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The Impact of Functional Electrical Stimulus and Proprioceptive Neuromuscular Facilitation to Scapula Adductor on Upper Limb Functions and Gait of the Patients with Stroke

The present study examined the effects of functional electrical stimulus(group 1), proprioceptive neuromuscular facilitation(group 2) and combined training of functional electrical stimulus and proprioceptive neuromuscular facilitation(group 3) with scapula adductor muscles on scapula movement, upper limb function and gait in fifteen subjects stroke patients.
The training was thirty minutes a day, five times a week for six weeks, obtained result as follow, upper limb function was significant difference in the group 2(p<.05) but no significant difference in other groups.
The change of weight bearing were significant difference in all the groups(p<.05), and increase of gait velocity were significant difference in all the group(p<.05).
In conclusion, when applied with functional electrical stimulus, proprioceptive neuromuscular facilitation and combined training to the scapular adductor muscles, it was oberved in the course of the experiment that proprioceptive neuromuscular facilitation was the most effective treatment among the three methods applied to the scapula adductors.

Key words: *Fuctional Electrical Stimulus; Proprioceptive Neuromuscular Facilitation; Scapular Movement; Stroke*

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INTRODUCTION

Jorgensen et al. suggested that in the recovery process from stroke, the motor functions of the upper and lower limbs reaches the stabilized phase within 3-6 months(1), and stroke is the major cause for the impairments in adults, typically accompanying loss of motor function(2). One of the major causes to disturb the motor function is the muscle weakness, which is also the major cause for the physical disability in the patients with stroke(3) and usually occur in the non-paralyzed part as well as the paralyzed part(4, 5).

Pattern and colleagues asserted that such muscle weakness can be primarily attributed to the reduced or changed neuronal activities and secondarily to neuronal inactivity, the muscle atrophy due caused by the reduced muscular activity and the change in the compositional ratio in the muscle fibers(6).

Another major cause that disturbs the motor function is hypertonicity, which occurs as an almost common problem both in the upper and lower limbs after the stroke attack; causes the physical disability and pain(7); results in the increase in muscle tone due to the nonsuppression of the regulating mechanism for the muscle tone; reduces the range of motion(ROM) in the affected limbs(8). Consequently, the wrong proprioceptive input may disturb the movement of motion, which results in the disturbance in the limb motions(9).

Hypertonicity often causes in the retraction in scapula. According to Paine and Voight(10), the muscles around the scapula should be line up for the shoulder stability and these muscles should be located in the dynamically position to facilitate the movements of glenohumeral joint. In addition, Ellenbecker and Davies propose that the movement of one joint affects other proximal and distal part(11). It is known that various factors including muscle weakness and hypertonicity restrict the limb functions, and Lai et al. suggested that even 6 months later after the impairment is recovered to some extent, there are still 55-80% of the patients with residual disturbances in the upper limb, which can cause the permanent functional impairment in performing the activities daily living(ADL)(12).

Stroke restricts the restoration of daily living, social participation and other ADL(13). In particular, according to Jorgensen et al. 21% of the patients with stroke died; 18% were not able to do functional walking; 11% needed assistance in walking; only the rest 50% were able to do independent walking(1). Kelly et al. reported that the patients with stroke showed slower walking than the normal population, greater energy consumption and shorter duration in walking time(14).

Walking is closely associated with trunk rotation, among which the rotational coordination between the thoracic vertebrae and pelvis is essential. In particular, the thoracic vertebrae, along with major/minor rhomboids and trapezius meddle fiber, is connected with many muscles and involved in the stability of scapula and the movements of the upper limb. The major/minor rhomboids, trapezius meddle fiber and levator scapulae work in a manner that the glenoid fossa faces toward downside by pulling the scapula inferior angle into superior medial and raising the scapula. With respect to the motility of the upper limb, especially it is reported that 2° of glenohumeral abduction or flexion leads to 1° of the upward rotation in scapulothoracic joint, and the glenohumeral movement occurs at 2:1 ratio compared to the scapulothoracic joint movement(16).

Although there are a variety of studies using the functional electrical stimulus(FES), proprioceptive neuromuscular facilitation(PNF) and both methods, relatively fewer studies have been conducted on the impacts of scapula adductor on the scapular movements, upper limb functions and walking in the patients with stroke.

Therefore, this study aims to the impact of the training using FES, PNF and combining both to the scapula adductor on the patients with stroke.

MATERIALS AND METHODS

Subjects

The study subjects include 15 patients admitted to Phillip Hospital located in Seoul, Korea. The subjects were diagnosed as hemiplegia due to stroke at least 6 months ago, classified as class 4 or above in the recovery period of hemiplegia according to Brunnstrum's classification system. Only the patients with the spasticity in the scapula adductor were included. In addition, they were all scored 20 or above in the MMSE-K without any cardiovascular, internal and orthopedic disorders that may affect the treatment. Among the candidate subjects, those with the ability to walk over 10m independently were randomly selected and 5 patients were assigned to each of FES, PNF and combined group to implement the treatment program consisting of five 30-minute-long sessions per week for total 6 weeks.

Measuring Instrument

To assess the upper limb functions, total 8 movement methods were implemented as follows: shoulder flexion, shoulder abduction, bringing hand to the occipital region, touching hand to the back, grasp, pinch grasp, moving cubic object and pegboard. The total score for these 8 movements was 32. The manual function test(MFT) and the pressure detection sensor attached to the slipsole measured the pressure onto the front foot and the heel, and this walking data obtained from the patients was sent to and temporarily stored by the portable compact controller attached to the ankle. Then this data was wirelessly sent to the computer installed with the 'Smartstep' software which assesses the walking function.

Experiment Method

The subjects were sufficiently informed of the purpose and methodology of this study. The unnecessary behaviors that may affect this study were restricted. They were assigned to each of FES, PNF and combined group.

For the electrical stimulus in FES group, the FES device named 'Microstim' made by Medel GmbH in Germany. Using Valutrode(Axelgard, USA), it was attached to the origin and insertion of the rhomboideus major and minor muscles, which is a scapula adductor. Then, the indirect electrical stimulus method was adopted which stimulates the sensory receptor connected to muscle, GTO or sensory nerves. This stimulator allows the control of frequency, contraction and relaxation time and conduction time and provides the two options of the functional electrical stimulus mode for function training and the transcutaneous electrical nerve stimulus mode for pain reduction. The intensity was set as high as it can induce the muscle contraction when electricity flows and the subjects would not complain pain.

Proprioceptive neuromuscular facilitation is a therapeutic exercise method introduced by Dr. Herman Kabat in 1940s, which recognizes and embodies the mass movement based on neurophysiological ground such as Sherrington's reciprocal nerve innervation and inhibition as well as progress of irradiation, and the characteristics of spiral and diagonal patterns.

As for the PNF group, depending on the subject's capacity, their scapula movements were activated using the positions of sidelying position, sitting position, anterior elevation and posterior depression pattern of scapula. Furthermore, after the movements of scapula and the upper limb were activated using the flexion-adduction-external pattern and the extension-abduction-internal rotation pattern combining the movements of both, the combination of isotonic and dynamic reversal techniques were applied to induce free movements in each pattern.

For the combined group, each of FES and PNF method was applied for 15 minutes in the same manner described above. The PNF method was applied for 15 minutes following the PNF applied first.

Data Analysis

The data from this study was submitted to SPSS version 12.0 for statistical analyses. The significance level(α) was .05. The training program was implemented for 6 weeks to each of the FES, PNF and combined group. For the comparative analyses between the groups, a non-parametric testing method, Wilcoxon signed-rank test was adopted.

RESULTS

General Characteristics of Subjects

Study group 1(FES group) consisted of 4 males and 1 female; study group 2(PNF group) consisted of 4 males and 1 female; study group 3(combined) consisted of 4 males and 1 female. The average age was 52.40± 7.05 for study group 1; 49.80±12.91 for study group 2; 53.40±12.46 for study group 3. The average weight was 66.20±7.46kg for study group 1; 72.40±17.96kg for study group 2; 70.40±8.98kg for study group 3. The average height was 170.00±5.14cm for study group 1; 173.00±9.69cm for study group 2; 169.60±6.58cm for study group 3 (Table 1).

Table 1. The general characteristics of study subjects

	group 1 (n=5)	group 2 (n=5)	group 3 (n=5)
Sex			
male	4(26.7%)	4(26.7%)	4(26.7%)
famale	1(6.7%)	1(6.7%)	1(6.7%)
Paralysis side			
right	3(20%)	3(20%)	2(13.3%)
left	2(13.3%)	2(13.3%)	3(20%)
Classification of brain damage			
infarction	1(6.7%)	2(13.3%)	3(20%)
hemorrhage	4(26.7%)	3(20%)	2(13.3%)
Age	52.40±7.05	49.80±12.91	53.40±12.46
Weight(kg)	66.20±7.46	72.40±17.96	70.40±8.98
Height(cm)	170.00±5.14	173.00±9.69	169.60±6.58

Comparative Analysis of Upper Limb Functions of Each Study Group

The comparative analysis between before and after the program in upper limb function showed that the upper limb function increased from 5.60±3.57 to 6.00±4.47 in study group 1, which was not statistically significant. In study group 2, the upper limb function increased from 9.20±5.06 to 13.80±5.40, which was statistically significant($p<.05$). Finally, the limb function increased from 5.00±4.35 to 6.80 ± 3.83 in study group 3, which was not statistically significant(Table 2)(Fig. 1).

Table 2. Changes of upper limb function in each study group

(score)

	Subject group	Pre-training	Post-training	p
MFT	group 1	5.60±3.57	6.00±4.47	.317
	group 2	9.20±5.06	13.80±5.40	.041*
	group 3	5.00±4.35	6.80±3.83	.066

*$p<.05$

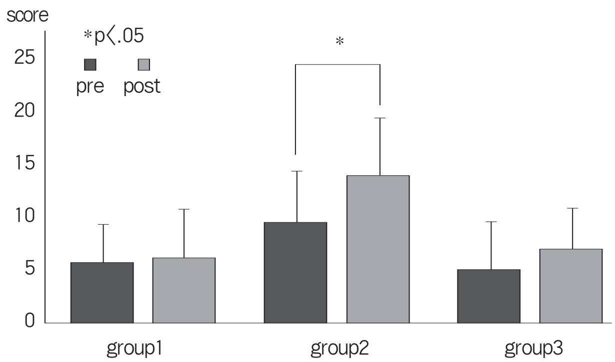

Fig. 1. Function tests pre and post the frequency change

Comparative Analysis of Changes in Weight Bearing

The comparative analysis of the changes in weight bearing between before and after the program showed that the weight bearing increased from 53.70±8.55 to 54.62±8.60 in study group 1; increased from 60.28±10.28 to 64.06±9.93 in study group 2; increased from 62.25±9.86 to 63.05±9.20 in study group 2. These increases in all study groups were statistically significant($p<.05$)(Table 3)(Fig. 2).

Table 3. Changes in weight bearing of each study group

(kg)

	Subject group	Pre-training	Post-training	p
Weight bearing	group 1	53.70±8.55	54.62±8.60	.048*
	group 2	60.28±10.28	64.06±9.93	.038*
	group 3	62.25±9.86	63.05±9.20	.044*

*p<.05

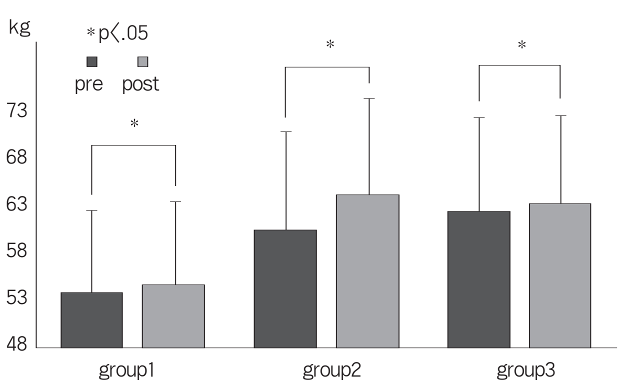

Fig. 2. Pre and post the change of weight-bearing

Comparative Analysis of Gait Velocity of Each Study Group

The measures of the walking distance(m) per minute for each group before and after the program showed that the walking velocity increased from 20.57±16.63 to 21.98±17.16 in study group 1; from 32.37±7.07 to 35.18±.05 in study group 2; finally from 20.99±15.11 to 22.52±5.48 in study group 3. These increases in-between before and after the program in all study groups were statistically significant ($p<.05$)(Table 4)(Fig. 3).

Table 4. Changes in gait velocity of each study group

(m/min)

	Subject group	Pre-training	Post-training	p
Velocity	group 1	20.57±16.63	21.98±17.16	.039*
	group 2	32.37±7.07	35.18±7.05	.017*
	group 3	20.99±15.11	22.52±15.48	.033*

*p<.05

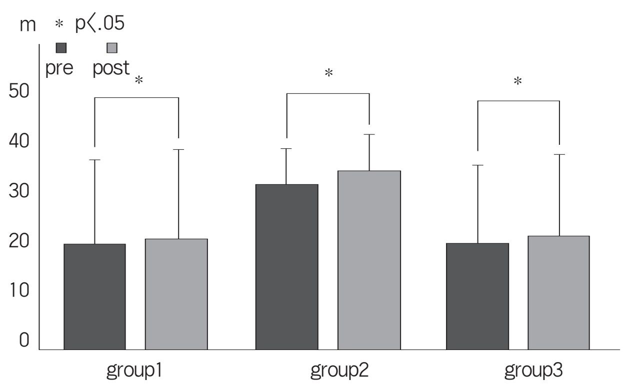

Fig. 3. Changes in gait velocity pre and post

DISCUSSION

Stroke generally induces negative consequences to life along with impairments and the neurological symptoms after the damaged cerebral artery mainly causes the damage to one cerebral hemisphere and to the body and limbs in the other side(16). In the interventions of physical therapy, functional recovery is the top priority purpose. The survey results on the symptoms following the damage showed that there are many symptoms following the damage including inability to use the hands muscle weakness, reduction of the sensory-motor function, hypertonicity, reduction of the coordination and many others(5).

There are many treatment methods for stroke and many studies report the effectiveness of one of those methods, FES in the treatment of upper limb function and walking(17-21).

For the upper limb to move well, the glenohumeral joint should move well against scapulothoracic joint and it is reported that the movement of glenohumeral joint is combined with the movements of trunk and scapula(4, 22). This study also found that the PNF was more effective for the upper limb function than FES or the method combining both.

Pontzer et al. found that the motion to shake the upper limb while walking affect and is closely associated with the motions of scapula and pelvis(23). Choi et al. reported that the motions of the pelvis and lower limb in the affected side increase the walking velocity and amount in the hemiplegia patients as well as increase the walking stride of the lower limb in the affected side(24).

Although the lower limb was not directly exercised in this study, all of the FES, PNF and combined method applied to the scapula adductor closely related to the motion of lower limb were effective for the increase in weight bearing and walking velocity. In particular, PNF was more effective than the other two. These results suggest that the scapula movement and the upper limb function are closely related to walking as shown in Pontzer et al. and Choi et al.(23, 24).

Munih et al. reported that the more effective intervention than PNF is the method combining FES and PNF, which is different from the findings of this study(25). Although this study also applied combined FES and PNF, the methodology was slightly different. While the study of Munih et al. applied FES and PNF simultaneously, this study applied FES in a half of the given intervention time and PNF in the other half(25). Thus, the different results may be attributed to the difference in the study methodology. While different methodologies may lead to different results, the result may be subject to change depending on how long the intervention lasts; that is, the duration of the intervention applied.

This study found that PNF applied to the scapula adductor is effective in the upper limb function and walking in the affected side. Therefore, the future studies need to investigate more various patterns, techniques and the possibility to combine FES simultaneously.

CONCLUSION

This study examined the impacts of FES, PNF and the combined intervention of the two applied to the scapula adductor on the upper limb function and walking in the affected side with total 15 patients with stroke assigned to each of the FES-only group (study group 1; 5 patients), PNF-only group(study group 2; 5 patients) and the FES-PNF combined group(study group 3; 5 patients).

The results from the manual function test to measure the upper limb functions showed that while there was a significant difference in the PNF group($p<.05$), there was no significant difference in the FES and combined group. With respect to the weight bearing, it was increased significantly in all three groups ($p<.05$). AS for walking velocity, it was also increased significantly in all three groups($p<.05$). Therefore, the implication of this study, as a clinical research on the impacts of FES, PNF and the combined method of the two on the changes in the upper limb functions, weight bearing and walking of the patients with stroke, is that the findings of this study will be an important data in treating the patients with stroke. It is suggested that based on the findings of this study, future studies are needed to generalize them further.

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