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Effects of gait training with horizontal impeding force on gait and balance of stroke patients

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Abstract. [Purpose] The purpose of this study was to investigate the effects of treadmill training with a horizontal impeding force applied to the center of upper body mass on the gait and balance of post-stroke patients. [Subjects and Methods] Twenty-four subjects with hemiplegia less than 3 months after stroke onset were randomly assigned to 2 groups: an applied horizontal impeding force on treadmill training (experimental) group (n = 12), and a control group (n = 12). Both groups walked on a treadmill at a comfortable or moderate speed for 20 minutes per day, 3 sessions per week for 8 weeks after a pre-test. The experimental group also had a horizontal impeding force applied to the center of their upper body mass. [Results] All groups demonstrated significant improvement after 8 weeks compared to baseline measurements. In intra-group comparisons, the subjects' gait ability (CGS, MGS, cadence, and step length) and balance ability (TUG, BBS, and FRT) significantly improved. In inter-group comparisons, the experimental group's improvement was significantly better in CGS MGS, cadence, step length, TUG, and BBS, but not in FRT. [Conclusion] Treadmill training was identified as an effective training method that improved gait and balance ability. A horizontal impeding force applied during treadmill training was more effective than treadmill walking training alone at improving the gait and dynamic balance of patients with stroke.
Key words: Treadmill gait, Horizontal impeding force, Upper body

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INTRODUCTION

More than half of those disabled by a stroke have difficulty in walking or cannot walk within 3 months following stroke onset[1)]. Maximally, 70% of them recover to normal walking within 1 year, 45–60% can walk without help but have a disability, and 5–9% have gait disturbance necessitating complete reliance on others[2)]. Thus, the biggest goal of stroke patients is to improve walking function[3)]. To improve ambulatory function, gait training using a treadmill is often suggested for many patients[4)].

Although studies have analyzed the movement of the upper body during walking[5–7)], most studies investigating the body's forward movement ability while walking have focused on physical intervention for the lower body, such as loading weight on the paretic limb of stroke patients doing standard treadmill exercise[8–10)], or underwater treadmill gait training[11)]. Most studies focusing on physical intervention for the upper body have applied a horizontal force to the waist area while subjects, including athletes, walked or ran[12–18)].

However, few studies have sought to determine changes in ambulation and balance resulting from physical intervention for the upper body of stroke patients.

This study examined the effect of gait training on walking ability (stable walking speed, maximal walking speed, number of steps per minute, and stride) and balance (timed up and go test [TUG], Berg balance scale [BBS], and functional reach test [FRT]) of stroke patients.

SUBJECTS AND METHODS

The subjects were 24 stroke patients who visited the National Rehabilitation Center and received exercise treatment. Of the stroke patients who had experienced their first stroke within the previous 3 months, we selected those who (1) had scores of >3 on the Functional Ambulation Category (FAC), indicating they could walk independently under observation; (2) had scores of >24 in the Mini-Mental State Examination Korea (MMSE-K), indicating they could communicate; (3) did not have other orthopedic diseases, acute pain affecting walking, or progressive neuropathy; (4) did not take drugs that might have influenced balance ability; and (5) provided their written consent after receiving explanation of the research purpose (Table 1)[19, 20)].

All experimental protocols and procedures were explained to each subject and approved by the institutional review board of the National Rehabilitation Center, Korea (NRC-2011-02-005).

The subjects were assigned to a treadmill walking group with a horizontal impeding force (HIF) and a control group. Before the intervention a pre-test was conducted to deter-

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mine the subjects' maximal walking speed, stable walking speed, stride, number of steps per minute, TUG, BBS and FRT. The tests were repeated after 8 weeks, following the intervention. A physical therapist oversaw the treadmill gait training and treadmill test at the National Rehabilitation Center, and the author and an assistant performed the pre-test and final assessment.

During training, the HIF group and the control group wore harnesses for safety, which was the first priority. Each subject's weight and treadmill walking speed were measured. The gradient during gait training was 0, and a physical therapist provided oral instructions for foot position when needed. Subjects received a detailed explanation of the Borg (1970) 15-point scale (rating of perceived exertion [RPE] scale, 6–20 points). To determine each subject's RPE, they were asked to indicate the relevant number (6–20) on a Korean language Borg scale orally or with their finger. The test was started at a speed at which the subjects felt safe, then the treadmill speed was slowly increased. The standard of feeling of safety was the level of comfort or an average RPE of 9–11 points while walking on the treadmill for 3 minutes. When if required, 5 minutes were allowed to adapt to the treadmill speed before the training. The walking speed of the second training was carried out by increasing or reducing the speed until an RPE of 9–11 points was achieved, based on the treadmill walking speed of the first step. Tests were started after subjects consented to undergo treadmill training for 20 minutes per day, 3 times per week, for 8 weeks.

HIF subjects received HIF against the center of gravity of the upper body while walking at a pre-measured speed. The HIF applied was within 0–15% of subject' measured body weight[16], and the treadmill speed was set at a speed corresponding to an RPE of 9–11 points, which is the level of comfort or average on the Borg scale. The first training session was performed with minimal pulling capacity (1 kg), at a pre-measured comfortable walking speed. In the second HIF training session, the speed was set so that an RPE of 9–11 points was maintained for 3 minutes. When necessary, % minutes were allowed to adapt to the treadmill speed and HIF before the training. If subjects expressed a desire to continue the test after the adaptation time, training was carried out at the prescribed walking speed and HIF. For the third training bout, a RPE of 9–11 points was the target, and HIF was adjusted accordingly. Training was conducted in manner for eight weeks.

For HIF, we used a cable to provide a constant pull resistance. The cable can be loaded in 1 kg units from 0 to 50 kg, and it is possible to adjust its height in 10 cm intervals from 14 cm to 225 cm. Also Cables are available in a range of up to 3 m.

In this study, because we applied backward traction during the treadmill training, a SHUMA DA-3000 harness was worn by the subjects to prevent falls.

The MT- 400 treadmill has the same features as a general treadmill as well as a primary and emergency power-off device that can be operated by user. When users press the button on the handle the treadmill is stopped. Therefore, this device was used in consideration of safety and the prevention of accidents .

Statistical analyses were performed using SPSS version 12.0 software. The paired t-test was used to verify differences in the pre- and post-test mean values of maximal walking speed, stable walking speed, stride, number of steps per minute, TUG, BBS, and FRT in each group. The independent t-test was used to verify differences between the HIF group and the control group. All statistical significance levels (α) were chosen as 0.05.

Table 1. General and clinical characteristics of the subjects

Distribution	HIF group (n = 12)	Control group (n = 12)
Male (n)	8	9
Female (n)	4	3
Right side (n)	6	8
Left side (n)	6	4
Hemorrhage (n)	8	5
Infarction (n)	4	7
Age (years)	51.3 ± 7.3[a]	52.92 ± 8.3[a]
Height (cm)	166.7 ± 6.7	165.25 ± 6.3
Weight (kg)	63.8 ± 6.9	67.50 ± 5.1
Disease duration (months)	5.42 ± 1.67	5.17 ± 1.6
FAC (score): 3	8	6
FAC (score): 4	4	6
MMSE-K (score)	26.0 ±2.0	27.0 ±2.2

HIF: Horizontal impeding force, FAC: Functional ambulation category, MMSE-K: Mini-Mental State Examination Korea
[a]Values are presented as mean ± SD

RESULTS

Compared to their pre-test values, the post-test values of stable walking speed, maximal walking speed, number of steps per minute, and stride significantly increased in both groups ($p < 0.05$). There were greater differences in the HIF group than in the control group ($p < 0.05$).

Compared to their pre-test values, the post-test values of TUG and BBS significantly increased in both groups ($p < 0.05$), and there were greater differences in the HIF group than in the control group ($p < 0.05$). FRT significantly increased in both groups ($p < 0.05$).

DISCUSSION

The main finding of the present study was that a treadmill walking training program improved stable walking speed, maximal walking speed, number of steps per minute, and stride.

While there are some small discrepancies between reports in the elapsed time and walking speed after stroke, it has generally been reported to be within the range of 0.25–0.5 m/s[21]. The pre-training stable walking speeds of the present study were consistent with this range.

Robinett and Vondran[22] suggested 0.5 m/s as the lowest possible walking speed on a road in general. Perry, Garrett, Granley, and Mulroy[23] suggested 0.8 m/s as a speed enabling functioning and independent action in various environments and social settings. A walking speed sufficient to cross roads

Table 2. Results of stable walking speed, maximal walking speed, number of steps per minute, and stride

		HIF group	Control group
Stable walking speed (sec/10 m)	Before	20.93 ± 5.61[a]	19.84 ± 10.62[a]
	After	11.83 ± 3.70	15.73 ± 8.40
	Difference	9.10 ± 4.71***†	4.11 ± 3.78**
Maximal walking speed (sec/10 m)	Before	14.39 ± 3.09	14.13 ± 7.23
	After	9.61 ± 2.75	11.73 ± 6.24
	Difference	4.78 ± 2.69***†	2.39 ± 2.15**
Number of steps per minute (step/min)	Before	84.62 ± 15.04[a]	87.02 ± 17.74[a]
	After	102.54 ± 21.06	93.77 ± 20.58
	Difference	17.91 ± 13.73**†	6.75 ± 9.88*
Stride (cm)	Before	34.26 ± 8.57	41.97 ± 14.71
	After	53.70 ± 8.88	47.98 ± 12.61
	Difference	19.44 ± 10.21***††	6.01 ± 6.12*

[a]Values are presented as mean ± SD
Significant difference, paired t-test: *: $p<0.05$; **: $p<0.001$; ***: $p<0.0001$
Significant difference, independent t-test: †: $p<0.05$; ††: $p<0.001$

Table 3. Changes in TUG, BBS, and FRT

		HIF group	Control group
TUG (sec)	Before	21.85 ± 3.75[a]	18.17 ± 8.05[a]
	After	14.42 ± 2.85	15.12 ± 7.42
	Difference	7.42 ± 3.33***††	3.04 ± 2.27**
BBS (points)	Before	40.83 ± 3.27	42.58 ± 7.53
	After	50.50 ± 3.11	47.00 ± 7.50
	Difference	9.66 ± 3.86***††	4.41 ± 2.50***
FRT (cm)	Before	24.35 ± 5.54	20.69 ± 9.12
	After	30.96 ± 5.62	27.29 ± 7.92
	Difference	6.60 ± 6.10*	6.6 0± 6.13*

[a]Values are presented as mean ± SD
HIF: Horizontal impeding force, TUG: Timed up and go test, BBS: Berg balance scale, FRT: Functional reach test
Significant difference, paired t-test: *: $p<0.05$; **: $p<0.001$; ***: $p<0.0001$
Significant difference, independent t-test: †: $p<0.05$; ††: $p<0.001$

at traffic lights in a business area that does not affect social life is suggested to be 1.2 m/s. Compared to these values, the present research reports speeds that, though they may have a small effect on social functioning, enabled the patient to walk safely, independently, and without great inconvenience for stable social activies.

Table 2 shows that the number of steps per minute and stride significantly improved in both groups after training. This provides evidence that treadmill gait training is a very effective way of improving walking ability. Moreover, the number of steps per minute and stride significantly increased in the HIF group compared to the control group, suggesting that adding HIF to the center of gravity of the upper body during treadmill training more effectively improves walking ability than treadmill training alone and is a very effective way of improving gait training.

It has been reported that both the number of steps per minute (r = 0.75) and stride (r = 0.78) are highly correlated with walking speed[24)], suggesting that walking speed in the present report increased due to the significantly increased number of steps per minute and stride. This further suggests that the subjects could walk more stably, at a brisker pace, in longer strides, for a greater number of steps, and over a greater distance, than before training.

Choi, Lee, and Jang[25)] reported that improvements in walking speed were mostly due to an increase in strides. Considering that a slow walking speed increases the risk of accidental falls, improving walking speed could help prevent accidental falls as well as improve walking ability. Therefore, as walking speed and stride increased more when HIF was applied to the upper body during treadmill gait training, it suggests that adding of HIF to gait training is a more effective way of improving walking ability and preventing accidental falls.

To test the effecacy of treadmill training, with or without HIF, on balance ability, TUG, BBS, and FRT were measured. The results show that both groups showed significant improvements in TUG, BBS, and FRT after training, compared with before training, providing evidence that treadmill gait training is a very effective way of improving dynamic and static balance abilities (Table 3).

Podsiadlo and Richardson[26)] reported that a TUG time <10 seconds in the elderly aged 60–90 years indicates functional freedom and independence; >10 seconds to <20 seconds indicates independent movement for a basic bath or shower, and the ability to go up most stairs and out by themselves; if it takes > 13.5 seconds, the risk of fall increases; if >30 seconds, most activities are dependent. These results suggest that treadmill gait training is an effective way of reducing the risk of fall, particularly as the TUG time of the HIF group decreased from a mean of 21.85 seconds to 14.35 seconds. This suggests that it is an effective way of training which considerably reduces the risk of fall and enables activities of daily living such as a bath or shower and going out alone.

Along with a study[27)] reporting that if BBS was >41 points, the possibility of fall was low, Kornetti, Fritz, Chiu, Light and Velozo[28)] reported that if BBS >45 points, independent safe walking was possible. Our present results show that the BBS scores of both groups were >45 points and improved following training. Thus, it is evident that treadmill gait training is an effective way of training for independent safe walking. Stevenson[29)] also reported a significantly improved change in BBS in stroke patients. Thus, treadmill gait training with HIF applied to the center of gravity of the upper body is a more effective way of training for independent, safe ambulation.

Future research on HIF during gait training for stroke patients needs to examine the height at which applying the pulling power can generate the optimal effect, the optimal amount of HIF, and the muscle activity most influenced by HIF during treadmill gait training and gait training, as long as safety is guaranteed. Moreover, the present study used only HIF. Horizontal aiding force is another factor that studies should consider, and comparisons of the effects of HIF and horizontal aiding force on the walking ability and balance of stroke patients are necessary.

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