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The effects of treadmill training on dynamic balance and gait function in stroke patients: a pilot randomized controlled trial

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Objective: The objective of this study is to investigate the effect of treadmill gait trainig on dynamic balance and gait functions in stroke patients.
Design: Randomized, double-blind, controlled pilot study.
Methods: Four subjects following first stroke participated in this study. They were divided randomly into the treadmill gait trainig group (TM group) (n=2) and the control group (n=2). Subjects in both groups received general training five times per week. Subjects in the TM group practiced an additional treadmill gait trainig program that consisted of 60 minutes, three times per week, during a period of four weeks. Timed up and go test (dynamic balance) and the GAITRite test (gait function) were evaluated before and after the intervention.
Results: In dynamic balance (timed up and go test), the TM group (−14.235 sec) showed a greater decrease than the control group (−13.585 sec). In gait functions, the TM group showed a greater increase in gait speed (12.8 cm/s vs. 10.15 cm/s), step-length (5.825 cm vs. 3.735 cm), and stride-length (5.005 cm vs. 1.55 cm) than the control group.
Conclusions: The treadmill gait trainig improved dynamic balance and gait functions. Further research is needed in order to confirm the generalization of these findings and to identify which stroke patients might benefit from treadmill gait trainig.

Key Words: Balance, Gait, Stroke, Treadmill

Introduction

A stroke is the rapidly developing loss of brain function due to a disturbance in the blood supply to the brain. This can be due to ischemia (lack of blood flow) caused by blockage (thrombosis or arterial embolism) or due to a hemorrhage (leakage of blood) [1]. After a stroke, motor, sensory, perceptual, or cognitive deficits may occur, and these impairments can have various impacts on individual functioning through generation of disabilities, affecting rehabilitation potential [2]. Gait impairment is a large contributor to long-term disability and ambulatory function in daily living [3]. However, many patients lose the ability to walk independently, and in addition, a large proportion do not regain their normal walking speed following a stroke [4,5].

As classical treatments for gait training after central nervous system injury, there are weight shift or weight transfer in a static position and balance training [6,7]. However, in spite of muscle contraction patterns and improvement of a patient's general condition, abnormal gait is continuously observed [8]. Previous studies have reported that treadmill gait trainig on a treadmill resulted in improved walking performance in patients with stroke [9]. The existing treadmill has been used clinically for examination of patients with cardiovascular disorder, whereas treadmill gait trainig has been used for rehabilitation of hemiplegia patients or patients

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with gait disturbance [9,10]. In combination with general training, treadmill gait trainig was reported to show significant improvement in results of gait characteristics [11].

Waagfjörd *et al*. [12] reported that treadmill gait trainig is helpful in lengthening the stance phase of an affected limb, when a hemiplegia patient is walking, in order to achieve an increase in the step length of an unaffected limb, thereby achieving an effect of facilitating a symmetric gait pattern.

In addition, Hesse [11] claimed that, for hemiplegia patients, treadmill gait trainig using particular weight bearing could lengthen a weight bearing period of an affected limb, compared with general overground gait training, improve symmetrical posture, and reduce spastic plantar flexor to cause regular activity modes of plantar flexor, thereby helping their balance abilities. Patients can combine three elements of gait, weight shift, gait, and balance, during treadmill gait as a functional and task-oriented approach [13].

Therefore, the purpose of this study was to examine the effect of treadmill gait trainig on balance and gait functions in stroke patients.

Methods

Subjects

This study employed a randomized controlled pilot design. Four subjects who had hemiplegia secondary to stroke were enrolled in the study. All subjects had been referred by a physician for inpatient physical therapy evaluation and intervention. Subjects were randomized into two groups, the experimental treadmill gait trainig group (TM group) and the control group, with mean ages of 35.5 years and 37.5 years, respectively (Table 1).

Subjects were required to meet the following stringent criteria in order to be eligible to participate: (1) first ever stroke (ischemic or hemorrhagic) in the last six months; (2) independent gait ability with or without walking aid for a minimum of 15 m; (3) a mini-mental state examination score greater than 24/30 [14]; (4) adequate vision and hearing for completion of the study protocol, as indicated by the ability to follow written and oral instructions during screening; and (5) the capacity to understand and follow instructions.

Exclusion criteria were: (1) a history of previous stroke or other neurologic diseases or disorders; (2) patients with pusher syndrome (defined as leaning to the hemiparetic side and giving resistance to any attempt at passive correction); (3) terminal illness; and (4) pain, limited motion, or weakness in the non-paretic lower extremity that affected performance of daily activities (by self-report). Each participant signed an informed consent prior to participation.

Table 1. General characteristics of the subjects

Variable	Treadmill group (n=2)		Control group (n=2)	
	P1	P2	P3	P4
Sex	F	M	F	F
Age (yr)	35	36	30	45
Height (cm)	159	179	163	161
Weight (kg)	58	77.5	49	75
Month poststroke	16	21	14	16
Side of hemiplegia	L	R	L	R
Type of stroke	H	H	I	H

F: female, M: male, L: left, R: right, H: hemorrhage, I: infarction.

Procedures

Four subjects who met the inclusion criteria were enrolled and their medical history, prevalence, more affected side, and etiology by doctor's treatment were recorded. Pretests included measurement of dynamic balance function (timed up and go test, TUG), and gait function (gait speed, step-length, and stride-length). Subjects were randomly divided into the TM group (two subjects) and the control group (two subjects). Subjects in both groups participated in a general training program for five sessions, 60 minutes per week, during a period of four weeks. Subjects in the TM group practiced additional treadmill gait trainig for three sessions of 60 minute per week, for a period of four weeks. All training for both groups was conducted by the same physical therapist who had been trained in the techniques.

Treadmill training program

In this study, the Skylife 5300 (Sky Life, Korea) was used for treadmill training. It was provided for patients in order to control the speed in person according to their gait abilities. Safety grab bars were provided on both sides and on the front side for subjects to grasp for balance during gait training. However, they were encouraged to shake their hands, if possible, instead of grasping the safety bar, during gait training. In addition, a safety pin attached to the subject was automatically set to stop movement of the treadmill when it was removed during gait training.

In consideration of their speed-dependent gait training, the gait speed of the treadmill was maintained as the maximum achievement speed, and the training was executed for 60 minutes three times per week for a period of four weeks.

The training time was 50 minutes in total, and, 15 minutes after training, a break was given for 2 minutes and 30 seconds, two times in total (Table 2).

In addition, a warmup and a cooldown were provided for 5 minutes each, before and after training. At this time, for safety of the subjects, the training was performed under the supervision of a physical therapist, who would lead patients to immediately stop gait training, in case of non-weight bearing for the stance phase of an affected limb or dragging their feet, unbalanced trunk and lower limb postures, fatigue, pain complaint, difficult breathing, changes of countenance, and others.

General training program

The physical therapist conducted man-to-man ROM training, mat training, and gait training at the degrees of difficulty suitable for the patients' gait abilities.

Outcome measures

In this study, TUG and the GAITRite test (CIR Systems, USA) were used in assessment of dynamic balance and gait function of the subjects.

The TUG was performed for evaluation of dynamic balance. Subjects were seated in a chair with armrests and then instructed to stand (using the armrests, if desired) and walk as quickly and as safely as possible for a distance of 3 m. Subjects then turned around, returned to the chair, and sat down. The time from the point at which their spine left the back of the chair until they returned to that same position was recorded using a stopwatch. A practice trial was provided, followed by three test trials. The average time of the test trials was calculated. High intrarater (intraclass correlation coefficient [ICC]=0.99) and interrater (ICC=0.99) reliability have been demonstrated using this measure [15].

Table 2. Treadmill gait training

Warming up	5 minutes set
Treadmill gait training group	15 minutes set 2 minutes and 30 seconds break 15 minutes set 2 minutes and 30 seconds break 15 minutes set
Cool down	5 minutes set

The GAITRite was used for evaluation of gait function. The GAITRite system provided temporal (time) and spatial (distance) gait parameters via an electronic walkway connected to the serial port of a personal computer. The standard GAITRite walkway contained six sensor pads encapsulated in a rolled-up carpet with an active area of 3.66 m length and 0.61 m width. As the subject walked along the walkway, the sensors captured each footfall as a function of time and transferred the gathered information to a personal computer for processing of the raw data into footfall patterns. The computer calculated the temporal and spatial gait parameters. The validity and reliability of the GAITRite system has been well established [16]. Subjects were asked to walk at their comfortable speed, without use of an assistive device, along a 10 m hallway. The GAITRite walkway was placed in the middle of the 10 m hallway to eliminate the effect of acceleration or deceleration. The temporal-spatial parameters recorded were velocity (cm/s), affected step length (cm), and affected stride length (cm). Excellent paper and pencil and GAITRite correlations (ICC $>$ 0.95) were observed for spatial measures and excellent video-based and GAITRite correlations (ICC $>$ 0.93) were observed for temporal measures [17].

The independent variables of this study was treadmill gait training. The dependent variables were dynamic balance test and gait function (velocity, step length, stride length). All averages and standard deviations of dependent variables were calculated.

Results

A summary of the demographic data of the subjects is shown in Table 3.

The before and after TUG scores for subjects in the TM group decreased from mean 51.64 sec to mean 37.405 sec after participation in treadmill training; the control group showed a reduction, from mean 51.99 sec to mean 38.405 sec after exercise.

Gait function measured velocity (cm/s), step length (cm), and stride length (cm) of the affected side. Velocity showed an increase in both groups. The TM group showed an increase, from mean 51.85 cm/s to mean 64.65 cm/s, and an increase from mean 50.10 cm/s to mean 60.25 cm/s was observed in the control group. The step length of the affected side increased from mean 32.59 cm to mean 38.415 cm in the TM group; the control group showed a change (mean 45.955

Table 3. The comparison of dynamic balance and gait function on pre-test and post-test of the treadmill group and control groups

Variable	Treadmill group (n=2)		Control group (n=2)	
	P1	P2	P3	P4
Dynamic balance				
TUG (sec)	63.56	39.72	54.10	49.88
	48.26	26.55	33.11	43.70
Gait function				
Gait speed (cm/s)	53.6	50.1	51.2	49.0
	61.9	67.4	59.3	61.2
Affected side	23.07	42.11	45.05	46.86
step-length (cm)	29.46	47.37	45.56	53.82
Affected side	45.58	79.28	67.68	83.91
stride-length (cm)	50.14	84.73	71.53	83.16

TUG: timed up and go test.

cm to mean 49.69 cm) after exercise. The stride length of the affected side showed an increase in both groups. The TM group showed an increase from mean 62.43 cm to mean 67.435 cm, and an increase from mean 75.795 cm to mean 77.345 cm was observed in the core group.

Discussion

This study examined the effect of treadmill gait trainig on dynamic balance and gait functions in stroke patients. Stroke patients experience muscle weakness and sensory changes, which can cause dysfunctions, such as difficulties in trunk control, instability of balance, low gait ability, and difficulty in performance of the activities of daily living [18]. Balance is the ability to maintain the center of gravity of the body within the base of support with minimal postural sway [19]. In a study reported by Harris *et al*. [20], the high risk of fall due to reduced balance and gait disturbance remained after discharge and added difficulty in performance of activities of daily living among stroke patients.

Standing balance can be divided into static (immobility) and dynamic (mobile stability) balance. In dynamic balance tests determined using the TUG, ranges of TUG scores have been reported for various samples of elderly people. A previous study of 10 men and women without known pathology, aged 70 to 84 years (mean=75 years), reported a mean TUG score of 8.50 seconds (range=7-10) [15]. Geiger *et al*. [21] reported that conduction biofeedback and conventional physical therapy programs resulted in a decrease in TUG of 23.08 before participation in an exercise program to 14.62 after participation in an exercise program. In our study, the before and after TUG score of subjects in the TM group decreased, from mean 51.64 sec to mean 37.405 sec after treadmill training; a reduction from mean 51.99 sec to mean 38.405 sec was observed after exercise in the control group.

More than 85% of stroke survivors eventually walk with or without assistance [4]. Common features of walking after stroke include decreased gait velocity and asymmetrical gait pattern [22,23]. Achievement of normal gait patterns and speed is usually the ultimate goal of gait training. Bohannon [24] reported that mean comfortable gait speed ranged from 127.2 cm/s for women in their 70s to 146.2 cm/s for men in their 40s. Mean maximum gait speed ranged from 174.9 cm/s for women in their 70s to 253.3 cm/s for men in their 20s. Both gait speed measures were reliable (coefficients ≥ 0.903) and showed significant correlation with age ($r \geq -0.210$), height ($r \geq 0.220$), and the strengths of lower extremity muscle actions (r=0.190-0.500). Holden *et al*. [25] reported that the velocity of gait in hemiparetic subjects (n=10) was 41% of normal. Lau and Mak [26] examined the effect of speed-dependent treadmill training on gait functions in patients with sub-acute stroke. They found that gait speed showed a significant increase, by 85%, and stride length by 36%. In our study, the increase in gait speed, step length, and stride length in the TM group after four weeks of training was 19.8%, 15.2%, and 7.4%, respectively. However, in the control group, gait speed increased by 16.7%, step length by 7.52%, and stride length by 2.01%.

Wagenaar and Beek [27] reported that gait after stroke is characterized by delayed gait cycle induced by shortened stride and increased time of double limb support. Reduced stability and single limb support may alter gait in this way. On the treadmill, several experiments in post-stroke patients have demonstrated a more symmetrical kinematic gait pattern and decreased step-to-step variability, compared to overground walking [28,29]. The results of this study show that a treadmill gait trainig program has a positive effect on dynamic balance and gait function of stroke patients. Conduct of further research is needed in order to confirm the generalization of these findings and to identify which stroke patients might benefit from treadmill gait trainig.

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