The Effects of Task Oriented Stair Gait Training on Muscle Activities of the Lower Extremity and Balance in Stroke Patients

Yong-Hwan Kim, PT, MPT[1], Young-Dong Kim, PT, PhD[2], Ji-Hye Kim, PT, PhD[3], Hye-Joo Jeon, PT, PhD*[4]

[1]*Dept. of Physical Therapy, Dongbaek Woori Care Hospital,*

[2]*Dept. of Physical Therapy, Daejeon Heath Sciences College,*

[3]*Dept. of Physical Therapy, Gangdong College,*

[*4]*Dept. of Physical Therapy, Bobath memorial hospital*

Purpose This study was conducted to know how task oriented stair walking training (forward, backward and sideway) has an effect on muscle activities in the lower extremity and the balance ability, and to suggest an approach to improve the ability of stroke patients. ***Methods*** 12 hemiplegia patients who were diagnosed with a stroke participated in the study. The subjects were assigned randomly to either an experimental group or a control group. Participants in the experimental group received a task oriented stair walking training (forward, backward, sideway) for 30 minutes. The control group received a balance training on the mat for 30 minutes. Both groups received each training for 5 times per week, for 5 weeks. Muscle activities were measured by EMG in both affected and non-affected tibialis anterior (TA), rectus femoris (RF), biceps femoris (BF). The balance ability was measured using a Berg Balance Scale (BBS), Timed "Up and Go" (TUG) and Functional Reach Test (FRT). ***Results*** There were numerically increased muscle activities in both groups. However, there was no significant difference in muscle activity change. There were significant increases ($p<.05$) in BBS, FRT in both groups. The experimental group showed a significantly decrease ($p<.05$) and the control group was numerically decreased but there was no significant difference in TUG. But there is no significant change between two groups. ***Conclusion*** With that reason, the intervention was considered to have an impact on not only improvement of static functional balance but also improvement of dynamic mobility.

Key words stroke, task oriented, stair gait, muscle activities, balance.

Corresponding author Hye-joo jeon (hy32hj@naver.com)

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I. Introduction

Stroke is the sudden loss of neurological function caused by an interruption of the blood flow to the brain affected by cerebrovascular disease, heart disease and diabetes[1)], that is the third leading cause of death and annual incidence of stroke of 48.2 per 100,000 population in the Republic of Korea.[2)] Forty percent of patients are left with moderate functional impairments and 15% o 30% with severe disability.[3)] A variety of deficits are possible, including impairment of sensory, motor, cognitive, perceptual and language functions.[4)] Especially, A difficulty to maintain a position (steadiness) as well as postural alignment and position (symmetry) within the base of support make decrease the ability to shift weight to the paretic side during walking and dynamic stability.[5)] Patients with hemiplegia due to stroke develop asymmetric postures the lower limbs on their paretic sides support only 25-43% or less of their weight in a standing position[6)], such asymmetric alignment of trunk and pelvic decrease their stability of trunk and proximal part and make a disability to maintain their balance and upright posture, that leads to an asymmetrical gait pattern.[7)] Most of post stroke rehabilitation intervention have focused a recovery of gait symmetry through decrease asymmetric movement pattern and asymmetric weight

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distribution with achieved in stable upright postures.[4] Backward walking has been used in sport medicine, orthopedic and rehabilitation as a method of increasing quadriceps strengthening while decreasing the joint compressive forces about the knee.[8] The study of backward walking training on ground after stroke showed improving of gait asymmetry, gait speed and cadence[9], During a backward walking elicit a greater qudriceps strengthening and cardiopulmonary response than forward walking not to be able to affected just appropriate levels while spending a long times.[1] Also, Side walking training is being used current therapy on stroke patient to increase stability capability because there is a change of movement pattern through dynamic weight transfer from side to side.[10] Reported that side walking training of hemiplegic stroke patient attributed to their gait cycle such as a gait velocity, stride of both legs and foot angle also increase of symmetric weight distribution.[4] On the other hand, walking on a stair is frequently used ambulation method, that was required a more strengthening of legs and dynamic effort to weight shifting to forward and upward compared with walking on a flat surface.[11] Also, Walking on a stair is essential for independence in activities of daily living, that attributed to important factor for stroke rehabilitation for legs function recovery and increase the quality of their life.[12, 13, 14] Currently, it has reported that walking training on a variety plane (flat, incline and stair) attributed to stability of pelvis and strengthening of leg[15], also affected weight shifting ability to affected leg during swing phase of unaffected legs and then influence the ability to ambulation and balance. That`s why constant walking training on stair can be effective treatment for independent activity of hemiplegic patient and also decrease the fall down.[12] In rehabilitation approach, task-oriented training, the practice of goal-directed, functional movement is carried out in a natural environment[16], that focused on special functional task-related training program to be combined with neural plasticity.[17] Further, task-oriented training effective therapeutic method to be presented a variety sensory stimulation and functional activity and then to be affected a increase ability of daily living based with motor learning.[18] It has reported that task-oriented training during stair walking on 10 stroke patient attributed to increase the Trunk Impairment Scale and Berg Balance Scale and to decrease the times of 10m walking test.[19] As far as we know, forward, backward and sideway walking on a stair training may be effective to increase a strengthening of legs, balance ability and capability of movement. However, the study about a variety direction walking training on a stair are lacking. Therefore, the purpose of present study examine the effectiveness of the forward, backward and sideward walking on a stair on a muscle activity of lower extremity and balance in stroke patient.

II. Materials and Methods

1. Participants

A total of 12 hemiplegia admitted to D and S hospital in Y-si and H-si, Gyeonggi-do who underwent image studies such as brain computed tomography (CT) or magnetic resonance imaging (MRI) to identify their stroke diagnosed were recruited for this study from june to october 2017.

specific inclusion criteria were as follows.

1) a patient who has been diagnosed with hemiplegia more than 6 month
2) a patient who have not had any other orthopedic disease and sensory deficit of lower extremity
3) a patient who was able to walk 10-meter in dependently with or without walking aid.
4) a patient who had MMSE-K grade more than 24[20]
5) a patient who had not participated in any other similar study
6) a patient who understood the content of study and agree to participate

2. Study design

This study was designed to be a randomized(using a two card printed in “1” or “2”), prospective clinical trial, with 6 participant assigned to a task oriented stair walking training and 6 participant assigned balance

Table 1. General Characteristics of subjects (N=12)

(Value: mean ±SD)

Variable	total	Experimental group (n=6)	Control group (n=6)	x^2	p
Gender				.22	.54
Female	8(66.7%)	3(50.0%)	5(83.3%)		
male	4(33.3%)	3(50.0%)	1(16.7%)		
affected				1.00	1.00
left	6(50.0%)	3(50.0%)	3(50.0%)		
right	6(50.0%)	3(50.0%)	3(50.0%)		
				t	p
Age(years)	63.83 ±17.02	66.00 ±17.37	61.67 ±18.00	.42	.68
height(cm)	161.17 ±11.50	166.17 ±10.55	156.17 ±10.94	1.61	.98
weight(kg)	60.98 ±20.52	70.30 ±23.31	51.67 ±13.23	1.70	.07
onset	28.46 ±16.72	26.12 ±15.06	30.80 ±19.37	−.46	.27
K-MMSE(score)	26.75 ±2.301	27.17 ±2.13	26.33 ±2.58	.60	.62

K-MMSE : Mini Mental State Examination-Korea

and weight transfer training. The training was 30 minutes per day, 5 days per week for 5weeks. in addition to the training, conventional therapeutic exercise including ROM, strengthening and stretching is provided to all subjects in this study. In this study, physical therapists who had clinical experience more than 4years and received a education of Neuro-Develpment Treatment supplied a therapy to participants.

3. Outcome Measures

1) Electromyography: EMG

In this study, surface EMG data were recorded using a Delsys-Trigno Wireless EMG system (Trigno EMG sensor, Delsys Inc., Boston, MA, USA), EMG data were collected from Tibialis anterior muscle and Rectus femoris, and Biceps femoris on the paretic and non-paretic sides. Electrodes were situated as followed: for the TA, upper part of one third of the distance between the fibular head and medial malleolus; for the Rectus femoris, one half of the distance between ASIS and patella; for biceps femoris, one half of the distance between ischial tuberosity and leteral epicondyle. Before placing elcetrodes, the skin were shaved and cleaned using alcohol cotton to reduce skin resistance. The sampling rate for the EMG signal was set a 2,000 Hz; the band-pass filter was set between 20-45hz. Raw data were transformed into root mean square (RMS) data.[21] To normalize EMG data, there are method of maximal voluntary isometric contraction (MVIC) and reference voluntary contraction (RVC). In this study, all of collected data were transformed into RMS, muscle activation were normalized by %RVC. %RVC were calculated by equation below.

%RVC = dynamic sit to stand RMS / static standing RMS ×100

2) Berg Balance Scale: BBS

The Berg Balance Scale is mainly used for balance assessment for high risk falls in older community-dwelling adults and neurological patients composed to activities common in everyday life. There are three dimensions to the test: maintenance of a position, postural adjustment to voluntary movement, and reaction to external disturbances and are simple quick mobility test. The BBS is a 14-item scale that including sitting to standing, standing unsupported, sitting unsupported, standing to sitting, transfers, standing with eyes closed, standing with feet together, reaching forward with outstretched arm, Retrieving object from floor, turning to look behind, turning 360 degrees, placing alternate foot on stool, standing with one foot in front and standing on one foot. The items are scored from 0 to 4, the score may range from zero to 56. High score represent good balance. The BBS is valid measurement as inter-rater (r=.99) and intra-rater (r=.98).[22]

3) Timed “up and go” test: TUG

Timed “up and go” test measure functional movement including dynamic balance and gait ability. There are simple and quick mobility including a rise from a chair, walk three meters, turn, walk back, and sit down, timed subjects sits on a standard arm chare (seat height 50cm) and walk to a line on the floor 3m away, turns, walk backs to the chair, and sits down again. The mean of time to be measured is recoded more than two. This test is very useful for hemiplegia with spasticity and lower extremity disability because it is very simple. The TUG is valid measurement as inter-rater (r=.98) and intra-rater (r=.99).[23]

4) Functional Reach Test: FRT

Functional reach test measures a limits of stability with assessment of dynamic balance. To perform the Functional Reach test subjects stand comfortably parallel to a wall 10cm, make a fist, and raise their arms to 90 degree of flexion. The examiner measures and records the placement of the end of the subject`s third metacarpal when one reach forward while standing and maintaining a fixed base of support. The FRT was found to have high inter-rater (r=.89) and intra-rater (r=.98)reliability.[24]

4. Interventions

1) Task oriented stair gait training (experimental group)

For the task oriented stair gait training, Furnished with hardwood stair with 7.5cm for height, 25cm for tread depth and 70cm for width in physical therapy room was used for this training.(Fig.1). After warming-up (sitting in arm chair front of stair, stretching on the range of motion of cervical and shoulder, shaking and marching in place with both legs) and stair training (forward, backward and sideway walking) were carried out. Both warming up and stair training were performed for 6 minute each other and took a rest for 2 minute after stair training. Sticking a Anti-slip tape to the tread and wearing gait belt for patient to hold by physical therapist is to prevent the falls. If patients complains with painful, difficulty breath, fatigue and changes of face, training was stopped immediately.[24,25,26] In Emergency state, doctor and nursing was called and made to treat the patient.

2) Weight shifting training on the mat (control group)

For balance and weight transfer training, Treatment

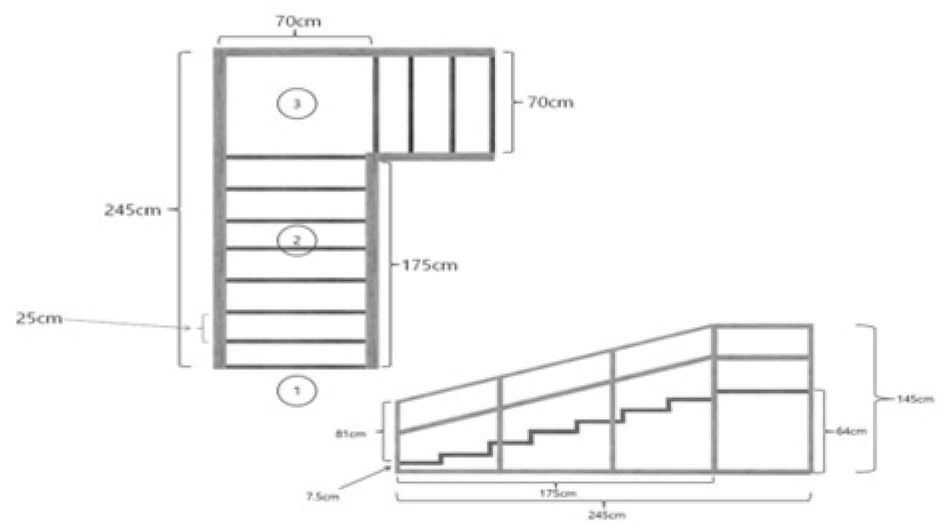

Figure 1. Plan of the stairs

component included supine position (balance training), sitting posture (weight shifting training), standing position(balance and weight shifting training) on the Mat and undertook each training for 10minutes.

5. Statistical analysis

In this study, SPSS 20.0 and Excel (2010) were used for the statistical analysis. Chi-squared test and Independent t-test were used to compare the general characteristics of subjects before training. To compare the effect of intervention within group before and after 5weeks, Wilcoxon signed rank test were performed. Also, Mann-Whitney U were used to calculates the difference of the change of before and after intervention between experimental and control group and to be statistically significant. All of significance level was set at $p<.05$.

III. Results

1. Comparison the change of muscle activities before and after training

1) Comparison activities non-affected tibialis anterior: NTA muscle and affected tibialis anterior:ATA before and after training

(1) Muscle activities of NTA showed 92.87±113.15 at before-training and 143.67±31.44 at after-training in experimental group. There is a numerically increase but no significant differences in experimental group. There were a numerically increased with 112.20±103.53 at before-training and 161.75±157.33 at after training in control group. Also no significant differences were observed in control group <Table 2>.

And muscle activities of ATA showed 179.30±227.38 at before-training and 94.81±52.24 at after-training in experimental group. There were numerically decreased but no significant differences in experimental group. There were a numerically decreased with 294.53 ±516.87 at before training and 65.49±.93 at after-training in control group. Also no significant differences wore observed in control group <Table 2>.

No significant difference between experimental group and control group were observed <Table 2>

2) Comparison activities non-affected rectus femoris: NRF: muscle and affected rectus femoris:ARF before and after training

(1) Muscle activities of NRF showed 122.65±108.70 at before-training and 477.71±907.16 at after-training in experimental group. There were numerically increased but no significant difference in experimental group. There were numerically decreased with 85.73 ±77.01 at before-training and 38.89 ±81.51 at after-training in control group. Also no significant difference were showed in control group <Table 3>.

And muscle activities of ARF showed 100.81±88.71 at before-training and 72.11±55.78 at after-training in

Table 2. Comparison of the changes in NTA and AT muscle activities at before and after training

(Unit: %RVC ±standard deviation)

		Control group (n=6)	Experimental Group (n=6)	Comparison between the two group
NTA	before-training	92.87 ±113.15	112.20 ±103.53	
	after-training	143.67 ±31.44	161.75 ±157.33	
	p	.34	.91	.52
ATA	before-training	179.30 ±227.38	294.53 ±516.87	
	after-training	94.81 ±52.24	65.49 ±89.93	
	p	.60	.24	.74

* $p<.05$.
NTA(non-affected tibialis anterior)
ATA(affected tibialis anterior)

Table 3. Comparison of the changes in NRF and ARF muscle activities at before and after training

(Unit: %RVC ±standard deviation)

		Control group (n=6)	Experimental Group (n=6)	Comparison between the two group
NRF	before-training	122.65 ±108.70	85.73 ±77.01	
	after-training	477.71 ±907.16	38.89 ±81.51	
	p	1.79	.34	.20
ARF	before-training	100.81 ±88.71	94.85 ±48.89	
	after-training	72.11 ±55.78	61.81 ±99.00	
	p	.60	.34	.74

* p<.05.
NRF(non-affected rectus femoris)
ARF(affected rectus femoris)

experimental group. There were numerically decreased but no significant difference in experimental group. There were numerically decreased with 94.85 ±48.89 at before-training and 61.81±99.0 at after-training in control group. Also no significant difference were showed in control group <Table 3>.

No significant difference between experimental group and control group were observed<Table 3>

3) Comparison activities non-affected biceps femoris: NBF muscle and affected biceps femoris:ABF before and after training

(1) Muscle activities of NBF showed 76.89±41.51at before-training and 94.42±56.99 at after-training in experimental group. There were numerically increased but no significant difference in experimental group. There were numerically decreased with 634.14± 1187.73 at before-training and 48.41±73.02 at after-training in control group. Also no significant difference were showed in control group <Table 4>.

And muscle activities of ABF showed 83.43 ±60.16 at before-training and 58.70±51.74 at after-training in experimental group. There were numerically increased but no significant difference in experimental group. There were significantly decreased with 213.04±273.30 at before-training and 34.65±45.97 at after-training in control group (p>.05)<Table 4>.

No significant difference between experimental group and control group were observed<Table 4>

Table 4. Comparison of the changes in NBF and ABF muscle activities at before and after training

(Unit: %RVC ±standard deviation)

		Control group (n=6)	Experimental Group (n=6)	Comparison between the two group
NBF	before-training	76.89 ±41.51	634.14 ±1187.73	
	after-training	94.42 ±56.99	48.41 ±73.02	
	p	.46	.11	.055
ABF	before-training	83.43 ±60.16	213.04 ±273.30	
	after-training	58.70 ±51.74	34.65 ±45.97	
	p	.46	.04*	.10

* p<.05.
NBF (non-affected bicecps femoris)
ABF (affected bicecps femoris)

3. Comparison of change in a balance ability at before and after training

1) Comparison of change in Berg balance scale: BBS

With regard to changes in BBS, there was a significant increased (p>.05) with 29.16±7.85 at before-training and 41.00±8.74 at after-training in experimental group (p>.05). Also there was a significant increased with30.50±5.75 at before-training and 40.33±7.81 at after-training in control group (p>.05).

No significant difference between experimental group and control group were observed (Figure 2)

2) Comparison of change in Timed "up and go"Test: TUG

With regard to changes in TUG, there was a significantly decreased with 39.55±39.01 at before-training and 24.94±16.42 at after-training in experimental group (p>.05), control group showed a numerically decreased with 29.82±16.05 at before-training and 28.05±19.82 at after-training and no significant difference.

No significant difference between experimental group and control group were observed (Figure 3)

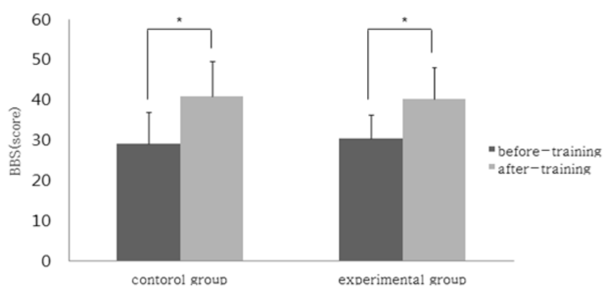

Figure 2. Comparison of the changes in BBS at before and after training

3) Comparison of the change in Functional reach test: FRT

With regard to Change of FRT, there was a significantly increased with 11.99±5.05cm at before-training 17.38±5.00cm at after-training in experimental group (p>.05). Also there was a significant increased with 10.38±5.44cm at before-training and 16.66 ±3.52cm at after-training (p>.05)

No significant difference between experimental group and control group were observed (figure 4)

IV. Discussion

Patients with hemiplegia due to stroke are at a risk a fall because they have a significantly lower physical function for activity daily living like a strength and walking ability and diminished balance, in comparison to normal. Therefore, Finding out a most effective method for recovery of physical function has a very important meanings.[27] It has reported that gait training with PNF technique on a ramp and stairs improved gait ability for hemiplegia patient.[28] But there is no statistically significant differences in between three group, most increase were showed in stair gait exercise group. However, previous studies on stair gait training with various direction for task oriented were deficient. Therefore, this study was performed to determine effect of forward, backward and sideway stair gait training on muscle activities in lower extremity and the balance ability in stroke patients and to suggest the training method to increase function on stroke patients. Delsys-Trigno Wireless EMG system

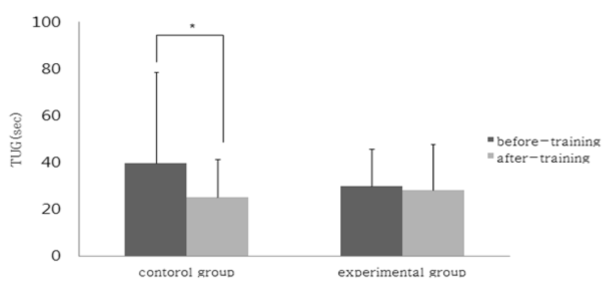

Figure 3. Comparison of the changes in TUG at before and after training

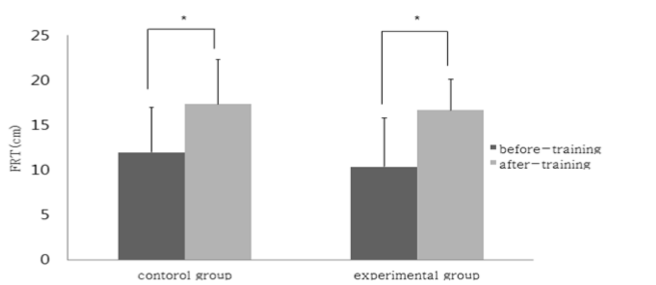

Figure 4. Comparison of the changes in FRT at before and after training

was used for measuring the EMG data and also BBS, TUG and FRT were used to measure balance ability.

In this study, there were no significant differences in muscle activities of NTA, ATA, NRF and ARF both experimental group and control group, but ABF in control group was showed significantly decrease (p>.05). It has reported that both box-step training and stair-step training on stroke patient were showed significant differences on change in muscle activities of biceps femoris, tibialis anterior and gastrocnemius.[29] But there is a different result with this study, this is because there is a short duration to make a change in muscle activities of patient being able to independent gait as a control the variable. Also, Shaving and cleaning the skin was not enough to reduce the skin resistance completely and there were limitation to acquire precise on-set point except noise. So much so that it lead to limit the muscle activity measuring because patient could be nervous to be applied the surface EMG, but this study was performed with patient who was raged scored more than 24 point in K-MMSE. Both two group showed significant increase in BBS for measuring the balance ability at before and after training(p>.05). Similar to this result, this study has investigated the comparison of BBS for measuring functional balance ability at before and after training then there was statistically significant increase in both two group (p>.05)[30] and there was more significant increase in experimental group than control group (p>.001). And, change of TUG at before and after training was showed significant decrease in experimental group (p>.05), but no significant difference in control group. That is because a recovery of dynamic balance ability was improved with stair gait training with various direction more than simple and simple and general gait training on the floor. Similar to this result, this study has investigated that that the gait velocity at after stair gait training on stroke patients was showed significant differences with 0.44.08m/s at before -training and 0.75 .18m/s at after-training (p>.05).[31] Also, reported that the comparison of TUG for measuring dynamic balance ability was showed statistically significant decrease in both two groups (p>.05) and significant decrease in experimental group more than control group (p>.001).[30] Lastly, Comparison in a change of FRT at before and after training was significantly increased (p>.05), but no significant difference between two groups. As a result, both Mat training and stair gait training produce an effect of improving static balance ability. There are several limitation of this study. Firstly, the study was limited to subject who was admitted specific hospital. Secondly, there was difficulty to control the factor to change the result apart from training. Finally, because the study was limited to subjects who never have a experience similar study, their stress to measuring equipment could be produce an effect of result. Thus, future study need a specific program to reduce subject stress to be applied equipment like a EMG, movement analyzer and have more reliability.

V. Conclusion

This study showed that there was numerically difference even though no statistically significant difference in muscle activities of lower extremity at after both task oriented (forward, backward and sideway) stair gait training and balance and weight shift training on the mat. And, Task oriented stair gait training group showed significant differences in BBS, TUG and FRT for measuring the balance ability. In weight shifting training on the mat group, there was a significant difference in only BBS and FRT and no significant difference in TUG. As a result, training on mat produced significant effect of static balance and weight shifting ability and insufficient dynamic balance caparison with task oriented stair gait training. Therefore, task oriented stair gait training should be suggested to improve not only static functional balance but also dynamic mobility and further general training improve the functional activity for stroke patient.

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