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Original Article

Improvement of gait ability with a short-term intensive gait rehabilitation program using body weight support treadmill training in community dwelling chronic poststroke survivors

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Abstract. [Purpose] Most previous studies have shown that body weight support treadmill training (BWSTT) can improve gait speed poststroke patients. The purpose of this study was to evaluate effectiveness of a short-term intensive program using BWSTT among community dwelling poststroke survivors. [Subjects] Eighteen subjects participated in this study. The treatment group was composed of 10 subjects (2 women; 8 men; mean age, 59.1 ± 12.5 years; time since stroke onset, 35.3 ± 33.2 months), whereas the control group was made up of 8 subjects (3 women; 5 men; mean age, 59.8 ± 6.3 years; time since stroke onset, 39.3 ± 27.3 months). [Methods] The treatment group received BWSTT 3 times a week for 4 weeks (a total of 12 times), with each session lasting 20 minutes. The main outcome measures were maximum gait speed on a flat floor, cadence, and step length. [Results] No differences were observed in the baseline clinical data between the 2 groups. The gait speed in the treatment group was significantly improved compared with that in the control by 2-way ANOVA, while the other parameters showed no significant interaction. [Conclusion] These results suggested that short-term intensive gait rehabilitation using BWSTT was useful for improving gait ability among community dwelling poststroke subjects.

Key words: Hemiparesis, Community-dwelling, Body weight support

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INTRODUCTION

Body weight support treadmill training (i.e., BWSTT) is one of the most famous gait training methods in recent years. After BWSTT was introduced[1], many reports established its effectiveness in spinal cord injury[2–5], cerebrovascular disease[6–10], Parkinson's disease[11, 12], bone and joint disease[13, 14], and neuromuscular disease[15, 16]. This method, developed by Nudo et al.[17], is based on thinking of the "functional organization of brain", and it is classified as a task-specific method using a neurorehabilitation theory.

In Japan, most stroke patients receive rehabilitation under universal healthcare systems (health insurance programs or the long-term care insurance system), which limit the frequency of rehabilitation to a maximum of 13 units (one unit = 20 minutes) per month for poststroke patients at more than 180 days after stroke onset. Most previous trials have shown that BWSTT can improve gait speed in subjects[6–10, 18], and this method may satisfy the demands of the patients.

Despite substantial recovery of independent ambulation by survivors following unilateral stroke, persistent gait abnormalities are observed in a large percentage of these persons[19, 20]. In these circumstances, a short-term intermittent and intensive rehabilitation program for chronic stroke survivors is thought to be particularly efficient for shoring up their independence, and the present study focused on the possibility of BWSTT as a special program for improving gait ability. The purpose of this study was to evaluate the effectiveness of a BWSTT intervention within the Japanese insurance systems and to clarify whether or not BWSTT is useful as a short-term intensive program for chronic stroke survivors.

SUBJECTS AND METHODS

Subjects

Eighteen subjects were recruited from community-

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dwelling poststroke survivors. Subjects were included if they fulfilled 4 criteria: (1) It had been their first stroke. (2) More than 6 months had passed since the stroke onset. (3) They had slight-to-moderate motor deficits (stages III to V of the Brunnstrom recovery stages (i.e., BRS)[21)]). (4) They could walk with or without walking aids (ambulation score of functional independence measure (i.e., FIM)[22)] > 4). Patients were excluded if they had any of the following 3 conditions: (1) a higher brain function disorder or cognitive deficit affecting their ability to understand and describe symptoms (< 24 on Mini-Mental State Examination[23)]), (2) a severe heart disorder affecting gait movement intensity, or (3) a severe bone and joint disease affecting gait movement.

Subjects were randomly assigned to either the treatment group or control group using a computer-generated sequence. For both groups, the study period was 12 weeks: a baseline phase of 4 weeks (i.e., BLp), an intervention or nonintervention phase of 4 weeks (i.e., INT), and an observation phase of 4 weeks (i.e., OSV). The subjects in the treatment group performed the BWSTT intervention 3 sessions/week (total 12 sessions over the course of 4 weeks at 20 minutes/session/day), whereas the control group did not perform BWSTT in the INT phase. The same BWSTT was provided for any subjects in the control group who wished to perform it after the study period. The subjects continued the same rehabilitation or exercise they were doing before the study began during the study period.

This study was approved by the ethics committee of Tsukuba Memorial Hospital, and all participants or their legal representatives gave written informed consent to participation in this study.

Methods

The BWSTT apparatus consisted of a Biodex Unweighing System (Biodex Medical Systems, Shirley, NY, USA) and a Gait Training System (Biodex Medical Systems, Shirley, NY, USA). The system was composed of an overhead suspension system and a harness that supported the user vertically over a treadmill[7)].

The BWSTT duration was 20 minutes once a day. The amount of body-weight support was fixed at 20% in all sessions. In the first BWSTT session, each subject set the treadmill speed by himself to as fast as possible under the body weight support conditions within his maximum gait speed on the floor, and that speed was used throughout the training. The subjects received no assistance during training; however, they could grip the handrail of the Gait Training System and could use their usual leg braces. Each patient's blood pressure and heart rate were continuously monitored during and immediately after training until the heart rate returned to a value in the normal range.

Demographic data, including age, time since onset of stroke, affected side, and paralysis grade of the lower extremity according to BRS, were collected for all subjects. The main outcome measures were gait speed, cadence, step length, and the Timed Up and Go test (i.e., TUG)[24)] time, and each of these outcome measures were measured once a week. The time and number of steps in a 10-meter walk on the floor at maximum effort were recorded for assessment of gait speed, cadence, and step length. Cadence and step length were calculated by the following formulas.

(1) cadence (steps / min) = number of steps / 10-meter walk time

(2) step length (m) = 10 / number of steps

Step length was the average of all steps of both the affected and non-affected sides. The measurements were performed three times for each subject, and those at the best speed were used for our parameters. The TUG measures the time in seconds that it takes an individual to stand up from a standard chair, walk a distance of 3 meters, turn, walk back to the chair, and sit down again. Patients were allowed to use their usual walking aids, but no therapeutic assistance was allowed during any tests. For the main outcome measures, the average of 4 BLp data (i.e., BLa) was calculated, and the changes in gait speed, cadence, step length, and TUG time from BLa were designated as INT1-4 and OSV1-4, respectively.

For demographics and subject characteristics, the Student's t-test was used to test differences in means for continuous variables, and Fisher's exact test was used to test for differences in proportions of categorical variables. Two-way repeated measure analysis of variance was used to examine the main effect on gait-related parameters of group (treatment and control), time (BLa, INT1-4, OSV1-4), and group × time interaction. Pearson's product-moment correlation coefficient was used to determine the correlation between gait-related parameters (gait speed and cadence, gait speed and step length, cadence and step length). At this time, data for INT1-4 and OSV1-4 (8 points for each person) were used. All statistical analyses were performed using SPSS (version 20.0). Statistical significance was set at $p<0.05$. Results are reported as the mean ±standard deviation of the mean.

RESULTS

The subjects' demographic data are shown in Table 1. The treatment group had 10 subjects (2 women; 8 men; mean age ± standard deviation, 59.1±12.5 years; time since stroke onset ± standard deviation, 35.3±33.2 months), whereas the control group had 8 subjects (3 women; 5 men; mean age, 59.8±6.3 years; time since stroke onset, 39.3±27.3 months). The demographic data of each group were not statistically different. The rehabilitation or exercise regimens that the patients continued during the study period consisted of attending a hospital for rehabilitation (5 patients) in the treatment group; in the control group, they were outpatient rehabilitation (1 patient), training at a gym (1 patient), and home-visit rehabilitation (1 patient). All regimens lasted 30 minutes to 1 hour per day and were done 1 to 3 days per week.

None of the evaluated measures were statistically different in BLa (Table 1). Table 2 shows the changes in gait speed, cadence and step length, and TUG. All values are expressed as the change from the BLa values. Two-way ANOVA showed a significant interaction for gait speed ($p<0.05$).

As shown in Table 2, the gait speed of the treatment group was remarkably improved compared with that of the control group. The other parameters showed no significant interaction (cadence, p=0.11; step length, p=0.14; TUG, p=0.60). Analyzing the main effects, gait speed was significant for group, and all gait-related parameters and the TUG time were significant for time. On the other hand, cadence, step length, and TUG time did not show a significant main effect for group.

The correlation coefficients between gait speed and cadence, between gait speed and step length, and between cadence and step length were 0.78 (p<0.05), 0.74 (p<0.05), and 0.19 (p=0.08) (Table 3), respectively.

Table 1. Characteristics and initial assessment data for both groups

	Treatment	Control
n	10	8
Sex[a]		
Male	8	5
Female	2	3
Age (y)[b]	59.1±12.5	59.8±6.3
Diagnosis[a]		
CI	7	4
ICH	3	4
Paralyzed side[a]		
Right	5	6
Left	5	2
BRS		
III	1	2
IV	6	3
V	3	3
Poststroke interval (mo)[b]	35.3±33.2	39.3±27.3
FIM gait score[b]	6.2±0.6	6.0±0.0
Gait speed (m/sec)[b]	0.9±0.3	0.7±0.3
Cadence (steps/min)[b]	108.0±30.6	94.4±22.8
Step length (m)[b]	0.5±0.1	0.5±0.1
TUG (sec)[b]	18.5±11.4	18.5±5.8

Data are numbers or means ± SD for all subjects.
Gait speed, cadence, step length, and TUG represent Bla values.
[a]Fisher's exact tests. [b]Student's t-test. Statistical significance was set at p<0.05.
Bla, average of baseline phase values; BRS, Brunnstrom recovery stage; CI, cerebral infarction; FIM, functional independence measure; ICH, intracerebral hemorrhage; TUG, timed Up and Go test

DISCUSSION

Our results showed improvement in gait speed after 12 sessions of gait rehabilitation using BWSTT. Although our protocol had fewer intervention sessions than previous studies[7, 8]), there was similar efficacy in improving gait ability in chronic stroke survivors. For example, Visintin et al. reported 6 weeks of BWSTT at a frequency of 4 times per week, and Nilsson et al. reported 3–19 weeks of BWSTT at a frequency of 5 times per week; both of these protocols were found to improve gait speed in chronic poststroke patients[7, 8]). Our protocol was 4 weeks of BWSTT at a frequency of 3 times per week, and this was a shorter period and lower frequency than those of previous studies; however, the improvement in gait speed was relatively similar. This was an important point of our study. In a BWSTT intervention, the proportion of body weight support and the treadmill speed are selectable during each session; however, there is no standard for selection. As the duration of the sessions ranged from 20 to 40 minutes in previous works[6–10]), 20 minutes was selected in the present study because the Japanese national insurance system sets 20-minute man-

Table 3. Correlation coefficient of the parameters

	Gait speed	Cadence	Step length
Gait speed	-	0.78*	0.74*
Cadence	0.78*	-	0.19
Step length	0.74*	0.19	-

Data are shown as correlation coefficients.
Pearson's product-moment correlation coefficient was used to determine the correlations.
*p<0.05

Table 2. Changes in gait-related measurements and TUG time

Measures	Change values																	
	Treatment									Control								
	BLa	INT1	INT2	INT3	INT4	OSV1	OSV2	OSV3	OSV4	BLa	INT1	INT2	INT3	INT4	OSV1	OSV2	OSV3	OSV4
Gait speed (m/s)*	0.00	0.08 (0.09)	0.10 (0.12)	0.19 (0.18)	0.21 (0.21)	0.23 (0.20)	0.19 (0.20)	0.22 (0.18)	0.20 (0.18)	0.00	0.02 (0.07)	0.04 (0.06)	0.01 (0.06)	0.01 (0.08)	0.04 (0.06)	0.05 (0.08)	0.07 (0.08)	0.03 (0.08)
Cadence (steps/m)	0.00	3.86 (8.30)	4.71 (8.30)	10.50 (12.30)	11.39 (18.10)	14.82 (13.80)	12.03 (14.40)	11.36 (10.20)	14.03 (12.40)	0.00	2.62 (10.00)	5.00 (8.40)	0.99 (6.40)	0.93 (6.10)	7.76 (6.50)	1.01 (6.60)	5.75 (6.10)	4.03 (7.40)
Step length (m)	0.00	0.02 (0.05)	0.03 (0.04)	0.05 (0.05)	0.06 (0.06)	0.05 (0.05)	0.04 (0.05)	0.06 (0.05)	0.04 (0.05)	0.00	0.00 (0.02)	0.01 (0.02)	0.01 (0.03)	0.01 (0.04)	0.00 (0.04)	0.03 (0.04)	0.02 (0.04)	0.00 (0.03)
TUG (s)	0.00	−1.14 (0.93)	−0.65 (1.59)	−0.50 (2.58)	−0.70 (1.68)	−2.68 (2.44)	−1.99 (1.09)	−1.79 (1.18)	−2.33 (3.05)	0.00	−0.49 (2.72)	−0.93 (1.40)	−1.05 (1.87)	−0.91 (1.16)	−1.55 (1.60)	−2.62 (1.86)	−1.16 (1.66)	−1.77 (2.69)

Values are means (1SD). *p for interaction < 0.05, two-way repeated ANOVA.
Bla, average of base line phase; INT, intervention (or nonintervention) phase; OSV, observation phase; TUG, timed Up and Go test.

to-man training as one unit of rehabilitation and limits coverage of rehabilitation to at most 13 units per month for chronic stroke patients. The proportion of body weight support varied from 15 to 50% in previous works[6–10], and Aaslund et al. argued that during treadmill walking, the choice of walking speed had a greater impact on kinematic walking characteristics than the proportion of body weight support[25]. So, the proportion of body weight support was set at 20% in all sessions, and the subjects selected the treadmill speed on their own to a speed that was as fast as possible but was below their gait speed on the floor. Under our conditions, none of the subjects dropped out of the study, and they could walk safely on the treadmill. Thus, our protocol may be suitable for gait rehabilitation for chronic stroke survivors who can walk with or without any walking aids.

Recent studies suggested that walking-related indexes were improved by intensive gait rehabilitation or several rehabilitation programs for chronic stroke survivors[26–34]. Gait speed has been recognized as an indicator of gait performance[35], and it is composed of step length and cadence[36]. In our study, gait speed showed a significant increase during and after the BWSTT intervention. A recent studies suggested that BWSTT activates the central pattern generator in the human spinal cord[37, 38] and produces a constant rhythm of walking in poststroke survivors. In addition, Murray et al. reported that subjects tended to use a faster cadence during treadmill walking than during floor walking[39]. It is suggested that these two mechanisms caused the improvement in gait speed in this study. Furthermore, step length and cadence increased slightly (nonsignificantly) in the treatment group, and since both step length and cadence were associated with gait speed, as shown in Table 3, their combination effects caused an increase in gait speed.

On the other hand, the change in TUG time did not show a significant difference between groups in our study as well as in previous studies. For example, Dean showed that 4 weeks of circuit training 3 times a week, which focused on strengthening the affected lower limb and practicing functional tasks involving the lower limbs, significantly improved walking speed and endurance, although TUG speed did not change for chronic stroke subjects[26]. Moreover, Takatori reported that, for chronic stroke survivors, an intensive rehabilitation program (2 times a week for 12 weeks) of muscle strengthening, balance training, and aerobic training significantly improved arterial function, but not physical functions including the TUG time[40]. A TUG consists of several components: standing up, walking straight ahead, turning, and sitting down. As shown in Table 2, the TUG time improved in both groups. The subjects were measured 12 times each, and the process of performing the measurements might improve the TUG time. As that is speculation, however, additional investigation might be necessary. That is to say, BWSTT could be an intervention that specifically improves gait speed. If therapists are able to secure sufficient time to perform rehabilitation for patients, they might provide chronic patients with various therapeutic treatments[41]. On the other hand, it is very important to gain advantageous results under the constraints of limited time and funding, as is the case in Japan. A recent report suggested that no significant differences in improvement of functional walking ability were found for an early intervention using BWSTT, late intervention using BWSTT, and home exercise at 1 year after stroke[42]. Considering these results together with our results, BWSTT might be a practical intervention for chronic poststroke survivors to improve their gait ability in a short period of time.

The major limitation of this study was the small sample size. In order to make our results more reliable, research with a large sample is needed to obtain more accurate results.

In conclusion, the major findings from this study indicated that a 12-session BWSTT intervention resulted in significant improvements in gait ability among community-dwelling chronic poststroke survivors. These results suggest that a gait rehabilitation program using BWSTT is useful for chronic stroke survivors with gait disability. Further studies with a randomized design to compare this program with other gait rehabilitation programs may be necessary to establish its efficacy.

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