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Impact of WALKBOT on the Gait and Balance Recovery of Patients with Acute Neurologic Disorders

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Abstract This study investigated the effects of WALKBOT robotic-assisted gait training (RAGT) on lower extremity strength, functional ability, balance, and gait in patients with acute neurologic disorders. Twenty-six patients with acute hemiplegia, paraplegia, or quadriplegia resulting from cerebrovascular accident (n = 14) or spinal cord injury (n = 12) received RAGT 10–15 times over 2 weeks (up to 5 times or 20 min per day), combined with neurodevelopmental treatment. The main outcomes were pre- and post-intervention Motricity Index (MI), Berg Balance Scale (BBS), and Functional Ambulation Category (FAC). The secondary outcomes were comparison of combined pre- and post-intervention scores for all patients (spinal cord injury and cerebrovascular accident) on 14 items in the BBS. There were significant improvements in MI, BBS, and FAC scores after WALKBOT RAGT ($p < .001$). After WALKBOT RAGT, the BBS scores on items 1–11 increased for all patients with acute neurologic disorders ($p < .05$); no significant differences were observed for items 12–14 ($p > .05$). WALKBOT RAGT improves balance and gait in patients with acute neurologic disorders.

Keywords Balance, Cerebrovascular Accident, Robotic-Assisted Gait Training, Spinal Cord Injury

1. Introduction

Spinal cord injury (SCI) or cerebrovascular accident (CVA) may cause hemiplegia, paraplegia, or limb paralysis, as well as abnormal balance and gait [1]. Patients with limb paralysis have muscle weakness, paresthesia, and joint stiffness. These patients have decreased functional ability and increased risk of falls, making it difficult for them to perform activities of daily living (ADLs) or live independently [2, 3]. Therefore, gait recovery is the goal of rehabilitation therapy for patients with paralysis [2-6].

Because gait is an ADL, it is used as an index of quality of life and various strategies have been developed for gait rehabilitation [7]. The strategies in clinical use include neuro-developmental training, proprioceptive neuro-muscular facilitation, and functional electrical stimulation [8]. In recent decades, task-oriented gait training (e.g., partial weight-supported treadmill training [PWSTT]) has been increasingly used for gait rehabilitation [2]. PWSTT is administered to paralyzed patients by a therapist; it is effective for gait recovery and improving the contraction sequence of leg muscles [9, 10]. However, PWSTT requires extensive preparation and involves slow administration; moreover, it increases the risk of falls. PWSTT is administered by 2 or 3 therapists to control the torso and limb movements of patients, and it exhausts both the therapist and patient [11, 12]. In addition, the efficacy of PWSTT depends on the therapist's level of expertise, and there are limited repetitions of the walking cycle [3]. Robotic-assisted gait training (RAGT), based on intensive repetitions of tasks, is widely used for improving stance and gait in paralyzed patients [13-15]. RAGT improves gait through biomechanical feedback and high-intensity repetitive walking in a real-like environment [14, 15].

WALKBOT (P&S Mechanics Co., Ltd., Seoul, Korea), an exoskeleton-type robot system used for gait training, reduces the limitations of classical gait rehabilitation in paralyzed patients [16]. WALKBOT uses the exoskeleton and a body weight support harness to induce stepping movements in accordance with a stored normal biomechanical walking pattern. The robot's joints have axes similar to the axes of human legs; this allows natural walking movements on all leg joints, as well as exercises involving individual joint muscles. The use of WALKBOT improves gait in paralyzed patients and has the advantage of individualizing therapy for patients based on their physical characteristics [1, 3].

In this study, we evaluated the effects of gait rehabilitation using WALKBOT on lower extremity strength, function, balance, and gait in patients with acute neurologic disorder.

2. Methods

2.1. Participants

We administered RAGT rehabilitation to 26 patients (SCI: 12; CVA: 14) hospitalized for hemiplegia, paraplegia, or quadriplegia at a general hospital in Wonju, Gangwon-do, South Korea (Table 1). We included patients with onset ≤ 2 months, Functional Ambulation Category (FAC) < 3, American Spinal Cord Injury Association grade C or D for SCI patients, and a score ≥ 24 on the Korean version of the Mini-Mental Status Examination. We excluded patients with American Spinal Cord Injury Association grade A or B, Modified Ashworth's Scale score > 2, uncontrolled diabetes (and corresponding guidance to avoid exercise), obesity (weight > 135 kg), or height < 150 cm [1].

Table 1. Description of the general characteristics of patients

		SCI (n = 12)	CVA (n = 14)
Sex	Male	11	11
	Female	1	3
Age (years)		48.92±14.33α	60.13±10.32
Height (m)		170.25±3.96	166.87±8.42
Weight (kg)		69.25±12.15	66.07±1.19

SCI: spinal cord injury
CVA: cerebrovascular accident
αmean ±standard deviation

2.2. Experimental Methods

We used three scales for evaluation before and after training in all patients: Motricity Index (MI), Berg Balance Scale (BBS), and FAC. MI was used to grade muscle strength in terms of hip flexion, knee extension, and ankle dorsiflexion. Muscle strength was scored for each posture (maximum score of 6 per posture), and the scores were summed. BBS was used to evaluate balance during 14 static and dynamic tasks required for ADLs and the scores were summed. FAC was used to assess the need for help during walking (maximum score of 6).

2.3. Procedures

Patients underwent RAGT 10–15 times over 2 weeks, up to 5 times per week, 20 min per day (total 200~300 min). For the RAGT, a WALKBOT (robot-driven aid with posture control), a weight-bearing device, and a treadmill were used. Compared with other products, the independent drive of ankle joint with WALKBOT prevents excessive plantarflexion and foot drag.

Each patient received partial weight assistance in accordance with their functional requirement, using a harness that connected the patient's lumbar spine and pelvis to a body weight-bearing device. After the axes of hip, knee, and ankle joints had been adjusted using anthropometric data, patients underwent RAGT at various gait speeds and ranges of motion. The walking speed was initially set to 1.2 km/h and subsequently modified in accordance with the patient's condition, up to a maximum of 1.6 km/h.

2.4. Statistical Analysis

Statistical analyses were performed using SPSS Statistics software (version 23 for Windows; IBM Corp., Armonk, NY, USA). Data were expressed as means ± standard deviations. Paired Student's t-tests were used to compare differences in pre- and post-intervention MI, BBS, and FAC scores between patients with SCI and patients with CVA. In addition, paired Student's t-tests were used to compare the combined BBS scores of patients with SCI and patients with CVA, before and after WALKBOT. A p-value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of Clinical Outcomes

There were significant improvements in MI, FAC, and BBS scores after WALKBOT RAGT in patients with acute incomplete SCI ($p < 0.05$) (Table 2) and patients with CVA ($p < 0.001$) (Table 3).

Table 2. Comparison of pre- and post-intervention clinical outcomes in patients with incomplete SCI (n=12)

Tests	Pre-test	Post-test	p-values
FAC	0.33±0.65α	1.17±1.27	.034*
MI	49.33±20.64	60.08±18.17	.023*
BBS	7.67±9.33	19.08±12.29	.004*

FAC: Functional Ambulation Category
MI: Motricity Index in legs
BBS: Berg Balance Scale
αmean ±standard deviation
*p< .05

Table 3. Comparison of pre- and post-intervention clinical outcomes in patients with CVA (n=14)

Tests	Pre-test	Post-test	P-values
FAC	0.07±0.27ɑ	1.43±0.85	.000*
MI	34.29±22.22	53.42±18.07	.000*
BBS	5.00±4.74	15.79±9.49	.000*

FAC: Functional Ambulation Category
MI: Motricity Index in legs
BBS: Berg Balance Scale
ɑmean ± standard deviation
*p< .05

3.2. Comparison of Combined BBS Scores before and after WALKBOT RAGT

After WALKBOT RAGT in paralyzed patients, there were significant improvements in the BBS scores for items 1–11th ($p < 0.05$), but not for items 12–14th (12: placing alternated foot on stool; 13: standing with one foot in front; 14: standing with one foot) ($p > 0.05$) (Table 4). After WALKBOT RAGT to paralyzed patients with neurologic disorders, the changes of each item in BBS were confirmed. WALKBOT RAGT has shown significant improvement from item 1st to 11th in BBS ($p < 0.05$). However, WALKBOT RAGT did not show significant differences from items 12th 'placing alternated foot on stool' to 14th 'standing with one foot'in the BBS ($p > 0.05$) (Table 4).

4. Discussion

We hypothesized that WALKBOT RAGT would improve recovery of lower extremity strength, balance, and gait in paralyzed patients with SCI or CVA. Similar to previous findings, our results suggest significant improvement in lower extremity strength, functional ability, balance, and gait after WALKBOT RAGT.

RAGT uses a task-oriented approach for paralyzed patients based on the motor re-learning theory through repetitive, high-intensity tasks [17]. WALKBOT eliminates the therapist errors and fatigue associated with traditional physical therapy. In addition, RAGT intensity and gait parameters (e.g., stride length, gait velocity, and gait frequency) can be adjusted with WALKBOT in accordance with the patient's requirements. Partial support for the patient's weight makes WALKBOT safer than traditional physical therapy [1, 11, 21]. Traditional gait therapy allows 50–100 steps to be practiced each hour for wheelchair-dependent patients, whereas RAGT allows 1000–2000 steps to be practiced in 30 min [14]. Recent study has suggested that RAGT was effective treatment method for nonambulatory patients with neurologic disorders than ambulatory patient [7].

Table 4. Comparison of pre- and post-intervention BBS outcomes in patients with neurologic disorders (n=26)

No	Item	Pre-test	Post-test	P-values
1	Sitting to standing	0.77±1.14ɑ	2.27±1.32	.000*
2	Standing unsupported	0.65±1.26	1.81 ±1.60	.001*
3	Sitting unsupported	2.42±1.50	3.85±0.46	.000*
4	Standing to sitting	0.88±1.07	2.65±1.35	.000*
5	Transfers	0.81±0.89	2.27±1.12	.000*
6	Standing with eye closed	0.35±0.89	1.27±1.43	.001*
7	Standing with feet together	0.12±0.13	1.00±1.39	.002*
8	Reaching forward with outstretched arm	0.27±0.67	0.85±1.12	.003*
9	Retrieving object from floor	0.15±0.46	0.77±1.18	.004*
10	Turning to look behind	0.35±0.85	1.00±1.17	.002*
11	Turning 360 degrees	0.08±0.27	0.58±0.86	.003*
12	Placing alternated foot on stool	0.04±0.20	0.76±0.27	.574
13	Standing with one foot in front	0.03±0.20	0.12±0.43	.425
14	Standing on one foot	0.00±0.00	0.03±0.19	.327
	Mean	6.92±7.90	18.54±11.25	

BBS: Berg Balance Scale
ɑmean ± standard deviation
*p< .05

Our study demonstrated significant improvement in lower extremity strength with WALKBOT RAGT in patients with CVA or incomplete SCI. Nyberg & Gustafson reported that the lower extremity strength of CVA patients depends on their walking ability. The use of RAGT improves lower extremity strength and functional ability, compared with traditional gait rehabilitation [19]. Husemann et al. reported significantly increased muscle mass and reduced body fat after RAGT in CVA patients, possibly because gait training increases aerobic metabolism. In addition, several studies have demonstrated that RAGT improves gait and reduces knee and ankle joint spasticity in SCI patients. This reduction in spasticity is associated with smooth, coordinated contraction and relaxation of agonist and antagonist muscles [1, 10, 21].

In addition, WALKBOT can be used for lower extremity resistance training during walking; it is associated with improved cognitive functions through repeated visual and auditory stimulation. Finally, WALKBOT reinforces the motivation of patients with neurologic disorders to comply with rehabilitation [1, 16].

Donoghue and Stokes divided the BBS score (range, 0–24) into four intervals and determined that the minimum detectable change based on a 95% confidence interval (MDC95%) for each interval was 4.6 points. In our study, WALKBOT significantly increased the BBS score, and the MDC95% of 4.6 points was valid for use during treatment. However, WALKBOT did not improve the BBS scores of items 12–14th (12th: placing alternated foot on stool; 13th: standing with one foot in front; 14th: standing with one foot), which evaluate a combination of static and dynamic movements. Impairments of central nervous system functions are associated with loss of body scheme, causing difficulty in maintaining balance using stepping strategy on narrow base of support in a limited time. In our study, the short duration of WALKBOT use did not allow sufficient time for patients to adapt to the impaired sensorimotor function and perform difficult balancing tasks used in the BBS. In further study, Whether or not to perform difficult level items (12-14th of BBS items) could be used as an indicator of improvement of complex balance ability.

Mehrholz et al. reported that the usage of WALKBOT increases the chances of walking independently and improves cardiopulmonary functions in severely impaired CVA patients. Long-term use of RAGT in these patients improves the quality of life, controls visceral movements, and increases bone density [23].

Our study had several limitations. The sample size was small, not homogenous (14 with CVA and 12 with SCI), and there was no control group for comparison of outcomes. In addition, we did not consider the effects of natural recovery on the outcomes. Future studies should use a randomized, controlled design to evaluate the effects of WALKBOT on gait rehabilitation.

5. Conclusions

This study was aimed to investigate the effects of WALKBOT RAGT on lower extremity strength, balance, and gait in paralyzed patients with the acute phase of incomplete SCI and CVA.

WALKBOT RAGT had significant improvements in MI, FAC, and BBS scores in patients with acute neurologic disorders. In addition, the WALKBOT RAGT protocol used this study might be affected on improving the performance of patients on the difficult balancing tasks used in the BBS.

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