Improvement of Symmetrical Gait Index in People with Chronic Stroke

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Abstract

Objective: To compare the effect of the forward and the backward partial body weight support (PBWS) treadmill training on gait symmetrical index (SI) in people with chronic stroke.

Methods: Twenty people with chronic stroke were allocated into two groups; the forward (n = 10) and the backward (n = 10) PBWS treadmill training groups. Participants in both groups were matched by age range and severity score assessing by the Brunnstrom stage. They received the training program for 80 minutes over at least 2 sessions per week for 12 sessions. The program consisted of 60 minutes of the conventional physical therapy treatment and 20 minutes of the treadmill training (backward or forward). Gait SI variables were assessed and were compared within and between groups.

Results: For within group comparisons, the forward PBWS treadmill training showed significant differences of the step length symmetry (p-value = 0.009) and the single support time symmetry (p-value = 0.037) between pre- and post-training. Whereas, no significant difference of any gait SI variables was found between pre- and post-training in the backward PBWS treadmill training group. In between groups comparison, participants in the forward PBWS treadmill training group showed greater walking improvement than those of the backward PBWS treadmill training group in step length symmetry (p-value=0.019). While, participants in the backward PBWS treadmill training group showed greater improvement than those of the forward PBWS treadmill training group in the step time symmetry (p-value = 0.049).

Conclusions: After 12 sessions of training, the forward PBWS treadmill training group showed significant improvement in the step length symmetry and the single support time symmetry. Whereas, the backward PBWS treadmill training group show no significant improvement in all gait SI. When compare difference between groups, the forward PBWS treadmill training group showed greater improvement than those of the backward PBWS treadmill training group in the step length symmetry. Whereas, the backward PBWS treadmill training group showed greater improvement than those of the forward PBWS treadmill training group in the step time symmetry.

Keywords: Stroke, Forward walking, Backward walking, Treadmill training with partial body weight support, Gait asymmetry

Introduction

Although 60-85% of people with stroke can walk independently after 6 months of post stroke but the recovery expressed with a wide range of walking deviated pattern (Wade, Wood, Heller, Maggs, & Langton Hewer, 1987, pp. 25-30). One of common waking deviations in people with stroke is gait asymmetry. It exhibited with 55.5% of temporal asymmetry and 33.3% of spatial asymmetry (Patterson et al., 2008, pp. 304-310). People with stroke preferred to bear their weight on the un-affected limb more than the affected limb when compared with the healthy persons. This led the affected limb had shorter stance time than that of the un-affected limb. Gait asymmetry also lead to the increased energy expenditure and risk of falls. Consequently, improvement in gait symmetry is play as the important clinical marker of rehabilitation recovery as it is associated with better motor functioning and functional independence (Yavuzer, 2006).

Several treatments have recommended to improve symmetrical gait pattern such as facilitation of weight bearing by therapists (Hesse et al., 1998, pp. 515-522), verbal and visual feedbacks of individuals' weight distribution (Van Peppen, Kortsmit, Lindeman, & Kwakkel, 2006), and musical motor feedback (Schauer & Mauritz, 2003, pp. 713-722). Besides, treadmill training is one of the recommended treatment techniques to restore gait symmetry. It is an effective method to achieve more symmetrical gait pattern and improve gait performance in people with stroke (Ivey, Hafer-Macko, & Macko, 2008, pp. 249-259). Specifically, it facilitates weight bearing on the affected limb, resulting in improved motor control, providing an opportunity to improve symmetry (Beauchamp et al., 2009, pp. 154-160). Other advantages of the treadmill training together with the partial body weight support (PBWS) usage is increased confidence during individuals performed walking function (Carr & Shepherd, 2010).

Backward walking training is a recently challenging task in people with stroke. It facilitates neuromuscular function (Chaloupka, Kang, Mastrangelo, & Donnelly, 1997, pp. 302-306), muscle strength (Chewwasung, Boonsinsukh, Bannarat, Thumpapong, & Meesukh, 2011, pp. 10-16), and balance (Weng et al., 2006, pp. 2635-2638). Furthermore, it has been recommended as the treatment strategy to improve forward walking function (Yang, Yen, Wang, Yen, & Lieu, 2005, pp. 264-273).

Previous studies reported that the backward walking training enhanced gait performances as shown by improvement in the affected step length (Kim, Lee, & Lee, 2014, pp. 1923-1927), stride length (Takami & Wakayama, 2010, pp. 177-187; Yang et al., 2005, pp. 264-273), cadence (Takami & Wakayama, 2010, pp. 177-187; Yang et al., 2005, pp. 264-273), affected step time (Kim et al., 2014, pp. 1923-1927), gait cycle (Yang et al., 2005, pp. 264-273), walking velocity (Takami & Wakayama, 2010, pp. 177-187; Yang et al., 2005, pp. 264-273), symmetrical index (SI) (Kim et al., 2014, pp. 1923-1927; Yang et al., 2005, pp. 264-273), Berg Balance Scale (Takami & Wakayama, 2010, pp. 177-187) and Rivermead Mobility Index score (Takami & Wakayama, 2010, pp. 177-187), However, very limited information about the effect of training between the forward and backward PBWS treadmill training (Kim et al., 2014, pp. 1923-1927). Hence, the present study aimed to compare the effect between the forward and the backward PBWS treadmill training on gait SI in people with chronic stroke.

Materials and Methods

Participants

Twenty people with chronic stroke were recruited from Physical Therapy Center, Faculty of Physical Therapy, Mahidol University, Bangkok, Thailand between January and August 2015. Participants were included if they fulfilled the following 7 criteria; 1) first stroke onset more than 12 months, 2) age range between 40 to 80 years old, 3) unilateral motor and/ or sensory deficits 4) lower limb motor function assessed by the Brunnstrom motor recovery stage from 2 to 5, 5) ability to independently walk 6 m with or without using gait aids or orthoses with a time of 35 seconds or lesser, 6) did not having cognitive impairment assessed by the Mini Mental State Examination-Thai (MMSE-Thai) score > 23, and 7) able to follow all testing procedures and intervention program. Participants were excluded if they had any of the following 2 conditions; 1) unstable medical condition and 2) having other neurological, cardiopulmonary, and lower limb musculoskeletal problems which might affect testing or training. All participants were allocated into either the forward (n=10) or the backward (n=10) PBWS treadmill training groups. Both groups were individually matched by age range and motor recovery by the Brunnstrom score. This study was approved by the Mahidol University Central Institutional Review Board (COA.No. 2014/160.1112). All participants received a written description and signed the informed consent prior to participate in the study.

Assessment

All participants were assessed and trained at the Neurological Clinic, Physical Therapy center, Mahidol University. The assessments were investigated at pre- and post-training. The participants were tested on a force distribution measurement platform (The zebris FDM-System - Gait Analysis, 1243020-0015-0816, Allgãu, Germany) with 100 Hz sampling frequency and synchronized with one video camera. The participants were instructed to walk with comfortable walking velocity. Four steps in three successful walking trials were recorded for calculating the mean score of spatiotemporal parameters. They included step length (m), step time (s), single support time (s), stance phase (%gait cycle), and swing phase (%gait cycle) were documented for the affected and un-affected limbs. The spatiotemporal parameters were calculated to obtain the absolute data of gait SI of the variables (X) with the following equation; SI of X = $(\lvert X_{un-affected} - X_{affected} \rvert / 0.5(X_{un-affected} + X_{affected}))x100$ (Blazkiewicz, Wiszomirska, & Wit, 2014, pp. 29-35); where X referred to any spatiotemporal variables. Values of gait SI can be ranged from 0-200. Zero value indicated a perfectly symmetrical gait pattern. While the greater SI value, the greater asymmetrical gait pattern was presented.

Intervention

Participants in both groups received intervention program for 80 minutes over at least 2 sessions per week for 12 sessions. The intervention program consisted of 60 minutes of conventional physical therapy training and 20 minutes of the treadmill training with PBWS (forward or backward). The physiotherapy program was individual's specific and consisted of strengthening, proprioceptive neuromuscular facilitation, function and mobility training, and gait training. For the treadmill training, it was started with a low load and progressed the difficulty by increase treadmill velocity. For the first-three sessions of training, gait speed was set at 25% of individual comfortable walking velocity performance. Velocity was increased 5% in every 3 sessions of training as summarized below;

- 1^{st} to 3^{rd} sessions: 25% of individual comfortable walking velocity
- 4^{th} to the 6^{th} sessions: 30% of individual comfortable walking velocity
- $7^{th}$to the 9^{th} sessions: 35% of individual comfortable walking velocity
- $10^{th}$to the 12^{th} sessions: 40% of individual comfortable walking velocity

The participants' comfortable walking velocity at baseline ranged from 0.23 to 0.82 m/s and ranged from 0.19 to 0.82 m/s for the forward group and the backward group, respectively. There was no significant difference of the comfortable walking velocity between two groups. For the forward group, the treadmill training' velocities were started at the ranged from 0.06 to 0.21 m/s and ended at the ranged from 0.09 to 0.33 m/s. For the backward group, it started at the ranged from 0.05 to 0.21 m/s and ended at the ranged from 0.08 to 0.33 m/s.

During training, they were allowed to use abled their hands for support as needed. Two physical therapists provided assistance to move the participant's limb in the correct pattern. The amount of body weight support was fixed at 30% of individual body weight and treadmill inclination was set at 0^0 in all sessions. During treadmill training, participants were asked about their rate of perceived exertion (RPE) by therapist and were investigated heart rate and blood pressure at every 10 minutes. All intervention sessions were performed by qualified and experienced physical therapists.

Treadmill training and other interventions were stopped if participants demonstrated the following conditions;1) systolic blood pressure (SBP) >160 mmHg and diastolic blood pressure (DBP) >110 mmHg for intracerebral hemorrhage individuals and SBP >200 mmHg and DBP >110 mmHg for ischemic stroke individuals, 2) mean blood pressure increased by 30 mmHg or decreased by 20 mmHg, 3) heart rate >110 beats/min at rest or increased 30%, and 4) rating perceived exertion >15scores from a full score of 20.

Data analysis

Based on the sample size calculation from our pilot study with the number of participants of five, the number of participants for each group was at least nine participants. Thus, a total of ten participants was used for the comparisons in the study. However, the number of participants of the study was small, the non-parametric statistics was used to compare the variables within and between groups. Continuous data were given as median and IQR (ranged from the 25th to the 75th percentile). While, the discrete data were given as counts and percentages. The Mann-Whitney U test and chi-square test were used to compare demographic and clinical characteristics between groups. Comparisons between pre- and post-training gait SI data within each group were analyzed by using the Wilcoxon Signed-Rank test. In order to investigate the effectiveness of whether the backward or the forward PBWS treadmill training was superior, the different values (subtracting of the data between pre- and post-training) were compared by using the Mann-Whitney U test. All statistical analyses were analyzed using the SPSS statistical package version 19 for windows. Statistically significant for all analyses were set at *p*-value <0.05.

Results

Demographics and clinical characteristics of the forward and backward PBWS treadmill training groups are presented in Table1. Results show median and interquartile range for age and the stroke onset and show frequency count and percentage for gender, affected limb, and Brunnstrom stage of the lower limb. There was no significant difference in any variables between two groups.

Table 2 present comparisons of gait SI data between pre- and post-training in each group. The forward PBWS treadmill training group demonstrated partial improvement between pre- and post-training in the step length symmetry (p = 0.009) and the single support time symmetry (p = 0.037). While, there was no significant improvement (p > 0.05) in all gait SI variable between pre- and post-training in the backward PBWS treadmill training group.

Table 3 present comparisons of the gait SI between the forward and backward PBWS treadmill training groups. Results demonstrated significant differences of the step length symmetry (p = 0.019) and the step time symmetry (p = 0.049) between two groups. Whereas, no significant differences were found in the single support time symmetry (p = 0.821), stance phase symmetry (p = 0.496), and swing phase symmetry (p = 0.650).

Table 1 Demographic and clinical characteristics for both groups

Variables	Forward PBWS treadmill training group (n=10)	Backward PBWS treadmill Training group (n=10)	*p*-value
Age (years)[a]	58.50 (53.50, 63.25)	61.50 (56.00, 67.25)	0.404
Onset (months)[a]	43.00 (24.25, 58.25)	30.00 (17.50, 60.25)	0.910
Gender[b]			
Male	9 (90%)	8 (80%)	0.545
Female	1(10%)	2(20%)	
Affected limb[b]			
Left	5 (50%)	6 (60%)	0.655
Right	5 (50%)	4 (40%)	
Brunnstrom stage of the lower limb[b]			
Stage 3	2 (20%)	2 (20%)	1.000
Stage 4	4 (40%)	4 (40%)	
Stage 5	4 (40%)	4 (40%)	

[a] Median (first to third quartile), tested by the Mann-Whitney U test

[b] Tested by the chi-square test (χ^2)

Table 2 Comparisons of gait SI between pre- and post-training in the forward and the backward PBWS treadmill training groups

Gait SI	Forward PBWS treadmill training group			Backward PBWS treadmill training group		
	Pre-training	Post-training	*p*-value	Pre-training	Post-training	*p*-value
Step length symmetry	33.74 (19.55,57.55)	14.06 (5.21,39.08)	0.009**	10.10 (1.80,26.05)	11.63 (4.72,19.03)	0.799
Step time symmetry	23.34 (13.67,47.12)	35.35 (16.88,49.02)	0.508	28.93 (13.33,38.32)	21.11 (6.36,39.04)	0.114
Single support time symmetry	60.25 (33.34,66.72)	47.25 (36.92,58.31)	0.037*	29.52 (19.65,59.79)	26.66 (4.08,43.73)	0.074
Stance phase symmetry	21.91 (10.87,27.14)	15.71 (7.04,26.43)	0.169	13.44 (9.04,18.29)	10.40 (4.02,19.82)	0.169
Swing phase symmetry	57.42 (43.39,64.36)	59.26 (36.15,66.84)	0.799	45.75 (13.21,64.43)	29.55 (11.37,45.11)	0.139

Median (first to third quartile), *$p<0.05$, **$p<0.01$ tested by the Wilcoxon Signed-Rank test

Table 3 Comparisons of different values of gait SI between the forward and the backward PBWS treadmill training groups

Gait SI	Forward PBWS treadmill training group	Backward PBWS treadmill training group	*p*-value
Step length symmetry	-14.42 (-21.98,-6.03)	-2.64 (-9.25,8.61)	0.019*
Step time symmetry	2.60 (-6.53,13.88)	-7.90 (-10.46,-0.71)	0.049*
Single support time symmetry	-9.39 (-16.28,2.00)	-9.79 (-18.59,-0.68)	0.821
Stance phase symmetry	-1.89 (-8.54,2.06)	-4.52 (-7.48,2.88)	0.496
Swing phase symmetry	1.12 (-13.46,4.60)	-11.32 (-20.63,9.50)	0.650

Median (first and third quartile), *$p<0.05$ tested by the Mann-Whitney U test

Discussion

In this study, we examined the effect of forward and backward PBWS treadmill training on gait SI in people with chronic stroke. According to the results, the forward PBWS treadmill training showed significant improvement in the step length symmetry and the single support time symmetry. Comparisons of the gait SI between two groups showed significant difference in the step length symmetry and the step time symmetry.

Significant improvements of the step length symmetry and the single support time symmetry was found in the forward PBWS treadmill training group. These result are consistent with the results of a study conducted by Pheung-phrarattanatrai and colleagues (Pheung-phrarattanatrai,Bovonsunthonchai, Heingkaew, Prayoonwiwat, & Chotik-anuchit, 2015, pp. 113-118). They found that the effect of motor imagery able to enhance step length symmetry in people with stroke. Kim and colleagues (Kim et al., 2014, pp. 1923-1927) studied effect of training in 36 chronic stroke people. They were divided into 3 groups; the forward and backward progressive body weight supported treadmill training, the backward progressive body weight supported treadmill training, and the forward progressive body weight supported treadmill training groups. They found significance improvement of single support time SI after training in all groups. However, no difference was found among groups after training.

Asymmetry in the step length and the single limb support is assumed to be related with a decreased ability to bear weight on the affected limb (Hsu, Tang, & Jan, 2003, pp. 1185-1193). Weight shift to the affected limb is essential in walking as it allows the un-affected limb to be moved and, consequently, a step to be taken. The individual's step length symmetry and single limb support symmetry in the forward PBWS treadmill training group may improve because velocity of treadmill training program was set at 25-40% of individual's comfortable walking velocity. The participants had more time to bear their weight on the affected limb, this led to the increased quadriceps muscle strength (Zaky & Hassan, 2013, pp. 413-418) and confident to weight bearing on the affected limb.

Although, there was no significant difference improvement in all gait SI in the backward PBWS treadmill training group but there was a tendency of gait SI improvement. In contrast to the previous study, Yang and colleague (Yang et al., 2005, pp. 264-273) studied in 25 chronic stroke people who allocated into the experimental group that performed backward over ground walking training plus conventional physical therapy and the control group that only received conventional physical therapy. Both groups were trained at a frequency of 3 times per week for 3weeks. After 3 weeks, the experimental group showed significance improvement in single support time SI between pre- and post-training. We think the gait SI was not improved significantly in the backward PBWS treadmill training group because the backward walking training was not a real task-oriented training. Although backward walking was near a mirror image of forward walking(Winter, Pluck, & Yang, 1989, pp. 291-305) and may contribute to the improvement of the affected limb to be move easily from repetitive alternating flexion with extension of lower extremity training (Yang et al., 2005, pp. 264-273). However, explanation may relate with the improvement of gait SI mainly be focused on the task-oriented training approach rather than on the movement pattern (Yavuzer, 2006).

When compare the different values between two groups, there were significant differences in the step length symmetry and the step time symmetry. The forward PBWS treadmill training group showed more significant improvement in the step length symmetry than the backward PBWS treadmill training group. This may come from the forward PBWS treadmill training was closely to the task-related training more than the backward PBWS treadmill training. It induced a higher activation of brain reorganization and bring to improvement of step length symmetry (Van Peppen et al., 2004, pp. 833-862). Whereas, the backward PBWS treadmill training group showed more significant improvement in the step time symmetry more than the forward PBWS treadmill training group. Many studies reported that step time asymmetry was associated with impaired joint position sense, increase plantarflex or spasticity, and decreased dorsiflex or strength (Hsu et al., 2003, pp. 1185-1193; Lin, Yang, Cheng, & Wang, 2006, pp. 562-568). The step time symmetry can be increased in the backward PBWS treadmill training group may explained by higher activation of the ankle dorsiflex or muscle during training with the backward walking when compared to the forward walking (Chewwasung et al., 2011, pp. 10-16). Furthermore, backward walking can eliminate visual cues, it required greater reliance of neuromascular control and may stimulate joint proprioceptive sense (Yang et al., 2005, pp. 264-273).

The limitations of this study include the number of participants was small, no follow up was taken, and mainly measure quantities of gait performance. In addition, further study should investigate in a larger amount of participants, be assessed the long term effects, and should be considered to investigate other parameters such as muscle activity, kinematics, and kinetics.

Conclusions

After 12 sessions of training, the forward PBWS treadmill training group showed significant improvement in the step length symmetry and the single support time symmetry. Whereas, the backward PBWS treadmill training group show no significant improvement in all gait SI. When compare difference between groups, the forward PBWS treadmill training group showed greater improvement than those of the backward PBWS treadmill training group in the step length symmetry. Whereas, the backward PBWS treadmill training group showed greater improvement than those of the forward PBWS treadmill training group in the step time symmetry.

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