ORIGINAL ARTICLE

The Effectiveness of Body Weight–Supported Gait Training and Floor Walking in Patients With Chronic Stroke

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ABSTRACT. Peurala SH, Tarkka IM, Pitkänen K, Sivenius J. The effectiveness of body weight–supported gait training and floor walking in patients with chronic stroke. Arch Phys Med Rehabil 2005;86:1557-64.

Objective: To compare body weight–supported exercise on a gait trainer with walking exercise overground.

Design: Randomized controlled trial.

Setting: Rehabilitation hospital.

Participants: Forty-five ambulatory patients with chronic stroke.

Interventions: Patients were randomized to 3 groups: (1) gait trainer exercise with functional electric stimulation (GT_{stim}), (2) gait trainer exercise without stimulation (GT), and (3) walking overground (WALK). All patients practiced gait for 15 sessions during 3 weeks (each session, 20min), and they received additional physiotherapy 55 minutes daily.

Main Outcome Measures: Ten-meter walk test (10MWT), six-minute walk test (6MWT), lower-limb spasticity and muscle force, postural sway tests, Modified Motor Assessment Scale (MMAS), and FIM instrument scores were recorded before, during, and after the rehabilitation and at 6 months follow-up.

Results: The mean walking distance using the gait trainer was 6900±1200m in the GT_{stim} group and 6500±1700m in GT group. In the WALK group, the distance was 4800±2800m, which was less than the walking distance obtained in the GT_{stim} group ($P=.027$). The body-weight support was individually reduced from 30% to 9% of the body weight over the course of the program. In the pooled 45 patients, the 10MWT ($P<.001$), 6MWT ($P<.001$), MMAS ($P<.001$), dynamic balance test time ($P<.001$), and test trip ($P=.005$) scores improved; however, no differences were found between the groups.

Conclusions: Both the body weight–supported training and walking exercise training programs resulted in faster gait after the intensive rehabilitation program. Patients' motor performance remained improved at the follow-up.

Key Words: Cerebral infarction; Exercise therapy; Rehabilitation.

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STROKE IS A LEADING CAUSE of a permanent handicap. There is increasing evidence that even chronic stroke patients—those over 6 months poststroke—can still improve their motor abilities.[1,2] Therapeutic methods to improve gait include walking with appropriate walking aids, such as a cane, and with verbal and manual guidance. Walking exercises usually are made overground but also in other circumstances such as on the stairs or over uneven terrain. The paretic leg muscles can be activated in a controlled manner by functional electric stimulation (FES),[3] in which the stimulation replaces or assists the functional movement lost after stroke.

Body weight–supported training is a recent addition to walking exercises. Barbeau and Rossignol[4] noticed that spinalized (ie, no supraspinal control) cats could walk and support the weight of their hindquarters after walking training of their hindlimbs on a treadmill. Encouraged by such studies, treadmill training with body weight support (BWS) has been applied to patients with neurologic disorders, such as spinal cord injury,[5] stroke,[6,7] and Parkinson's disease.[8]

The rehabilitation of patients with subacute stroke with or without BWS on a treadmill was compared by Visintin et al.[7] Their program consisted of 6 weeks of training 4 times a week, with 20 minutes at each session. Patients in the BWS group were provided with up to 40% BWS at the beginning of training, and the percentage of BWS was progressively decreased as each patient's gait pattern and ability to walk improved. Patients in both groups showed improvements in balance, motor recovery, walking speed, and endurance. The BWS group, however, scored significantly higher, and they continued to have higher scores in overground walking speed and motor recovery at a 3-month follow-up. Body weight–supported training can also be combined with FES of the leg muscles. Thus, combined therapy has led to improvements in the walking ability of nonambulatory stroke patients.[9]

Hesse et al[10-12] developed an electromechanical gait trainer enabling patients to perform repetitive practice of the gait-like movement (fig 1). Each patient is supported by a harness and stands with his/her feet on the motor-driven footplates. Patients can practice gait-like movements on the gait trainer; this leads to better symmetry of posture, larger hip extension during the stance, and less knee flexion and less ankle plantarflexion during the swing when compared with simple treadmill walking.[11] Only 1 therapist is needed to assist the patient on the gait trainer. In a study[13] of subacute, nonambulatory stroke patients performing 6 weeks of walking exercises, Werner et al found no differences between treadmill training with BWS and gait trainer exercises using such outcome measures as the Functional Ambulation Category (FAC), gait velocity, Rivermead Motor Assessment score, or Modified Ashworth Scale (MAS) score. The gait trainer was at least as effective as treadmill therapy with partial BWS.

Until now, no controlled studies with follow-up have compared similar amounts of different gait training methods, such as gait training with BWS or traditional walking training, in the chronic stage of stroke. The purpose of our study was to compare exercise with a body weight–supported electromechanical gait trainer with conventional therapeutic methods in

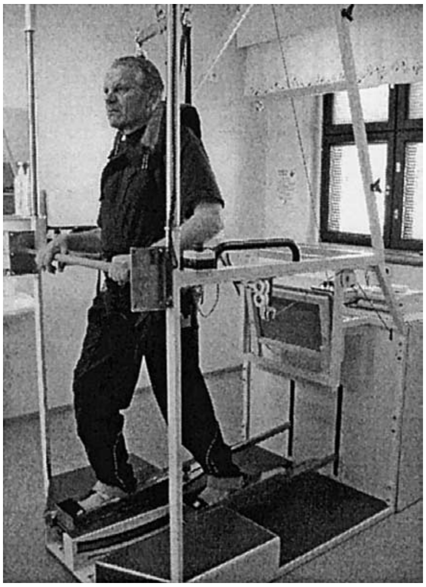

Fig 1. A patient with chronic stroke practices in the electromechanical Gait Trainer with the BWS.

their abilities to improve the gait in patients over 6 months poststroke. In addition, 1 gait trainer group received FES. Our hypothesis was that intensive gait-oriented rehabilitation is effective regardless of the method used to provide this training. A battery of measurements was performed at the start, during, and at the end of intervention and at follow-up after 6 months.

METHODS

Participants

Participants were chronic stroke patients (>6mo) under 65 years of age entitled to receive a 3-week inpatient rehabilitation period financed by the National Social Insurance Institution. Patients with a first supratentorial stroke were selected for the study if they had (1) slow or difficult walking, (2) no unstable cardiovascular disease, (3) no severe malposition of joints, and (4) no severe cognitive or communicative disorders. All patients were initially diagnosed with magnetic resonance imaging (MRI) or computed tomography (CT). An investigator, not involved in the study, randomized the patients to 3 different groups with the help of concealed envelopes. Patients provided written informed consent, and the local ethics committee approved the study.

The patient group consisted of 45 patients (37 men, 8 women) with chronic stroke (fig 2). Patient characteristics are presented in table 1. Twenty-two patients had left-sided and 23 had right-sided hemiparesis. The cause was a supratentorial infarction in 25 cases and an intracerebral hemorrhage in 20 cases. All patients had been initially diagnosed with MRI or CT. Seventeen patients had aphasia, and 5 had neglect based on assessment by a neuropsychologist or speech therapist. The mean time since the onset of stroke ± standard deviation (SD) was 2.9±3.8 years. The Scandinavian Stroke Scale (SSS)[14] was used to assess each patient's functional status. This scale includes items in consciousness, orientation, eye movements, facial palsy, motor function of arm, hand and leg, gait, and speech. Each item is scored from 0 to 12, with a maximum score of 58. The mean SSS score of the patients was 42.6±7 points. Twenty-eight patients had normal position sense of the ankle on the hemiparetic side. All patients had a clinically assessed asymmetric hemiplegic gait pattern, and most used a cane and/or an orthosis for everyday ambulation. None of the patients were classified as FAC[15] 1 (needs 2 assistants to walk). Four patients needed someone to support them to maintain balance (FAC 2), 6 patients needed to have someone walking beside them to give them confidence (FAC 3), 18 patients could move independently but needed help with stairs or if they were walking on uneven ground (FAC 4), and 17 were independent in walking (FAC 5). Although some of the patients were fairly independent in walking, their walking speed was very slow (see table 1).

Intervention

The objective of the 3-week inpatient rehabilitation for our patients with chronic stroke was to improve their walking independence at home. Each patient practiced for 20 minutes walking either (1) in the electromechanical gait trainer (Gait Trainer[a]) (fig 1) with FES (GT_{stim} group), (2) in the gait trainer without stimulation (GT group), or (3) overground (WALK group). The duration of the walking exercise in each group was 20 minutes. Each patient also received other physiotherapy (PT) for 55 minutes daily every workday for 3 weeks. The PT sessions and the walking exercises were based on individually set goals but were always aimed at improving gait.

In the gait trainer (GT_{stim}, GT), a patient is supported with a harness and his/her feet are placed on motor-driven footplates. The speed of the gait trainer can be selected from 0 to 2km/h,

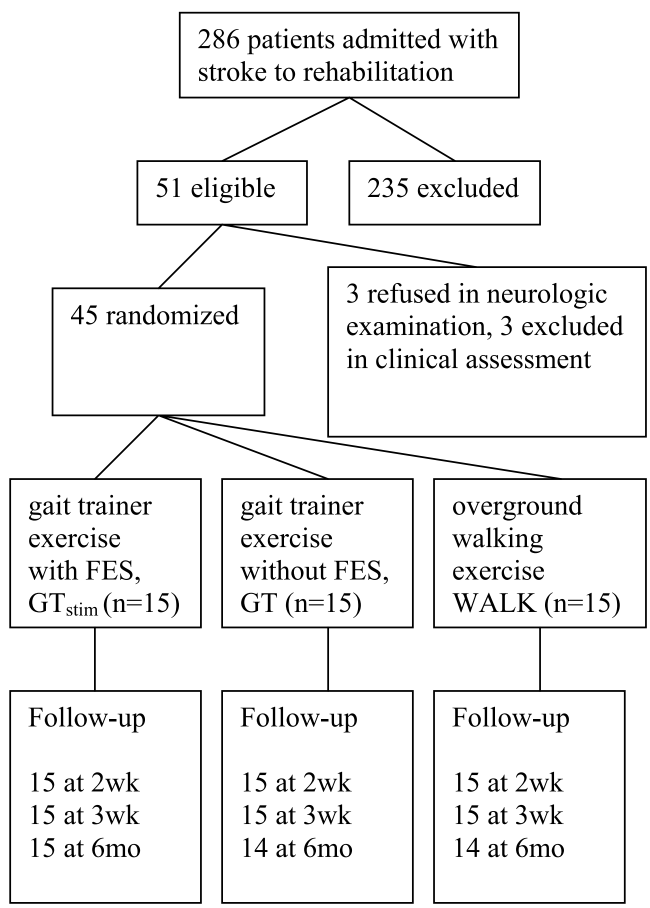

Fig 2. The CONSORT flow diagram.

Table 1: Characteristics of Patients in the Gait Trainer Groups and Walking Exercise Group

Characteristics	GT_{stim} (n=15)	GT (n=15)	WALK (n=15)	*P**	*df*	F/χ^2
Age (y)	53.3±8.9	51.2±7.9	52.3±6.8	.770	2,42	0.26
Poststroke (y)	2.6±2.4	2.4±2.6	4.0±5.8	.505	2,42	0.69
Weight (kg)	79.8±12.9	89.9±13.5	79.4±14.9	.072	2,42	2.81
Height (cm)	171.5±7.2	175.6±7.0	172.5±6.9	.263	2,42	1.38
Heart rate at rest	72.4±12.6	68.8±9.7	63.5±10.5	.097	2,42	2.47
SSS score (points)	43.8±6.9	44.0±7.3	40.1±6.2	.230	2,42	1.52
10MWT time (s)	44.0±36.2	39.6±35.4	39.5±25	.911	2,42	0.09
Men/women	13/2	13/2	11/4	.544	2	1.22
Infarction/hemorrhage	10/5	7/8	8/7	.533	2	1.26
Left/right hemiparesis	9/6	8/7	5/10	.315	2	2.31
Aphasia (no/yes)	10/5	11/4	7/8	.293	2	2.46
Neglect (no/yes)	14/1	12/3	14/1	.407	2	1.80
Position sense norm/abnorm	10/5	10/5	8/7	.685	2	0.76
Patients in FAC 2	1	2	1	.987[†]	6	0.95
Patients in FAC 3	2	2	2	NA	NA	NA
Patients in FAC 4	7	5	6	NA	NA	NA
Patients in FAC 5	5	6	6	NA	NA	NA

NOTE. Values are mean ± standard deviation (SD) or n.
Abbreviations: abnorm, abnormal; NA, not applicable; norm, normative; SSS, Scandinavian Stroke Scale; 10 MWT, ten-meter walk test.
**P* values obtained using 1-way analysis of variance or Pearson chi-square. $P<.05$ is considered significant.
[†]FAC and group table.

which determines the number of steps during each session. The amount of the body weight supported by the harness is chosen according to each patient's needs. In the GT_{stim} and GT groups, the training progression was carried out by increasing the speed and aiming to support less than 20% of the body weight.[16,17] The GT_{stim} group received FES with surface electrodes[b] for the 2 individually selected muscles that were weakest on each patient's paretic lower extremity. The frequency of the stimulation was 25Hz, with a pulse width of 0.3ms. The onset of stimulation was electrically synchronized to the gait pattern.

The duration of the stimulation at each muscle was set with the help of an oscilloscope[c] for the individually functionally beneficial phase of the gait cycle. The duration of the stimulation decreased while the gait speed increased. The stimulation was delivered at an appropriate phase of the gait cycle, depending on the muscle to be stimulated. The synchronization trigger was delivered by the motor, which controlled the movement of the footplate propulsion. The WALK group practiced walking overground or over uneven terrain with their individual walking aids. In the WALK group, the training progression was carried out by increasing the speed with the aim of decreasing reliance on walking aids or different surfaces for walking. Physiotherapists verbally and/or manually guided the patients in all 3 groups.

Assessments

Each patient rated his/her perceived exertion according to the Borg Scale[18] from 6 to 20 (eg, 7, very marginally strenuous; 19, extremely strenuous), and the heart rate was recorded during the last minute while the patient was performing the walking exercise. The therapy parameters from the gait trainer and in the WALK group were recorded by the physiotherapist.

The efficacy of our 3-week PT program was measured by (1) 10-m walking time, (2) 6-minute walking distance, (3) postural sway, (4) spasticity, (5) muscle force, (6) motor ability, and (7) functional independence. In the ten-meter walk test (10MWT),[19] each patient was asked to walk as quickly as possible. In the six-minute walk test (6MWT),[20] each patient was asked to walk as quickly as possible but to pace the walk so that he/she could complete the task. The 6MWT was performed by walking along a marked distance (1 lap, 54m). In the walking tests, patients were allowed to use walking aids, such as a dynamic orthosis or a cane. The same walking aids had to be used in pretesting and posttesting. Postural sway recordings were made with a force plate.[21,d] The center of pressure (COP), that is, the point location of the vertical ground reaction force vector, was recorded with 3 strain gauges of the forceplate. The sampling rate was 50Hz. For the static balance test, patients chose a comfortable standing position on the plate with their feet apart. Data for patients with orthoses were recorded with patients' shoes on (n=29). Three patients had data recorded while barefoot; all others felt too unstable to stand on the forceplate without shoes. The COP change was recorded for 40 seconds in 2 consecutive trials, and the means were calculated. The speed of the COP change was analyzed in the anteroposterior (AP) and mediolateral (ML) directions. Sway measures were corrected for each subject's height. The dynamic test included 3 lateral weight transfers, which patients were required to perform as quickly as possible. The test was guided by the computer screen. Five consecutive trials always were recorded for the mean time and distance of the COP movement. Spasticity of the paretic leg was assessed with the MAS.[22] The MAS is scored from 0 (no increase in muscle tone) to 5 (affected part rigid in flexion or extension). Muscle force was tested in hip flexors, knee extensors, and ankle dorsiflexors and was scored from 0 (no movement) to 5 (full range of movement against power and the same force as on the opposite side). Each patient's motor abilities were assessed with the Modified Motor Assessment Scale (MMAS).[22] The MMAS items (score range, 0–6; max, 48) were supine to side lying, supine to sitting, balanced sitting, sitting to standing, walking, upper-arm function, hand movements, and advanced hand activities. The FIM instrument[23] included 18 items in personal care, sphincter control, mobility, locomotion, and communication. Each item was scored from 1 (total assistance required) to 7 (complete independence); thus, the FIM score ranges from 18 to 126.

Patients were assessed at the start, after 2 weeks, and at the end of the 3 weeks of rehabilitation. With the exception of the FIM, all measurements also were performed at 6 months fol-

Table 2: Total Amount of Walking Exercise and Exertion in Each Group During Rehabilitation (N=45)

Rehabilitation Variables	GT_{stim}	GT	WALK	*P**	*df*	F
Walking distance† (m)	6906±1268	6523±1735	4871±2862	.023	2,42	14.11
Borg Scale (score)	13.1±2.4	14.0±1.7	14.0±1.5	.361	2,42	1.04
Speed 1st session (km/h)	1.3±0.2	1.2±0.2	NA	.300	NA	NA
Speed 10th session (km/h)	1.7±0.3	1.6±0.3	NA	.644	NA	NA
Speed last session (km/h)	1.7±0.3	1.7±0.3	NA	.745	NA	NA
BWS 1st session (%)	26.1±16.4	29.6±20.1	NA	.610	NA	NA
BWS 10th session (%)	11.1±17.9	12.0±13.4	NA	.880	NA	NA
BWS last session (%)	9.1±18.4	8.5±12.0	NA	.916	NA	NA
20% BWS‡	2.6±2.0	3.2±3.7	NA	.614	NA	NA

NOTE. Values are mean ± SD. The development of training speed and BWS is presented for the GT and GT_{stim} groups. The WALK group received traditional training.
**P* values obtained using independent-samples *t* test or 1-way ANOVA. $P<.05$ is considered significant.
†Cumulated in 15 sessions.
‡Session when below 20% BWS.

low-up. The FIM was performed by a nurse and other tests by the same researcher.

Statistical Analysis

The statistical analyses were done with SPSS, version 10.0.[e] The means of age, time since stroke onset, weight, height, heart rate, SSS score, 10MWT (in seconds), total distance (in meters) of 15 gait sessions, and Borg Scale score in the GT_{stim}, GT, and WALK groups were compared using 1-way analysis of variance (ANOVA) with the Tukey test to assess the similarity of the groups (see tables 1, 2). In addition, the frequencies of sex, diagnosis, side of hemiparesis, aphasia, neglect, and FAC score in each group were compared with the Pearson chi-square test. For the GT_{stim} and GT groups, mean values of the speed and amount of BWS were compared with the independent-samples *t* test.

To assess the effect of rehabilitation, we first tested the normal distributions of the results by the Kolmogorov-Smirnov test. If the distribution was not normal, then we performed a logarithmic adjustment. We made this adjustment for assessing the results of the 10MWT, MMAS, and sway parameters. We used repeated-measures ANOVA (2-way ANOVA) to evaluate the changes between the beginning and the end of the rehabilitation and to study group differences and interactions between the study groups and duration of rehabilitation (the repeated contrasts analysis). Because the interactions and group differences were nonsignificant, our main focus was to study changes in the motor ability of the pooled 45 patients. We used Friedman tests to evaluate the changes from the start to the end of rehabilitation in the nonparametric variables. When differences were found, we performed a Wilcoxon signed-rank test. We used a paired-sample *t* test to compare MMAS, 10MWT, 6MWT, and dynamic balance variables results at the end of rehabilitation and at 6-month follow-up to see whether the variables had remained stable. The results were considered significant if *P* was less than .05. We calculated the effect size for walking distance in each group. The effect size was considered small (Cohen d, ≥0.2), medium (d, ≥0.5), and large (d, ≥0.8).[24] Effect sizes were also interpreted in terms of the percentage of nonoverlap of the scores of the GT_{stim} group with those of the GT and WALK groups.

RESULTS

Exercise Intensity

The characteristics of patients in the 3 groups were similar (table 1). The treatments in the GT_{stim} and GT groups were performed similarly (table 2). The mean speed in the gait trainer started at 1.3±0.2 and 1.2±0.2km/h and ended at 1.7±0.3 and 1.7±0.3km/h, respectively. The mean weight support in the gait trainer started at 26.1%±16.4% and 29.6%±20% of body weight and ended at 9.1%±18.4% and 8.5%±12.0% for GT_{stim} and GT groups, respectively. Patients achieved below 20% BWS in the gait trainer during their third training session. In the GT_{stim} group, the muscles most often stimulated were the hip and knee extensors (table 3). In 6 patients, the 2 stimulated muscles of the paretic lower extremity were hip extensors plus knee extensors, in 3 patients hip extensors plus knee flexors, in 3 patients knee extensors plus knee flexors, in 2 patients knee flexors plus ankle pronators, and 1 patient received stimulation only to the hip extensors. The intensity of the stimulation was about 40mA. In the gait trainer, assistance was sometimes needed to prevent knee overextension. In the WALK group, 11 patients mainly used a cane during the 20-minute walking, but 4 patients walked without walking aids. Eight patients needed manual guidance during walking. Many patients in the walk group practiced their gait also over uneven terrain, even walking in snow.

The mean perceived exertion in the GT_{stim}, GT, and WALK groups was similar during the 20-minute walking training (see table 2). The heart rate at different time points remained stable, near 100 beats/min in every group. The walking distances that the patients were able to obtain in the mechanical gait trainer were 6906±1268m in the GT_{stim} and 6523±1735m in GT groups (see table 2). In the WALK group, the distance was 4871±2862m, which was less than the walking distance obtained in the GT_{stim} group ($P=.023$; WALK vs GT group only, $P=.084$). The effect size for the walking distance between the GT_{stim} and GT groups was small ($d=.25$), and their percentage

Table 3: Muscle Groups Stimulated With FES (25Hz with 0.3-ms pulse width) in the GT_{stim} Group (n=15)

Muscle Group	n	Gait Trainer Speed	Duration of Stimulation (ms)
Hip extensors	10	1.2–2.0	400–1400
Knee extensors	9	1.4–2.0	600–1600
Knee flexors	8	1.2–2.0	300–1600
Ankle pronators	2	1.5–1.7	800–1350

NOTE. Fourteen patients received stimulation to 2 muscles and 1 patient to 1 muscle on the paretic lower extremity. The onset of stimulation was synchronized to the gait pattern, and its duration was adjusted individually.

Table 4: Gait, Balance, and Motor Task Performance of Patients With Chronic Stroke at the Start, After 2 Weeks, and at the End of the Rehabilitation Period

Parameter	Group	n	At Start	2 Weeks	3 Weeks	Repeated-Measures P*
10MWT time (s)	GT_{stim}	15	44.0±36.2	37.1±28.2	35.9±29.9	
	GT	15	39.6±35.4	33.7±30.9	30.3±23.6	
	WALK	15	39.5±25.5	31.8±14.7	32.1±15.9	.000
Repeated contrasts P value				.000	.032	
6MWT distance (m)	GT_{stim}	15	127.1±87.2	145.4±95.6	151.7±97.4	
	GT	14	152.3±89.6	175.9±105.8	177.5±111.5	
	WALK	15	111.8±57.3	133.5±72.8	135.1±67.9	.000
Repeated contrasts P value				.000	.531	
Static balance test, VM (mm^2/s)	GT_{stim}	15	55.8±119.1	57.4±120.4	74.7±175.7	
	GT	15	37.6±29.4	46.8±47.0	33.3±28.9	
	WALK	15	42.1±31.5	44.7±29.0	36.1±20.8	.142
Static balance test, AP speed of COP (mm/s)	GT_{stim}	15	16.8±19.1	16.0±16.1	17.6±23.5	
	GT	15	12.6±5.2	13.5±7.2	12.1±5.2	
	WALK	15	15.3±7.0	15.2±5.8	13.7±4.9	.136
Static balance test, ML speed of COP (mm/s)	GT_{stim}	15	11.5±17.1	12.0±17.0	12.9±19.9	
	GT	15	8.7±5.3	9.0±6.7	7.6±4.3	
	WALK	15	10.2±5.5	10.4±5.1	9.0±3.9	.256
Dynamic balance time (s)	GT_{stim}	14	13.6±9.4	8.7±4.6	7.1±3.0	
	GT	14	10.8±5.6	7.9±3.3	6.5±1.9	
	WALK	15	9.8±5.3	8.0±4.9	7.1±3.3	.000
Repeated contrasts P value				.000	.000	
Dynamic balance trip (mm)	GT_{stim}	14	955.9±520.9	903.6±709.7	786.6±342.8	
	GT	14	1015.6±640.9	794.4±434.2	841.1±407.3	
	WALK	15	1021.1±464.5	850.5±276.2	834.0±201.3	.005
Repeated contrasts P value				.001	.883	
MMAS score (points)	GT_{stim}	15	19.0±7.2	21.1±6.8	23.2±7.1	
	GT	15	20.6±6.3	22.6±6.7	22.8±5.8	
	WALK	15	20.1±6.7	21.5±6.5	22.5±6.1	.000
Repeated contrasts P value				.000	.001	
FIM score (points)	GT_{stim}	15	99.2±12.8	98.9±10.8	100.9±12.3	
	GT	15	106.9±10.0	106.3±10.0	106.8±10.2	
	WALK	15	100.7±11.4	101.9±10.3	102.3±10.9	.225

NOTE. Values are mean ± SD.
Abbreviation: VM, velocity moment.
*P values were obtained using ANOVA for repeated measures. The P values are for the pooled data, because the interactions and the group differences were nonsignificant. $P<.05$ is considered significant.

of nonoverlap was 18%. The effect size between the GT_{stim} and WALK groups was large (d=.92), and their percentage of nonoverlap was 52%. The effect size between the GT and WALK groups was medium (d=.70), and their percentage of nonoverlap was 43%.

All patients participated in 75 minutes of individual PT sessions each day. The actual amount of walking exercise per patient was 300 minutes during the 3-week rehabilitation period. In addition, each patient received 825 minutes of other types of PT. The detailed content of their regular PT is described elsewhere.[25] Thirty minutes of PT was spent in an upright position, and this included balance exercises. The rest of the time was spent in the sitting position or in lower initial positions.

Effects of Rehabilitation

Three weeks of gait-oriented rehabilitation significantly improved the motor abilities of the pooled 45 patients with chronic stroke. The gait speed, dynamic balance, and motor task performance improved irrespective of group. In 3 weeks, 10MWT time decreased by 18% to 24%, and 6MWT distance increased by 14% to 17% ($P<.001$) (table 4). The improvement in speed was achieved in all patients at 2 weeks ($P<.001$), and an additional benefit was achieved after 1 more week (P=.032).

The patients' postural stability also improved irrespective of group. The dynamic test time shortened at each recording by 28% to 48% ($P<.001$) (see table 4). An improved ability to control the center of the mass in relation to the base of support was seen in the distance that the COP moved in the dynamic test. The distance decreased by 18 % (P=.005). The static postural sway parameters did not change (see table 4).

The motor ability improved in the pooled data during the rehabilitation: MMAS points increased by 10% to 18% ($P<.001$). The third week provided further improvement (P=.225). The FIM score did not change in our patients with chronic stroke (P=.241). The GT_{stim}, GT, and WALK groups did not differ in 10MWT time, 6MWT distance, balance measures, MMAS points, or FIM points. Ankle spasticity, but not knee or hip, decreased only in the WALK group by the last week of rehabilitation (P=.021). The ankle dorsiflexion force increased in the GT_{stim} group (P=.033), as did the hip flexion force in the GT group (P=.019).

Table 5: Gait, Balance and Motor Task Performance of Patients With Chronic Stroke at the End of the Rehabilitation Period and at 6-Month Follow-Up

Parameter	n	3 Weeks	Follow-Up	*P* (*t* test)*
10MWT time (s)	43	32.4±23.8	39.2±47.9	.343
6MWT distance (m)	42	157.9±92.9	160.9±102.4	.523
Static balance test, VM (mm^2/s)	42	45.6±105.3	39.5±66.7	.795
Static balance test, AP speed of COP (mm/s)	42	13.9±14.3	13.4±11.4	.911
Static balance test, ML speed of COP (mm/s)	42	9.3±11.8	8.9±9.6	.671
Dynamic balance time (s)	41	6.9±2.9	7.6±4.3	.297
Dynamic balance trip (mm)	41	818.1±326.3	855.3±541.6	.982
MMAS score (points)	43	22.3±5.7	21.4±5.7	.018

NOTE. Values are mean ± SD.
*$P<.05$ is considered significant.

Follow-up tests were performed 23.5±3.1 weeks after the rehabilitation. Only 2 patients were not available for follow-up assessments. One patient refused to attend, and one had fallen ill. We found no differences between the groups at 3 weeks, thus comparisons between the end of rehabilitation and the follow-up were performed for all patients together (n=43). With the exception of the MMAS, all parameters had remained unchanged since the end of rehabilitation (table 5).

DISCUSSION

In our study, although all patients were over 6 months post-stroke, they improved their motor performance during the 3-week rehabilitation period. The intensive gait-oriented rehabilitation was effective irrespective of the type of walking exercise. In the study by Werner et al,[1] chronic nonambulatory stroke patients regained better walking ability when they received PT plus treadmill training with BWS compared with conventional therapy. However, these researchers provided twice as much therapy for the treadmill group, and their achieved difference waned by 4 months. Trueblood[2] showed that treadmill training with BWS in patients with chronic stroke could normalize gait and improve balance. His results remained at the 3-month follow-up; however, his study had no control group. There is evidence that subacute stroke patients benefit from walking training either on a treadmill with BWS or on the ground after Motor Relearning Program or using aggressive bracing and that these procedures are similarly effective.[26,27] Furthermore, treadmill training with BWS was shown to be more effective than PT in improving gait, based on the commonly used Bobath concept.[6] In our study, when the same amount of walking training was given, walking in the gait trainer with BWS (with or without electric stimulation) and walking overground resulted in similar motor performance improvements in patients with chronic stroke, and at the 6-month follow-up most of the improvements were still present.

Patients considered the exercise to be only slightly strenuous or strenuous, even though the amount of exercise was more than usually provided. Our results support the results obtained by others,[28] showing that repetitive training appears to be the key to improved activity and functional ability of the paretic extremity through behavioral recovery and potential brain reorganization. The mean walking distance in the GT_{stim} and GT groups was over 6900 and 6500m, respectively, compared with 4800m in the WALK group. Although the improvements in motor performance were similar, the same time frame in the gait trainer allowed more repetitions of steps and longer walking distance. After effect size calculation, the percentage of nonoverlap indicated that 52% of the GT_{stim} group truly benefited and that 43% of the GT group benefited compared with the WALK group. An additional benefit is that less manual guiding effort of the therapist is required if the patient is using the gait trainer compared with walking exercises overground.

The individual effectiveness of exercise in the gait trainer was enhanced by adding speed and decreasing BWS. Both the GT_{stim} and GT groups reached below 20% of BWS in the third session (see table 2). Reducing the weight support is important if one wishes to effectively activate lower-limb muscles and increase energy expenditure.[16,17] Patients were able to increase gait trainer speed by 0.5km/h over the 3 weeks. In a study[29] of subacute ambulatory stroke patients, the use of an interval training program on the treadmill to increase gait speed resulted in faster overground walking, increased cadence, stride length, and FAC classification compared with training without speed increases or conventional gait training. In our study, the speed in the gait trainer groups was increased steadily.

Patients in the GT_{stim} group received FES to 2 muscles in the paretic lower extremity. Because of the mechanical support provided to the ankle dorsiflexion by the gait trainer, the stimulation of the peroneal nerve was not useful, whereas in many studies[30-32] of patients with chronic stroke this muscle is commonly stimulated. Hesse et al[9] compared combined treadmill training and multichannel electric stimulation to a comprehensive neurodevelopmental PT program in nonambulatory subacute patients with hemiparesis. Patients improved their functional ambulation capacity only with combined treadmill training and electric stimulation. The combined therapy proved to be more effective also at improving walking velocity.[9] Barbeau et al[33] also recommended combining treadmill training with FES. In our study, the stimulation of 2 muscles during walking in the gait trainer with surface electrodes added to the obtained walking distance, as seen in the effect size calculation. In the review of Daly et al,[34] it is noted that stimulation is useful (especially with intramuscular electrodes) but that the more muscles that are stimulated, the better the gait improvements that can be expected.

In our study, the WALK group had more possibilities to increase the demands of practice than the GT_{stim} and GT groups, for whom the maximum speed was 2km/h. The WALK group could practice without a cane or in different conditions. This may have contributed to the good progress of the WALK group. It has been reported that more severely impaired and/or older subacute stroke patients can be mobilized more effectively using BWS.[6,26,35] In our study, the number of severely impaired patients was too small to allow comparison between those severely and those less affected. The somewhat independent walking ability and young age (mean age, 52y) may explain the similar results between the groups. In addition, the initial walking speeds of our patients were variable, which further obscured differences between the groups.

The enhanced gait-oriented rehabilitation resulted in improvement in gait speed, dynamic balance, and motor tasks, irrespective of how the walking exercise was undertaken. After rehabilitation, our patients with chronic stroke walked .07m/s (18%–24%) faster, and their 6MWT distances increased by about 24m (14%–17%). These improvements are in line with the studies of Ada[36] and Silver[37] and colleagues in patients with chronic stroke. In Ada's study, 12 sessions of 4 weeks of combined treadmill and overground walking training resulted in an .18-m/s (24%) increase in walking speed (10MWT) and a 99-m (26%) increase in walking capacity (6MWT). Their patients' initial walking velocity was .62m/s, whereas the speed of our patients was .24m/s. Their initial 6MWT distance was 296m, whereas in our study it was 112 to 152m. It appears that with additional effort, a 20% to 30% increase in walking speed of patients with chronic stroke can be obtained.

Various balance functions are known to affect gait.[38-40] The more a patient sways, the worse is the balance and, consequently, his/her gait abilities.[38] In our study, patients exhibited a large postural sway to maintain their standing posture, as seen in the speed of the COP change. The static postural sway parameters did not change during rehabilitation, unlike the dynamic balance. The COP movement time and distance after lateral weight transfers decreased in all groups. Patients' initial MMAS scores were about 42% of the maximum score, this being mainly due to asymmetric weight shifting and the paretic upper limb. Two weeks of rehabilitation lead to an improvement of 2 points, and the third week gave another point in MMAS score. In a previous study[36] of patients with chronic stroke, the motor performance improved but the handicap/independence scales did not changed. Also, here the FIM score remained stable throughout the study period.

CONCLUSIONS

Our patients with chronic stroke maintained their improved walking and dynamic balance up to 6 months after an intensive 3-week rehabilitation, regardless of how the walking exercise was done. Gait trainer exercise with BWS and overground walking exercise are both good choices for those ambulatory stroke patients who are slow but fairly independent in their gait; however, the best result was obtained with the gait trainer combined with electric stimulation. Further study will clarify whether gait trainer exercise with BWS is more useful for very seriously handicapped patients with chronic stroke.

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References

1. Werner C, Bardeleben A, Mauritz KH, Kirker S, Hesse S. Treadmill training with partial body weight support and physiotherapy in stroke patients: a preliminary comparison. Eur J Neurol 2002; 9:639-44.
2. Trueblood PR. Partial body weight treadmill training in persons with chronic stroke. NeuroRehabilitation 2001;16:141-53.
3. Bogataj U, Gros N, Kljajic M, Acimovic R, Malezic M. The rehabilitation of gait in patients with hemiplegia: a comparison between conventional therapy and multichannel functional electrical stimulation therapy. Phys Ther 1995;75:490-502.
4. Barbeau H, Rossignol S. Recovery of locomotion after chronic spinalization in the adult cat. Brain Res 1987;412:84-95.
5. Wernig A, Nanassy A, Muller S. Laufband (LB) therapy in spinal cord lesioned persons. Prog Brain Res 2000;128:89-97.
6. Hesse S, Bertelt C, Jahnke MT, et al. Treadmill training with partial body weight support compared with physiotherapy in nonambulatory hemiparetic patients. Stroke 1995;26:976-81.
7. Visintin M, Barbeau H, Korner-Bitensky N, Mayo NE. A new approach to retrain gait in stroke patients through body weight support and treadmill stimulation. Stroke 1998;29:1122-8.
8. Miyai I, Fujimoto Y, Yamamoto H, et al. Long-term effect of body weight-supported treadmill training in Parkinson's disease: a randomized controlled trial. Arch Phys Med Rehabil 2002;83: 1370-3.
9. Hesse S, Malezic M, Schaffrin A, Mauritz KH. Restoration of gait by combined treadmill training and multichannel electrical stimulation in non-ambulatory hemiparetic patients. Scand J Rehabil Med 1995;27:199-204.
10. Hesse S, Uhlenbrock D, Werner C, Bardeleben A. A mechanized gait trainer for restoring gait in nonambulatory subjects. Arch Phys Med Rehabil 2000;81:1158-61.
11. Hesse S, Uhlenbrock D, Sarkodie-Gyan T. Gait pattern of severely disabled hemiparetic subjects on a new controlled gait trainer as compared to assisted treadmill walking with partial body weight support. Clin Rehabil 1999;13:401-10.
12. Hesse S, Uhlenbrock D, Werner C, Bardeleben A. A mechanized gait trainer for restoring gait in nonambulatory subjects. J Rehabil Res Dev 2000;37:701-8.
13. Werner C, Von Frankenberg S, Treig T, Konrad M, Hesse S. Treadmill training with partial body weight support and an electromechanical gait trainer for restoration of gait in subacute stroke patients: a randomized crossover study. Stroke 2002;33:2895-901.
14. De Haan R, Horn J, Limburg M, Van Der Meulen J, Bossuyt P. A comparison of five stroke scales with measures of disability, handicap, and quality of life. Stroke 1993;24:1178-81.
15. Holden MK, Gill KM, Magliozzi MR, Nathan J, Piehl-Baker L. Clinical gait assessment in the neurologically impaired. Reliability and meaningfulness. Phys Ther 1984;64:35-40.
16. MacKay-Lyons M, Makrides L, Speth S. Effect of 15% body weight support on exercise capacity of adults without impairments. Phys Ther 2001;81:1790-800.
17. Colby SM, Kirkendall DT, Bruzga RF. Electromyographic analysis and energy expenditure of harness supported treadmill walking: implications for knee rehabilitation. Gait Posture 1999;10: 200-5.
18. Borg G. Psychophysical bases of perceived exertion. Med Sci Sports Exerc 1982;14:377-81.
19. Wade DT. Measurement in neurological rehabilitation. Oxford: Oxford Univ Pr; 2000. p 388.
20. Guyatt GH, Pugsley SO, Sullivan M, et al. Effect of encouragement on walking test performance. Thorax 1984;39:818-22.
21. Era P, Avlund K, Jokela J, et al. Postural balance and self-reported functional ability in 75-year-old men and women: a cross-national comparative study. J Am Geriatr Soc 1997;45:21-9.
22. Wade D. Measurement in neurological rehabilitation. Oxford: Oxford Univ Pr; 1992.
23. Keith RA, Granger CV, Hamilton BB, Sherwin FS. The functional independence measure: a new tool for rehabilitation. Adv Clin Rehabil 1987;1:6-18.
24. Cohen J. Statistical power analysis for the behavioral sciences. Hillsdale: Lawrence Earlbaum Associates; 1988.
25. Peurala SH, Pitkanen K, Sivenius J, Tarkka IM. How much exercise does the enhanced gait-oriented physiotherapy provide for chronic stroke patients? J Neurol 2004;251:449-53.
26. Kosak MC, Reding MJ. Comparison of partial body weight-supported treadmill gait training versus aggressive bracing assisted walking post stroke. Neurorehabil Neural Repair 2000;14: 13-9.
27. Nilsson L, Carlsson J, Danielsson A, et al. Walking training of patients with hemiparesis at an early stage after stroke: a compar-

ison of walking training on a treadmill with body weight support and walking training on the ground. Clin Rehabil 2001;15:515-27.
28. Dombovy ML. Understanding stroke recovery and rehabilitation: current and emerging approaches. Curr Neurol Neurosci Rep 2004;4:31-5.
29. Pohl M, Mehrholz J, Ritschel C, Ruckriem S. Speed-dependent treadmill training in ambulatory hemiparetic stroke patients: a randomized controlled trial. Stroke 2002;33:553-8.
30. Taylor PN, Burridge JH, Dunkerley AL, et al. Clinical use of the Odstock dropped foot stimulator: its effect on the speed and effort of walking. Arch Phys Med Rehabil 1999;80:1577-83.
31. Burridge JH, Taylor PN, Hagan SA, Wood DE, Swain ID. The effects of common peroneal stimulation on the effort and speed of walking: a randomized controlled trial with chronic hemiplegic patients. Clin Rehabil 1997;11:201-10.
32. Granat MH, Maxwell DJ, Ferguson AC, Lees KR, Barbenel JC. Peroneal stimulator; evaluation for the correction of spastic drop foot in hemiplegia. Arch Phys Med Rehabil 1996;77:19-24.
33. Barbeau H, Norman K, Fung J, Visintin M, Ladouceur M. Does neurorehabilitation play a role in the recovery of walking in neurological populations? Ann N Y Acad Sci 1998;860:377-92.
34. Daly JJ, Marsolais EB, Mendell LM, et al. Therapeutic neural effects of electrical stimulation. IEEE Trans Rehabil Eng 1996;4:218-30.
35. Barbeau H, Visintin M. Optimal outcomes obtained with body-weight support combined with treadmill training in stroke subjects. Arch Phys Med Rehabil 2003;84:1458-65.
36. Ada L, Dean CM, Hall JM, Bampton J, Crompton S. A treadmill and overground walking program improves walking in persons residing in the community after stroke: a placebo-controlled, randomized trial. Arch Phys Med Rehabil 2003;84:1486-91.
37. Silver KH, Macko RF, Forrester LW, Goldberg AP, Smith GV. Effects of aerobic treadmill training on gait velocity, cadence, and gait symmetry in chronic hemiparetic stroke: a preliminary report. Neurorehabil Neural Repair 2000;14:65-71.
38. Nichols DS. Balance retraining after stroke using force platform biofeedback. Phys Ther 1997;77:553-8.
39. Chou SW, Wong AM, Leong CP, Hong WS, Tang FT, Lin TH. Postural control during sit-to-stand and gait in stroke patients. Am J Phys Med Rehabil 2003;82:42-7.
40. Nadeau S, Arsenault AB, Gravel D, Bourbonnais D. Analysis of the clinical factors determining natural and maximal gait speeds in adults with a stroke. Am J Phys Med Rehabil 1999;78:123-30.

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