



Original Article

Effect of the use of a body weight-supported walker on gait parameters in hemiplegic stroke patients

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Abstract. [Purpose] This study investigated gait parameter changes in hemiplegic stroke patients who walked with a body weight-supported (BWS) walker and evaluated the usefulness of using the BWS walker in a walking exercise. [Participants and Methods] Nineteen hemiplegic stroke patients hospitalized in a convalescent rehabilitation ward were enrolled in the study. Trunk acceleration was used to evaluate walking with and without a BWS walker. Gait speed, cadence, stride length, step time symmetry, stride time variability, and stride time regularity were calculated from the accelerometer waveform. [Results] Hemiplegic stroke patients had a faster gait speed, walked more symmetrically, and had less variation in their gait cycle when using the BWS walker than when not using it. [Conclusion] Using a BWS walker may help hemiplegic stroke patients learn to walk more efficiently in terms of their gait speed.

Key words: Stroke, Hemiplegia, Body weight-supported walker

(This article was submitted Jan. 12, 2021, and was accepted Feb. 23, 2021)

INTRODUCTION

Improving gait function is one of the most important issues for hemiplegic stroke patients, given that improved gait function is not only directly linked to improvement in activities of daily living and quality of life but may also prevent secondary disuse syndrome associated with lack of physical activity. Accordingly, physical therapists have long attempted a variety of approaches for improving gait function in hemiplegic stroke patients. One approach that has attracted attention in recent years is body weight-supported treadmill training (BWSTT)¹⁻³⁾.

In BWSTT, the patient practices walking on a treadmill while suspended by a suspension device and a harness jacket. The harness prevents falls, and the difficulty of the exercise can be adjusted based on the load setting, enabling patients who have difficulty walking to engage in the walking exercise. In a study in which stroke patients either walked normally or underwent BWSTT, Hesse reported that patients who underwent BWSTT demonstrated greater improvement in gait symmetry and further reduction in plantar flexor spasticity, demonstrating that BWSTT can correct gait⁴⁾. In addition, performing walking exercises with BWSTT is reported to reduce the amount of assistance and improve gait speed, form, and other aspects of actual gait ability in hemiplegic stroke patients¹⁻³⁾. Thus, for hemiplegic stroke patients, BWSTT can be conducted for severely ill patients who require assistance to walk and yields a powerful motor-learning effect that can improve gait speed and symmetry. However, BWSTT often involves suspending patients from the ceiling; consequently, it is expensive to set up, can only be set up in certain places, and is difficult to move to another location once it is set up.

A recently developed alternative to BWSTT, the body weight-supported walker (BWS walker), is currently being applied in clinical practice. There are several reports on the BWS walker, such as studies on healthy individuals^{5, 6)} and case reports

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on patients with chronic brain injury⁷), but there is no report showing the usefulness of walking practice using the BWS walker in hemiplegic stroke patients. The BWS walker, which combines a walker with a weight-support device, is easy to move and relatively cheap to use. If the BWS walker becomes common for walking exercises in hemiplegic stroke patients, it could be applied in acute care hospitals and at home, where BWSTT is difficult to use. This study aimed to determine how gait parameters change when hemiplegic stroke patients walk when using the BWS walker and to examine the usefulness of the BWS walker in walking exercises based on differences with normal walking.

PARTICIPANTS AND METHODS

Participants were 19 hemiplegic stroke patients hospitalized in a convalescent rehabilitation ward. Patients capable of walking at least 16 m were included. Exclusion criteria were absence of consent to participate in the study, no evident palsy, and being deemed ineligible to participate by a physician based on factors such as general condition. Participants provided consent following thorough written and oral explanations about the purpose of the study, its methods, the disadvantages of participation, and the protection of personal information. For participants who could not sufficiently comprehend the written explanation or sign the consent form themselves, consent was obtained from the patients' legal guardians. The study was approved by the institutional review boards of Nanto Municipal Hospital (notification no. 222) and Kinjo University (notification no. 2019-07).

The walker component of the BWS walker was a Relief Walking Lift POPO (Moritoh Co., Ltd., Ichinomiya, Japan) (Fig. 1). Using this device, the patient is suspended in a harness with a belt attached to the walker in order to limit the load on the lower extremities. The BWS walker can support up to 100 kg of weight and pass through corridors with a width of at least 80 cm. The weight support was set at 25% of body weight.

Measurements were first taken after participants walked 10 m normally (i.e., without the BWS walker). Following a 5-min rest, participants walked 10 m with the BWS walker, and measurements were taken again. Participants walked down a flat track roughly 16 m long. In a 10-m section of the track, we measured trunk acceleration on the lateral (x), vertical (y), and anteroposterior (z) axes. During normal walking, the participant was asked to walk with their usual walking aid. When using the BWS walker, the participant walked with their trunk in the harness, and 25% of their body weight was supported; participants who were incapable of grasping as a result of palsy in the upper extremities were asked to hold the handle with the upper extremity on their unaffected side. Hemiplegic stroke patients walked 10 m either with assistance or close monitoring, or independently. During both normal walking and walking with the BWS, participants were instructed to walk at their most comfortable speed. Background characteristics were gender, age, height, body weight, diagnosis, days since stroke, affected side, degree of palsy (Brunnstrom Recovery Stage), gait ability (Functional Ambulation Category)¹, use of a walking aid (yes/no), and use of an orthosis (yes/no).

Trunk acceleration was measured by a gait analysis accelerometer (Gait-Kun MG-M1110-HW; LSI Medience Corporation, Tokyo, Japan) and analyzed with a computer specially configured for gait analysis (Gait View MG-M1110-PC). Prior to measurement, the accelerator was calibrated (zero-point adjustment) for each participant. The accelerator was secured to the spinous process of the third lumbar vertebra with a special belt containing a pocket⁸. Measurements were recorded and analyzed at a sampling frequency of 100 Hz.



Fig. 1. BWS walker.

Based on the acceleration waveforms obtained from the above measurements, we identified the scope of measurement for 10 m of walking as the time between a remote-control switch being pushed at the start of the walk and again at the end of the walk. We identified the characteristic acceleration waveforms during gait and were able to determine heel contact at the peak of the acceleration waveform for the anteroposterior component. The method of determining heel contact at the peak of posterior acceleration is reported to be reliable and valid⁹⁾, and we identified the time at which heel contact occurred accordingly. Based on the acceleration waveforms obtained from the 10-m walk, we calculated gait speed (m/s), cadence (steps/min), stride length (m), and gait parameters (i.e., step time symmetry, stride time variability (%), and stride time regularity). For the gait parameters, the values of the average waveform over 10 m were used, except for the stride time regularity.

Step time symmetry was assessed as the symmetry ratio, which is an indicator of bilateral gait symmetry. Symmetry ratios are used to indicate symmetry according to ratios of time and distance factors on the affected side versus the unaffected side^{10, 11)}. A ratio of 1 represents perfect symmetry. In the present study, we used step time as an expression of symmetry ratio. Step time was defined as the length of time from heel contact of one foot to heel contact of the other foot. Step time ratio was calculated with the step time of the affected side as the numerator. Stride time variability is a coefficient of variation in gait cycle time, with a larger value representing greater variation in gait cycles; thus, stride time variability demonstrates gait stability¹²⁾. Stride time regularity, which represents acceleration waveform conformity, can be calculated based on the autocorrelation coefficient for each gait cycle¹³⁾. Values closer to 1 represent higher regularity.

For statistical analysis of normal walking and walking with a BWS walker, Wilcoxon signed-rank test was used to compare gait speed, cadence, stride length, step time symmetry, stride time variability, and stride time regularity. Statistical analysis was performed using JMP[®] version 14.2 (SAS Institute, Cary, NC, USA). A p-value less than 0.05 was considered statistically significant.

RESULTS

Table 1 shows the participant characteristics. Of the 19 hemiplegic stroke patients who participated in the study, 5 had previously been diagnosed as having orthopedic disorders (knee osteoarthritis in 4 participants, lumbar spinal stenosis in 1 participant), and 2 participants experienced recurrence of stroke that did not hinder activities of daily living.

Table 2 shows comparisons of data between walking with and without the BWS walker. Significant differences were

Table 1. Characteristics of hemiplegic stroke patients who participated in comparisons between normal walking and walking with a BWS walker

	N=19
Age (years)	75.0 ± 9.5
Gender	Males: 14, Females: 5
Diagnosis	Cerebral infarction: 11, Cerebral hemorrhage: 8
Time since stroke (days)	88.9 ± 28.8
Affected side	Right: 8, Left: 11
Lower extremity BRS	II: 1, III: 8, IV: 6, V: 4
Gait ability (FAC)	1: 6, 2: 6, 3: 5, 4: 2
Walking aid	T-handle cane: 4, Quad cane: 10, Hemi walker cane: 5
Orthosis	Yes: 14, No: 5

Mean ± SD.

BRS: Brunnstrom Recovery Stage; FAC: Functional Ambulation Category.

Table 2. Comparisons between normal walking and walking with a BWS walker in hemiplegic stroke patients

	Normal	BWS walker	p-value
Speed (m/s)	0.21 ± 0.14	0.41 ± 0.21	<0.0001*
Cadence (steps/min)	54.7 ± 14.1	77.0 ± 14.3	<0.0001*
Stride length (m)	0.45 ± 0.16	0.62 ± 0.25	0.0017*
Step-time symmetry	2.47 ± 0.67	1.66 ± 0.49	<0.0001*
Stride-time variability (%)	10.86 ± 3.66	7.39 ± 3.77	<0.0001*
Stride-time regularity (lateral)	0.20 ± 0.12	0.43 ± 0.14	0.0002*
Stride-time regularity (vertical)	0.09 ± 0.10	0.24 ± 0.21	0.0017*
Stride-time regularity (anteroposterior)	0.32 ± 0.14	0.36 ± 0.17	0.3321

Mean ± SD. *p<0.05.

observed in gait speed, cadence, stride length, step time symmetry, stride time variability, and stride time regularity (lateral and vertical components). Gait speed, cadence, and stride length all increased significantly when using the BWS walker. As for gait parameters, walking with a BWS walker significantly reduced stride time variability and significantly improved bilateral symmetry and stride time regularity (lateral and vertical components).

DISCUSSION

The use of a BWS walker in walking exercises for hemiplegic stroke patients requires confirmation of differences between walking with and without the BWS walker. In this study, the use of a BWS walker led to increased gait speed, cadence, stride length, and stride time regularity (lateral and vertical components) compared with normal walking, whereas values for step time symmetry and stride time variability decreased. Thus, when hemiplegic stroke patients walked with the BWS walker, gait speed was faster, bilateral gait was more symmetrical, and gait cycles were more consistent compared with normal walking. These results show that walking with and without a BWS walker differ for hemiplegic stroke patients and that both forms of walking involve their own specific movements. Thus, walking with a BWS walker, which is superior to normal walking in terms of speed and form, needs to be examined thoroughly to determine whether it is effective as a walking exercise in hemiplegic stroke patients.

A small number of studies have reported on gait training at high speeds in hemiplegic stroke patients. For example, Yamada et al. found that when hemiplegic stroke patients in the subacute period walked at 130% of comfortable gait speed in the second week after stroke, gait time and distance factors resembled those of gait at 100% of comfortable gait speed in the sixth week¹⁴). Based on these results, performing walking exercises at high gait speed might help patients learn future gait patterns at an earlier stage¹⁴). In addition, Wada et al. found that gait training for hemiplegic stroke patients on a treadmill at 120% of maximum gait speed improved gait speed during normal walking¹⁵). As these studies indicate, performing walking exercises at a fast speed helps patients learn to walk quickly and effectively.

Bilateral symmetry is associated with fast gait speed in hemiplegic stroke patients¹⁰). Therefore, improving bilateral symmetry is considered important for improving gait speed and form. In learning to walk, the more similar movements are, the more transferable they become and the more similar relative timing becomes important¹⁶). For walking exercises aimed at improving bilateral symmetry, it is important to consider that three-point gait and two-point gait differ in terms of relative timing and are not very transferable. Thus, if the ultimate goal of the walking exercises is to master two-point gait, performing walking exercises with a two-point gait from an early stage would seem to be logical not only for improving bilateral symmetry but also for learning to walk efficiently. The partial weight support and the safety features of the BWS walker allow hemiplegic stroke patients to maintain favorable balance on their affected side, facilitating the unaffected side swing leg, and in turn enabling patients to learn a highly reproducible bilaterally symmetrical form of walking. These benefits may make walking with a BWS walker a more efficient form of walking exercise. Furthermore, Gama et al. compared BWSTT and BWS overground walking, and reported that BWS overground walking is superior to BWSTT in the situation where BWS is used, because BWS overground walking improves symmetry more¹⁷). In this sense, BWS walker may be superior to BWSTT in improving symmetry because of its ground walking.

Based on the above, walking with a BWS walker facilitates a fast, bilaterally symmetrical, highly reproducible form of walking, thereby enabling hemiplegic stroke patients to learn to walk efficiently. Accordingly, walking with a BWS walker may be considered an effective walking exercise for hemiplegic stroke patients.

A limitation of this study is that it is unclear whether hemiplegic stroke patients were able to transfer the gait learned through the BWS-walker walking exercise to normal walking. Although we confirmed the value of introducing a BWS walker as a form of walking exercise for hemiplegic stroke patients, a future study must examine whether these BWS walker-induced changes are learned and retained by hemiplegic stroke patients.

Funding and Conflict of interest

The authors declare no conflicts of interest.

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