Effects of progressive backward body weight-supported treadmill training on gait ability in chronic stroke patients: A randomized controlled trial

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Abstract

BACKGROUND AND OBJETIVE: The Stroke patient with hemiplegic gait is generally described as being slow and asymmetric. Body weight-supported treadmill training and backward gait training are recent additions to therapeutic gait trainings and may help improve gait ability in stroke patient with hemiplegic gait. Therefore, the examined to effect on gait ability using progressively backward body weight-supported treadmill training in chronic stroke patients with hemiplegic gait. Thirty subjects were divided to experimental group and control group.

METHODS: The experimental group of 15 patients underwent progressively backward body weight-supported treadmill training and control group of 15 patients underwent general treadmill gait training on five times per week, for a total of four weeks. The OptoGait was used to analyze gait kinematics, and the dynamic gait index (DGI) and results of the 6-minute walk test were used as the clinical evaluation indicators, and a follow-up test was carried out four weeks later to examine persistence of the exercise effects.

RESULTS: The experimental group showed statistically significant results in all dependent variables until the 4 weeks compared to the control group. However, until the eighth week, only the dependent variables of affected step length (ASL), stride length (SL), and DGI differed significantly between the two groups.

CONCLUSION: This study verified that progressively bodyweight-supported treadmill training had a positive influence on the temporospatial characteristics of gait and the clinical gait evaluation index in chronic stroke patients.

Keywords: Backward body weight supported treadmill, chronic stroke, gait ability

Introduction

Regaining gait ability in stroke patient with hemiplegic gait is very important [1]. Because, 40–55% of stroke patient do need assistance and 5–9% of stroke patient experience gait disability and are completely dependent [2]. Also, stroke patient with decreased lower limb muscle strength and motor coordination was unable to participate in continual gait training.

Body weight supported treadmill training (BWSTT), which allows performance of treadmill training with a reduced burden on the lower limbs, is currently used as a therapeutic approach at stroke patient [3, 4]. BWSTT is useful when weight shifting and foot positioning for correct the gait pattern, because of decreasing the patient's weight, thereby promoting coordination and motor control of the lower extremities and supporting the patient's posture [4]. Therefore, BWSTT has been reported to be more effective in the retraining of symmetric and efficient gait in stroke patient, due to BWSTT stimulates repetitive and rhythmic stepping and, supports in the trunk upright position and bearing weight on the lower limbs [5].

Forward and backward treadmill training are widely used in clinical settings [6-8]. But, Forward treadmill training alone may lead to an asymmetrical gait pattern and lesser improvement in the quality of the gait [9]. Therefore, Learning to backward treadmill training is also recommended to improve movement components required to forward treadmill training [10]. One of the advantages of backward treadmill training is that it minimizes knee joint stress and strengthens the quadriceps muscle [11]. In addition, patients' energy consumption rate and muscle activity are higher during backward treadmill training than during forward treadmill training [6]. Backward treadmill training combines hip extension with knee flexion and is particularly effective in patients with synergistic movement in the lower extremities. Thus, it has been suggested that backward treadmill training may offer additional benefits besides those experienced with forward treadmill training [9].

Recently, there are increased the use of treadmill training for rehabilitation of patients with stroke and gait disability in the rehabilitation unit [5]. Also there are increased the use of BWSTT, with weight-training parameters [12, 13] in the onset period [14], and investigated the comparisons with over ground gait training [3, 12].

Based on previous recommendations, we developed a gait training strategy for stroke patients that involves the use of BWSTT [4] with backward treadmill training [10]. The hypothesis was that subjects trained using progressively backward BWSTT would show greater improvements than forward treadmill training on gait ability at the end of a 4–week training period and at a 8-week follow-up. The examined to effect on gait ability using progressively backward BWSTT in chronic stroke patients with hemiplegic gait.

2. Material and Methods

2.1 Design

This study was a two-group pretest-posttest design with two independent intervention groups. This study was conducted with stroke patients to evaluate the effects of progressively backward BWSTT and was approved by the Institutional Human Research Review Board of (Blinded). All participants signed an informed consent form based on the ethical code of the World Medical Association.

2.2 Participants

The participants' diagnosis, age, sex, affected side, and onset of stroke were obtained by interview and review of the medical charts. A total of 30 patients with post stroke who were consecutively admitted to the rehabilitation unit and satisfied the inclusion criteria, Stroke patients was defined as the acute onset of neurological deficit lasting more than 24 hours or leading to death, with no apparent cause other than cerebrovascular disease. Participants were screened according to the following inclusion criteria: 1) diagnosis of stroke by MRI or computed tomography; 2) no joint contracture, pain, or fractures of the musculoskeletal system, or hemianopia based on medical records; 3) Functional Ambulatory Category (FAC) scores exceeding four and five points; 4) Mini-Mental State Examination (MMSE) score >24; and 5) having a good understanding of the content of study and participate the this study by oneself. The exclusion criteria were: 1) any comorbid disability other than stroke that would preclude gait training; 2) total hip replacement or severe hip, knee and ankle contracture; 3) participation in other studies; and 4) cardiovascular or other disorders that would interfere with the study.

2.3 Randomization

The subjects were randomly assigned to one of both groups to minimize selection bias. The assignments were stored in numbered, sealed envelopes; the subjects and therapists were not provided any information on the interpretation of these numbers. The random allocation of numbers was completed for one group and the process was repeated for the other group by the number selected in the box. Fifteen subjects were assigned to the progressively backward BWSTT (number 1), and the other 15 subjects were allocated to the forward treadmill training (number 2) (Fig. 1).

2.4 Procedure

This study was a single-blinded study, in which provided the two different interventions by two therapists with 5 years of clinical experience. And there were blinded to group assignment and, performed all of the outcome measures a therapist with 5 years of clinical experience. The study duration was 8 weeks, from April 2014 to June 2014. Experimental group was conducted the progressively backward BWSTT for 30 minutes, five times per week, for 4 weeks, and a follow-up after 4weeks. Control group was performed the conventional forward treadmill training for 30 minutes, five times per week, for 4 weeks, and a follow-up after 4 weeks. The assessment was continued after 8 weeks to monitor the persistence of exercise effects in both groups. Participants trained four times training for 30 minutes, in which each session consisted of 5-minute of treadmill training bouts and 2.5 minutes of resting time. A summary of the general characteristics of 30 subjects with a chronic stroke, who fulfilled the inclusion criteria for this study, is shown in Table 1.

2.5 Intervention of experimental group

The participant`s initial resting blood pressure and heart rate were checked at the start of each training session. During progressively backward BWSTT, the weight support was progressively reduced, and backward treadmill training was performed at the same time with the subject in a suspension device on a treadmill (QUASAR MED, HP COSMOS, Deutschland). The weight support was progressively reduced, with a 40% decrease in weight in the first week of the training program, 30% decrease in the second week, 20% decrease in the third week, and 10% decrease in the fourth week [14-16]. The subjects' average speed of progressively backward BWSTT ranged from 0.08 to 0.22 m/s. The speed was increased by 0.1 km/h each time a change was made [18, 19]. The increased speed was maintained for over 20 seconds to allow the participants to attain a stable gait pattern on the moving treadmill. The speed of treadmill training was then increased by 5% the during next training session [20]. Two physical therapists assisted the subjects during progressively backward BWSTT. One physical therapist positioned himself right behind the subject and helped the subject support and move his/her weight. The other physical therapist was positioned by the subject's paretic leg and aided in the motor control of the lower limbs during the swing and stance phases as well as provided manual assistance during training for 30 minutes using his hands.

2.6 Intervention of control group

In the control group, in which they performed forward treadmill training with no body weight support, the speed and intensity of treadmill training were determined according to the subjects' comfort level, and the interval of rest was freely decided [9]. The speed was increased by 0.1 km/h per week during the intervention period [18, 19]. One physical therapist positioned himself right behind the subject and provided support with weight shifting to minimize the risk of falling.

In both groups a rest period was allowed as needed in case of exhibiting fatigue, abnormal respiration, and changes in complexion or complaint of pain.

2.7 Outcome Measures

There was used conducted with quantitative analysis of the subjects' gait types by, gait analyzer (OptoGait, MicrogateS.r.l, Italy, 2010) or evaluating the temporal characteristics of gait, the paretic step length (PSL) and stride length (SL) were analyzed; for spatial characteristics of gait, the paretic single support (PSS), total double support (TDS), paretic step time (PST), stride time, cadence, and gait speed. In order to eliminate variations among the examiners, a proficient therapist performed all measurements without a gait aid such as a weight supporter or suspension device.

The dynamic gait index (DGI) consists of eight different gait tasks: gait on flat ground, gait with changes in speed, gait with horizontal rotation of the head, gait and axial rotation, gait with the head moving in a vertical direction, gait passing through an obstacle, gait around an obstacle, and gait while ascending and descending stairs, which may be required for gait in the community or at home. Three different grades were assigned according to the level of performance. A four-point scale (normal: three points, minor impairment: two points, moderate impairment: one point, and severe impairment: zero point) was employed as an evaluation tool [21]. The test-retest reliability was r=0.96, and the inter-rater reliability was r=0.96, with stroke patients as the subjects [2].

A 6-minute walk test was conducted in the hospital corridor. This involved gait a 25 m-long footpath (round-trip distance) without assistance and with the floor marked at 1-m intervals. When required, the subjects were allowed to rest. The intra-rater reliability in stroke patients was r=0.99 [23].

2.8 Statistical Analysis

Statistical analyses were carried out by using Windows PASW Statistics 18.0. The sex, diagnosis, paretic side, and the Functional Ambulatory Category were tested with the chi-square test. And the age, height, weight, MMSE score, and post-stroke duration, as well as homogeneity of the dependent variables prior to the training were tested by using the independent-samples t-test. Repeated measures ANOVAs was conducted to examine the differences within the both groups among the treatment periods (zero, four, and eight weeks of training) and to examine the differences between the both groups resulting from training before the training, after 4 weeks training, and after 8 weeks training. Statistical significance was set at $\alpha=0.05$.

Results

Table 1 indicates the group means and standard deviations for general characteristics and dependent variables. No significant differences in terms of baseline values were observed between the progressively backward BWSTT and forward treadmill training (Table 1).

As shown in Table 2, two-way repeated measure ANOVA revealed significant interaction effect (time group) for PSL, SL, PST, GC, Cadence and DGI across the baseline, 4 weeks post training, and follow-up post training. All groups had a significant time main effect but there were no group main effect. there were improved within each group, the training results of the progressively backward BWSTT were improved from those of the forward treadmill training group at 4 weeks, and the ASL, SL, and DGI were improved between the both groups at 8 weeks. In terms of the temporal·spatial characteristics of gait, the PSL (t1,28=6.747, P<0.05), SL (t1,28=4.997, P<0.05), PSS (t1,28=4.565, P<0.05), TDS (t1,28=4.549, P<0.05), PST (t1,28=4.347, P<0.05), gait cycle (t1,28=6.661, P<0.05), cadence (t1,28=6.475, P<0.05), gait speed (t1,28=4.843, P<0.05), DGI scores (t1,28=7.547, P<0.05) and 6-minute walk test (t1,28=4.718, P<0.05) improved between the both groups at 4 weeks. The PSL (t1,28=6.009, P<0.05), SL (t1,28=4.703, P<0.05) and DGI scores(t1,28=10.570, P<0.05) were improved between the both groups at 8 weeks. But the other variables were not improved between the both groups at 8 weeks (Table 2).

Discussion

In this study, progressively backward BWSTT was used in stroke patients and its effect on gait ability was examined. There were improved within each group and between the both groups at 4 weeks. However, at 8 weeks, improved were noted between the two groups only in the PSL, SL, and DGI, and not in the other variables.

This study used the Optogait to examine gait variables and obtain the PSL and SL, which demonstrated a significant increase in the both groups. Yang et al. [10], on 25 patients post stroke, the control group underwent ordinary gait training, while the experimental group received additional backward gait training for 30 minutes, three times per week for 3 weeks, and the experimental group demonstrated improved stride from 0.78 m prior to the intervention to 0.88 m, which was consistent with the present study. The continuing effect after the 8 weeks of training is believed to be due to the fact that backward treadmill training increased the muscle activity of the quadriceps during the stance phase, which resulted in sustained knee extension and a high COG (center of gravity) on the ground [24]. Obtaining a new base of support to back up the body's COG rather than continuous movement of the lower limbs and upper arms related to sensory input and muscle activities is an important factor for controlling balance responses [25].

This study measured the PST and stride time to examine gait variables, which demonstrated an significant increase in the both group. A comparison of the both groups revealed improved at 4 weeks in the progressively backward BWSTT group compared to the forward treadmill training group, but there were not improved between the both groups at 8 weeks. Yang et al (2005) did a study on 25 patients post stroke where, the control group underwent ordinary gait training, and the experimental group received additional backward gait training for 30 minutes, three times per week for 3 weeks; the experimental group's stride time decreased from 1.96 s prior to the experiment to 1.62 s after the intervention, which is consistent with the present findings [10]. Changes in lower limb muscle strength by progressive BWSTT reduced the dragging of the foot during the swing phase, thereby shortening the paretic lower limb's period of staying in the air and enabling weight shifting to the paretic side.

For an assessment of gait variables, this study derived the PSS, TDS, Cadence, and gait speed which demonstrated an increasing in both groups. A comparison of the both groups revealed an improvement in the PSS, TDS, Cadence, and gait speed in the progressively backward BWSTT group compared to the treadmill training group at 4 weeks. But, there were not improved between the both groups at 8 weeks. Cho et al. (2014) used real-life video photographing-based treadmill gait training in patients post stroke for 6 weeks, the patients' PSS increased and their TDS decreased, which is also consistent with the present findings [18]. According to Silver et al. [26], three months of treadmill training improved the number of steps per minute by 9% from 89 steps/min to 97 steps/min in patients post stroke. Miller et al. [4], used BWSTT in two chronic patients post stroke for 6–7 weeks on flat ground and reported 46% and 22% improvement in gait speed; this is consistent with the present findings.

The gait speed improved in both the experimental group and the control group, but clinically meaningful changes in speed were witnessed only in the backward gait group, which showed the changes of 1.8 m/s and 0.07 m/s at 4 weeks post training in experimental and control group, respectively [27]. This is believed to be due to the fact that progressive BWSTT provided feedback as time passed and assisted to maintain maintained a certain step time, with noticeable changes in gait speed [28].

In the present study, the DGI scored was shown to increase within each group. The changes in the DGI scores at the different periods were significantly improved between the both groups. Michael et al. [29], patients post stroke received active physical therapy three times per week for 6 months, and they demonstrated a significant change in balance, DGI scores, and 6-minute walk test performance. This is consistent with the result of a previous study in which the DGI scored increased from 13.7 prior to the training to 19.0 after the training. Through continued training at 8 weeks, proprioceptive senses were improved with a repetitive treadmill speed and with the vision restricted. With motor development strategies, gait ability was enhanced through repetitive task-oriented training and continual input of concentric information through the soles.

In the present study, a 6-minute walk test was conducted, with both groups demonstrating an improved performance. A comparison of the two groups revealed that the test results in the progressively backward BWSTT group showed improved comparing the gait training group at 4 weeks, but there was no improvement between the two groups at 8 weeks. Nadeau et al. [30], used forward gait training and backward gait training in healthy adults and observed that the gait time frequency and, spatial characteristics, were increased and gait endurance was enhanced, which is consistent with the present findings. During forward gait, the quadriceps muscle contracts eccentrically in the deceleration phase, and during backward gait, knee stability is provided by isometric as well as concentric contraction in the acceleration phase [31]. Therefore, more energy consumption is required during backward gait [7].

Backward gait eliminates visual acceptance, requiring more dependence on proprioceptive senses [10]. Backward gait creates a complex movement involving knee flexion and hip extension [10]. We observed that the effectiveness of backward gait training group was obscure over times at the follow-up periods. Another possible explanation why the significant difference at follow-up period were not shown may be because training periods of 4 weeks is insufficient for chronic stroke to change motor pattern and after training, we could not consider an amount of exercise in daily life.

Our study has several limitations. First, it was performed in a single center, with a relatively small sample size. Another limitation is that the subject and therapist were not blinded to intervention. This may contribute some bias. Furthermore, generalization of the results should be performed with caution because the patients with Functional Ambulatory Category (FAC) scores below four and five points were not included.

Conclusion

This study verified the positive influence of progressively backward BWSTT on the temporospatial characteristics of gait and the clinical gait evaluation index in patients post stroke, and established that progressively backward BWSTT is more effective than conventional forward treadmill training. Therefore, it should be utilized as a gait training program for patients post stroke in rehabilitation, as well as those who can walk independently and will return to the community.

Declaration of Interest

The authors declare not to have any conflict of interests.

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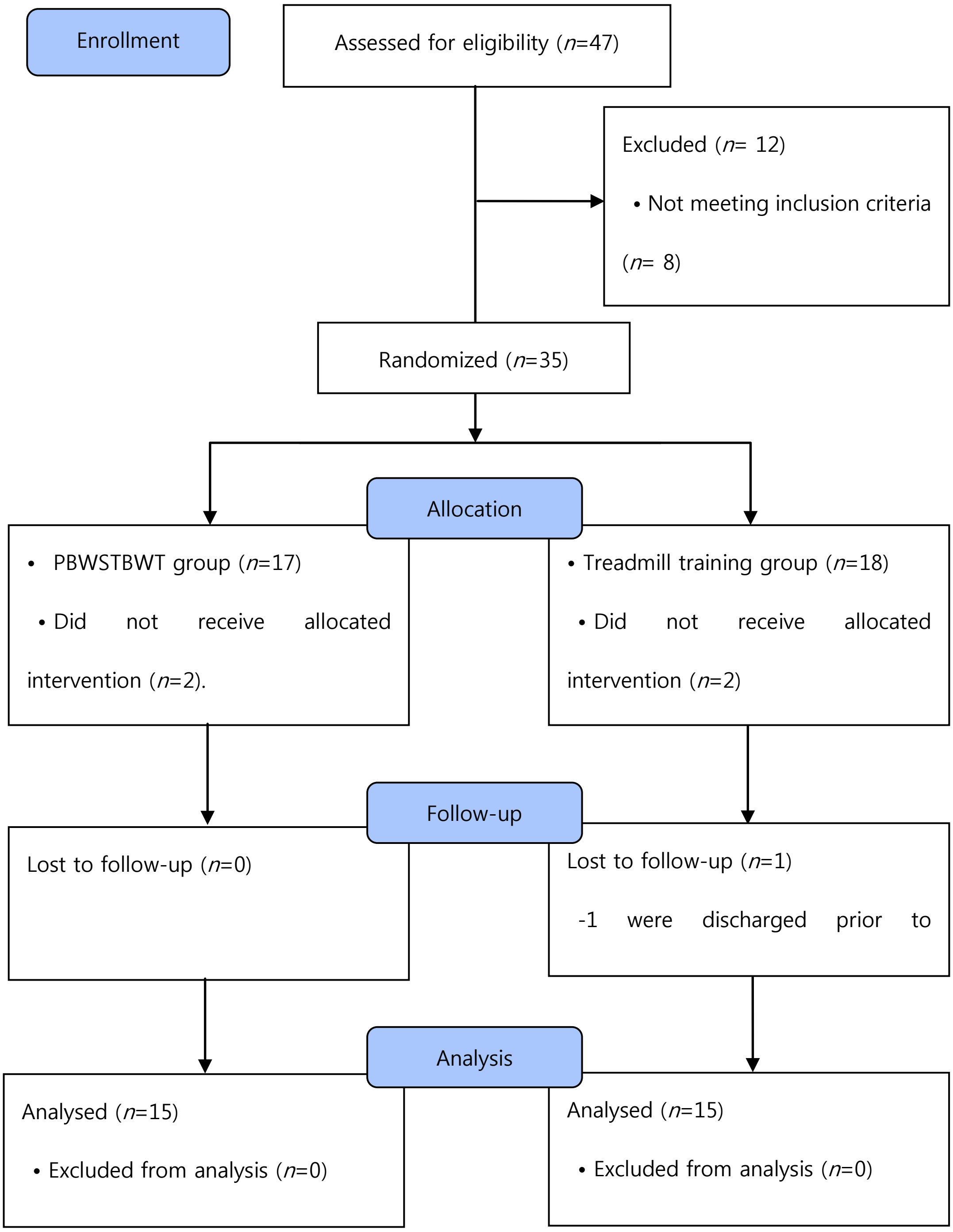

Fig. 1. Flow diagram of the study.

Table 1. The general characteristics of the subjects

	PBWSTBWT group (n=15)	Treadmill train group (n=15)	X^2/t (p) values
General characteristics			
Gender			
Male/female (%)	11/4 (73.3/26.7)	7/8 (46.7/53.3)	2.222 (.136) [a]
Affected side			
Left/right	10/5 (66.7/33.3)	8/7 (53.3/46.7)	.556 (.456) [a]
Etiology			
Infarction/hemorrhage	4/11 (26.7/73.3)	6/9 (40/60)	.600 (.439) [a]
Brain lesion location			
Cortex/subcortex/mixed (%)	2/9/4	1/7/7	-
Age, years	48.27 ± 16.05	50.73 ± 13.50	-.456 (652) [b]
Mass, kg	69.13 ± 7.68	64.66 ± 7.30	1.633 (.114) [b]
Height, cm	165.11 ± 6.58	163.09 ± 3.03	1.080 (.293) [b]
MMSE, score	26.80 ± 1.82	27.07 ± 1.87	-.396 (.695) [b]
Post stroke duration, months	10.93 ± 3.67	11.27 ± 4.10	-.243 (.809) [b]
Functional ambulatory scale (4/5)	4/5 (26.7/73.3)	6/9 (40/60)	.600 (.439) [a]
Spasticity (1/1+/2)	7/5/3	5/9/1	-
Dependent variables			
Paretic step length (cm)	40.95 ± 6.90	39.14 ± 5.37	.803 (.429) [b]
Stride length (cm)	82.29 ± 15.04	80.65 ± 11.43	.336 (.739) [b]
Paretic Single Support (%)	31.03 ± 6.58	32.11 ± 6.68	-.447 (.658) [b]
Total Double Support (%)	35.69 ± 8.84	32.73 ± 7.81	.974 (.338) [b]
Paretic step time (sec)	1,37 ± 0.32	1.32 ± 0.27	.394 (.696) [b]
Gait cycle (%)	2.64 ± 0.67	2.59 ± 0.56	.216 (.831) [b]
Cadence (step/sec)	0.54 ± 0.12	0.53 ± 0.11	.385 (.803) [b]
Gait speed(㎧)	0.74 ± 0.31	0.73 ± 0.25	.431 (.944) [b]
Dynamic Gait Index (score)	16.73 ± 2.69	16.53 ± 2.47	.706 (.834) [b]
6 min Walk Test (m)	237.27 ± 48.12	237.07 ± 51.01	.001 (.991) [b]

Values are N (%) or Mean ± standard deviation, ns = not significant, PBWSTBWT: Progressive Body Weight Supported Treadmill Backward Walking Training, Mixed= cortex level + subcortex level

[a] Chi-square test.
[b]Independent-t test

Table 2. Comparison of walking ability between PBWSTBWT and treadmill groups at baseline, 4 and 8weeks

Group Variable	PBWSTBWT group (n=15)			Treadmill train group (n=15)			ANOVA*		
	Baseline	4 weeks	8 weeks	Baseline	4 weeks	8 weeks	Time Main Effect	Group Main Effect	Time x Group interaction
Paretic step length (cm)	40.95±6.90	46.01±8.32†	49.76±8.16	39.14±5.37	41.52±5.86†	43.53±5.50‡	97.346(<.001)	2.980(.095)	10.986(<.01)
Stride length(cm)	82.29±15.04	92.95±17.05†	98.81±16.41‡	80.65±11.43	86.81±11.21†	90.12±10.86‡	95.149(<.001)	1.151(.293)	6.177(.008)
ParetícSingle Support (%)	31.03±6.58	37.31±5.86†	39.03±5.68‡	32.12±6.68	34.53±5.62†	37.24±5.69‡	37.707(<.001)	.333(.568)	3.414(.061)
Total Double Support (%)	35.69±8.84	28.38±8.37†	27.04±7.36‡	32.73±7.81	29.91±5.52†	26.87±5.32‡	34.047(<.001)	.047(.830)	3.175(.069)
Paretic Step Time (sec)	1.37±0.32	1.00±0.15†	0.98±0.14‡	1.32±0.27	1.11±0.28†	1.08±0.27‡	67.650(<.001)	.468(.499)	4.117(.049)
Gait cycle (%)	2.64±0.67	2.03±0.36†	1.94±0.33‡	2.59±0.56	2.37±0.48†	2.28±0.50‡	35.366(<.001)	1.291(.266)	5.689(.022)
Cadence (step/sec)	0.54±0.12	0.70±0.12†	0.74±0.10‡	0.53±0.11	0.60±0.09†	0.66±0.13‡	54.532(<.001)	2.743(.109)	4.066(.036)
Gait speed (㎧)	0.74±0.31	0.92±0.37†	0.98±0.36‡	0.73±0.25	0.80±0.31†	0.86±0.36‡	19.151(<.001)	.528(.474)	2.319(.120)
Dynamic Gait Index (score)	16.73±2.69	20.20±2.11†	21.13±2.03‡	16.53±2.47	18.67±1.95†	20.60±1.96‡	212.667(<.001)	.954(.337)	5.522(.011)
6 min Walk Test (m)	237.27±48.12	272.60±48.64†	279.87±45.78‡	237.07±51.01	262.33±47.68†	270.60±45.58‡	155.543(<.001)	.145(.706)	2.956(.078)

p*<.05*p*<.01, Values are Mean ± standard deviation, †significantly different compared with 0 ～ 4 weeks, ‡significantly different compared with 4 ～ 8 weeks, PBWSTBWT: Progressive Body Weight Support Treadmill Backward Walking Training