The Effect of Backward Walking Training Methods on Walking in Stroke Patients

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Purpose: The purpose of the present study was to examine, in stroke patients, differences between backward walking training applied on a treadmill and the same training applied on the ground.

Methods: Twenty seven stroke patients were divided into a treadmill backward walking group of 14 patients and a ground backward walking group of 13 subjects. Each group performed their respective training method for 8 weeks (15 min per day, 4 days a week). Walking ability was measured using a 10 m MWS (Maximal Walking Speed) test and the GAITRite system to examine changes in walking. Cadence, stridelength, step time, step length and symmetry index of the less affected side were measured to examine changes in stance phase of the lower extremity of the more affected side.

Results: 10 m MWS, cadence, stride length, step time and step length of the less affected side significantly increased and symmetry index significantly decreased after training in both groups. The treadmill backward walking group experienced a significantly greater increase in step time and step length and a significantly greater decrease in symmetry index than the ground backward walking group.

Conclusion: The two walking training methods were effective for improving stability in stance phase of the lower extremity of the more affected side, but the treadmill method was more effective. The present studyis meaningful in that it analyzed the effects of backward walking training methods on walking and the differences of the training methods to provide information necessary for effective treatmentof stroke patients.

Keywords: Backward walking, Treadmill walking, Ground walking, Stroke

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I. Introduction

Stroke is one of the top three causes of death along with cancer and heart disease, and its prevalence is gradually increasing. Although survival rate is increasing due to developments in the medical sciences, stroke survivors have many dysfunctions, and social costs for their treatment are high.[1] Stroke patients maintain abnormal postures and experience low efficiency when walking due to imbalances in the body, lack of a sense of balance, imbalances in muscle strength, inadequate weight bearing, co-contraction, and degradation of motor ability control.[2] Furthermore, patients diagnosed with stroke experience degradation in quality of life together with decreased physical functions.[3] In particular, the gait disturbance of hemiparesis patients resulting from stroke causes difficulties in body movement and in daily life and has negative effects on prognosis. Thus, most patients don't recover normal walking after the onset of a stroke.[4] Characteristic walking patterns of stroke patients include a slow walking cycle, a short stance phase on the more affected side, and a relatively long swing phase.[5] Stroke patients may partially recover their walking ability, but most patients live with a slow walking speed and low endurance, and their independent movement at home and in society are limited.[6] The improvement and recovery of walking ability is closely related to the return of stroke patients to work and society.[7] Accordingly, recovery of walking ability is a major goal in the functional recovery of stroke patients.[8]

Diverse approaches are used in order to enhance walking ability[9-11] and interest in backward walking that is easily accessible has recently increased. Studies on backward walking of healthy persons and stroke patients are increasing. It has been reported that, based on the results of studies on backward walking of healthy persons, lower extremity muscle strength increased[12]. And it has been reported that as a result of stroke patients' backward walking on a treadmill, walking speeds increased.[13] It has also been reported that as a result of stroke patients' backward walking on the ground, lower extremity muscle strength increased and consequently, balance ability and walking speeds increased.[14,15]

Although studies on backward walking training have been recently conducted in order to improve stroke patients' functions, these studies have been conducted either on the ground or on a treadmill. There has been no study of effective methods for applying backward walking training. Therefore, the purpose of the present study was to examine differences in backward walking training – applied either on a treadmill or the same training applied on the ground.

II. Study Method

1. Subjects

The present study was done on 27 stroke patients who were under treatment after being hospitalized in OO Hospital in Deagu Republic of Korea between December 2008 and April 2009 and who were at least 6 months after stroke onset (to minimize the possibility of natural recovery).

The subjects were recruited among those who could walk with a walking aid or alone for at least 10 m, whose MAS (Modified Ashworth Scale), whichmeasures the stiffness of the lower extremities of the more affected side, was G2 or lower, who had no orthopedic diseases on either of their lower extremities, who had no limitations in range of motion, whose Korean mini-mental state examination (MMSE-K) score was at least 24, and who voluntarily agreed to participate in the study.

2. Experimental Method

The present study performed backward walking training in addition to balancing therapy for weight bearing or weight shifting and general exercise therapy for strengthening walking and muscle strength. The subjects were randomly assigned to a ground backward walking group of 13 subjects or a treadmill backward walking group of 14 subjects. The two groups conducted their respective exercises for 15 minutes per session, 4 sessions a week, for a total of 8 weeks.

1) Treatment Method

The training method for the ground backward walking group is described below. The training program was based on the method presented by Davies.[16] The details are as follows. At first, subjects trained inside the parallel bars and then outside them. The training was divided into four levels. First, the subjects were asked to set foot backwards inside the parallel bars and when necessary, support themselves with the hand of the less affected side. The therapist helped the subjects so that they could move in the right pattern. Once the subjects were able to move their bodies in the right pattern, the therapist slowly decreased the amount of help. Second, as the subjects were trained inn elements of movement, they were able to actively perform the exercise with only a little help, and the therapist facilitated their backward walking inside the parallel bars. Third, the subjects were able to actively walk backwards? outside the parallel bars. Fourth and last, the subjects gradually increased the distance and speed of backward walking.

The above-mentioned procedure was applied on a treadmill (Cima fitness, Korea) for the treadmill backward walking group. Before the experiment, we explained about the treadmill for the treadmill backward walking group so that they would become familiar with the machine. The slope of the treadmill was set to zero, and the patients were trained with a suspension device (composed of hydraulic top and bottom electronic devices and a harness) for safety. However, they were not allowed to partially bear their weight on the suspension device. The treadmill (minimum start speed 0.1 km/hr and adjustable in 0.1 km/hr units) was started at a speed with which the patient felt comfortable. The speed was gradually increased as patient functions on the treadmill improved. During the training, two therapists helped the subjects when it was necessary. One therapist sat beside the paralyzed side of the subject and used hands to correct the subject's walking pattern with the lower extremities. The other therapist stood behind the subject and provided guided weight support on the paralyzed side. During every training session, the therapists gave appropriate feedback to facilitate the backward walking pattern. The patients were allowed to hold the treadmill with their less affected hand when necessary or could choose to wear a walking aid.[13]

2) Measurement Method

(1) 10 m MWS (maximal walking speed)

To evaluate walking performance, a 10 m MWS test was used that had been verified for its reliability and validity.[17] The 10 m MWS consisted of a 14 m straight walking passage using tapes with a width of 10 cm between two points. Furthermore, mark lines were drawn at 2 m inward from both ends of the 14 m walking passage. The 2 m distances from the beginning and from the end were designated as the area for acceleration and deceleration. Walking times for 10 m in the middle of the walking area were measured with a stop watch. The walking test was performed three times and the average was determined.

(2) GAITRite system

To measure the elements of walking, we evaluated cadence, stride length, step time, step length, and symmetry index using the GAITRite system (CIR System Inc., USA). In particular, symmetry index was calculated using the formula:

SI = 2*[(single limb support phase of the more affected side - single limb support phase of the less affected side)/(single limbsupport phase of the more affected side + single limb support phase of the less affected side)]*100

A symmetry index of less than 10% was regarded as acceptable symmetry.[18] The GAITRite system has been proven for its reliability and validity in analyzing the temporal and spatial elements of walking. It is an electronic walking plate with a length of 366 cm and a width of 61 cm and has attached 13,824 sensors. The system collects data at a sampling rate of 80 Hz per second and sends the data to a computer for analysis through a serial interface cable. To measure the actual leg length before measuring walking elements, the length from the anterior superior iliac spine to the medial malleolus of the ankle joint in the supine position was measured and inputted to the GAITRite system. The subjects were asked to walk on the walking plate starting from 2 m before the walking plate according to the oral instructions of the tester. The walking task was performed three times and averages were determined.

3. Data Analysis

Data were analyzed with SPSS for Windows version 17. To test the homogeneity between subjects in the two groups, qualitative data were analyzed using the Chi-square test. Among quantitative data, age, height, weight, time since stroke and step time satisfied normality tests and thus were analyzed using two sample t-tests, which are parametric tests. The 10 m MWS, cadence, stride length, step length and symmetry indexes did not satisfy normality tests and thus were analyzed using the Wilcoxon rank sum test, which is a nonparametric test. To compare the changes between pre-test and post-test of training in each group, step time was analyzed using paired t-test as step time satisfied normality tests. Since 10 m MWS, cadence, stride length, step length and symmetry indexes did not satisfy normality tests, these were analyzed using Wilcoxon signed rank test which are nonparametric tests. To compare mean changes between the groups after the training, step time was analyzed using two sample t-tests. 10 m MWS, cadence, stride length, step length and symmetry indexes were analyzed using Wilcoxon rank sum tests. The statistical significance level αα was set to 0.05.

III. RESULTS

1. Group Homogeneity Test

gender, age, height, weight, paralyzed site, cause of disease, and period of disease did not show significant differences between the two groups ($p>0.05$) (Table 1).

Table 1. General characteristics of subjects

	Treadmill (n=14)	Ground (n=13)	p-value*
Gender (male/female)	6 / 8	6 / 7	0.87
Age (year)	62.5±4.8*	63.8±4.1*	0.47
Height (cm)	163.1±6.9*	165.5±6.3*	0.34
Weight (kg)	62.3±8.6*	61.9±5.5*	0.88
Paretic side			
Right	8	8	0.82
Left	6	5	
Type			
Infarction	5	6	0.60
Hemorrhage	9	7	
Time since stroke (month)	7.4±5.1*	6.6±2.1*	0.60

* The data reported as Mean±standard deviations

2. Comparison of 10 m MWS

The average values for the 10 m MWS before and after training on the treadmill backward walking group were 50.39 cm/s and 79.41 cm/s, respectively. So walking speeds increased significantly after training ($p<0.05$). The average values for the 10 m MWS before and after training of the ground backward walking group were 68.12 cm/s and 92.60 cm/s, respectively. So this group also increased significantly after training ($p<0.05$). The mean change in 10 m MWS showed no significant difference between the two groups ($p>0.05$) (Table 2).

3. Comparison of cadences

The average cadences before and after training of the treadmill backward walking group were 81.72 steps/min and 95.45 steps/min, respectively. So this parameter increased significantly after training ($p<0.05$). The average values of cadence before and after training of the ground backward walking group were 73.09 steps/min and 85.36 steps/min, respectively. So it too increased significantly after training ($p<0.05$). The mean change in cadence showed no significant difference between the two groups ($p>0.05$) (Table 2).

4. Comparison of stride length

The average stride lengths of the less affected side before and after training of the treadmill backward walking group were 57.23 cm and 73.31 cm, respectively. So it increased significantly after training ($p<0.05$). The average values for stride length of the less affected side before and training of the ground backward walking group were 60.08 cm and 72.21 cm, respectively. So it increased significantly after training ($p<0.05$). The mean change in stride length of the less affected side showed no significant difference between the two groups ($p>0.05$) (Table 2).

5. Comparison of step time

The average step times of the less affected side before and after training of the treadmill backward walking group were 0.20 sec and 0.28 sec, respectively. So it increased significantly after training ($p<0.05$). The average values for step time of the less affected side before and after training of the ground backward

Table 2. Comparison of gait variables in each group and between treadmill and ground groups

		Treadmill (n=14)	Ground (n=13)	p‡
10 m MWS (cm/sec)	pre	50.39±15.10	68.12±21.68	0.10†
	post	79.41±25.11*	92.60±31.51*	
	mean change	29.02±17.26	24.49±28.09	0.11‡
Cadence (steps/min)	pre	81.72±5.93	73.09±6.92	0.20†
	post	95.45±5.47*	85.36±5.33*	
	mean change	14.27±3.13	12.27±4.29	0.11‡
Stride length (cm)	pre	57.23±13.80	60.08±17.84	0.31†
	post	73.31±15.64*	72.21±19.07*	
	mean change	16.08±12.97	12.13±9.47	0.20‡
Step time (sec)	pre	0.20±0.09	0.17±0.06	0.25†
	post	0.28±0.09*	0.20±0.06*	
	mean change	0.08±0.05	0.03±0.02	0.006‡
step length (cm)	pre	19.42±9.41	24.35±12.16	0.66†
	post	33.26±9.86*	33.22±11.21*	
	mean change	13.84±9.35	8.86±7.93	0.04‡
Symmetry index	pre	-47.77±22.02	-40.98±21.97	0.50†
	post	-17.92±8.65*	-23.85±19.40*	
	mean change	29.85±16.42	17.14±14.96	0.04‡

* The comparison of gait variables between pre-test and post-testin each group.
† The Comparison of gait variables at pre-test between treadmill and ground groups.
‡ The mean change Comparison of gait variables between treadmill and ground groups

walking group were 0.17 sec and 0.20 sec, respectively. So it increased significantly after training ($p<0.05$). The mean change in step time of the less affected side showed a significant difference between the two groups ($p<0.01$) (Table 2).

6. Comparison of step length

The average step lengths of the less affected side before and after training of the treadmill backward walking group were 19.42 cm and 33.26 cm, respectively. So it increased significantly after training ($p<0.05$). The average step lengths of the less affected side before and after training of the ground backward walking group were 24.35 cm and 33.22 cm, respectively. So it increased significantly after training ($p<0.05$). The mean changein step length of the less affected side showed a significant difference between the two groups ($p<0.05$) (Table 2).

7. Comparison of symmetry index

The average symmetry indices before and after training of the treadmill backward walking group were −47.77 and −17.92, respectively. So it increased significantly after training ($p<0.01$). The average symmetry indices before and after training of the ground backward walking group were -40.98 cm and -23.85 cm, respectively. So it too increased significantly after training ($p<0.01$). The mean changein symmetry index showed a significant difference between the two groups ($p<0.05$) (Table 2).

IV. DISCUSSION

In the present study, walking related factors were compared between before and after backward walking. Based We found that backward walking training by stroke patients improved their walking ability. In particular, backward walking training on the treadmill improved the symmetry of walking more than the same training on the ground.

We also found significant differences after training in walking speed, cadence, stride length of the less affected side, step time, step length, and symmetry index, proving the effectiveness of backward walking training. Yang et al[14] conducted backward walking training for 3 weeks (3 sessions per week, 30 min per session) in addition to walking training for stroke patients in their experimental group. Their experimental group showed significant increases in walking speed and stride length, demonstrating the effectiveness of backward walking training just as the present study did. Weng et al[13] studied the effect of treadmill backward walking training for stroke patients. The experimental and control groups received the same training for 3 weeks (5 sessions per week, 60 min per session), except that the experimental group performed treadmill backward walking training for 30 min in each 60 min training session. The 10 m WMS of the experimental group increased significantly more than that of the control group. Thus, backward walking could become a beneficial walking training method.

Between group comparisons showed that the treadmill backward walking group experienced greater increases in step time and step length and a greater decrease in symmetry index than the ground backward walking group. This indicates that backward walking on a treadmill provides more effective training. Waagfjord et al[19] reported that treadmill training increased the step length of the less affected side by lengthening the stance phase of the hemiparesis patients while they are walking, thus effectively facilitating symmetric walking patterns. Winter[20] claimed that temporal and spatial parameters can be useful for walking assessment because they greatly affect walking ability. That investigator analyzed step time and step length rather than stride time and stride length, because these variables could significantly reveal the results by the asymmetry of the lower extremities.[21] Since our results present evidence for the effectiveness of treadmill training, it is thought that treadmill backward walking training in stroke patients can be a more effective method than backward walking training on the ground.

However, the present study did not examine kinetic changes during backward walking training for stroke patients and failed to present the mechanism of the effectiveness of such walking training. Therefore, more systematic studies regarding these issues will be required in the future. Furthermore, whereas previous studies separately performed ground and treadmill backward walking training, the present study directly compared ground and treadmill backward walking training. This provides useful information for future studies. The results of the present studywill provide basic information when selecting an appropriate therapy method when applying walking training to stroke patients in clinical settings in the future.

V. CONCLUSIONS

The present study was conducted to investigate differences in the effects of backward walking training on a treadmill or on the ground. Walking speed, cadence, stride length, step time and step length of the less affected side increased after training and the symmetry index decreased for both the treadmill and ground walking training groups. Differences before and after training between the two groups revealed that the step time and step length of the less affected side, and the symmetry index of the treadmill backward walking group improved more compared to the ground backward walking group. In conclusion, treadmill and ground backward walking training methods both improve the stability of the lower extremity stance phase of the less affected side. Treadmill backward walking is a better training method that can decrease the asymmetry of walking more than ground backward walking training.

Author Contributions

Research design: Kim SJ
Acquisition of data: Kim SJ, Jeon CB
Analysis and interpretation of data: Kim SJ
Drafting of the manuscript: Kim SJ, Jeon CB
Research supervision: Kim CS

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