Effect of coordination movement using the PNF pattern underwater on the balance and gait of stroke patients

Kyoung Kim, PT, PhD1, Dong-Kyu Lee, PT, MS2, Sang-In Jung, PT, MS2

1) Department of Physical Therapy, College of Rehabilitation Science, Daegu University, Republic of Korea
2) Department of Rehabilitation Science, Graduate School, Daegu University: 201 Daegudae-ro, Jillyang-eup, Gyeongsan-si, Gyeongsangbuk-do 712-714, Republic of Korea
3) Department of Physical Therapy, Sunhan Hospital, Republic of Korea

Abstract. [Purpose] To investigate the effect of coordination movement using the Proprioceptive Neuromuscular Facilitation pattern underwater on the balance and gait of stroke patients. [Subjects and Methods] Twenty stroke patients were randomly assigned to an experimental group that performed coordination movement using the Proprioceptive Neuromuscular Facilitation pattern underwater and a control group (n = 10 each). Both the groups underwent neurodevelopmental treatment, and the experimental group performed coordination movement using the Proprioceptive neuromuscular facilitation pattern underwater. Balance was measured using the Berg Balance Scale and Functional Reach Test, and gait was measured using the 10-Meter Walk Test and Timed Up and Go Test. To compare in-group data before and after the intervention, paired t-test was used. Independent t-test was used to compare differences in the results of the Berg Balance Scale, Functional Reach Test, 10-Meter Walk Test, and Timed Up and Go Test before and after the intervention between the groups. [Results] Comparison within the groups showed significant differences in the results of the Berg Balance Scale, Functional Reach Test, 10-Meter Walk Test, and Timed Up and Go Test before and after the experimental intervention. On comparison between the groups, there were greater improvements in the scores of the Berg Balance Scale, Functional Reach Test, 10-Meter Walk Test, and Timed Up and Go Test in the experimental group. [Conclusion] The findings demonstrate that coordination movement using the Proprioceptive Neuromuscular Facilitation pattern under water has a significant effect on the balance and gait of stroke patients. Key words: Coordination movement using the PNF pattern, Balance, Gait

INTRODUCTION

Stroke results in impaired blood flow that hinders blood supply to the brain tissue, and this can cause brain damage1-4. Although stroke patients survive with appropriate emergency measures and early treatment, they may have defects in cognition, perception, language, sensibility, and exercise ability4, 5. Additionally, they may have difficulty in independently performing daily activities owing to physical and mental damage5, 6. Stroke patients exhibit hemiplegia paralysis on either the left or the right side of the body caused by weakening of muscles, and abnormal muscle contractions and movement patterns5, 6. Weakening of muscles and asymmetric posture due to hemiplegia increase posture disturbances and degrade balancing ability, leading to walking difficulties in stroke patients5, 6.

Functional approaches, neurodevelopment treatments controlling motion, Proprioceptive Neuromuscular Facilitation (PNF) using a diagonal movement pattern, and dual-task training are being used for improving the balance and gait of stroke patients5, 6. Recent studies reported that aquatic exercises have a positive effect on the neurological functions of stroke patients6, 7. The resistance from water while performing underwater exercises promotes balancing ability by enhancing the muscles of the lower limb and stimulating deep muscle proprioceptors6-9. Additionally, buoyancy effectively supports body weight and mitigates any shock on the joints9.

Coordination movement using the PNF pattern is devised by patterning the upper and lower limbs for exercise10, 11. Movements of the human body occurring in three dimensions through gait and induced motion of the body are analyzed11. Coordination movement using the PNF pattern integrates the patterns of each segment and standardizes them into a coordinated system10. This effectively promotes appropriate posture maintenance, as bilateral exercises in-
were informed of the study objectives and agreed to participate. The stroke patients diagnosed more than 6 months previously. The stroke patients were investigated for coordination movement using computed tomography and magnetic resonance imaging on balance and gait in stroke patients.

The purpose of this study was to investigate the effect of coordination movement using the PNF pattern under water on balance and gait in stroke patients.

**SUBJECTS AND METHODS**

The study included 20 individuals diagnosed with stroke by using computed tomography and magnetic resonance imaging more than 6 months previously. The stroke patients were informed of the study objectives and agreed to participate. They were randomly assigned to an experimental group that performed coordination movement using the PNF pattern under water (n = 10; five male and five female patients) and a control group (n = 10; five male and five female patients). The study included stroke patients who had 24 points on the Mini Mental State Examination (MMSE), could independently walk 10 meters, and did not have any visual impairment, visual field defect, and orthopedic disease in the upper and lower limbs. This study complied with the ethical standards of the Declaration of Helsinki, and written informed consent was received from each participant. The ethical committee of Daegu University approved this study. The general characteristics of the participants are presented in Table 1. The mean age, height, weight, and onset time were 65.9±6.2 y, 165.9±7.6 cm, 66.8±5.0 kg, and 11.3±1.1 months in the experimental group and 64.1±3.6 y, 165.3±5.3 cm, 66.4±7.5 kg, and 12.3±1.3 months in the control group, respectively.

Both the groups received neurodevelopment treatment (mat exercise, resistance exercise, postural control exercise, and functional activity exercise) for 30 minutes a day five times a week for 6 weeks. The experimental group additionally performed coordination movement using the PNF pattern underwater at a temperature of 32–34 °C and depth of 100 cm. The coordination movement using the PNF pattern involved the sprinter and skate patterns. In the sprinter pattern, the right upper limb and the left lower limb are in flexion, adduction, and external rotation, and simultaneously, the left upper limb and the right lower limb are in extension, abduction, and internal rotation. In the skate pattern, the right upper limb is in extension, adduction, and internal rotation and the left lower limb is in extension, adduction, and external rotation, and simultaneously, the left upper limb and right lower limb are in flexion, abduction, and internal rotation. The sprinter and skate patterns were required to be maintained for 10 s each from a standing posture in left and right alternation. One set included 10 movements, and a total of five sets were performed. Prior to the experimental intervention, the participants were acquainted with the sprinter and skate patterns through training.

Balance was measured using the Berg Balance Scale (BBS) and Functional Reach Test (FRT). The BBS is divided into three sections (sitting, standing, and changing posture) and includes 14 items. The total score is 56 points and a higher score indicates good balancing ability. The FRT measures the distance between the start and end positions while standing comfortably, raising an arm 90° from the torso, and reaching out without losing balance.

Gait was measured using the 10-Meter Walk Test (10MWT) and Timed Up and Go Test (TUGT). The 10MWT assesses walking speed. The participants walked 14 m, and the time taken to walk 10 m was measured, excluding the first 2 m and last 2 m. The TUGT assesses functional mobility. The time taken to sit on an armchair, stand up at the starting signal, walk 3m, and return to the sitting position is measured.

The collected data were analyzed using SPSS 12.0 (SPSS, Chicago, IL, USA). Descriptive statistics were processed using the general characteristics of the participants. The paired t-test was used to compare in-group data before and after the intervention. Moreover, the independent t-test was used to compare the changes in the results of the BBS, FRT, 10MWT, and TUGT between the experimental and control groups.

The changes in the results of the BBS, FRT, 10MWT, and TUGT are presented in Table 2. There were significant differences in these results before and after the experimental intervention.

**Table 1. General characteristics of subjects**

|                        | EG (n=10) | CG (n=10) |
|------------------------|-----------|-----------|
| Gender (male / female) | 5/5       | 5/5       |
| Age (years)            | 65.9±6.2  | 64.1±3.6  |
| Weight (kg)            | 66.8±5.02 | 66.4±7.5  |
| Height (cm)            | 165.9±7.6 | 165.3±5.3 |
| Paretic side (right / left) | 5/5       | 5/5       |
| Onset (months)         | 11.3±1.1  | 12.3±1.3  |

*Mean±SD. EG: Experimental Group, CG: Control Group

**Table 2. Comparison of the results of the BBS, FRT, 10MWT, and TUGT between the experimental and control groups**

| Test          | Group | Pre  | Post | D-Value |
|---------------|-------|------|------|---------|
| BBS           | EG    | 42.5±1.1 | 45.1±1.3* | 2.6±1.1* |
|               | CG    | 40.7±1.5 | 41.6±1.2 | 0.9±1.2  |
| FRT           | EG    | 18.3±1.1 | 20.4±0.8* | 2.1±1.2* |
|               | CG    | 18.8±0.9 | 19.4±1.0 | 0.6±0.9  |
| 10MWT         | EG    | 14.6±1.1 | 12.6±1.7* | -2.0±1.4#|
|               | CG    | 14.9±1.1 | 14.3±0.9 | -0.6±1.3 |
| TUGT          | EG    | 18.4±1.2 | 16.1±1.6* | -2.3±1.6*|
|               | CG    | 18.5±1.0 | 18.2±1.0 | -0.3±1.0 |

*Mean±SD. *p<0.05: paired t-test, # p<0.05: independent t-test

D-value: Difference value, EG: Experimental Group, CG: Control Group, BBS: Berg Balance Scale, FRT: Functional Reach test, 10MWT: 10-Meter Walk Test, TUGT: Timed Up and Go Test

The changes in the results of the BBS, FRT, 10MWT, and TUGT are presented in Table 2. There were significant differences in these results before and after the experimental intervention.

The collected data were analyzed using SPSS 12.0 (SPSS, Chicago, IL, USA). Descriptive statistics were processed using the general characteristics of the participants. The paired t-test was used to compare in-group data before and after the intervention. Moreover, the independent t-test was used to compare the changes in the results of the BBS, FRT, 10MWT, and TUGT before and after the intervention between the groups. The significance level was set at α=0.05.

**RESULTS**

The changes in the results of the BBS, FRT, 10MWT, and TUGT are presented in Table 2. There were significant differences in these results before and after the experimental intervention.
intervention. On comparison between the groups, there were greater improvements in the results of the BBS, FRT, 10MWT, and TUGT in the experimental group.

**DISCUSSION**

This study investigated the effect of coordination movement using the PNF pattern under water on the balance and gait of stroke patients. There were significant differences in the results of the BBS and FRT (used for balance) before and after the experimental intervention. On comparison between the groups, there were greater improvements in the results of the BBS and FRT in the experimental group. Lee et al. 14) and Jeong et al. 15) showed an improvement in balancing ability after applying coordination movement using the PNF pattern in stroke patients. Chol et al. 17) reported that coordination movement using a tapping and PNF combination pattern enhanced the balance of stroke patients. Previous studies differ from the present study in the treatment environment, but the results correspond. Coordination movement using the PNF pattern improves function and enhances balancing ability by stimulating a proprioceptive sense of the muscles and tendons 7–9). During coordination movement using the PNF pattern underwater, the water provides resistance and helps to strengthen the muscles 7–9). In a challenging condition with buoyancy and turbulent currents, muscle fibers are activated to maintain posture and balance, and this is expected to improve balance 7–9).

Gait is the fundamental motion in body movement that requires coordination of the upper and lower limbs and involves continuous and repetitive movements of each segment 18). Coordination is crucial for functional gait 18). Stroke patients exhibit an inefficient gait condition with high energy consumption, and they have difficulty in walking independently 19). In the present study, the results of the 10MWT and TUGT (used for gait) significantly differed before and after the intervention in the experimental group. On comparison between groups, the results of the 10MWT and TUGT showed greater improvements in the experimental group. Lee et al. 14) and Jeong et al. 16) showed an improvement in gait ability after applying coordination movement using the PNF pattern in stroke patients. Previous studies differ from the present study in the treatment environment, but the results correspond. Coordination movement using the PNF pattern has been designed by analyzing patterns of interrelated movements of each body segment 11–12). It improves posture and balance by efficiently working on the muscles on the paralyzed side and thus improves walking ability 11–13). An underwater environment promotes joint movement as it decreases gravitational influence 20). Additionally, it supports 75% of the body weight with buoyancy, and this partial weight support positively influences gait function 20, 21). The findings of this study indicate that coordination movement using the PNF pattern may be an appropriate therapy method for stroke patients who have problems with gait because of declined weight support and balancing ability.

This study has some limitations. The findings may not be generalizable as the participants were selected using specific criteria. Additionally, no follow up was conducted; therefore, the duration of the effect after the experimental intervention is unknown. Further studies are needed to address these issues.

**REFERENCES**

1) Kolb B, Gibb R: Brain plasticity and recovery from early cortical injury. Dev Psychobiol, 2007, 49: 107–118. [Medline] [CrossRef]
2) Perry J, Garrett M, Gromley JK, et al.: Classification and walking handicap in the stroke population. Stroke, 1995, 26: 982–989. [Medline] [CrossRef]
3) Carr JH, Shepherd RB, Nordholm L, et al.: Investigation of a new motor assessment scale for stroke patients. Phys Ther, 1985, 65: 175–180. [Medline]
4) Hankey GJ, Jamrozik K, Broadhurst RJ, et al.: Long-term disability after first-ever stroke and related prognostic factors in the Perth Community Stroke Study, 1989-1990. Stroke, 2002, 33: 1034–1040. [Medline] [CrossRef]
5) Eng JJ, Chu KS: Reliability and comparison of weight-bearing ability during standing tasks for individuals with chronic stroke. Arch Phys Med Rehabil, 2002, 83: 1138–1144. [Medline] [CrossRef]
6) Oujamaa L, Relave I, Froger J, et al.: Rehabilitation of arm function after stroke. Literature review. Ann Phys Rehabil Med, 2009, 52: 269–293. [Medline] [CrossRef]
7) Kim YN, Lee DK: Comparison between aquatic and ground environments of rhythmic initiation for postural control. J Phys Ther Sci, 2012, 24: 1269–1271. [CrossRef]
8) Wang TJ, Belza B, Elaine Thompson F, et al.: Effects of aquatic exercise on flexibility, strength and aerobic fitness in adults with osteoarthritis of the hip or knee. J Adv Nurs, 2007, 57: 141–152. [Medline] [CrossRef]
9) Suomi R, Kooja DM: Postural sway characteristics in women with lower extremity arthritis before and after an aquatic exercise intervention. Arch Phys Med Rehabil, 2000, 81: 780–785. [Medline] [CrossRef]
10) Chu KS, Eng JJ, Dawson AS, et al.: Water-based exercise for cardiovascular fitness in people with chronic stroke: a randomized controlled trial. Arch Phys Med Rehabil, 2004, 85: 870–874. [Medline] [CrossRef]
11) Adler SS, Beckers D, Buck M: PNF in practice: An illustrated guide, 2nd ed. Springer, 2002.
12) Dietz B: Let’s sprint, let’s skate: Innovationen im PNF-Konzept, 1st ed. Springer, 2009.
13) Kim TV: The effects of strengthening exercise using the sprinter/skater patterns. J Korean Proprioceptive Neuromuscular Facilitation Assoc, 2006, 4: 71–79.
14) Lee MK, Yun TW, Kim YH, et al.: Effect of gait training using PNF on balance and walking ability in person with chronic stroke (Single Subject Design). J Korean Proprioceptive Neuromuscular Facilitation Assoc, 2011, 11: 281–292. [CrossRef]
15) 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 Contents Assoc, 2012, 12: 318–328. [CrossRef]
16) Choi YK, Nam CW, Lee JH, et al.: The effects of tapping prior to PNF treatment on lower extremity proprioception of hemiplegic patients. J Phys Ther Sci, 2013, 25: 1119–1122. [Medline] [CrossRef]
17) Roerdink M, Lamoth CK, Kwakkel G, et al.: Gait coordination after stroke: benefits of acoustically paced treadmill walking. Phys Ther, 2007, 87: 1009–1022. [Medline] [CrossRef]
18) Dias D, Lains J, Pereira A, et al.: Can we improve gait skills in chronic hemiplegics? A randomised control trial with gait trainer. Euro Med Phys, 2007, 43: 499–504. [Medline] [CrossRef]
19) Arnold CM, Busch AJ, Schachter CL, et al.: A randomized clinical trial of aquatic versus land exercise to improve balance, function, and quality of life in older women with osteoporosis. Physiother Can, 2008, 60: 296–306. [Medline] [CrossRef]
20) [Medline] [CrossRef]
21) Jung T, Lee D, Charalamous C, et al.: The influence of applying additional weight to the affected leg on gait patterns during aquatic treadmill walking in people poststroke. Arch Phys Med Rehabil, 2010, 91: 129–136. [Medline] [CrossRef]