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The Effects of Trunk Stability Exercise Using PNF on the Functional Reach Test and Muscle Activities of Stroke Patients

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Abstract. [Purpose] This study was performed to investigate the effects of trunk stability exercise using the proprioceptive neuromuscular facilitation (PNF) technique on stroke patients' muscle activation and their results in the functional reach test (FRT). [Subjects] Adult hemiplegia patients (n=40) were randomly allocated to two groups: an experimental group and a control group. [Methods] The experimental group performed a trunk stability exercise using the PNF, while the control group performed only a general exercise program for 6 weeks (5 times a week). Pre- and post-experiment measurements were made of the FRT. For measuring muscle activation, the quadriceps, hamstring, tibialis anterior, and soleus muscles were recorded by electromyography (EMG) in the FRT. [Results] The results of this study show that after performing the therapeutic exercise program, the experimental group showed significant improvements in FRT, activities of quadriceps, hamstring, and soleus muscles on the affected side, and activities of the quadriceps, and soleus muscles on the non-affected side, the control group showed significant improvements only in activities of the quadriceps, and soleus muscles on the non-affected side. [Conclusion] These results indicate that trunk stabilizing exercises using PNF performed by stroke patients were effective at improving FRT and the muscle activities of the soleus and quadriceps.
Key words: PNF, Stroke, Functional reach test, EMG

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INTRODUCTION

Characteristics that commonly appear in stroke patients are exercise-related disorders, which are key causes that obstruct patients' functional recovery. Stroke patients show impaired balance, ability to selectively control motions, and muscle strength[1)]. Problems in posture control occur because of poor interactions between motor, sensory, and cognitive functions, and reduced ability to control posture is one of the major causes of the mobility problem suffered by stroke patients[2)]. Due to the loss and asymmetry of the ability to control postures, when implementing tasks, stroke patients adopt abnormal posture control strategies[3)] and their body center moves to the non-affected side so symmetric body weight loads are not achieved and stability is reduced[4)]. The focus of stroke patients' functional recovery is on improving balance and functional movements[5)].

Stability is the ability of the musculoskeletal system to maintain balance when minor interruptions of motions or control appear[6)]. The stability of the trunk relies on synchronized activity of many trunk muscles. Muscles anterior, posterior, and lateral to the spine produce stable and strong contractility and contract in cooperation in order to secure stability in momentary postures, speeds, and diverse states of loads imposed on the spine[7)]. As intervention methods for improving stability neurophysiotherapy methods such as proprioceptive neuromuscular facilitation (PNF), the Brunnstrom approach, and the Bobath method focus on improving voluntary movements of the extremities on the affected side of patients with hemiplegia resulting from brain damage[8)].

PNF is a method facilitating or increasing the reactions of neuromuscular mechanisms through proprioceptive stimuli. It is frequently used in therapeutic exercise for stroke as an alternative to progressive resistance exercises in order to avoid injury[9)]. PNF in therapeutic exercise for stroke to train patients in functional activities or avoid various kinds of injury[10)] and has been widely used in physical therapy for functional training, stretching exercises, and to strengthen muscles. It induces patients to use the affected extremities voluntarily in order to facilitate functional recovery, and improves balance and the ability to control motions. It can improve functional independency through treatment that emphasizes symmetry between the affected side and the non-affected side[11)]. The objective of PNF treatment of hemiplegia patients is to increase interactions between the two sides of the body and diagonal and spiral motor patterns[12)], and to induce muscle contraction in fixed areas on the affected side through

Table 1. Characteristics of the subjects

Category	Experimental group (n=20)	Control group (n=20)
Age (yrs)	51.4 ± 5.7	53.5 ± 7.1
Height (cm)	168.0 ± 7.0	164.6 ± 5.4
Weight (kg)	67.7 ± 7.1	63.9 ± 8.8
Gender (Male/Female)	17/3	14/6
Diagnosis (Infarction/Hemorrhage)	12/8	11/9
Hemiplegic side (Right/Left)	12/8	12/8
Onset period (month)	22.9 ± 12.2	26.8 ± 12.8

resistance exercises of the non-affected side using physiological motor overflows or irradiation[13]. Recently, it has been suggested that irradiation effects are maximized by maximally mobilizing relevant body parts in order to solve problems in damaged body areas[14].

Despite therapeutic exercises using PNF having been frequently performed by stroke patients, most information on the effect of the exercises relates to the effect of patterns or upper extremities. Information on the effect of trunk stabilizing exercises using PNF on functional movements or the lower extremities through irradiation is rare. Given this gap in the literature, this study investigated the effects of trunk stabilizing exercises using the stabilizing reversal (SR) and rhythmic stabilization (RS) of PNF on the FRT and lower extremity muscle activity of stroke patients.

SUBJECTS AND METHODS

In this study, 40 patients diagnosed with hemiplegia due to stroke were randomly assigned to a trunk stability exercise using PNF group (experimental group) of 20 patients and a general exercise group (control group) of 20 patients. The study subjects were selected from among patients diagnosed with stroke who could walk by themselves without being helped by others or could walk at least 10 m using a walking aid, scored at least 24 points in the mini-mental state examination-K (MMSE-K), had spasticity of Grade 2 or lower in the affected lower extremity as evaluated by the Modified Ashworth Scale (MAS), had no orthopedic problem that could affect the treatment, and could receive training for 30 minutes or longer. The intention of this study and the overall contents of the experiment were sufficiently explained to the subjects who gave their voluntary agreement to participation. The general characteristics of the study subjects are shown in Table 1.

The experimental group received therapeutic intervention of PNF using SR and RS for 10 minutes during 30 minutes of general therapeutic exercise, implemented five times a week for six weeks. Stabilizing reversal is alternating muscle contraction which aims to stabilize a subject with a static command. Due to the changing of grip a small movement is allowed. One method of applying stabilizing reversal is to start in the strong direction with resistance and approximation and ask the patient to stay in that position and add resistance in all three directions of the pattern. When the patient is properly responding to the therapist's resistance, the therapist moves one hand to the opposite direction and then asks the patient to resist the new direction and the therapist changes his other hand. Rhythmic stabilization, also known as alternating isometrics, is alternating isometric contraction against resistance. No motion by the patient should occur and no relaxation between the changes of muscle contractions. With this technique the therapist resists a static contraction and the patient maintains the same position. The resistance is increased slowly and when the patient resists strongly, the therapist changes his hands to control the opposite direction. The new resistance is built up slowly and the therapist prepares the next change again. Stabilizing reversal and rhythmic stabilization were performed with correct techniques in both the sitting and standing positions.

The control group received only general therapeutic exercise for 30 minutes, five times a week for six weeks. The general therapeutic exercise was composed of stretching exercises and exercises for the range of motion of joints. The PNF provided to the experimental group was implemented after the exercise programs were explained and demonstrated by professionally trained therapists so that the subjects would sufficiently understand the exercise programs.

FRT measures the maximum horizontal distance that can be reached by stretching the upper extremity while maintaining the base of support in a comfortable standing position. It is a reliable test tool that can measure the limit of stability accurately and conveniently. FRT was also developed to identify balance disorder or test changes in balancing abilities over time in clinics[15].

An MP150WSW, which is a surface electromyogram (EMG) device, was used to measure the activities of the quadriceps, hamstring, tibialis anterior, and soleus of the subjects. Referring to previous studies, electrodes were attached to the quadriceps, hamstring, tibialis anterior, and soleus[16]. A process of normalization is necessary in order to minimize differences in surface EMG signals among individuals and among areas in each individual. The EMG data measured from the muscles were converted to root-mean-square (RMS) values that provide values close to actual output values of the EMG signals. For quantification, EMG signal volumes as a percentage of the reference voluntary contraction (%RVC) were measured. For this, %RVC was measured in a 45° squat posture. The muscle activity of each muscle was measured three times in succession; data values for five seconds were converted to RMS values and the EMG signal amplitudes for the three seconds in the middle (excluding data for the first one second and for the last one second) were used as %RVC.

Before beginning the experiment, EMG was measured by performing the FRT, and when the experiment had finished, individuals were measured again by the same. All the measurements were repeated three times and average values were calculated.

Collected data were analyzed using SPSS (version 12.0) statistical program. To examine whether the measured data were normally distributed, the Kolmogorov-Smirnov test (which is a method to test the goodness of fit of normal distributions) was conducted. The significance of differences between before and after the intervention in each group was tested by the paired t-test, and the significance of differences between individual groups was tested by the independent t-test. The statistical significance level, α, was chosen as 0.05.

RESULTS

Comparing FRT before and after the intervention in the two groups, the experimental group showed significant increases ($p<0.05$), while the control group did not show any significant difference ($p>0.05$). No significant difference between the experimental group and the control group before the intervention was found ($p>0.05$), but significant differences after the intervention were shown ($p<0.05$) (Table 2).

Comparing soleus muscle activity during FRT before and after the intervention in the two groups, soleus muscle activity significantly increased on the affected side of the experimental group ($p<0.05$), while significantly decreasing on the non-affected side ($p<0.05$). The control group did not show significant difference on the affected side ($p>0.05$), but showed a significant decrease on the non-affected side ($p<0.05$). There was no significant difference between the experimental group and the control group on either the affected side or the non-affected side before the intervention ($p>0.05$), while there were significant differences between the experimental group and the control group on both the affected side and non-affected side after the intervention ($p<0.05$).

Regarding tibialis anterior muscle activity during FRT before and after the intervention in the two groups, no significant difference was shown by the experimental group or the control group on either the affected side or the non-affected side before the intervention ($p>0.05$). There was no significant difference between the experimental group and the control group on either the affected side or the non-affected side before or after the intervention ($p>0.05$).

Regarding hamstring muscle activity during FRT before and after the intervention in the two groups, the experimental group showed significant increases on the affected side ($p<0.05$), but showed no significant difference on the non-affected side ($p>0.05$). The control group did not show significant difference on either the affected side or the non-affected side ($p>0.05$). There was no significant difference between the experimental group and the control group on either the affected side or the non-affected side before or after the intervention ($p>0.05$).

Regarding quadriceps muscle activity during FRT before and after the intervention in the two groups, the experimental group showed significant increases on the affected side ($p<0.05$), but showed significant decreases on the non-affected side ($p<0.05$). The control group did not show significant difference on the affected side ($p>0.05$), but showed significant decreases on the non-affected side ($p<0.05$). There was no significant difference between the experimental group and the control group on either the affected side or the non-affected side before the intervention ($p>0.05$), while after the intervention, there were significant differences between the experimental group and the control group on the affected side ($p<0.05$), but not on the non-affected side ($p>0.05$) (Table 3).

Table 2. Comparison of FRT between pre-and post-intervention (mean ± SD) (unit: cm)

Group	Pre-test	Post-test
Experimental group (n=20)*	23.5 ± 7.0	28.1 ± 7.3
Control group (n=20)	23.1 ± 5.3	23.2 ± 5.3
		†

*: paired t-test value, †: independent t-test value, $p<0.05$.

Table 3. Comparison of EMG between pre-and post-intervention (mean ± SD) (unit: %RVC)

Group	Muscle		Pre-test	Post-test
Experimental group (n=20)	soleus	A*	132.7 ± 25.5	148.0 ± 27.6
		N*	281.5 ± 87.1	223.9 ± 77.6
	tibialis anterior	A	122.7 ± 47.5	121.4 ± 48.4
		N	104.0 ± 42.9	104.1 ± 44.0
	hamstring	A*	119.0 ± 35.3	142.2 ± 47.8
		N	170.8 ± 110.3	185.6 ± 106.1
	quadriceps	A*	107.6 ± 35.6	125.0 ± 44.2
		N*	176.4 ± 52.0	134.7 ± 42.9
Control Group (n=20)	soleus	A	125.7 ± 21.0	126.2 ± 23.6
		N*	277.3 ± 51.2	267.9 ± 53.1
	tibialis anterior	A	116.3 ± 56.2	113.9 ± 52.8
		N	123.3 ± 51.0	113.0 ± 69.0
	hamstring	A	121.6 ± 32.3	128.3 ± 36.6
		N	178.9 ± 104.1	228.7 ± 156.7
	quadriceps	A	103.3 ± 34.4	98.7 ± 37.1
		N*	155.5 ± 42.2	136.1 ± 46.8

*: $p<0.05$, A: affected side, N: non-affected side.

DISCUSSION

The effect of trunk stabilizing exercises using PNF on hemiplegia patients' FRT and lower extremity muscle activity necessary for functional reaching was investigated using stabilizing reversal and rhythmic stabilization PNF therapeutic interventions in the sitting and standing positions.

Among daily life motions, many factors are required simultaneously, when trying to grab an object in a standing position, such as fixing the eyes on the object, reaching for the object, stabilizing the posture, and maintaining balance[17]. The FRT is used to check changes in balance ability over time, etc[14]. In this study, during the FRT, balance ability significantly increased in the experimental group after the intervention compared to the control group. This result supports the results of previous studies indicating that the actions of muscles used when PNF is applied are similar to muscle actions occurring when diverse exercises are performed and, thus, that PNF is better at improving the ability to implement tasks than exercises to move in simple directions[18]. This means that the application of trunk stabilizing exercises using appropriate PNF is effective for improving the implementation of tasks in daily life.

In static standing positions, when undertaking a task to lift an object with upper extremity reaching, the ratio of body weight support is increased on the lower extremity on the same side in the case of normal persons. However, in the case of hemiplegia patients, when the task was given to the affected side, rate of body weight support on the non-affected side was shown to be significantly higher[19]. Based on the EMG of lower extremity muscles, it was reported that during upper extremity reaching, by normal persons, the hamstring and quadriceps of the same side lower extremity were mobilized first and showed high activity; the activity of the hamstring of the other side lower extremity was also high, while the activity of the quadriceps of the other side lower extremity did not show any change. Both the soleus of the same side and that of the other side showed high activity but the tibialis anterior on the same side or the other side did not show any changes. In the case of the hemiplegia patients, the activity of the hamstring and quadriceps of the non-affected side lower extremity was high; the affected side lower extremity showed high activity of the hamstring only; and the non-affected side lower extremity showed low activity of the soleus and moderately high activity of the tibialis anterior. Thus, the stroke patients showed lower cooperative ability among the lower extremity muscles than normal persons[20]. In this study all the subjects showed results similar to results previously reported. Moreover, in the experimental group, during the FRT, the activity of the soleus, hamstring, and quadriceps of the affected side significantly increased and the activity of the quadriceps and soleus of the non-affected side decreased. We consider that the recruitment of trunk muscles that could be used to overcome resistance was increased to bring about the irradiation effect which was induced by increasing the muscle activity of the lower extremity of the affected side, and, accordingly, the muscle activity of the non-affected side decreased to show a symmetric pattern of activities. However, in the present study, muscle activity of the tibialis anterior did not show significant difference, unlike in previous study. We consider this is because of the effect of learned disuse syndrome, since the previous study was conducted with patients with 3 months or shorter durations after stroke, whereas the present study was conducted with patients with durations of 24.8 ± 12.5 months after stroke.

Trunk stabilizing exercises using PNF performed by patients with hemiplegia resulting from stroke induced significant increases in muscle activity in FRT in the lower extremity muscle activities. The experimental group showed significant differences in soleus and quadriceps muscle activities compared to the control group; thus, the asymmetrical lower extremity muscle activities before the intervention were altered to symmetrical ones after the intervention. Based on these results, we consider that trunk stabilizing exercises using PNF affect the lower extremity muscles of patients with hemiplegia resulting from stroke, and provide functional motor control. Statistically significant differences were not shown between the two groups, except for the muscle activities of the tibialis anterior and hamstring in the lower extremities. Thus, we consider that wider studies will be necessary with different intervention periods, intervention times and environments, and more diverse tasks.

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