Original Article

Effects of a novel walking training program with postural correction and visual feedback on walking function in patients with post-stroke hemiparesis

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Abstract. [Purpose] This study aimed to elucidate the effects of a novel walking training program with postural correction and visual feedback on walking function in patients with post-stroke hemiparesis. [Subjects] Sixteen subjects were randomly allocated to either the experimental group (EG) or the control group (CG), with eight subjects in each. [Methods] EG and CG subjects performed a 30-min treadmill walking training exercise twice daily for 2 weeks. EG subjects also underwent postural correction using elastic bands and received visual feedback during walking. The 10-m walk test was performed, and gait parameters were measured using a gait analysis system. [Results] All parameters showed significant main effects for the group factor and time-by-group interactions. Significant main effects for the time factor were found in the stride length and stance phase ratios. [Conclusion] The novel walking training program with postural correction and visual feedback may improve walking function in patients with post-stroke hemiparesis.
Key words: Postural correction, Stroke, Walking function

INTRODUCTION

In general terms, stroke is a pathologic condition that alters postural tone, and causes muscle weakness, loss of proprioceptive awareness, and anomalous motor control[1]. These symptoms change the alignment of axioskeletal parts in space, such as the trunk and the shoulder and pelvic girdles, altering the distribution of weight loads on affected and unaffected lower limbs, followed by abnormal walking and movement patterns. In particular, these changes reduce perceptual space skills during walking and cause difficulties in maintaining an erect posture and segmental movement of the trunk and limbs, thereby decreasing walking ability[2–4]. Faulty motor control interferes with the awareness of normal movements during everyday activities[5].

As a result, previous studies were designed to determine the best solution for restoring postural symmetry and trunk stability, thereby improving walking function in patients with post-stroke hemiparesis[6–10]. Trunk stabilization training has been commonly recognized as an advantageous option for optimizing postural trunk control and facilitating stable movement patterns during walking[9]. Additionally, therapeutic suits[6] and adjustable harnesses[10] have been used as main interventions to correct body alignment, and outcomes supported the benefits of these methods for enhancing walking performance and balance. However, despite the various benefits of these approaches, they have some disadvantages for clinical use, including the time-consuming preparation for treatment, the use of vertical resistance only for correcting postural alignment, and a lack of feedback information to improve symmetrical weight load during walking.

To the best of our knowledge, clinical interests have focused on selectively performing individual treatments rather than simultaneously applying them to enhance functional performance. Often, it might be a specific issue that afferent inputs of proprioceptive and vestibular receptors cause changes in motor control during functional movement; therefore, evidence should be cautiously applied to a range of therapies, and should be assessed in clinical settings. Accordingly, this study aimed to identify the effects on walking function in patients with post-stroke hemiparesis who underwent a novel walking training program that provides three-dimensional postural correction and sustained visual feedback on body alignment.

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SUBJECTS AND METHODS

Sixteen patients with chronic stroke volunteered for this study, and were randomly assigned to either the experimental group (EG) or the control group (CG), with eight subjects in each group. Inclusion criteria were as follows: (1) stroke onset duration of >6 months, (2) no cognitive impairment (score of >25 on the mini-mental state examination-Korean version)[11], (3) no orthopedic or cardiopulmonary problems, and (4) no psychological and emotional disorders. Prior to participation, general guidelines about the experimental procedure and safety were provided, and all subjects gave written informed consent. Ethical approval for this study was granted by our university's Institutional Review Board. General characteristics of the subjects are presented in Table 1.

To compare the training effects between the two groups, gait parameters (step length, step time, stride length, and stance and swing phases in the gait cycle) were measured during treadmill walking using a gait analysis system (Functional Training System, Marpe Co., Ltd., Jeonju, South Korea), which consisted of a treadmill, front display monitor, connecting cable, back camera presenting body alignment in the coronal plane, and the main computer system. Load cells built into a baseplate under the walking belt of the treadmill system detected foot position and weight load during a 1-minute treadmill walk, and computed gait parameters (step length, step time, stride length, and stance and swing phases). The ratio of the value of the affected side to that of the unaffected side for each parameter was calculated. In addition, the subjects performed 10-m walk test (10MWT) and thus any clinical effects of the intervention could be determined. For the 10MWT, subjects walked through a straight, 13-m course at a comfortable speed. Testing was performed using a stopwatch (AST, KK-5898, USA) during the middle 10-m, excluding 1.5 m each from the first and last segments of the course. The 10MWT has been shown to be highly reliable for clinical use[12].

Subjects were randomly assigned to groups based on the blind drawing of a card from an envelope with two cards marked "EG" or "CG." Subjects in both groups performed 30-minute treadmill walking, twice daily for 2 weeks. Walking speed (2–4 m/s) was comfortably adjusted for each subject. Additionally, for EG subjects, postural analysis while standing was performed using equipment with a camera displaying postural alignment in the coronal plane, and the symmetry of weight load on the foot was measured. Initial postural measurements were used as basic information to guide the application of elastic bands for controlling body alignment in the coronal plane, and for adjusting symmetrical weight bearing on the foot. The monitor displayed specific information about the correction of body alignment abnormalities, demonstrating two separate lines at a regular interval from the midline, for defining postural deviation in the coronal plane. The subjects' body alignment was adjusted to maintain their postures within the lines by anchoring elastic bands into the frame of the machine from thoracic and lumbar straps. Treadmill walking training was performed after normal alignment was assured in the coronal plane, and feedback information on foot pressure distribu-

Table 1. General characteristics of the subjects (N = 16)

	EG (n_1 = 8)	CG (n_2 = 8)
Age (years)	62.8 ± 13.0	57.9 ± 17.7
Gender (male/female)	3/5	5/3
Height (cm)	162.8 ± 7.3	166.0 ± 4.5
Weight (kg)	61.13 ± 8.9	68.75 ± 9.8
Hemiplegic side (right/left)	3/5	4/4
Types of stroke (hemorrhage/infarction)	3/5	2/6
Duration since stroke onset (months)	11.3 ± 6.9	15.9 ± 21.1

Data are presented as mean ± SD, unless otherwise noted. EG: experimental group, CG: control group

tion and postural alignment were provided by the monitor during treadmill walking.

Data analysis was performed with the Statistical Package for the Social Sciences version 20.0 (SPSS Inc., Chicago, IL, USA) for Windows. Data were presented as mean ± standard deviation (SD). General characteristics (age, height, weight, and onset duration) of subjects in the EG and CG were compared by using an independent t-test. A 2 × 2 analysis of variance (ANOVA) with one within-subjects factor (time: pre-test and post-test) and one between-subjects factor (group: EG and CG) was used to determine the main effects and the interaction for the 10MWT and gait parameters. Significance level was set at $p < 0.05$.

RESULTS

Table 2 summarizes the results for gait parameters in both groups after the intervention. The 10MWT results revealed a significant main effect for time ($F_{1,14}$ = 6.559, p = 0.023) and group ($F_{1,14}$ = 59.804, p = 0.000), and there was a significant time-by-group interaction ($F_{1,14}$ = 5.585, p = 0.033). Furthermore, significant main effects for the time and group factors were found in stride length ratio ($F_{1,14}$ = 9.325, p = 0.009, and $F_{1,14}$ = 714.380, p = 0.000) and stance phase ratio ($F_{1,14}$ = 5.134, p = 0.040, and $F_{1,14}$ = 1678.886, p = 0.000), respectively. Step length ratio ($F_{1,14}$ = 1214.427, p = 0.000), step time ratio ($F_{1,14}$ = 785.939, p = 0.000), and swing phase ratio ($F_{1,14}$ = 95.256, p = 0.000) showed significant main effects for the group factor. Significant time-by-group interactions were found for step length ratio ($F_{1,14}$ = 7.075, p = 0.019), step time ratio ($F_{1,14}$ = 5.138, p = 0.040), stride length ratio ($F_{1,14}$ = 7.611, p = 0.015), and stance phase ratio ($F_{1,14}$ = 8.238, p = 0.012).

DISCUSSION

Research is currently underway to determine therapeutic solutions for recovery from functional impairments following stroke. It is therefore important to extend the application range of various approaches, and to provide evidence of their efficacy to the greatest extent. Our study focused on offering additional options (postural correction and sustained visual feedback) to enhance the clinical efficacy of the treadmill walking training program in patients with post-stroke hemiparesis. Our findings support the clinical efficacy of walking training with postural correction and visual feedback for

Table 2. Outcome of the 10-m walk test and gait analysis parameters in both groups (N = 16)

Parameters	EG (n_1 = 8)		CG (n_2 = 8)	
	Pre-test	Post-test	Pre-test	Post-test
10MWT (s)	17.22 ± 9.66	21.05 ± 11.57	17.77 ± 8.38	17.92 ± 8.84
Step length ratio	0.71 ± 0.17	0.97 ± 0.04	0.77 ± 0.13	0.70 ± 0.16
Step time ratio	0.66 ± 0.12	0.85 ± 0.13	0.71 ± 0.18	0.70 ± 0.11
Stride length (cm)	55.32 ± 7.79	65.88 ± 7.68	54.42 ± 11.19	54.96 ± 10.28
Stance phase ratio	0.76 ± 0.08	0.93 ± 0.10	0.83 ± 0.11	0.81 ± 0.13
Swing phase ratio	1.96 ± 0.88	1.31 ± 0.17	1.79 ± 1.44	1.78 ± 0.99

Data are presented as mean ± SD. EG: experimental group, CG: control group, 10MWT: 10-meter walk test

patients with post-stroke hemiparesis.

The repetitive use of faulty movement patterns during functional activities among stroke patients has a tendency to recognize these abnormal movements in the motor area of the brain, consequently hindering the creation of a normal motor program[5]. We added two intervention options to increase the efficacy of the walking training program: One was to modify the postural alignment of the trunk and the shoulder and pelvic girdles. Another was to offer sustained visual feedback for good postural alignment on the display monitor during treadmill walking. A three-dimensional real-time display of body posture in our training system provided improved opportunities for postural correction, with anchoring elastic bands from thoracic and lumbar straps to maintain body alignment within a range of correction lines on the monitor. These options aimed to allow the subjects to experience normal postural control during walking, which may encourage normal awareness related to functional performance.

The main results of our study were that incorporating postural correction and visual feedback into treadmill walking training improved the walking function of patients with post-stroke hemiparesis by increasing the length of the stance phase on the affected lower limb during treadmill walking. After stroke, symptoms contribute to changes in movement and postural control[1–3], and motor learning gives way to abnormal movement patterns from an asymmetrical postural control strategy[5]. The creation of a biased engram in the motor cortex acts as a factor that limits sensorimotor processing in normal movements. Therefore, clinically, the best functional recovery results from repeated experience of normal postural control during functional movement. In stroke rehabilitation, the therapeutic approach is often to achieve normal movement that involves optimal proprioceptive input and appropriate anticipatory central control while walking. Based on this previous concept, our results may be understood as therapeutic evidence for maintaining postural correction and sustained efforts during walking training.

Postural correction with anchoring elastic bands facilitates symmetrical weight-bearing on both lower limbs while standing and walking, and the repetitive use of a corrected posture during treadmill walking may reinforce normal walking patterns, and may also be associated with increased walking velocity[5, 6]. Therefore, the fundamental mechanism underlying our findings is probably reflected by the improved proprioceptive and vestibular input resulting from optimal posture during walking, which is considered to have potential for enhancing central control and executive process of walking movements[5]. Furthermore, this mechanism may be supported by sustained visual feedback related to the symmetrical distribution of foot pressure and good postural alignment during treadmill walking.

Notwithstanding the favorable outcomes of our intervention, we acknowledge several limitations that should be the focus of further studies. First, the small number of subjects is a major factor that limits the generalizability of our results to the entire population. Second, the absence of long-term follow-up data may make it difficult to state that our findings are conclusive. Finally, this study did not provide kinematic data for subjects during walking. Further robust studies with large sample sizes and long-term follow-up are needed in this field.

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