The immediate effect of PNF pattern on muscle tone and muscle stiffness in chronic stroke patient

Joong-San Wang, PT, PhD, Sang-Bin Lee, PT, PhD, Sang-Hyun Moon, PT, MS

1) Department of Physical Therapy, Howon University, Republic of Korea
2) Department of Physical Therapy, Institute for Elderly Health and Welfare, Namseoul University, Republic of Korea
3) Department of Physical Therapy, Yongin University: 470 Samga-dong, Cheoin-gu, Yongin-si, Republic of Korea

Abstract. [Purpose] The purpose of this study was to investigate the immediate effect of proprioceptive neuromuscular facilitation on muscle tone and muscle stiffness in stroke patients. [Subjects and Methods] The subjects consisted of 15 patients with chronic stroke (stroke group) and 15 healthy persons (healthy group). We measured the effects of proprioceptive neuromuscular facilitation intervention on the lower extremity using a muscle tone measurement device; this detected changes in muscle tone and stiffness in the lower extremity muscles. [Results] Measurements taken before the intervention showed that, on average, the lower extremity muscles of the stroke group showed abnormally increased muscle tone and stiffness compared to the lower extremity muscles of the healthy group. After the intervention, the average muscle tone and stiffness in the lower extremity muscles of the stroke group decreased, but this change was insignificant, and the differences between the two groups were also insignificant. [Conclusion] Based on the findings of this study, we recommend proprioceptive neuromuscular facilitation treatment of both affected and non-affected sides to decrease the abnormally increased muscle tone and stiffness in the lower extremity muscles of chronic stroke patients.

Key words: Muscle tone, Proprioceptive neuromuscular facilitation, Stroke

INTRODUCTION

Stroke is a leading cause of physical functional impairment and one of the principal causes of increased morbidity and mortality in adults. Stroke causes secondary neural and muscular changes due to upper motor neuron lesions, which lead to abnormally increased muscle tone and stiffness due to muscle atrophy and hypertonia. Since approximately 50–60% of stroke patients experience some degree of motor impairment, even after general rehabilitation, efforts should be made to maintain and improve physical function and to reduce abnormally increased muscle tone and stiffness through therapeutic exercise.

Proprioceptive neuromuscular facilitation (PNF) treatment is a very effective therapeutic exercise for the improvement of muscle thickness, dynamic balance, and gait, and widely used in clinical settings to improve the physical functioning of stroke patients. Studies conducted to verify the therapeutic effects of the PNF technique mostly focus on muscle activity; very few studies verify the changes in muscle tone and stiffness that increase due to post-stroke spasticity. Therefore, we decided to quantitatively determine the immediate effects of PNF treatment on changes in muscle tone and stiffness and to compare the muscle tone and stiffness of chronic stroke patients with those of healthy people.
Recent studies have reported comparisons in muscle tone and stiffness between the affected and non-affected sides in neurologically disordered patients. This study was therefore conducted to verify the effects of the PNF exercise by analyzing the immediate effects of the PNF treatment on the lower extremity regarding the abnormal muscle tone and stiffness in the lower extremity (LE) muscles in hemiplegic patients who were at least six months past the onset of a stroke.

**SUBJECTS AND METHODS**

The subjects in this study included 15 chronic stroke patients, hospitalized in D Hospital in Seoul, and 15 healthy persons. All of the chronic stroke patients had hemiplegia for at least six months after their stroke diagnosis via CT or MRI. The inclusion criteria for the subjects were a score of 24 or higher on the Korean version of the mini-mental state exam (MMSE). We also excluded those with degenerative arthritis in their LE joints, or who had suffered a fracture in the last year.

The local ethics committee of the Namseoul University of Cheonan approved this study. All subjects signed an informed consent form after listening to the purpose of the study.

We classified subjects into either a stroke group or a healthy group. The stroke group was then sub-divided into an affected side and a non-affected side. For the healthy group, we performed the intervention and measurements on their dominant side. For the PNF intervention, we applied a lower extremity hip extension-abduction-internal rotation with knee extension pattern, together with the rhythmic initiation of a repeated stretch and a combination of isotonic techniques. Among the many important muscles used in balancing and walking, this pattern simultaneously stimulates the rectus femoris (RF), the medial gastrocnemius (MGCM), the lateral gastrocnemius (LGCM), the biceps femoris (BF), and the semitendinosus (ST). We measured the muscle tone and stiffness of the subjects in the resting condition before and after the PNF intervention using the Myoton® PRO (MyotonAS, Estonia). The measuring device has proven reliability and validity in objectively quantifying the muscle tone and stiffness of patients with stroke.

For the stroke group, we measured the RF, MGCM, LGCM, BF, and ST of both sides. For the healthy group, we only measured the dominant side. Before the measurement, we applied skin markers symmetrically to the highest points on the muscle belly of the RF in the supine position and on the muscle bellies of the MGCM, LGCM, BF, and ST in the prone position. We placed the measurement device vertically above the skin marker in the maximally relaxed condition both in the supine position and in the prone position. We made the measurements twice and used the average values.

We applied the intervention for one day to both the affected side and the non-affected side in the stroke group. For the healthy group, we applied the intervention to the dominant side for 30 minutes. One therapist, of the International Proprioceptive Neuromuscular Facilitation Association, who had completed the PNF level-5 course, performed all the measurements and interventions. We conducted the study in an independent space; the average room temperature was 23°C.

We encoded and analyzed all the data collected from this study with a statistics application (SPSS 21.0/PC, USA). We calculated the means and standard deviations of the generation characteristics of the subjects using descriptive statistics. Homogeneity was checked using a paired t-test with no significant difference found. Furthermore, we performed a paired t-test to compare the changes in each group after the intervention and one-way ANOVA to compare the variations within each group. The significance level of every test was set to $\alpha = 0.05$.

**RESULTS**

The demographic characteristics of the subjects are in Table 1. In this study, the stroke group had abnormally increased muscle tone and stiffness in all the LE muscles compared to the healthy group. After the intervention, the stroke group showed decreased muscle tone and stiffness in all LE muscles, but the changes were insignificant. The healthy group showed a significant decrease in the stiffness of the MGCM ($p < 0.05$). However, the differences between the groups in the changes after the intervention were insignificant (Table 2).

**DISCUSSION**

After a stroke, abnormally increased muscle tone and stiffness appear. Before this intervention, the stroke group showed increased muscle tone and stiffness of the LE muscles on both the affected and non-affected sides compared to the healthy group. It appears that the muscle tone and stiffness of the LE muscles increase abnormally due to overuse in walking and weight support by the non-affected side as well as the affected side of the stroke patient due to their UMN lesion. However, after the PNF intervention, the stroke group did not show significant changes, even though their hypertonia and stiffness in all LE muscles decreased.

In a preceding study, Chuang et al. compared the muscle tone and stiffness on the affected side and the non-affected side of the upper extremity (UE) in stroke patients at Brunnstrom stage III or above for the UE, and at MAS grade 2 or lower. They found that the flexor carpi radialis of the affected side showed significantly lower muscle tension and stiffness than that on the non-affected side. Additionally, they found that the non-affected side of the extensor digitorum and flexor carpi ulnaris showed slightly less muscle tone and stiffness than those on the affected side. Woo et al. reported that stroke patients at
Brunnstrom stages II or III showed decreased muscle tone on the affected side after the PNF intervention on the non-affected side.

Unlike the previous studies, this study compared the immediate changes to muscle tone and stiffness of the LE muscles in chronic stroke patients. Thus, it is difficult to compare the results directly with those of previous studies. However, this study found that the application of the PNF technique to the non-affected side as well as the affected side, where both had abnormally increased muscle tone and stiffness due to a post-stroke upper motor neuron lesion, had positive effects. Furthermore, the PNF combined pattern is an effective treatment method for increasing the muscle activity of the rectus femoris, vastus medialis, tibialis anterior, lateral hamstring, and lateral gastrocnemius in stroke patients. Therefore, continuous application of the PNF intervention could decrease abnormally increased muscle tone and stiffness while increasing the muscle activity of the LE muscles.

This study has limitations as we could not control the drugs that the stroke patients were taking and, we only examined immediate effects. However, the immediate effects were intentionally examined to eliminate factors that might result from medical treatment and therapeutic interventions if the intervention period had been longer.

The findings of this study verify that the widely used PNF treatment, for the therapeutic exercise of stroke patients, can decrease the abnormally increasing muscle tone and stiffness of the LE muscles on the affected side.

Table 1. General characteristics of subjects

| Characteristics | Stroke group (n=15) | Health group (n=15) |
|-----------------|---------------------|--------------------|
| Gender Male (%) | 12 (80)             | 6 (40)             |
| Female (%)      | 3 (20)              | 9 (60)             |
| Age (yrs)       | 59.8 ± 6.2          | 63.2 ± 5.2         |
| Weight (kg)     | 70.8 ± 8.7          | 65.5 ± 6.1         |
| Height (cm)     | 169.2 ± 5.9         | 163.7 ± 8.8        |
| Side of stroke  | Left 6 / Right 9    | Left 0 / Right 15  |
| K-MMSE          | 28.0 ± 1.4          | 30.0 ± 0.0         |
| Post-stroke duration (months) | 45.7 ± 28.6 |

Value are means ± SD
K-MMSE: Korea version of Mini-Mental State Examination

Table 2. Comparison of before and after intervention values

| Muscle          | Group | Side             | Muscle tone (Hz) | Stiffness (N/m) |
|-----------------|-------|------------------|------------------|-----------------|
| Rectus femoris  | Stroke| Affected side    | Before: 15.6 ± 0.5, After: 15.6 ± 0.5 | Before: 307.0 ± 12.8, After: 306.8 ± 13.6 |
|                 |       | Non-affected side|                  |                 |
|                 | Health| Dominant side    | Before: 15.8 ± 0.5, After: 15.6 ± 0.5 | Before: 307.8 ± 13.2, After: 296.2 ± 9.8 |
| Medial gastrocnemius | Stroke| Affected side    | Before: 14.3 ± 0.4, After: 14.7 ± 0.4 | Before: 271.5 ± 10.1, After: 273.5 ± 9.0 |
|                 |       | Non-affected side|                  |                 |
|                 | Health| Dominant side    | Before: 14.9 ± 0.3, After: 14.7 ± 0.4 | Before: 275.8 ± 8.1, After: 274.9 ± 8.2 |
| Lateral gastrocnemius | Stroke| Affected side    | Before: 16.0 ± 0.7, After: 15.6 ± 0.4 | Before: 313.4 ± 10.0, After: 304.8 ± 11.4 |
|                 |       | Non-affected side|                  |                 |
|                 | Health| Dominant side    | Before: 14.9 ± 0.2, After: 14.8 ± 0.2 | Before: 278.0 ± 4.8, After: 278.3 ± 6.1 |
|                 | Stroke| Affected side    | Before: 15.5 ± 0.7, After: 15.2 ± 0.4 | Before: 277.3 ± 11.9, After: 270.4 ± 12.1 |
| Biceps femoris  | Stroke| Non-affected side| Before: 15.2 ± 0.4, After: 15.0 ± 0.3 | Before: 271.6 ± 10.8, After: 272.2 ± 12.7 |
|                 | Health| Dominant side    | Before: 14.7 ± 0.3, After: 14.6 ± 0.3 | Before: 267.6 ± 5.5, After: 269.5 ± 5.4 |
| Semitendinosus  | Stroke| Affected side    | Before: 15.5 ± 0.7, After: 15.3 ± 0.7 | Before: 281.8 ± 14.2, After: 273.6 ± 15.2 |
|                 |       | Non-affected side| Before: 16.0 ± 0.6, After: 15.6 ± 0.6 | Before: 278.6 ± 14.5, After: 276.6 ± 19.0 |
|                 | Health| Dominant side    | Before: 14.9 ± 0.3, After: 14.7 ± 0.4 | Before: 267.8 ± 9.0, After: 266.8 ± 7.4 |

Values are means ± SE
*Significant difference between values before and those after the intervention in each group (p < 0.05)

Bruinmstorm stages II or III showed decreased muscle tone on the affected side after the PNF intervention on the non-affected side.

Unlike the previous studies, this study compared the immediate changes to muscle tone and stiffness of the LE muscles in chronic stroke patients. Thus, it is difficult to compare the results directly with those of previous studies. However, this study found that the application of the PNF technique to the non-affected side as well as the affected side, where both had abnormally increased muscle tone and stiffness due to a post-stroke upper motor neuron lesion, had positive effects. Furthermore, the PNF combined pattern is an effective treatment method for increasing the muscle activity of the rectus femoris, vastus medialis, tibialis anterior, lateral hamstring, and lateral gastrocnemius in stroke patients. Therefore, continuous application of the PNF intervention could decrease abnormally increased muscle tone and stiffness while increasing the muscle activity of the LE muscles.

This study has limitations as we could not control the drugs that the stroke patients were taking and, we only examined immediate effects. However, the immediate effects were intentionally examined to eliminate factors that might result from medical treatment and therapeutic interventions if the intervention period had been longer.

The findings of this study verify that the widely used PNF treatment, for the therapeutic exercise of stroke patients, can decrease the abnormally increasing muscle tone and stiffness of the LE muscles on the affected side.
REFERENCES

1) Pan A, Sun Q, Okereke OI, et al.: Depression and risk of stroke morbidity and mortality: a meta-analysis and systematic review. JAMA, 2011, 306: 1241–1249. [Medline] [CrossRef]

2) Ingall T: Stroke—incidence, mortality, morbidity and risk. J Insur Med, 2004, 36: 143–152. [Medline]

3) Chuang LL, Wu CY, Lin KC: Reliability, validity, and responsiveness of myotonometric measurement of muscle tone, elasticity, and stiffness in patients with stroke. Arch Phys Med Rehabil, 2012, 93: 532–540. [Medline] [CrossRef]

4) Lundy-Ekman L: Neuroscience: Fundamentals for Rehabilitation, 3th ed. Elsevier, 2007.

5) Schaechter JD: Motor rehabilitation and brain plasticity after hemiparetic stroke. Prog Neurobiol, 2004, 73: 61–72.

6) Park SE, Wang JS: Effect of joint mobilization using KEOMT and PNF on a patient with CLBP and a lumbar transitional vertebra: a case study. J Phys Ther Sci, 2015, 27: 1629–1632. [Medline] [CrossRef]

7) Seo K, Park SH, Park K: The effects of stair gait training using proprioceptive neuromuscular facilitation on stroke patients’ dynamic balance ability. J Phys Ther Sci, 2015, 27: 1459–1462. [Medline] [CrossRef]

8) Shimura K, Kasai T: Effects of proprioceptive neuromuscular facilitation on the initiation of voluntary movement and motor evoked potentials in upper limb muscles. Hum Mov Sci, 2002, 21: 101–113. [Medline] [CrossRef]

9) Jeong WS, Park SK, Park JH, et al.: Effect of PNF combination patterns on muscle activity of the lower extremities and gait ability in stroke patients. J Korea Cont Socie associ, 2012, 12: 312–328.

10) Marusiak J, Jaskólska A, Budrewicz S, et al.: Increased muscle belly and tendon stiffness in patients with Parkinson's disease, as measured by myotonometry. Mov Disord, 2011, 26: 2119–2122. [Medline] [CrossRef]

11) Kwon YC, Park JH: Korean version of Mini-Mental State Examination (MMSE) Part I: development of the test for the elderly. J Korean Neuropsychiatr Assoc, 1989, 28: 125–135.

12) Adler SS, Beeck D, Buck M: PNF in Practice: an illustrated guide, 4th ed. Heidelberg: Springer, 2013.

13) Woo YK, Cho GH, Yoo EY: Effect of PNF applied to the unaffected side on muscle tone of affected side in patients with hemiplegia. Phys Ther Korea, 2002, 9: 175–178.