

Feasibility of Overground Gait Training Using an Exoskeletal Wearable Robot in Older Patients with Brain Disorders: A Case Report

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고령 뇌질환 환자에서 외골격 착용형 로봇을 활용한 지상 보행훈련의 유용성: 증례보고

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Abstract

We describe the effects of overground robot-assisted gait training (RAGT) with an untethered exoskeletal wearable robot in two cases of ambulatory older patients with brain disorders. An 80-year-old patient with idiopathic Parkinson's disease (case 1) was taken through 6 sessions of overground RAGT for 3 weeks. On the other hand, an 84-year old patient with stroke (case 2) received overground RAGT for 6 sessions of overground RAGT for 2 weeks. Each overground RAGT session was conducted for 20 min. Berg balance scale (BBS) in case 1 showed a significant improvement after a 3 weeks intervention, and case 2 showed a significant improvement of Functional Ambulatory Category and BBS after an overground RAGT. In addition, there were no significant side effects in each patient during and after the overground RAGT. We demonstrated the feasibility and safety of overground RAGT with an untethered exoskeletal wearable robot in older patients with brain disorders.

Key Words

Robot-assisted gait training, Parkinson Disease, Stroke, Rehabilitation

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Introduction

Ambulation plays a great role in daily life and enables wider social interactions. After stroke, about 50% of patients are initially unable to walk, 12% can walk with assistance, and 37% can walk independently.¹ In addition,

20% of the worldwide population over the age of 80 years have parkinsonism associated gait disturbance.² Various rehabilitation strategies, both traditional and modern special rehabilitation treatments, are available to patients with gait disturbance.³ With the recent advancement in robotics, rehabilitation using robots has been in the spotlight, and

various results have been reported.⁴

Tethered exoskeleton robot has been shown to improve gait function in patients with subacute stroke in robot-assisted gait training (RAGT).⁵ In conventional robots, a tethered exoskeleton can reduce muscle activities by limiting the movement of active participants because the patient can follow a set trajectory and move only at a set time. In addition, gait training with the trunk passively supported by a harness in a tethered exoskeleton robot implies less need for active dynamic stabilization.⁶ To overcome these limitations, overground gait training using an exoskeletal wearable robot may provide a better opportunity for stroke patients to improve ambulatory function.

A newly developed type of robot, an untethered wearable robot, provide patients with a lot of freedom and a realistic walking experience.⁷ In addition, overground gait training using an untethered wearable robot has been proposed to promote the activation of the nervous system by inducing an active participation from the patient who performed active balance control, weight shift, and muscle activation.⁸ Recently, it has been reported that the untethered exoskeletal wearable robot could be effective in improving gait function in pediatric cerebral palsy patients.⁹ However, there is no research on RAGT with the untethered exoskeletal wearable robot in older patients.

In this case report, we describe the effects and demonstrate the feasibility and safety of overground RAGT with the untethered exoskeletal wearable robot in two cases of older patients with brain disorders.

Case Report

1) Cases

Case 1 was an 80-years-old male patient with a 3 years history of idiopathic Parkinson's disease (IPD). He visited the outpatient clinic for proper management of gait disturbance. Although he was able to walk independently and showed no motor weakness in all 4 extremities, he

complained of freezing of gait (FoG) and shuffling gait patterns. He showed no impairments in visual, cognitive and language functions. In addition, he showed no lower back and lower extremity musculoskeletal pain.

Case 2 was an 84-years old male patient who was diagnosed with right posterior cerebral artery (PCA) infarction 10 days ago. He was transferred to the department of rehabilitation medicine for comprehensive rehabilitation. He showed left side ataxia and could ambulate on level surface without manual contact of another person but requires standby guarding of one person either for safety or verbal cueing. His motor grade at the left upper and lower extremities was grade IV without any spasticity. The visual field test demonstrated the right lower homonymous quadrantanopia. And he showed no lower back and lower extremity musculoskeletal pain.

2) Robot-assisted gait training (RAGT)

(1) Wearable torque-assisted exoskeletal robot

The robot used for this study was a wearable torque-assisted exoskeletal robot [Angel-legs M (ANGEL ROBOTICS Co., Ltd., Seoul, Korea)] which is a medical device designed to be used with the help of an assistant. This robot has active joints generate flexion torque during the swing phase and extension torque during the stance phase, respectively, at both the hip and knee joints. The remaining ankle joint is mechanically controlled using the articulated ankle-foot-orthosis. Those joints can help the user walk by generating different torque along each gait phase with the actuator modules consist of brushless direct-current motors, customized gear sets, and sensors for measuring the motor angular position and the absolute angle of the human joint.¹⁰

(2) Training protocols

Each session of overground RAGT was conducted for 20 min except don and doff time. First, each patient practiced sit-to-stand movement and stability to adapt to the robot. Next, gait training was performed using a wheeled walker. All the training sessions were conducted by a physical

therapist. Case 1 was taken through 6 sessions of the overground RAGT for 3 weeks (2 times a week) and case 2 received the 6 sessions of overground RAGT for 2 weeks (Fig. 1). Both case 1 and 2 received additional conventional gait training for 30 min and 90 min, respectively, on the same day by a physical therapist.

3) Clinical evaluation

A clinical evaluation was conducted before and after the overground RAGT with Berg balance test (BBS),¹¹ Functional Ambulation Category (FAC)^{12,13} and 6-min walk test (6MWT).¹¹

(1) Berg balance test

BBS was developed as a performance-oriented measure of the elderly individuals' balance. BBS consists of 14 items that score from 0 to 4. If the participant is unable to perform the task, 0 points are given, and if the task can be completed according to the given criteria, 4 points are given. The highest score on the test is 56.¹¹

(2) Functional ambulatory category

FAC is a six-point functional walking test that determines how much human support the patient needs when walking, regardless of whether or not a human assistance device is

used.^{12,13}

(3) 6-min walk test

6MWT is used to measure the maximum distance a person can walk for 6 minutes. The 6MW is a favorable tool because of its ease of administration and similarity with normal daily activities.¹¹

4) Satisfaction questionnaire

Each patient was also assessed by a satisfaction questionnaire after the overground RAGT. The satisfaction questionnaire was assessed to show how much the patient was satisfied with the overground RAGT with the wearable torque-assisted exoskeletal robot (Table 1). It consisted of three items and each item scored 1 to 5 on the Likert scale (1: unsatisfied to 5: satisfied).

5) Progress

Each patient completed the overground RAGT training and showed no adverse event during and after each session. Table 2 shows the clinical evaluation results before and after the overground RAGT. In BBS, case 1 and 2 showed improvement from 41 to 44 in the total score and

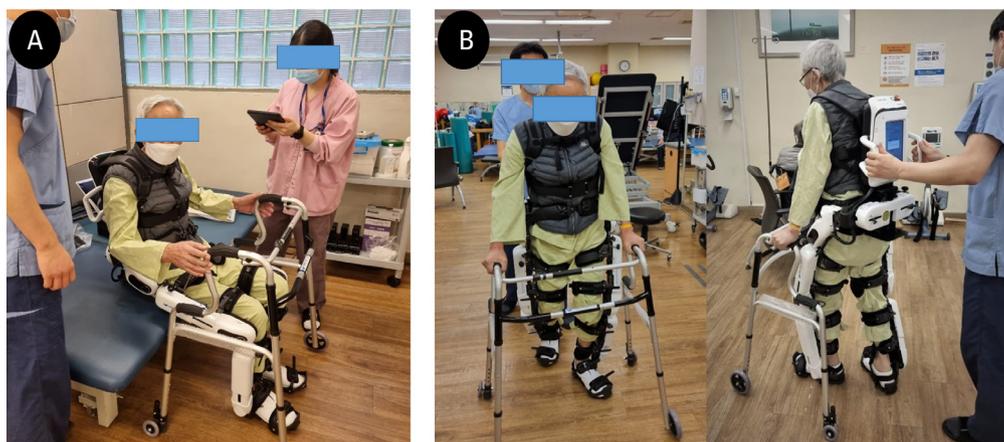


Fig. 1. Overground robot-assisted gait training in Case 2. A: Preparation of overground robot-assisted gait training, B: Overground robot-assisted gait training with a physical therapist.

Table 1. Satisfaction Questionnaire

Items	
Q1	How much are you satisfied with robot-assisted gait training?
Q2	How much do you like to keep using robot-assisted gait training?
Q3	How much do you want to recommend robot-assisted gait training to other patients?

Each question scored 1 to 5 of the Likert scale (1: unsatisfied, 5: satisfied)

from 13 to 48 in the total score, respectively, after the overground RAGT. In case 2, FAC improved from 3 to 5 after the overground RAGT; however, case 1 showed no improvement in FAC. 6MWT was conducted only in case 2 and he showed an increase in gait distance from 180 m to 255 m after the overground RAGT. Each patient scored a total score of 15 which means they were totally satisfied with the three questions (Table 3).

Discussion

This case series investigated the feasibility of overground gait training using an exoskeletal wearable robot in elderly patients with brain disorders. Two over 80-year-old patients with different brain disorders received gait training with untethered exoskeleton wearable robots. After a short-term training, each patient showed improvements in balance or gait function. In addition, none of the patients complained of adverse events such as skin abrasion or musculoskeletal discomfort during and after the training sessions.

Picelli et al.¹⁴ reported a significant improvement in gait function in patients with IPD who were treated with RAGT compared with conventional treatment. Lokomat, a representative tethered exoskeleton robot, showed improvement in stroke patients compared to those who did not use robots in balance.⁵ However these studies used the RAGT with the tethered exoskeletal robot which reduces

Table 2. Changes of Clinical Evaluations

		Before intervention	After intervention
Case 1	FAC	4	4
	BBS	38	44
Case 2	FAC	3	5
	BBS	18	48
	6MWT (m)	180	255

BBS: Berg Balance Test, FAC: Functional Ambulation Category, 6MWT: 6-min Walk Test

Table 3. Satisfaction Questionnaire

	Q1	Q2	Q3	Overall score
Case 1	5	5	5	15
Case 2	5	5	5	15

device portability and requires a relatively larger spatial space to be set.¹⁵ Untethered exoskeletal robot is a relatively small-sized suit-type robot. Therefore, it is a portable device with the possibility to provide assistive help during ADLs activities.¹⁵

The untethered exoskeleton robot enables active ground walking in response to the patient's intention. It has joint movement sensors and its motion is enhanced by the mechanical joint force. Therefore, patients can literally move around and this helps improve treatment compliance.^{9,16} However, it also could act as a load to other muscles not involving normal gait cycle,¹⁰ and therefore a risk of adverse effects; this provoking muscle strain through consumption of other muscle strength to achieve balance in elderly patients. In addition, a fall might be the most serious adverse effect of untethered exoskeleton robots compared with tethered exoskeleton robots. In this case, RAGT with the untethered exoskeleton robot was performed by a physical therapist to prevent a fall. There was no adverse

effect in the two cases in this study. These results showed that overground gait training using an exoskeletal wearable robot might be used in RAGT as a tethered exoskeletal robot in elderly patients with brain disorders.

Case 1 BBS results showed an improvement of balance function, however, there was no change of FAC. This may be due to a ceiling effect or a relatively short duration of training. The most common measurement for FoG is FoG questionnaire (FoG-Q).¹⁷ FoG-Q was not conducted in case 1, because it evaluates the degree of FoG in the last week. It could not demonstrate to clearly the improvement on FoG in Case 1; however, it might be estimated that there was an improvement in FoG and gait patten considering the high satisfaction for overground RAGT of this study in Case 1. However, further research is needed to clarify the effects on FoG of overground RAGT in the future. Case 2 in this study showed remarkable improvement in balance and gait functions. However, it was difficult to confirm whether these were effects of overground gait training using an exoskeletal wearable robot alone, because he also received conventional rehabilitation therapy. In addition, quantitative assessment of ataxia was not performed. This is one of limitations in this case study. Therefore, further studies with the case-control trial will be needed to elucidate the effects of overground gait training using an exoskeletal wearable robot on balance and gait function.

In conclusion, this case report demonstrated the feasibility and safety of overground RAGT with the untethered exoskeletal wearable robot in older patients with brain disorders. It showed versatility and safety in that it can be used in elderly people with brain problems, and effectiveness in that it resolved gait disturbance and improved balance and gait endurance. However, further study with a larger number of patients is needed to elucidate the effects of the overground RAGT in spite of the feasibility observed in this study.

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