



Original Article

Effects of trunk stability exercise using proprioceptive neuromuscular facilitation with changes in chair height on the gait of patients who had a stroke

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Abstract. [Purpose] The purpose of this study was to identify the effects of trunk stability exercise using proprioceptive neuromuscular facilitation with changes in chair heights on the gait of stroke patients. [Subjects and Methods] The subjects of this study were 11 stroke patients. The intervention method was trunk stability exercise using proprioceptive neuromuscular facilitation with different chair heights (50, 60, and 70 cm). These exercises were performed 5 times per week for 6 weeks. Gait velocity, cadence, stride length, gait cycle, and stance phase duration were used to measure gait function. [Results] Significant changes in gait velocity, cadence, and stride length were observed on the affected side. However, no significant changes in gait cycle and stance phase were observed on the affected side. [Conclusion] These results indicate that trunk stability exercise using proprioceptive neuromuscular facilitation with change in chair heights were effective in improving gait velocity, cadence, and stride length on the affected side. However, in this study, no significant changes were observed in gait cycle and stance phase on the affected side. Therefore, various interventions for stroke patients should be investigated in further studies.

Key words: Trunk stability, Proprioceptive neuromuscular facilitation, Stroke

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INTRODUCTION

Stroke is the most common cause of disability in activities of daily living (ADL). Trunk control is a crucial component for performing ADL¹⁾. Good trunk stability is essential for balance and extremity use during daily functional activities and higher level tasks²⁾. Furthermore, it contributes to upper extremity function³⁾.

Dickstein et al. reported that the anticipatory activity of trunk muscles is impaired in stroke patients⁴⁾. Therefore, improving trunk stability is the major goal of rehabilitation in many stroke patients. Rehabilitation treatments should especially focus on enhancing activation levels of the latissimus dorsi, external oblique, and rectus abdominis muscles on the affected side⁵⁾.

The proprioceptive neuromuscular facilitation (PNF) technique is a method to improve the trunk stability of stroke patients⁶⁾. PNF stimulates proprioceptors within the muscles and tendons, thereby improving functions and increasing muscle strength, flexibility, and balance⁷⁾. The PNF approach utilizes a typical diagonal pattern to stimulate proprioceptive sensation⁸⁾. Improving proprioceptive sensation is most important for trunk stability, and PNF exercises are useful for improving trunk stability⁹⁾.

Kim et al. reported that trunk-stabilization exercises using PNF were effective at improving muscle activities of the soleus

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and quadriceps in stroke patients⁶). This means that trunk stabilization exercises using PNF improve the lower limb muscle strength of stroke patients, positively influencing their gait.

Gait disturbance is a serious problem in stroke patients. Compared with unimpaired walking, the gait of stroke patients is characterized by reduced preferred walking speed, cadence and stride length as well as reduced symmetry, leading to prolonged stance duration on the non-paretic side and reduced step length on the paretic side¹⁰.

Verheyden et al. reported that training in the sitting position is effective in improving postural control ability¹¹). Especially, the upright sitting position was significantly associated with increased internal oblique and transverse abdominis muscle activities¹²). O'Sullivan et al. reported that electromyographic activities of the superficial lumbar multifidus, internal oblique, and thoracic erector spinae muscles was significantly higher during upright sitting than during slumped sitting¹³).

Many previous studies applied different interventions in an upright sitting position, but there research in which interventions with change in chair height were applied are lacking. Differences in the heights of a chair or cushion lead to differences hip joint angles, which significantly affect the muscle activity of the trunk and knees¹⁴). Accordingly, this study intends to examine the effects of trunk stability exercise using PNF with change in chair heights in the upright sitting position on gait the of stroke patients.

SUBJECTS AND METHODS

This study was conducted in D Rehabilitation Hospital (Seoul, South Korea). The study included 11 individuals who had a stroke diagnosed by using computed tomography and magnetic resonance imaging more than 6 months previously. The study included stroke patients who scored 24 points in the Korean version of the Mini Mental State Examination, could independently maintain the sitting posture, and did not have any visual impairment, and orthopedic disease in the upper and lower limbs.

This study complied with the ethical standards of the Declaration of Helsinki. The subjects agreed to participate in the study after receiving explanations regarding the purpose and procedures of the experiment, and signing an informed consent statement before participation. The study protocol was approved by the local ethics committee of Yongin University (2-1040966-AB-N-01-201512-HSR-042-1). [Table 1](#) shows the general characteristics of the subjects.

The intervention was conducted for 30 min, 5 times per week, for 6 weeks. The intervention was application of PNF to the trunk area in an upright sitting position. The subjects were seated on an armless, backless chair. To achieve thoracic upright sitting, the subjects were instructed to sit with their shoulder blades slightly retracted and their thoracolumbar spine extended. The height of the chair was set at 3 different heights (low, middle, and high). In the low height position, the mat was placed at 50 cm from the foot; in the middle height position, the mat was placed at 60 cm from the foot; and in the high height position, the mat was placed at 70 cm from the foot ([Fig. 1](#)). If the height of the chair is low, an upright sitting position is difficult to maintain. Therefore, in this study, the chair height was set to 50 cm. At this height, the subjects maintained an upright sitting posture. Then the height of the chair was increased by 10 cm by using a Bobath table.

Trunk muscle stability exercises were performed by using a stabilizing reversal PNF technique. Stabilizing reversal technique involves alternating muscle contraction, which aims to stabilize the posture of the subject with a static command. A therapist gave the verbal command, "Please maintain," and isometric exercises were performed by using manual resistance. When the patient was properly responding to the therapist's resistance, the therapist moved one hand to the opposite direction and then asked the patient to resist the new direction. The therapist then shifts to the other hand⁶). The therapist had completed PNF level I and II courses. The therapist applied PNF from the front of the patient, thus minimizing the patient's sense of anxiety and preventing the patient from falling.

In this study, BTS G-WALK-AP1177 (Italy) was used to measure gait parameters. The subjects wore a G-sensor at the waist, which is a mobile analysis system developed by Bluetooth ([Fig. 2](#)). The G-sensor was used to measure gait velocity, cadence, stride length (affected side), gait cycle (affected side), and stance phase (affected side). The measurements were performed before and after the intervention. The values were each measured 3 times, and their average was calculated.

Data were analyzed by using SPSS 20.0. Descriptive statistics were processed by using the general characteristics of the subjects. The paired t-test was used to compare between before and after the intervention. The significance level was set at $\alpha=0.05$.

RESULTS

In this study, the gait parameters of the stroke patients were examined during trunk stability exercise using PNF with changes in chair height. The changes in the gait parameter values are presented in [Table 2](#).

Significant changes in gait velocity, cadence, and stride length (affected side) were observed. Gait velocity was significantly increased from 0.7 ± 0.0 to 0.9 ± 0.1 m/s ($p<0.05$). Similarly, cadence was significantly increased from 72.1 ± 6.1 steps/min to 83.2 ± 5.9 steps/min ($p<0.05$). Stride length on the affected side was significantly increased from 1.2 ± 0.0 cm to 1.3 ± 0.8 cm ($p<0.05$).

However, with respect to gait cycle and stance phase on the affected side, the values were decreased. The gait cycle on the affected side was decreased from $1.8 \pm 0.2\%$ to $1.6 \pm 0.1\%$ ($p>0.05$). In addition, the stance phase on the affected side was decreased from $69.0 \pm 2.9\%$ to $64.6 \pm 3.0\%$ ($p>0.05$).

Table 1. General characteristics of the subjects

Gender	Male: 6 / Female: 5
Age (years)	58.8 ± 4.0
Weight (kg)	65.2 ± 7.0
Height (cm)	164.9 ± 6.2
Time since stroke (months)	44.1 ± 38.2
Stroke type	Infarction: 8 / hemorrhage: 3
Affected side	Left: 4 / right: 7



Fig. 1. Trunk stability exercise using PNF with changes in chair height (A: 50 cm, B: 60 cm, and C: 70 cm)

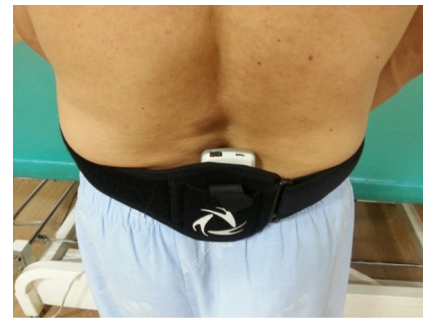


Fig. 2. BTS measurement (wearing the device at the waist)

Table 2. Comparison of gait parameters results

	Pre	Post
Gait velocity (m/s)	0.7 ± 0.0	0.9 ± 0.1*
Cadence (steps/min)	72.1 ± 6.1	83.2 ± 5.9*
Stride length on the affected side (cm)	1.2 ± 0.0	1.3 ± 0.8*
Gait cycle on the affected side (%)	1.8 ± 0.2	1.6 ± 0.1
Stance phase on the affected side (%)	69.0 ± 2.9	64.6 ± 3.0

Data are presented as mean ± SD.

*p<0.05

DISCUSSION

Stroke patients exhibit an inefficient gait condition with high energy consumption and have difficulty walking independently⁸). Moreover, after a stroke, the ability to maintain trunk control in the sitting and standing positions is a fundamental skill for performing activities of daily living. The trunk control performance of patients soon after a stroke has been found to be closely associated with long-term functional improvement¹⁵).

Several studies on trunk-stabilization exercises have been reported, but only few of these studies discussed the influence of trunk stability exercise using PNF with change in chair height. Lee and Lee reported that chair height can influence the ability to complete a sit-to-stand task without falling back on the chair¹⁶). Arborelius et al. reported that the height of a chair affected the myoelectrical activity of the lower limb muscles (quadriceps femoris, and hamstring muscles)¹⁷).

Therefore, this study investigated the effect of trunk stability exercise using PNF with changes in chair height on the gait of stroke patients. In order to assess gait function, gait velocity, cadence, stride length, gait cycle, and stance phase were evaluated and compared between before and after the intervention.

Significant changes in gait velocity, cadence, and stride length were observed on the affected side. Gait velocity increased from 0.7 ± 0.0 m/s to 0.9 ± 0.1 m/s (p<0.05). Cadence increased from 72.1 ± 6.1 step/min to 83.2 ± 5.9 step/min (p<0.05). Stride length on the affected side increased from 1.2 ± 0.0 cm to 1.3 ± 0.8 cm (p<0.05).

However, no significant changes in gait cycle and stance phase were observed on the affected side. The gait cycle on the affected side decreased from 1.8 ± 0.2% to 1.6 ± 0.1%. The stance phase on the affected side decreased from 69.0 ± 2.9% to

64.6 ± 3.0%.

Most stroke patients show asymmetrical gait patterns due to reduction in cadence and low gait velocity¹⁸⁾. Therefore, in the present study, increases in gait velocity and cadence is considered to have a positive effect on the gait of stroke patients. Choi et al. reported that trunk stabilization exercise using a Swiss ball improved the balance and gait of elderly women¹⁹⁾. In addition, Kim et al. reported that isometric trunk exercises had a positive effect on the gait function of elderly people. The isometric exercise group showed a significant change in gait velocity, cadence, and step length²⁰⁾. This result is consistent with the present study result, which showed that trunk stability exercise positively influences gait. However, in this study, no significant changes in gait cycle and stance phase were observed on the affected side. The study period of 6 weeks may be assumed to be inadequate to observe changes on the affected side.

Kim et al. reported that trunk stabilization exercises using PNF performed induced a significant increase in the muscle activity of the lower extremities of stroke patients⁶⁾. This indicates that the recruitment of trunk muscles, which are used for PNF, was increased to cause the irradiation effect induced by increasing the lower extremity muscle activity on the affected side. Therefore, the trunk exercises using PNF that were applied in the present study affected the lower limb muscle strength of the stroke patients, positively affecting their gait. Among the PNF techniques, the stabilizing reversal technique is used to enhance the strength of the postural muscles of the trunk, shoulder girdle, and hip joint, thus, stabilizing the muscles and increasing the stability of the relevant joints. The stabilizing reversal PNF technique applied in the present study increased trunk stability, thus positively affecting gait²¹⁾.

Park et al. reported that weakness of the plantar flexors in the push-off stage of gait is considered the most important factor of disability in stroke patients¹⁸⁾. Kim et al. reported that trunk stabilization exercises using PNF were effective at improving the soleus muscle activity in stroke patients⁶⁾. The soleus muscle plays the main role in ankle plantar flexion. Muscular strength of the ankle plantar flexors on the affected side has an effect on gait velocity²²⁾. Therefore, the intervention method applied in the present study increased the muscle activity of the soleus, thus positively affecting gait velocity.

Anan et al. reported that the height of a chair cushion affected the hip, knee, and ankle joints, which affected the muscle activity of the trunk and lower limbs¹⁴⁾. In the present study, the changes in chair height can be considered to have increased the activity of the trunk muscles, thus positively affecting gait. However, this study did not confirm which height was the most effective. Accordingly, in future research, exercise should be conducted according to the respective heights of a chair to examine the effect of chair height.

The present study examined the effects of trunk stability exercise using PNF with changes in chair heights in stroke patients. Gait velocity, cadence, and stride length on the affected side showed significant changes. However, gait cycle and stance phase on the affected side did not show a positive effect. Thus, future studies with different interventions and more diverse tasks are necessary.

This study included a limited number of subjects and did not include a control group. Therefore, future studies should be performed in a larger number of subjects. The authors hope that diverse treatment methods using PNF techniques will be used to treat stroke patients based on the findings of this present study.

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