in the sitting position (Table 5).

## DISCUSSION

In this study, we applied FES to stroke patients in sitting and supine positions for six weeks and found that the therapy had an effect on the patients' balance and activities of daily living. Verheyden et al.<sup>25)</sup> reported that stroke patients had functional disabilities such as difficulty with trunk control, unstable balance, and declining gait ability due to muscle weakness and sensory changes and that these changes affected activities of daily living. This study performed functional electrical therapy in a sitting position to improve these disabilities. FES is known to exert a greater effect on the upper limb than the lower limb because the flexion synergy during recovery is interrupted by the extension of the wrist and the fingers<sup>26)</sup>. There was an improvement in the ability of the lower limb but not the upper limb in this study. In previous studies, balance exercise in a sitting position induced the supporting of weight on the affected side and increased the muscle movement of the affected lower limb<sup>27, 28)</sup>. Thus, FES applied in a sitting position has a greater effect on inducing movement than FES applied in a supine position. A previous study of the use of FIM to determine the trunk control ability of stroke patients reported a correlation between trunk control, balance in a sitting position, and functional activities of daily living<sup>29)</sup>. This study found similar results, with a higher FIM score for improvement in balance ability after six weeks compared with the initial score. A weakness in muscle power and decrease in range of motion limit the functional activity and gait ability of patients. A decline in dorsiflexion is the most important risk factor<sup>30)</sup>. In the present study, FES improved the functional movement of the upper and lower limbs. Thus, FES can be expected to reduce patients' fears of falling. A previous study reported no significant difference in the effect of FES applied to patients in standing and supine positions<sup>18)</sup>. Likewise, in the present study, there was no statistical correlation between FES applied in the sitting and supine positions. However, FES exerted greater effects on patients in a sitting position compared with those in a supine position. Jennifer et al.<sup>31)</sup> compared the ability of the TUG test and the BBS score to determine the effect of FES on 15 subjects. Their results showed that the TUG values increased before ( $18.2 \pm 6.7$ ) and after ( $18.9 \pm 7.8$ ) the FES and that the Berg Balance Scale scores increased before ( $46.7 \pm 6.3$ ) and after ( $47.9 \pm 5.4$ ) the therapy. They also reported that the value of FIM in a sitting position after six weeks was increased by about 17 points. However, there were no statistical differences. Generally, the intensity of FES applied to stroke patients is different and depends on individual patient characteristics. The intensity of the stimulus can be decided by the current capacity through the pole, and it is proportional to the muscle contractile force. In other words, a strong contractile force requires a higher intensity stimulus<sup>32)</sup>. In this study, the intensity of the FES decreased as time progressed in both the sitting and supine positions. The differences were statistically significant, with FES exerting a greater effect on patients in the sitting position than in the supine position. The value of the TUG test was decreased and that of FIM was increased according to the decrease in the cur-

rent capacity. Thus, after the treatment, the patients can be expected to have more effective functional movement in a sitting position than in a supine position. Most patients in medical facilities undergo FES to improve body function after a stroke. In this study, the effect of FES on patients in a sitting position was better than in a supine position. Therefore, FES in a sitting position can be expected to improve the functional abilities of patients and to aid their ability to independently perform activities of daily living.

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