



Case Study

Effects of ankle plantar flexors stretching with closed kinetic chain on pelvic movements and gait speed in hemiplegia patients: a case study

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Abstract. [Purpose] The purpose of this study was to identify the effects of ankle plantar flexors stretching with closed kinetic chain (CKC) in hemiplegia patients. [Methods] This study used a reversal design (A-B-A') for a stroke with hemiplegia. The intervention program consisted of 30 min sessions, once a day, for 15 days. The subjects were trained for 15 sessions in total. Pelvic movements (anterior-posterior tilting, elevation, depression, forward-backward rotation) during walking and gait speed were measured in hemiplegia patients. [Results] Overall, the angle of pelvic movements was increased in Treatment and, Baseline II compared with Baseline I. The gait speed was maximally increased in Baseline II, followed by Treatment and Baseline I. [Conclusion] These results suggest that ankle plantar flexors stretching with closed kinetic chain had a positive effect on pelvic movements and gait speed in hemiplegia patients. Also, after treatment, its effect on gait of hemiplegia patients was maintained.

Key words: Plantar flexors, Stretching, Hemiplegia

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INTRODUCTION

Hemiplegia patients show a higher frequency of falls and a higher risk of secondary damage due to abnormal gait, muscle weakening, and other functional disorders¹⁾. Also, patients with hemiplegic symptoms generally have impaired coordination of the alternating movements in gait²⁾. In hemiplegia patients, crossing pelvic movements are difficult due to pelvic retraction, and it causes difficulty when the patient moves the affected leg forward³⁾. In addition, the stance phase on the affected side is shortened, and the gait speed consequently decreases⁴⁾.

Improving the gait is important for the rehabilitation of hemiplegic patients. The foot is very important for a functional gait⁵⁾. The foot provides thrust and absorbs the physical impact, and it determines the direction of progress⁵⁾. Therefore the ankle joints play an important role in providing thrust during gait and in assisting in maintenance of balance in response to movement of the center of gravity. To this end, a sufficient range of motion (ROM) of the ankle joint, ankle muscle strength, and a proprioceptive sense are necessary⁶⁾. In particular, when there is stiffness of the ankle plantar flexors, difficulties appear in gait due to asymmetric posture and loss of motor control⁷⁾.

The stretching exercises for ankle plantar flexors have a positive effect on ROM, balance and gait^{8, 9)}. Passive stretching is a technique used to maintain tension in extended muscles, thereby increasing the mobility and ROM of soft tissues¹⁰⁾.

Stretching exercises can be divided into open kinetic chain (OKC) and closed kinetic chain (CKC) exercises, according to whether mobilization of single joints or compound joints is needed¹¹⁾. Kim (2009) reported that CKC exercise is more effective in improving the walking ability and dynamic balance in patients with stroke¹¹⁾. Also, it is more specific, functional,

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and safer than OKC exercise¹²).

Therefore, the purpose of this study was to identify the effects of ankle plantar flexors stretching with CKC. This was a case study of three patients with hemiplegia. We evaluated pelvic movements during walking, and also the gait speed.

SUBJECTS AND METHODS

The subjects were selected from among the patients at the Dream hospital (Seoul, South Korea). Three patients who had suffered a stroke with hemiplegia were included in this study. The subjects were selected from among those who had a score of at least 24 points on the Korean Mini-Mental State Examination (K-MMSE), could walk 10 m independently, and sufficiently understood the purpose of this study. The subjects also had hypertonus and shortness of the ankle flexor muscles. This study was performed in compliance with the ethical principles of the Declaration of Helsinki. The subjects agreed to participate in the study after receiving explanations regarding the purpose and procedures of the experiment, as well as they signed an informed consent statement before participation. The protocol for this study was approved by the local ethics committee of the Namseoul University of Cheonan(1041479-201503-HR-012). Table 1 shows the general characteristics of subjects.

The design of this study was a reversal design (A-B-A'). The A and A' were the Baseline periods, and the B was the Treatment period (ankle plantar flexors stretching). The training program consisted of 30 minutes of training, once a day, for 15 days. The total period of this study was 33 days (9 days for the A, 15 days for the B, and 9 days for the A'). The subjects were trained for 15 sessions in total. The pelvic movements during walking and gait speed were measured once every three days (total 11 times).

The stretching training was applied to ankle plantar flexors on the affected side. Ankle plantar flexors stretching was carried out in a trunk flexion on standing position by leaning against a mat (Fig. 1). The foot of the affected side was placed on the back. The stretching training lasted 30 min. In this study, the BTS (G-walk-AP1177, Italy) was used to measure the pelvic movements and gait speed. The subjects wore a G-sensor on the waist, which is a mobile analysis system developed by Bluetooth (Fig. 2). The average and standard deviation were calculated using descriptive statistics. The values were measured three times and the average value was calculated.

RESULTS

This was a case study conducted in three hemiplegia patients. The pelvic movements (anterior-posterior tilting, elevation, depression, forward-backward rotation) and gait speed were measured. Tables 2-4 show pelvic movements on the affected side and gait speed during walking in each subject. Table 5 shows the average value of pelvic movements and gait speed of subjects.

In terms of the pelvic movements, the angle of anterior-posterior tilting, elevation and backward rotation was maximally increased in Treatment, followed by Baseline II and Baseline I. But the angle of depression and forward rotation was maximally increased in Baseline II, followed by Treatment and Baseline I. But generally, the angle of pelvic movements was increased in Treatment and, Baseline II compared with Baseline I. Gait speed was maximally increased in Baseline II, followed by Treatment and Baseline I.

Table 1. General characteristics of subjects

Gender (male/female)	2/1
Age (years)	58.3±1.5
Time after stroke (months)	40.3±25.1
Stroke type (infarction/hemorrhage)	2/1
Affected side (left/right)	2/1

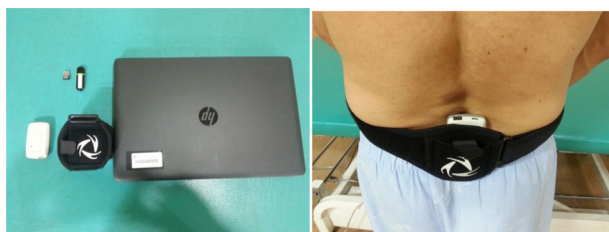


Fig. 2. BTS measurement Left: G-walk-AP1177, Right: wearing at the waist



Fig. 1. Ankle plantar flexors stretching position

Table 2. Pelvic movements and gait speed of subject 1

	Baseline I(A)				Treatment (B)				Baseline II(A')			
	1	2	3	4	5	6	7	8	9	10	11	
AT(°)	0.5	0.6	0.7	0.7	1.1	1.0	1.1	1.1	1.0	0.9	0.9	
PT(°)	0.5	0.6	0.7	0.9	1.0	0.8	1.0	0.8	0.8	0.8	0.9	
EV(°)	3.9	3.5	4.6	5.0	4.2	4.9	5.6	6.4	6.3	6.9	5.9	
DR(°)	6.1	6.4	5.0	5.3	5.0	7.0	6.6	8.4	7.4	8.8	7.1	
FR(°)	0.8	1.0	1.3	1.1	1.5	1.2	1.2	1.2	1.1	1.0	1.1	
BR(°)	0.7	0.9	1.0	1.0	1.5	1.1	1.4	1.3	1.2	1.3	1.2	
GS(m/s)	0.6	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.6	

AT: anterior tilting, PT: posterior tilting, EV: elevation, DR: depression
FR: forward rotation, BR: backward rotation, GS: gait speed

Table 3. Pelvic movements and gait speed of subject 2

	Baseline I(A)				Treatment (B)				Baseline II(A')			
	1	2	3	4	5	6	7	8	9	10	11	
AT (°)	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.9	0.7	0.7	0.7	
PT (°)	0.5	0.6	0.6	0.7	0.7	0.7	0.9	0.8	0.8	0.8	0.9	
EV (°)	2.7	2.5	3.4	3.0	5.3	3.7	4.0	4.2	3.8	3.6	3.8	
DR (°)	1.7	2.7	2.3	3.2	4.9	4.1	3.9	4.4	3.9	3.5	3.8	
FR (°)	1.3	1.2	1.3	1.2	1.3	1.4	1.6	1.7	1.5	1.3	1.6	
BR (°)	1.5	1.5	1.5	1.6	1.8	2.0	2.1	1.8	1.7	1.5	1.6	
GS (m/s)	0.6	0.6	0.5	0.7	0.5	0.7	0.7	0.8	0.7	0.6	0.7	

AT: anterior tilting, PT: posterior tilting, EV: elevation, DR: depression
FR: forward rotation, BR: backward rotation, GS: gait speed

Table 4. Pelvic movements and gait speed of subject 3

	Baseline I(A)				Treatment (B)				Baseline II(A')			
	1	2	3	4	5	6	7	8	9	10	11	
AT (°)	1.6	1.6	1.4	1.6	1.7	1.8	1.7	2.1	1.9	1.8	1.9	
PT (°)	1.4	1.4	1.5	1.7	1.6	1.5	1.8	2.1	1.7	1.7	1.6	
EV (°)	3.5	3.4	2.7	4.1	6.7	5.3	5.4	5.2	4.9	5.1	4.7	
DR (°)	5.4	4.7	5.7	6.7	5.8	6.9	7.3	7.8	6.4	6.7	6.3	
FR (°)	1.4	1.4	1.1	1.6	1.7	1.6	1.6	2.2	2.4	2.1	2.1	
BR (°)	1.4	1.7	1.6	2.1	1.8	2.0	2.1	2.6	2.2	2.4	2.3	
GS (m/s)	0.6	0.5	0.6	0.8	0.7	0.9	0.8	1.0	1.0	1.0	0.9	

AT: anterior tilting, PT: posterior tilting, EV: elevation, DR: depression
FR: forward rotation, BR: backward rotation, GS: gait speed

Table 5. Average value of pelvic movements and gait speed

	Baseline I(A)	Treatment (B)	Baseline II(A')
AT (°)	0.95±0.52	1.22±0.54	1.19±0.62
PT (°)	0.90±0.47	1.17±0.53	1.15±0.48
EV (°)	3.38±0.58	5.42±1.43	5.03±1.32
DR (°)	4.47±1.94	4.10±2.36	6.03±2.04
FR (°)	1.24±0.16	1.40±0.12	1.61±0.57
BR (°)	1.34±0.38	1.77±0.43	1.74±0.53
GS (m/s)	0.59±0.01	0.75±0.10	0.81±0.18

AT: anterior tilting, PT: posterior tilting, EV: elevation, DR: depression
FR: forward rotation, BR: backward rotation, GS: gait speed

DISCUSSION

When the stiffness of ankle plantar flexors is severe, it leads to asymmetric posture, balance disorders, and loss of motor control ability in the performance¹³. Limited ankle joint dorsiflexion is caused by calf muscle tightness and soft tissue contracture. Ankle joint stretching is commonly used in a rehabilitation program¹⁴. Kasutama et al. (2010) reported that ankle stretching resulted in stretching of the medial gastrocnemius muscle and Achilles tendon¹⁴.

Stroke patients showed higher resistance torque and joint stiffness, and these higher resistances were reduced significantly after the stretching intervention, especially in dorsiflexion¹⁵. Passive stretching reduced the stiffness of the ankle joint¹⁶. Therefore, the purpose of this study was to identify the effects of ankle plantar flexors stretching with CKC in hemiplegia patients. The pelvic movements during walking and gait speed were measured. Hemiplegic patients exhibit asymmetry of the trunk and pelvis due to weakened muscle strength and loss of sense on the affected side¹⁷. Especially the forward and backward pelvic tilt are frequently affected in stroke patients. Therefore, it is important to improve the stroke patient's ability to maintain or adjust the neutral posture of the pelvis¹⁸.

The results of this study revealed that the angle of pelvic movements was increased in Treatment and, Baseline II compared with Baseline I. It can be considered that ankle plantar flexors stretching with CKC had a positive effect on pelvic movements. Jang et al. (2011) reported that asymmetric pelvic movements influence the relationship between the foot center of mass during walking in hemiplegia patients¹⁷. This indicates that there is a correlation between pelvic movements and ankle joint during walking. Kong et al. (2015) reported that increased pelvic displacement had a positive effect on balance and gait in stroke patients¹⁸. The findings confirmed that pelvic displacement is correlated with gait.

In this study, gait speed was maximally increased in Baseline II, followed by Treatment and Baseline I. It means that ankle plantar flexor stretching had a positive effect on hemiplegic gait. Christiansen (2008) reported that hip and ankle stretching increased the gait speed¹⁹. The result of previous studies supported this study. Han et al. (2013) reported that when elderly persons performed plantar flexor static stretching for five minutes, static balance was improved, but dynamic balance and gait were not improved²⁰. The result of previous studies is inconsistent with this study; this may be due to the difference in stretching training time between the two studies. Gait speed is affected by the power of ankle and hip joints in hemiplegia patients⁴. In this study, the displacement of ankle and hip joints through ankle stretching training was considered to have a positive effect on gait speed.

Moseley (1997) reported that casting combined with stretching is an effective method of correcting ankle plantar-flexion contractures in patients with traumatic head injury⁹. Therefore, a relevant additional research is necessary. This was a case study of three patients with hemiplegia. Studies including a few patients have been conducted for gait analysis. In the future, a larger number of patients should be studied. But, this study is meaningful as it shows that ankle plantar flexors stretching with CKC can contribute to hemiplegia rehabilitation.

REFERENCES

- 1) Suzuki T, Yoshida H, Hashimoto T, et al.: Case-control study of risk factors for hip fractures in the Japanese elderly by a Mediterranean Osteoporosis Study (MEDOS) questionnaire. *Bone*, 1997, 21: 461–467. [[Medline](#)] [[CrossRef](#)]
- 2) Wang RY: Effect of proprioceptive neuromuscular facilitation on the gait of patients with hemiplegia of long and short duration. *Phys Ther*, 1994, 74: 1108–1115. [[Medline](#)]
- 3) Perry J: The mechanics of walking in hemiplegia. *Clin Orthop Relat Res*, 1969, 63: 23–31. [[Medline](#)]
- 4) Olney SJ, Richards C: Hemiparetic gait following stroke. *Gait Posture*, 1996, 4: 136–148. [[CrossRef](#)]
- 5) Lee JH: The effect of ankle joint muscle strengthening training and static muscle stretching training on stroke patients' plantar pressure and gait. Daegu University Rehabilitation Science Graduate School a Master's degree, 2011.
- 6) Donald AN: Kinegiology of musculoskeletal system: foundations for physical rehabilitation. Mosby, 2002, pp 528–529.
- 7) Caillet F, Mertens P, Rabaséda S, et al.: [Three dimensional gait analysis and controlling spastic foot on stroke patients]. *Ann Readapt Med Phys*, 2003, 46: 119–131. [[Medline](#)] [[CrossRef](#)]
- 8) Bressel E, McNair PJ: The effect of prolonged static and cyclic stretching on ankle joint stiffness, torque relaxation, and gait in people with stroke. *Phys Ther*, 2002, 82: 880–887. [[Medline](#)]
- 9) Moseley AM: The effect of casting combined with stretching on passive ankle dorsiflexion in adults with traumatic head injuries. *Phys Ther*, 1997, 77: 240–247, discussion 248–259. [[Medline](#)]
- 10) Pin T, Dyke P, Chan M: The effectiveness of passive stretching in children with cerebral palsy. *Dev Med Child Neurol*, 2006, 48: 855–862. [[Medline](#)] [[CrossRef](#)]
- 11) Kim YG, Kim TY, Oh DW: The effects of closed kinetic chain exercise and open kinetic chain exercise in improving the balance of patients with hemiplegia. *Korean J Ortho Manu Ther*, 2009, 15: 22–31. [[CrossRef](#)]

- 12) Snyder-Mackler L: Scientific rationale and physiological basis for the use of closed kinetic chain exercise in the lower extremity. *J Sport Rehabil*, 1999, 5: 2–12.
- 13) Kim TH, Yoon JS, Lee JH: The effect of ankle joint muscle strengthening training and static muscle stretching training on stroke patients' C.o.p sway amplitude. *J Phys Ther Sci*, 2013, 25: 1613–1616. [[Medline](#)] [[CrossRef](#)]
- 14) Kasuyama T, Sakamoto M, Kato K: Comparing change in the calf muscle during weight-bearing and non-weight-bearing stretching. *J Phys Ther Sci*, 2011, 23: 395–399. [[CrossRef](#)]
- 15) Gao F, Ren Y, Roth EJ, et al.: Effects of repeated ankle stretching on calf muscle-tendon and ankle biomechanical properties in stroke survivors. *Clin Biomech (Bristol, Avon)*, 2011, 26: 516–522. [[Medline](#)] [[CrossRef](#)]
- 16) Selles RW, Li X, Lin F, et al.: Feedback-controlled and programmed stretching of the ankle plantarflexors and dorsiflexors in stroke: effects of a 4-week intervention program. *Arch Phys Med Rehabil*, 2005, 86: 2330–2336. [[Medline](#)] [[CrossRef](#)]
- 17) Jang SH, Gong W, Kim JS: The effect of using trunk control pelvic movement exercise in the sitting and standing positions on the relative impulse of hemiplegic patients. *J Phys Ther Sci*, 2011, 23: 123–126. [[CrossRef](#)]
- 18) Kong SW, Jeong YW, Kim JY: Correlation between balance and gait according to pelvic displacement in stroke patients. *J Phys Ther Sci*, 2015, 27: 2171–2174. [[Medline](#)] [[CrossRef](#)]
- 19) Christiansen CL: The effects of hip and ankle stretching on gait function of older people. *Arch Phys Med Rehabil*, 2008, 89: 1421–1428. [[Medline](#)] [[CrossRef](#)]
- 20) Han MJ, Yuk GC, Gak H, et al.: Acute effects of 5 min of plantar flexor static stretching on balance and gait in the elderly. *J Phys Ther Sci*, 2014, 26: 131–133. [[Medline](#)] [[CrossRef](#)]