Department of Veterans Affairs

Journal of Rehabilitation Research and Development Vol. 38 No. 1, January/February 2001
Pages 69–78

The effect of treadmill training on the ambulation of stroke survivors in the early stages of rehabilitation: A randomized study

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Abstract—The objective of this study was to compare the effects of conventional over-ground gait training with treadmill training on the restoration of gait in people with hemiparesis following a stroke. Twenty-five individuals in the early stages of rehabilitation were alternately assigned to one of two treatment groups. In addition to conventional physical therapy, the experimental group participated in 15 treadmill-training sessions in which a handrail was used for external support. The control group received the same number of equal length sessions of over-ground ambulation. Treatment effects were established by pre- and posttreatment assessment of: 1) functional walking ability, 2) walking speed, 3) stride length, 4) temporal characteristics of gait, and 5) electromyographic activity of calf muscles. Normal values were obtained from eight healthy individuals of approximately the same age as the stroke survivors. The study demonstrates that individuals following a stroke are well able to tolerate treadmill training in the early stage of their rehabilitation process without the use of a weight support apparatus. Furthermore, the findings suggest that treadmill training may be more effective than conventional gait training for improving some gait parameters such as functional ambulation, stride length, percentage of paretic single stance period, and gastrocnemius muscular activity.

Key words: *gait, hemiplegia, rehabilitation.*

This material is based on work supported in part by a grant from the Ministry of Health, Chief Scientific Office, Jerusalem, Israel.

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INTRODUCTION

Loss and impairment of walking ability is one of the major devastating outcomes of post-stroke hemiplegia. While 25 percent of stroke survivors are never able to ambulate independently, in 50 percent walking impairments are still observed 3 months after the insult (1). Thus, the restoration and improvement of walking ability in these subjects constitutes a major treatment goal of physical therapy.

Numerous studies have examined the gait characteristics of persons who have sustained a stroke, as well as the effectiveness of various physical therapy approaches employed to improve their gait (2,3). While the use of a treadmill is common in the rehabilitation of individuals with cardiac and pulmonary deficiencies (4), and has been shown to produce substantial reductions in the energy expenditure and cardiovascular demands of walking in people with chronic hemiparesis (5), the potential benefits of treadmill gait training for the neurologically impaired is just beginning to receive the attention of investigators.

A novel approach introduced for early gait training of stroke survivors involves the use of body weight support during gait training on a motorized treadmill (6,7). The rationale for this approach is that while partial weight support removes some of the biomechanical and equilibrium constraints of full weight bearing, walking movements may be facilitated on the treadmill by the activation of spinal locomotion centers (8). Paraplegic patients treated with this method have exhibited improvement in walking capacity (9). Similarly, positive outcomes have been reported for people who have had a stroke (10–12). In one of these studies (10), for example, nine individuals who were non-ambulatory due to hemiparesis with a mean post-stroke interval of 129 days, were trained on a treadmill for 15 minutes in 25 sessions using partial weight support. Following treatment, subjects exhibited gains in functional and motor abilities, as well as in velocity and cadence. In four people, improvement in gait symmetry was also measured. In another study in which the effect of conventional physical therapy was compared with treadmill training with partial body weight support on seven people who were non-ambulatory secondary to hemiparesis, results pointed to an advantage of treadmill training (11). In a controlled study with 100 subjects, training effect on balance, motor tasks, and gait velocity pointed to the advantage of combining partial weight support with treadmill training over treadmill training by itself (12).

Fewer studies compared the effect of treadmill training without the use of partial weight support with the effect of conventional training (13–15). While some of these studies included treadmill training as part of an intense task-oriented gait-training program (13,14), the isolated effect of treadmill training rarely has been examined. In an A-B-A treatment, single-subject study of an individual with hemiparesis who was 3 years post-injury, a 3-week program of treadmill training had a positive effect on some aspects of gait (15).

In recent years, treadmill equipment has become more readily available in many physical therapy departments. In our experience, many subjects with hemiparesis are able to train on a treadmill without the use of partial weight support early on in the rehabilitation process, provided initial speed of the treadmill is as low as 0.2–0.4 km/hr. The present study was designed to gain more insight into the treatment effects of treadmill training without the use of partial weight support by comparing objective outcomes of stroke survivors during the early stages of rehabilitation who are undergoing conventional gait training with those undergoing treadmill training. We hypothesized that treadmill training without body weight support is often feasible in the early stage of stroke rehabilitation, and that more significant gains in gait characteristics will be observed following treadmill training as compared to floor ambulation. The following gait variables were used as criterion measurements: 1) functional walking ability, 2) self-selected speed, 3) stride length, 4) temporal gait characteristics, and 5) electromyographic (EMG) activity of the anterior tibialis (AT) and medial gastrocnemius (MG) muscles.

METHODS

The local Institutional Review Board approved the study, and each subject received a detailed explanation of the study and gave informed consent prior to participation. During a 6-month period, the hospital staff therapists referred to the researchers' 71 subjects following stroke who began ambulation training. Twenty-five subjects who met the following study criteria completed the study: 1) first supratentorial strokes in anterior brain circulation as evidenced by CT, 2) no additional neurological and/or orthopedic deficiencies impairing ambulation, 3) no cardiac, respiratory or medical condition that could interfere with protocol, 4) no severe cognitive or communication impairment that could hamper the understanding of simple instructions, 5) onset of stroke no more than 90 days prior to beginning of study, and 6) ability to walk on treadmill at a speed of at least 0.2 km/hr with minimal to moderate assistance for 2 minutes without rest. Subjects were then alternately assigned to either the control group (floor walking) or the experimental group (treadmill training) by order of admittance to study. In addition, measurements were taken from eight healthy male and female adults of approximately the same age as the stroke survivors. Subjects' characteristics are presented in **Table 1**.

Procedure

The study examined the gait characteristics of healthy adults and hemiparetic subjects in the early phases of rehabilitation. Gait characteristics of the healthy participants were tested once to provide for normal values of healthy individuals of approximately the same age, while all the stroke survivors were examined twice at a 3-week interval (pre- and post-intervention). During this interval all subjects from both the control and experimental groups continued to receive five daily physical therapy treatments per week. The treatments were based on the Bobath approach (16), and were provided by staff therapists who were blinded as to subjects' group placement. Occupational therapy and speech therapy were administered according to individual needs.

In addition to the routine treatment, all stroke survivors received five gait-training sessions a week (total of

Table 1.
Subjects' characteristics

	No	Gender	Age (SD)	Days post-stroke (SD)	Side of paresis	Etiology
Healthy	8	M=4 F=4	68(7.6)	—		
Floor walking	12	M=7 F=5	69.3(8.1)	35.8(17.3)	Rt=7, Lt=5	2 hemorrhages, 10 infarcts
Treadmill	13	M=7 F=6	66.6(7.2)	32.6(21.2)	Rt=8, Lt=5	4 hemorrhages, 9 infarcts

15 sessions), performed by other staff therapists. Gait training of the control group consisted of ambulating on floor surface at a comfortable speed using walking aids, assistance, and resting periods as needed. Gait training of the experimental group consisted of ambulating on a motor-driven treadmill (RTM3 Rehabilitation treadmill, Biodex Medical Systems), which was adjusted to the subject's comfortable walking speed. Generally, during the treadmill training, the subjects held onto a horizontal bar at their front or side, and a therapist standing on the floor beside them provided assistance with hip flexion and foot placement as needed. However, with the more limited or apprehensive subjects, treadmill training began with the treating therapist standing behind the subject on the treadmill, guarding the subject and providing manual assistance with hip flexion as needed. In most cases, after 2 or 3 such training sessions, the subjects were willing to stand alone on the treadmill and receive assistance from the therapist who stood on the floor alongside the subjects.

Actual walking time during training sessions (excluding rest periods) was identical for both groups: 4 minutes per day during the first week, 6 minutes per day during the second week, and 8 minutes per day during the third week. Total intervention periods (including rest periods) generally ranged between 8–20 minutes. It should be noted that this ambulation training was in addition to training received during the routine treatment.

Assessment

All pre- and post-intervention measurements were performed by the researchers who were blind as to group placement of the subjects.

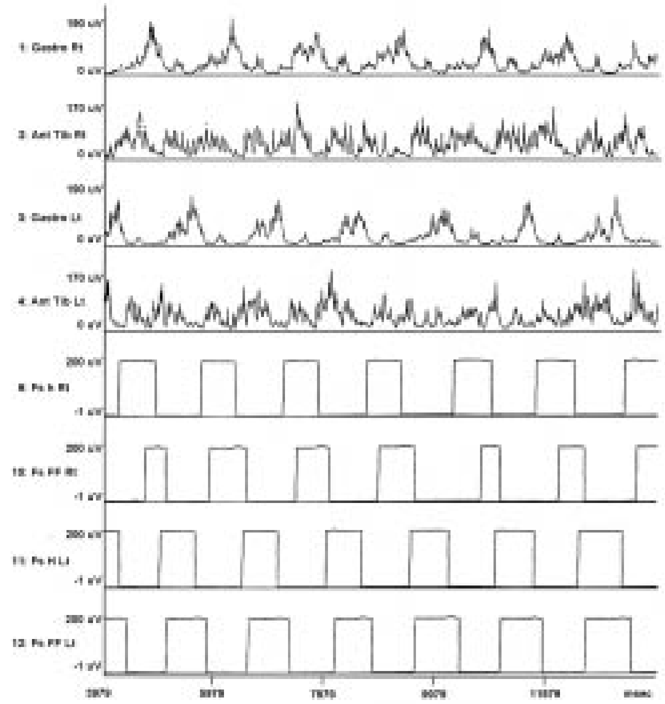
Functional walking ability was assessed by a) Functional Ambulation Category (FAC; reference17), b) Standing Balance Test (SBT; reference 18), and c) walking aids used during ambulation. The FAC distinguishes six levels of required support during gait, and was performed with the walking aid recommended by treating therapists, but without orthoses. Levels are defined as follows: level 0—the person cannot walk at all or requires the help of two or more people, level 1—the person needs continuous support from one person who helps to carry the patient's weight and helps with balance, level 2—the person is dependent on the continuous or intermittent support of one person to help with balance or coordination, level 3—the person needs only verbal supervision, level 4—help is required on stairs and uneven surfaces, and level 5—the person can walk independently anywhere.

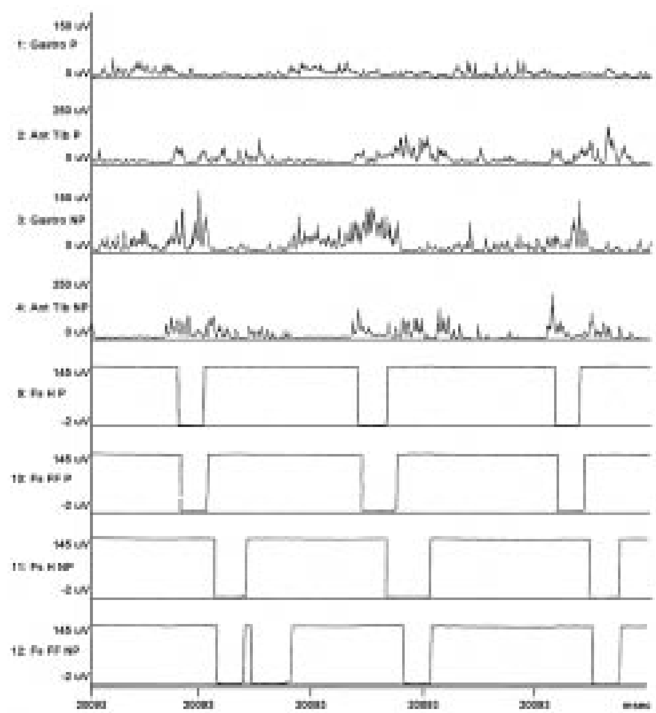
Standing posture was quantified by the SBT. Levels are defined as follows: level 0—person unable to stand; levels 1 and 2—person able to stand with feet apart for less than 30 seconds or more than 30 seconds, respectively; levels 3 and 4—same time parameters as levels 1 and 2, but with feet together. Since both the FAC and SBT tests do not include information on type of aid needed for ambulation, this was noted separately.

To determine ambulation velocity, the subjects were asked to walk 10 m at maximum speed while maintaining safety. Patients used, for the test, the assistive device selected in the regular physical therapy session. The required time to walk 10 m was measured with a stopwatch.

Stride length, percentage of swing, stance, and double stance periods on each foot were determined by the use of two pairs of foot switches attached to the heels and forefeet of the subjects' shoes. Foot switch signals were sampled at a rate of 1,000 Hz. Contact by either heel or forefoot switch indicated stance phase on limb. Input from the foot switches was obtained during an 8-m walk at comfortable speed level during which EMG data were also collected.

The EMG activity from the AT and from the MG muscles was recorded via pairs of surface AgCl disposable electrodes (diameter 0.9 cm) which, following skin preparation, were placed on the midline of the muscle bellies of both lower limbs. During testing, the EMG signals (bandwidth 0–1,000 Hz) were sampled at a rate of 1,000 Hz. Signals from the foot switches and EMG were fed into a personal computer. **Figures 1a, 1b, and 1c** demonstrate EMG and foot-switch signals obtained during the testing of one healthy subject and of one individual from the experimental group before and after treatment intervention.





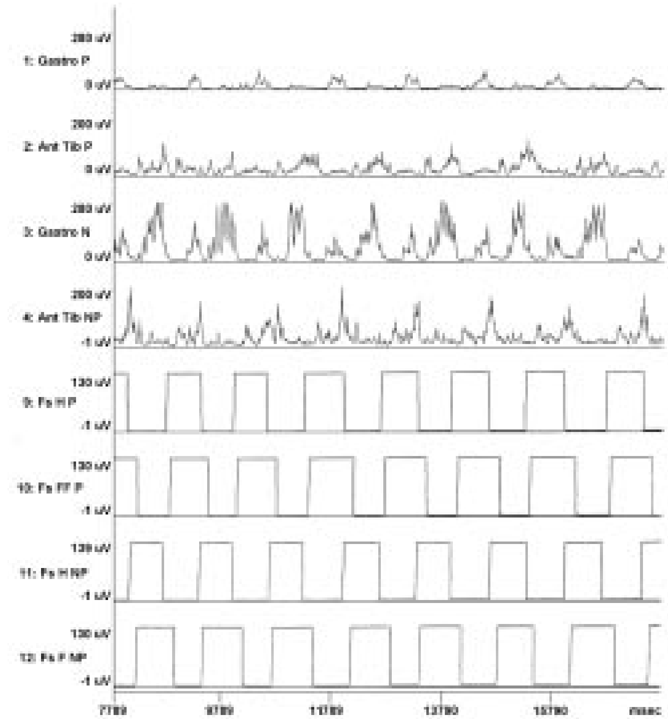


Figure 1.
EMG and foot-switch signals (upward deflection for stance phase) of a 10-second time segment recorded several seconds after onset of ambulation (x-axis—time since test onset in msec). Data displayed are of one healthy subject, **1a**, and of one patient trained by treadmill at pre- **1b** and post- **1c** intervention.

To facilitate the analysis and interpretation of the EMG data, the period between the consecutive foot contacts of the same leg was divided into three equal length phases. This division of the gait cycle was chosen, since the data from the foot switches indicated that duration of stance phase was approximately 2/3 that of the gait cycle, and that the swing phase generally corresponded to the third phase of the gait cycle. Symmetry in EMG magnitude was calculated as ratios between EMG amplitudes during corresponding phases in the 2 legs, with mean values of the paretic leg placed in the nominator and mean values of non-paretic leg in the denominator. For all between-group comparisons, the right leg of the healthy subjects was arbitrarily chosen to be compared with the paretic leg, and the left leg with the non-paretic leg.

Descriptive statistics were used to outline subject characteristics and to display major findings. One-way analysis of variance (ANOVA), followed by Bonferonni post hoc comparisons, were used for comparing between the three groups (i.e., healthy, control, and experimental). Paired and unpaired t-tests were used for comparing the 2 legs of the same subject, and for comparing between the 2 patient groups, respectively. The Wilcoxon signed rank test and the Mann-Whitney test were used for the nonparametric variables.

RESULTS

Of the 71 stroke survivors referred to the study, 42 were rejected for not meeting at least one of the six inclusion criteria defined by the researchers. Of the 29 stroke survivors admitted to the study, two subjects from each group did not complete the protocol (three were discharged prior to completion and one was readmitted to an acute hospital). There were no significant differences between the control and experimental groups in all preintervention tests.

Functional Walking Ability

Mean scores of the FAC and the SBT, and the walking aids used by both patient groups at pre- and posttreatment evaluations are presented in **Table 2**. While the FAC scores of the experimental group improved significantly (F=2.75, p=0.006), the FAC scores of the control group demonstrate a trend toward improvement (F=1.89, p=0.06). The between- group comparison of posttreatment functional walking ability indicates a statistically significant difference between groups (F=2.37, p=0.02). In the balance test, only the experimental group showed significant improvement (F=2.170, p=0.03), but comparison between the posttreatment scores of both patient groups does not show significant difference. Both patient groups progressed to using assistive devices, which provide less external support, with no significant differences between groups.

Table 2.
Mean FAC and SBT scores and assistive devices of both patient groups at pre- and posttreatment evaluations

	Floor Walking		Treadmill Training	
	Pretest	**Posttest**	**Pretest**	**Posttest**
FAC	1.92	2.75	2.18	3.82*
SBT	2.42	3.00	2.18	3.64*
Forearm walker	1	—	1	1
Walker	2	—	7	5
4-point cane	7	9	5	4
Straight cane	2	3	—	2
No assistive device	—	—	—	1

* Statistically significant improvement

Mean Walking Speed and Stride Length

Mean walking speed and stride length of all groups at the pre- and posttreatment tests are presented in **Table 3**. Walking speed of the two patient groups was significantly slower than that of the healthy subjects at both the pre- and posttreatment evaluations (T=2.54, p<0.05, for posttreatment difference). Velocity of both patient groups increased significantly between evaluations (T=2.68, p=0.02, and T=3.34, p=0.03 for control and experimental groups, respectively). Although improvement percentage was greater in the experimental group (135 percent *versus* 88 percent for experimental and control groups, respectively), the between-group comparison of posttreatment walking speed indicates no statistically significant difference between patient groups.

Mean stride length of both patient groups was significantly shorter than that of the healthy subjects at both pre- and posttreatment evaluations (T=2.54, p<0.05, for posttreatment difference). While the control group did not increase its stride length significantly, a significant increase in stride length was measured in the experimental group (T=2.56, p=0.02). Yet, the between-group comparison of posttreatment scores indicates no statistically significant difference between groups.

Temporal Gait Characteristics

Mean percentages of gait cycle spent in stance on each foot as well as in double stance are depicted in **Table 4**.

Paretic Leg

Percentage of stance and swing periods. There were no significant differences between stance and swing periods of the paretic leg in both pre- and postmeasurements of both groups. Nor was there a difference between these measurements and those of the healthy adults.

Percentage of single stance period. Single stance on paretic leg was significantly shorter in both patient groups as compared to the healthy group in both pre- and posttreatment tests (Bonferonni test, T=2.54, p<0.05, for posttreatment test). While comparison between pre- and postmeasurements of single stance on paretic leg indicates no significant improvement in the control group, a statistically significant lengthening of the percentage of the single stance period is noted in the experimental group (T=3.07, p=0.01). Still, the between-group comparison of posttreatment scores indicates no statistically significant difference between groups.

Table 3.
Mean walking speed and SD (m/sec) and stride length and SD (m) in pre- and posttreatment evaluations

	Healthy	Floor Walking		Treadmill Training	
		Pretest	Posttest	Pretest	Posttest
Walking speed	1.28(0.24)	0.18(0.16)	0.33(0.24)*	0.20(0.12)	0.47(0.40)*
Stride length	0.99(0.12)	0.40(0.16)	0.47(0.18)	0.36(0.14)	0.53(0.22)*

* Statistically significant improvement

Table 4.
Mean percentages of gait cycle (and SD) spent in stance, swing and double stance on each foot in pre and post treatment evaluation

	Healthy	Floor Walking		Treadmill Training	
		Pretest	Posttest	Pretest	Posttest
PSt	62.8(4.3)	60.2(23.1)	63.0(16.3)	67.8(21.0)	68.5(12.2)
PSi St (& NP Sw)	33.7(6.7)	14.6(13.2)	17.6(11.7)	14.4(16.0)	23.9(12.4)*
PSw (& NP St)	37.2(4.3)	39.8(23.1)	37.0(16.3)	32.2(21.0)	31.5(12.2)
DS	30.2(4.5)	51.2(24.8)	47.2(20.4)	55.6(25.5)	47.7(18.0)
NP St	66.3(6.7)	85.4(13.2)	82.4(12.0)	85.6(16.0)	76.1(12.4)

* Statistically significant improvement
PSt=paretic stance, PSi St=paretic single stance, NPSw=Non paretic swing, PSw=paretic swing, NPSi St=Non paretic single stance, DS=double stance, NPSt=Non paretic stance

Percentage of double stance period. Double stance periods were significantly longer in both patient groups than in the healthy subjects at both pre- and posttreatment evaluations (T=2.52, $p<0.05$, for posttreatment test). Comparison between pre- and posttreatment measurements indicates no statistically significant improvement in both patient groups.

Non-paretic Leg

Percentage of stance period on the non-paretic leg was significantly longer in both pre- and posttreatment evaluations of the two patient groups as compared to the corresponding periods in healthy subjects (T=2.72, $p<0.05$, for posttreatment test). Comparison between pre- and posttreatment measurements indicates no statistically significant improvement in both patient groups.

EMG Data

Mean Activity Level

In order to compare changes in calf musculature activity, the ratio between mean activity level of the corresponding muscles of the two legs for all subjects at the pre- and posttreatment measurements are shown in **Tables 5** and **6**. In the healthy subjects, there were no significant differences in activity levels of the corresponding muscles in each of the three gait phases, with the ratio between the mean activity of both legs close to 1.0. In contrast, in both stroke groups, muscular activity was significantly lower on the paretic when compared to the non-paretic leg for both the MG and TA muscles, in all three stride phases and in both pre- and posttreatment measurements ($p<0.05$ for all comparisons). Subsequently, between-group comparison indicated a significant ($p<0.05$) difference in the ratio between mean activity level of the corresponding muscles of the two legs, the difference being due to the significantly higher ratios of the healthy subjects as compared to either patient group ($p<0.05$ for all comparisons).

As the values in **Tables 5** and **6** indicate, all ratios of EMG activity between the paretic and non-paretic muscles of both patient groups increased following treatment. However, statistical analysis demonstrated significant improvement in the ratios only in the following cases: (a) the third phase of the AT muscle of the control group (T=2.48, p=0.03) and (b) the second and third phases of the MG muscle of the experimental group (T=2.10, p=0.06, and T=2.21, p=0.05, respectively).

Table 5.
Ratios (and SD) between mean EMG activity of AT muscles in the three gait phases at pre and post treatment evaluations

Group	Pretreatment			Posttreatment		
	Phase I	Phase II	Phase III	Phase I	Phase II	Phase III
Healthy[1]	1.18(0.44)	1.12(0.37)	1.12(0.24)			
Floor walking[2]	0.55(0.67)	0.31(0.28)	0.49(0.48)	0.65(0.90)	0.41(0.58)	0.71(0.64)*
Treadmill[2]	0.44(0.73)	0.40(0.32)	0.71(0.70)	0.40(0.24)	0.52(0.32)	0.69(0.40)

* Statistically significant improvement
[1]Mean activity of right AT muscle/mean activity of left AT muscle
[2]Mean activity of paretic muscle/mean activity of non-paretic muscle

Table 6.
Ratio (and SD) between mean EMG activity of MG muscles in the three gait phases at pre and post treatment evaluations

Group	Pretreatment			Posttreatment		
	Phase I	Phase II	Phase III	Phase I	Phase II	Phase III
Healthy[1]	1.01(0.30)	1.24(0.38)	1.28(0.43)			
Floor walking[2]	0.40(0.27)	0.27(0.22)	0.36(0.24)	0.53(0.38)	0.43(0.33)	0.40(0.31)
Treadmill[2]	0.60(0.36)	0.40(0.34)	0.41(0.36)	0.64(0.69)	0.54(0.40)*	0.84(0.78)*

* Statistically significant improvement
[1]Mean activity of right MG muscle/mean activity of left MG muscle
[2]Mean activity of paretic muscle/mean activity of non-paretic muscle

DISCUSSION

The present study examined the effect of treadmill training on the ambulation of stroke survivors in the early stages of rehabilitation. In agreement with observations of others, the study indicates that the gait of hemiparetic subjects is significantly different from the gait of healthy individuals of the same age (for review see reference 2). Characteristically, patients suffer from deficits in their functional ambulation capacity, balance, walking velocity, cadence, stride length, temporal gait pattern, and muscular activity pattern. Also in agreement with previous research, the study indicates that while stroke survivors in the early stages of rehabilitation may achieve significant gains in many of their gait characteristics, the performance of most patients remains deficient to a large extent despite intensive rehabilitation efforts (19–21).

The results of the present study indicate that treadmill training without weight support is feasible and well tolerated by subjects with hemiparesis even in the early stages of gait rehabilitation. Moreover, results indicate that for some gait characteristics, treadmill training may be more effective than over-ground ambulation. Although one must assume that spontaneous recovery as well as the routine treatment provided by staff therapists contributed to the gains of all participants, the research suggests that the differences in the magnitude of recovery of the two groups could be due to the difference in gait training technique.

While it has been previously demonstrated in an extensive study that gait training on a treadmill with partial body-weight support is more effective than without weight support (8), the findings of the present study, indicating feasibility and possible advantage of treadmill training without weight support over conventional over-ground training, has important practical significance. In our experience, treadmill training is easy to incorporate during conventional treatment, since unlike the use of a weight support system, it is not more time consuming or taxing for the therapist than over-ground training. Furthermore, in our experience the commonly used weight-support systems are often difficult to use with stroke survivors, as they do not accommodate well for the asymmetrical nature of weight bearing typical to individuals with hemiparesis.

While most subjects were rejected from the study due to reasons that had nothing to do with ability to use the treadmill (e.g., infarct in the brain stem, previous strokes, severe cognitive deficits, *et cetera*) records were not kept as to distribution of criteria for rejection. Further study is necessary to determine the proportion and characteristics of individuals in the early stages of stroke rehabilitation who are able to participate in treadmill training without body-weight support. In addition, the alternate design utilized in the present study may have led to some bias in the subjects' group placement, and further randomized studies are necessary to validate the results.

Of the three nonparametric variables examined, only the decrease in the use of assistive devices was comparable in both groups. The FAC and Balance scores improved significantly only in the experimental group. The difference between the average posttreatment FAC score of the control group (2.75) and the average posttreatment FAC score of the experimental group (3.82) may have clinical significance. It indicates that the group trained by treadmill has a better ability to negotiate stairs and uneven surfaces, which is one of the important determinants of community independence (22). These results are similar to those reported in a comparison between treadmill training with partial weight support and conventional therapy (11), and indicate the contribution of treadmill training to functional gait capabilities.

Gait velocity, which improved significantly in both treatment groups, has been shown repeatedly to be an important indicator of independence (22). Improvement in gait velocity of hemiplegic subjects has been shown to be related to increases in stride length as well as in cadence (20,23). In the present study stride length did not contribute to the significant increase in the gait velocity of the control group, and one must assume that gait velocity was affected primarily by an increase in cadence. Nakamura and colleagues (24) reported that the relationship between cadence and speed is linear up to a speed of about 0.33 m/s, with further gains primarily attributable to increases in stride length. The significant improvement in stride length observed only in the experimental group might be related to the fact that only this group achieved average speed greater than 0.33 m/s. Another possible explanation for the increased stride length of the experimental group may be related to an increase in hip flexion, which has been demonstrated in treadmill ambulation of healthy individuals (25). It seems likely that a similar pattern of increased hip flexion was induced in our subjects as the participants consistently expressed a fear of tripping on the treadmill and therefore made a conscious effort to clear the surface. These efforts, in turn, may have transferred into an increase in stride length in over-ground ambulation.

A third possible explanation for the increase in stride length observed in the experimental group may relate to the significant improvement in the ratio between the EMG activity of the MG muscles observed in the second phase of the gait cycle in this group. This may indicate an increase in the MG muscular activity in the push-off phase of the paretic limb of the experimental group, which has been shown to be important for the power generation needed for walking (26).

In agreement with previous studies, the percentage of time spent by stroke survivors in the swing and stance phases of their gait was comparable to those of the healthy adults. Yet, the percentage of time spent on the paretic limb during the single stance period was shorter than the norm, and the percentage of double stance period was prolonged (20). Studies indicate that these latter parameters, which describe the asymmetrical pattern of the hemiplegic gait, are particularly resistant to treatment (20,27). Therefore, it is of major significance that in contrast to gait training on a stationary surface, treadmill training increased the single stance period of the paretic leg.

The mechanism by which treadmill training may affect the gait of stroke survivors remains unclear. There are indications that the positive effect may stem from the activation of a spinal stepping generator (8). Such activation requires in primates intact reticulospinal motor pathways in the ventral section of the spinal cord, a condition that is met in hemiparetic subjects (28).

A second possible explanation for the changes induced by treadmill training may relate to the kinematic characteristics of treadmill ambulation mentioned in our discussion of stride length. In a kinematic comparison of over-ground and treadmill walking of healthy individuals (26), it was demonstrated that treadmill walking is characterized by greater maximal hip flexion and cadence and by a significant decrease in stance time. Further research is necessary to determine whether treadmill walking induces similar changes in stroke survivors.

It has also been suggested that the more intensive task-specific training provided by the treadmill may account for the greater improvement observed in several of the gait parameters of stroke survivors trained by treadmill ambulation. It has been shown, for instance, that gains in gait velocity are positively correlated to actual time spent practicing gait or gait-related activities, but not to total therapy time (14). In the present study, great care was taken to maintain the same training time for both patient groups. Yet, it is still possible that the experimental group received more gait-specific training. Ambulation on a stationary surface is frequently characterized by inconsistent ambulation speed as patients slow down as they fatigue. On the other hand, speed on the treadmill remains constant until subjects are unable to keep up with set speed and are forced into a rest period. Therefore, for equivalent ambulation time, the treadmill group may have actually practiced more gait cycles, thus receiving more intensive task specific training. It should be noted that this more intensive training was not more time consuming than conventional training.

In order to ensure relative functional homogeneity between subjects, the participants in the present study were carefully selected according to site and onset time of lesion. Nevertheless, a large variance in gait characteristics was observed. While such variance is characteristic of stroke survivors even in a clinically homogeneous group (21), it most probably affected ability to reach a more statistically significant conclusion concerning results. This large variance may explain the fact that while significant improvements were noted in several gait parameters (balance, stride length, EMG mean activity level of MG, and single stance period) only in the experimental group, posttreatment comparisons between groups did not indicate differences between groups. This variance may also be the reason why the greater increase in mean walking speed observed in the experimental group (a 135 percent *versus* an 88 percent increase in the control group) did not induce a statistically significant difference between patient groups in the posttreatment evaluation. Future work should include power analysis to indicate the number of subjects necessary to reach significant conclusions with such a heterogeneous sample. In future studies with larger sample groups, one should consider categorizing hemiplegic individuals not only by site and onset of lesion but by initial performance as well.

The present study piloted the effect of treadmill training early in the post-stroke period. The results have important implications on the design of rehabilitation treatment protocols for individuals with hemiparesis. However, extensive research is still necessary to further validate the results and their implications. Future studies should include larger randomly controlled groups, which will further analyze and compare the changes induced by the different treatment modalities, and will provide more information concerning effect of treadmill training on various patient subgroups. (e.g., different initial functional level, different etiology, *et cetera*). Further research should also investigate other important related issues such as long-term effect of training technique and relation between intensity of training and response.

CONCLUSION

The present study is unique in that, unlike most investigations in this field, partial body-weight support was not used during treadmill training of individuals with hemiparesis. The study demonstrates that subjects with hemiparesis with very limited gait abilities (e.g., average initial walking speed 0.20 m/s and average FAC 2.4), are well able to tolerate treadmill training without the necessity of partial body-weight support. Furthermore, it indicates that for some important gait parameters, which include functional walking ability, stride length, percentage of paretic single stance period, and MG muscular activity, treadmill training may induce changes not obtained by conventional gait training. Additional research with larger study groups and long-term information gathering is recommended to further evaluate the effectiveness of treadmill training in the early stages of stroke rehabilitation.

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Submitted for publication May 11, 1999. Accepted in revised form April 18, 2000.