J Int Acad Phys Ther Res 2018; 9(4): 1642~1650
ISSN 2092-8475

www.iaptr.org
https://doi.org/10.20540/JIAPTR.2018.9.4.1642

The Effect of Joint Mobilization with PNF Stretch Exercise on Ankle Joint Range of Motion, Plantar Pressure, and Balance in Patients with Stroke

The purpose of this study was to identify the effect of proprioceptive neuro-muscular facilitation (PNF) stretching exercise and joint mobilization on ankle joint range of motion (ROM), plantar pressure, and balance in subjects with stroke. Thirty patients (n=30) were organized into three groups, each of which received different treatments: PNF stretching (n=10), joint mobilization (n=10), and joint mobilization and PNF stretching combined (n=10). Each group received three exercise sessions per week for four weeks. The ankle ROM was measured using a goniometer, and plantar pressure and balance ability were measured using BioResque static posturography. In comparison within each group, the joint mobilization group and the joint mobilization with PNF stretching group showed significant improvements in ankle ROM, plantar pressure, and balance ability ($p<.05$). In comparison between the groups, a statistically significant difference was found in SECS change between the PNF stretching group, joint mobilization group and the joint mobilization with PNF stretching group. This study found demonstrates that the joint mobilization and joint mobilization with the PNF stretching methods were effective in improving ankle ROM, plantar pressure, and balance ability in stroke patients.

Key words: *PNF stretching, joint mobilization ankle ROM, plantar pressure, balance*

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Received : 25 October 2018
Revised : 27 November 2018
Accepted : 30 November 2018

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INTRODUCTION

Hemiplegia after stroke results in lack of muscle use as it causes secondary changes in muscles and nerves. The long-term non-use of muscles induces often adaptive muscle contraction and causes atrophy of the motor cortex that is responsible for each of the physical body parts, resulting in worsening paralysis [1], and creates limitations in contractile or non-contractile tissues, as well as reducing the range of motion in ankle joints [2]. It also induces changes in ankle joints due to the long-term limitation in mobility, thereby making functional physical activities difficult [3]. This results in musculoskeletal problems in ankle joints and problems in coordination activities in the neuromuscular system, which is responsible for balance control [4], making the balance control of patients with hemiplegia difficult [5]. The ankle joint, which is an important element in posture control, has a small motion at the standing position [6]. With the increase in ankle joint range of motion, balance ability increases, thereby improving the arrangement of the ankle joint of patients with stroke, and various interventions that facilitate the strengthening of ankles through repeated movements should be included [5, 7, 8].

Proprioceptive neuromuscular facilitation (PNF) is known to be a very effective intervention that improves muscle strength, flexibility, plantar pressure and balance by stimulating proprioception in muscles and tendons [12-14]. The application of PNF in a lower extremity pattern to patients with chronic stroke improves muscle tone and reduces muscle stiffness [14], and is highly effective in dynamic balance and improvements in walking [15].

Joint mobilization and stretching can be used as interventions to improve the limited range of motion in the dorsum of the foot. Joint mobilization is a

manual therapy that creates passive movements in the joint surface, which has been reported to have effects on pain control and functional movements and improvements in joint range of motion [16-18], increase hind foot plantar pressure [19], enhancement of static balance [18] and dynamic balance [19], and improvements in proprioceptive sense [20].

Various studies have been conducted on the application of joint mobilization and PNF stretching as an ankle joint intervention for stroke patients. Joint mobilization applied to ankle joints increased passive and active range of motion in ankles [20], and reduced the time required for sit-to-stand motions [21]. PNF stretching increased muscle strength and joint range of motion [15] as well as dynamic balance ability [20]. Despite the results of a previous study showing that two intervention methods were effective for the ankle joint functions of stroke patients, a few studies have been conducted on the application of two methods to stroke patients and a comparison of the results. Stroke patients have limitations in contractile or non-contractile tissues due to muscle stiffness, which requires intervention in joints and muscles. In previous studies, there have been many studies on the effects of single stretching type or single joint mobilization. Therefore, this study investigated the effects of these two forms of combined intervention. Thus, this study aims to determine the effect of a combination of joint mobilization and PNF stretching interventions on ankle joint range of motion, foot plantar pressure, and balance of stroke patients, and to provide a new combination method of interventions that can be applied to stroke patients.

METHODS

Subjects and Period

This study was conducted with 30 patients who were medically diagnosed with stroke via magnetic resonance imaging or computed tomography and admitted to D Hospital located in Gyeonggi-do from September 1, 2018 to October 31, 2018 for four weeks non-simultaneously. This study was conducted with all the subjects before the initial evaluation, who fully explained the purpose and signed the research agreement. Thirty stroke patients were selected, and the purpose and intention of the study were fully explained to them. The study was conducted after written consent was provided by the participants. The subjects were divided into 10 in the PNF stretching group group patients, 10 in the joint mobilization patients and 10 in the combined PNF stretching and joint mobilization group. The detailed selection criteria were as follows:

(1) Patients who could understand the study method and cooperate among those who had 24 points or higher in the Korean version of the Mini-Mental State Examination (MMSE-K).
(2) Patients who had spasticity level 2 or lower in stiffness in the modified Ashworth scale.
(3) Patients who could walk independently indoors without help.
(4) Patients who could understand the procedure and purpose of the study and participated voluntarily.
(5) Patients without severe visual impairment and visual field defects or hearing impairment based on the doctor's clinical finding.

Measurement Methods

Measurement of ankle joint range of motion

Subjects assumed a supine position in bed while extending all the hip and knee joints to measure range of motion of the ankle joint using a goniometer. To measure the range of motion, a method suggested by the American Academy of Orthopaedic Surgeons (AAOS, 1965) was used as follows: The axis of the standard goniometer was attached to the lateral malleolus. The fixed arm was arranged horizontally with the line connected to the outer fibular head and the moving arm was arranged horizontally with the line connected to the metatarsal bone in the fifth toe to calculate the moving angle of the moving arm while a neutral position between dorsiflexion (DF) and plantar flexion (PF) was set to 0°. The inter-rater reliability test results were as follows: DF was 0.63 of intraclass correlation coefficient (ICC) and PF was 0.73 of ICC). The intra-rater reliability test results were as follows: DF was 0.86 of ICC and PF was 0.84 of ICC [23].

Measurement of plantar pressure and balance ability

To analyze the plantar pressure and balance ability, BioResque static posturography (RM Ingénierie, France) was employed. BioResque Ingenierieco square force plate. The plantar pressure was measured by a proportion of body weight distributed between both feet, and the balance ability was measured by a sway area of center of gravity and mean sway speed.

Subjects were not allowed to see the monitor to prevent them receiving visual feedback during the measurement of the proportion of body weight in standing position. Two measurements were conducted, and a mean value was calculated from them and

a safety bar was placed in front of the patient for the safety of the subject. In the test-retest method of this instrument, the intraclass correlation coefficient (ICC = .84) was found to be as high as 0.84 or higher [24].

Intervention Method

All subjects performed the intervention three times a week for four weeks. Each participant in the PNF stretching group and joint mobilization group the conducted the intervention for 15 min. The joint mobilization and PNF stretching-combined group conducted PNF stretching first for 7 min 30 sec, followed by joint mobilization for 7 min 30 sec. All the initial measurements were conducted prior to starting the intervention, and follow-up measurements were conducted after four weeks when the intervention was about to finish non-simultaneously.

PNF stretching

The PNF stretching in this study was done as follows: Subjects were laid on a mat comfortably in a supine position and a pattern of hip joint extension, adduction, and internal rotation was applied in which the knees were extended, and plantar flexion and lateral rotation were applied to the joint ankle while the toe joint was extended and the hold-relax and contract-relax technique was applied. This pattern simultaneously stimulated many important muscles used in balance and gait, such as the rectus femoris muscle, medial gastrocnemius and lateral gastrocnemius, the biceps femoris, and semimembranosus, and among them, the contraction of the gastrocnemius was induced. This pattern was applied to increase the range of motion in dorsiflexion of the ankle joint. The hold-relax and contract-relax action consisted of contraction for eight sec and relaxation for seven sec. In one set, four contraction and relaxation actions took one min, and a total of 15 sets were applied for 15 min [14].

Joint mobilization

This study applied Grade 3 joint mobilization using the Maitland method [25]. Subjects laid their lower extremities side by side in a supine position, and towels were placed under the knees to prevent complete extension of the knees while the ankles were maintained at a natural position. Then, the therapist held the patient's calcaneus by the left hand, which was then supported on the right thigh of the therapist to maintain the ankle joint at a comfortable position. Posterior talocrural articulation gliding, and anterior and posterior subtalar gliding were then applied for four min each, and one min of rest was provided between exercises, making a total of 15 min joint mobilization [17, 20, 26]. Bernard et al. (2004) suggested that a strong stimulus above the threshold would give rise to a change in the actual postural control in order to give sufficient stimulation to the somatic sensory receptors located deep in the foot. In this study, grade III was applied to make it safer to patients who may have osteoporosis. The joint motion technique was performed in the range of motion of the joints to be applied with each set of four, including resting, within the range of no pain on the paralyzed ankle with reference to the position and motion of the joints. Each set of grade III was applied at a rate ranging from 30 to 60 times per minute [32, 33].

Data analysis

The data analysis in this study was conducted using SPSS version 20.0 for Windows. The homogeneity of the general characteristics of the subjects was verified using the descriptive statistics and Chi-square test. The difference within each group before and after the intervention was determined using a paired t-test. The statistical significance level of this study was α=.05.

RESULTS

General characteristic of subjects

General characteristic of the three groups are presented in Table 1. The gender in the PNF stretching group consisted of six males and four females. Four subjects were paralyzed in the right side and six were paralyzed in the left side. The types of symptoms were as follows: Four subjects had infarction, while six had bleeding. The mean age was 56.40±4.92 years, and the mean duration of illness was 17.50±2.79 months. The mean K-MMSE score was 26.40±1.77 points. The gender in the joint mobilization group consisted of five males and five females. Five subjects were paralyzed in the right side and five were paralyzed in the left side. The types of symptoms were as follows: Five subjects had infarction, while five had bleeding. The mean age was 60.20±3.19 years, and the mean duration of illness was 16.20±3.08 months. The mean K-MMSE score was 27.10±1.79 points. The gender in the joint mobilizationand PNF stretching-combined group consisted of eight males and two females. Four subjects were paralyzed in the right side and two were paralyzed in

the left side. The types of symptoms were as follows: Nine subjects had infarction, while one had bleeding. The mean age was 65.93±8.59 years, and the mean duration of illness was 13.67±3.34 months. The mean K-MMSE score was 25.70±1.34 points. Since there was no significant difference among the three groups, this study concluded that the groups were homogeneous (p>.05).

Changes in ankle joint range of motion before and after intervention

There was a significant increase in plantar flexion and dorsiflexion range of motion after the intervention in two groups. In the joint mobilization group, the range of motion in plantar flexion increased and in the joint mobilization and PNF stretching-combined

Table 1. General characteristics of the subjects. (N=30)

Variables \ Group	PS (n=10)	JM (n=10)	PS+JM (n=10)	X^2	p
Sex					
Male	6 (60 %)	5 (50 %)	7 (70 %)	.659	ns
Female	4 (40 %)	5 (50 %)	3 (30 %)		
Age (year)	56.40 ± 4.92	60.20 ± 3.19	57.10 ± 4.25	.864	ns
Side					
Right	4 (40 %)	5 (50 %)	5 (50 %)	.864	ns
Left	6 (60 %)	5 (50 %)	5 (50 %)		
I/H					
I	4 (40 %)	5 (50 %)	5 (50 %)	.875	ns
H	6 (60 %)	5 (50 %)	5 (50 %)		
MMSE	26.40 ± 1.77	27.10 ± 1.79	27.20 ± 1.75	463	ns
MAS					
1	4 (40 %)	5 (50 %)	4 (40 %)		
1+	4 (40 %)	3 (30 %)	4 (40 %)	.987	ns
2	2 (20 %)	2 (20 %)	2 (20 %)		
Duration of illness (month)	17.50 ± 2.79	16.20 ± 3.08	17.3. ± 2.94	.600	ns

ns: no significant, I: Infarction, H: Hemorrhage
PS: PNF stretching, JM: joimt mobilization, PS+JM: joint mobilization with PNF stretching, MAS : modified ashworth scale, K-MMSE: Korean Mini -Mental State Examination

Table 2. Comparison of change in ankle range of motion in each group(Unit: Degree).

Variables	Group	PS (n=10)	JM (n=10)	PS+JM (n=10)	F	p
PF	Pre	17.80±2.69	19.20±2.78	19.00±2.27	2.152	.136
	Post	18.00±2.66	20.30±2.75	20.00±2.66		
	p	.509	.003*	.001**		
DF	Pre	9.30±2.05	9.60±1.77	9.60±2.17	1.116	.342
	Post	9.90±2.51	11.00±1.63	11.20±2.04		
	p	.051	.000**	.000**		

Values are Mean ± standard deviation.
*p<.05, **p<.01, JM: joint mobilization, PS: PNF stretching, JM with PS: joint mobilization with PNF stretching, PF: Plantar flexion, DF: Dorsiflexion

Table 3. Comparison of change in plantar pressure in each group.

Variables	Group	PS (n=10)	JM (n=10)	PS+JM (n=10)	F	*p*
AA(㎟)	Pre	119.60±13.59	118.10±12.90	126.90±9.37	1.224	.310
	Post	123.50±13.72	122.80±13.51	130.60±9.24		
	p	.000**	.000**	.004*		
AN (㎟)	Pre	135.90±17.02	140.60±18.84	142.70±13.03	0.130	.879
	Post	133.70±17.26	136.70±19.20	137.10±11.51		
	p	.001**	.006*	.000**		
AF(㎟)	Pre	144.70±9.47	154.10±16.02	150.20±14.06	0.113	.894
	Post	142.00±9.56	148.20±16.09	142.80±12.93		
	p	.001**	.000**	.000**		
AB(㎟)	Pre	124.00±21.36	117.00±19.87	116.50±14.71	0.075	.928
	Post	124.90±19.37	122.00±19.53	122.80±11.78		
	p	.430	.000**	.002*		
PA(㎏/㎠)	Pre	48.15±6.68	48.06±6.85	46.31±2.45	0.087	.917
	Post	48.00±6.91	48.52±6.78	47.44±2.68		
	p	.637	.045*	.000**		
PN(㎏/㎠)	Pre	51.75±6.68	51.70±6.92	53.4±2.78	0.111	.895
	Post	51.54±6.62	51.50±6.80	52.56±2.68		
	p	.052	.554	.000**		

Values are Mean ± standard deviation.
*p<.05, **p<.01, JM: joint mobilization, PS: PNF stretching, JM with PS: joint mobilization with PNF stretching, AA: Area Affected, AN: Area Non-affected, AF: Area Forward, AB: Area Backward, PA: Pressure Affected, PN: Pressure Non-affected

group the range of motion increased significantly after intervention($p<.05$). and in the joint mobilization and PNF stretching-combined group the range of motion increased significantly after intervention ($p<.05$)(Table 2). However, no significant change between groups was found.

Changes in plantar pressure before and after intervention

The area contacted by the paralyzed foot significantly increased in the joint mobilization group and in the joint mobilization and PNF stretching-combined group after intervention($p<.05$)(Table 2). However, no significant change between groups was found. The area contacted by the non-paralyzed foot significantly decreased in the PNF stretching group and in the joint mobilization group after intervention($p<.05$). It also significantly decreased in the joint mobilization and PNF stretching-combined group after intervention($p<.05$). However, no significant change between groups was found. The area contacted by the forefeet in both sides significantly decreased in the PNF stretching group and in the joint mobilization group after intervention($p<.05$). It also significantly decreased after intervention($p<.05$). However, no significant change between groups was found. The area contacted by the hind-feet in both sides significantly increased in the joint mobilization group and in the joint mobilization and PNF stretching-combined group after intervention($p<.05$). However, no significant change between groups was found. The plantar pressure in the paralyzed foot significantly increased in the joint mobilization group and in the joint mobilization and PNF stretching-combined group after intervention($p<.05$). However, no significant change between groups was found. The plantar pressure in

the non-paralyzed foot significantly increased decreased after intervention($p<.05$), but no significant change between groups was found.

Changes in balance ability before and after intervention

The sway area with eyes open and standing on both feet significantly decreased in the PNF stretching group and in the joint mobilization group after intervention($p<.05$). It also significantly decreased the joint mobilization and PNF stretching-combined group after intervention($p<.05$). However, no significant change between groups was found.

The mean sway speed with eyes open and standing on both feet significantly decreased after intervention($p<.05$), but no significant change between groups was found.

The sway area with eyes closed and standing on both feet significantly decreased in the PNF stretching group and in the joint mobilization group after intervention($p<.05$). However, no significant change between groups was found.

The mean sway speed with eyes closed and standing on both feet significantly decreased in the joint mobilization and PNF stretching-combined group after intervention($p<.05$), and the post-hoc analysis exhibited a significant difference between the PNF stretching and combined intervention groups.

Table 4. Comparison of change in surface area and average speed of standing with eyes open in each group.

Variables \ Group		PS (n=10)	JM (n=10)	PS+JM (n=10)	F	*p*
SEOA(㎟/s)	Pre	207.30±83.40	176.80±88.82	176.50±102.49	1.341	.278
	Post	195.70±78.42	158.10±83.73	138.30±76.53		
	p	.003*	.003*	.005*		
SEOS (㎝/s)	Pre	1.13±0.25	1.05±0.26	1.02±0.28	1.562	.228
	Post	1.08±0.22	1.02±0.28	0.90±0.16		
	p	.052	.081	.000**		

Values are Mean ± standard deviation.
*p<.05,**p<.01, JM: joint mobilization, PS: PNF stretching, JM with PS: joint mobilization with PNF stretching, SEOA: Standing wuth Eyes Open Surface Area, SEOS: Standing with Eyes Open Average Speed

Table 5. Comparison of change in surface area and average speed of standing with eyes closed in each group.

Variables \ Group		PS (n=10)	JM (n=10)	PS+JM (n=10)	F	*p*
SECA(㎟/s)	Pre	378.50±182.15	289.20±208.48	344.30±165.58	0.720	.496
	Post	362.40±179.56	269.70±198.95	307.90±136.48		
	p	.004*	.001**	.136		
SECS(cm/s)	Pre	1.81±0.35	1.59±0.44	1.46±0.38	4.404	0.22*
	Post	1.78±0.41	1.45±0.37	1.31±0.96		
	p	.496	.061	.002*		

Values are Mean ± standard deviation.
*P<.05, **p<.01, JM: joint mobilization, PS: PNF stretching, JM with PS: joint mobilization with PNF stretching, SECA: Standing with Eyes Closed Surface Area, SEOS: Standing with Eyes Closed Average Speed

DISCUSSION

PNF stretching and joint mobilization applied to stroke patients are effective interventions that increase joint range of motion and improve balance ability [15, 21]. Previous studies reported that the addition of PNF stretching and joint mobilization to exercise therapy was more effective than exercise therapy intervention only. However, a few studies have been conducted on the effect of combined joint mobilization and PNF stretching of ankles on stroke patients. Thus, this study aimed to determine the effect of combined interventions of Maitland joint mobilization and PNF stretching on ankle joint range of motion, plantar pressure, and balance ability of stroke patients after applying the intervention to ankles of stroke patients.

The results of this study found that ankle joint range of motion, plantar pressure, and balance ability were significantly improved in the all groups. The present study results were consistent with previous study results in which extended spaces inside joints were related to improvements in range of motion in ankle joints [26, 27]. Thus, the joint mobilization intervention applied in this study increased joint range of motion. When flexion was conducted, the center of the body was moved to the front and force generated from the rear lower extremity was maintained, promoting correct body arrangement and improving balance ability.

When dynamic stretching was applied to stroke patients, the ankle joint range of motion increased [29, 30]; another study also reported the increase in dorsiflexion [8]. Also The other study reported an increase inrange of motion after conducting a repeated extension exercise of ankles using a machine while stroke patients were seated [31]. Thus, PNF stretching applied in the present study extended a tight portion in the articular capsule of ankle and joint soft tissues in hemiplegic patients due to stroke, thereby changing the structure of feet and ankles and recovering the movements inside the joint.

In the present study, the plantar pressure at the paralyzed side increased in the combined intervention group, whereas the plantar pressure at the non-paralyzed side decreased. In addition, the plantar pressure in the forefoot decreased, whereas that in the hind-foot increased significantly. This result was consistent with previous study results [8, 32], in which the angle of dorsiflexion at the paralyzed side increased, thereby increasing the length of the gastrocnemius muscle and muscle activity in the anterior tibialis, resulting in enhanced body support at the lower extremity in the paralyzed side.

The combined intervention group in this study had a significant increase in balance ability compared with that of the other two groups that applied PNF stretching or joint mobilization only. A previous study that applied the combined intervention to elderly participants reported an increase in waist range of motion greater than that achieved with single intervention [14]. When the combined interventions were applied to increase an ankle joint range of motion, dorsiflexion in the paralyzed-side foot increased, as did muscle activity in the anterior tibialis, resulting in increasing body weight support at the standing position. In particular, the reduction in mean sway speed with eyes closed and in a standing position resulted in the paralyzed-side foot contacting an increased area of ground, reduction in forefoot plantar pressure, and increase in hind-foot plantar pressure, thereby increasing balance ability.

This study found that the combined intervention of joint mobilization and PNF stretching was not more effective in stroke patients. In addition, since ankle joint range of motion, plantar pressure, and balance ability increased in the joint mobilization group, joint mobilization was found to be effective in stroke patients as an intervention to increase ankle joint range of motion. However, the number of study subjects was small, which made it difficult to generalize the study results. The other limitation of this study is that, out of many ankle functions, only ankle joint range of motion was evaluated. And of this study improvements cannot be fully elucidated without comparison to a control group and other intervention could not be fully controlled. Nonetheless, this study contributed to evaluation of body weight support, which was related to lower extremity functions after measuring areas and pressure of body weight load at the paralyzed side to evaluate plantar pressure. Thus, studies on many other functions of ankle joints, plantar pressure, and balance would be desirable for future research.

CONCLUSION

This study applied the combined intervention of PNF stretching, joint mobilization and joint mobilization with PNF stretching to ankle joints to increase ankle joint range of motion. The study subjects were 30 patients who had limited ankle joint range of motion due to spasticity caused by stroke. This study aimed to determine the effects of combined intervention on

changes in ankle joint range of motion, plantar pressure, and balance ability. The study results found that the joint mobilization method and joint mobilization with PNF stretching intervention method increased ankle joint range of motion, plantar pressure, and balance ability significantly. This study determined that the combined intervention of joint mobilization and PNF stretching was not more effective for increasing ankle joint range of motion, plantar pressure, and balance ability in stroke patients who had limited ankle joint range of motion.

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