



Case Presentation

Robot-Assisted Gait Training in a Patient With Hereditary Spastic Paraplegia

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Abstract

Robot-assisted gait training has been investigated for restoring walking through activity-dependent neuroplasticity in persons with various neurologic disorders. This case report presents the outcome of robot-assisted gait training combined with physiotherapy in a 28-year-old man with pure hereditary spastic paraplegia. The patient participated in 25 training sessions over 6 weeks. Improvements were noted in his walking speed and balance after the training, but gait kinematics and kinetics showed no remarkable changes before and after the training. Robot-assisted gait training may be useful for providing intensive gait training in patients with hereditary spastic paraplegia because the patient's walking speed and balance improved after the training.

Introduction

Hereditary spastic paraplegias (HSPs) are a group of heterogeneous genetic disorders characterized by progressive distal axonopathy, mainly involving the corticospinal tract. These disorders cause lower limb spasticity and weakness [1,2], and most patients present with difficulty walking or gait disturbance. Because no specific treatments exist for HSP, a symptomatic treatment approach is used [3]. Physical therapy is recommended for improving cardiovascular fitness, maintaining and improving muscle strength and gait, and reducing spasticity [4]. Antispasticity treatments, including oral medication, intrathecal baclofen, and botulinum toxin injection, also have been used in patients with HSP [3,4]. However, these treatments provide only short-term symptomatic improvement, and gait worsens slowly over years because of advancing spasticity and general muscular deconditioning in most patients.

Robot-assisted gait training has been investigated for improving gait function in persons with various neurologic disorders [5-8]. Theoretically, replicating a normal gait pattern using robot-assisted training restores walking through activity-dependent neuroplasticity of the spinal and supraspinal control mechanisms of walking [9]. Considering the markedly abnormal gait patterns of patients with HSP [10], intensive gait training

using a robot may be beneficial for gait biomechanics and function in these patients.

To our knowledge, no report has been made thus far on the effect of robot-assisted gait training in patients with HSP. This case report presents the outcome of robot-assisted gait training combined with physiotherapy in a patient with HSP.

Our hospital's Institutional Review Board approved this case report, and written informed permission was obtained from the patient (Institutional Review Board No. 1402-031-555).

Case Presentation

A 28-year-old man with uncomplicated HSP was diagnosed with SPG4 deletion (exon 5-17 and part of the *SLC30A6* gene) by a genetic study that used the multiplex ligation-dependent probe amplification technique. The patient had undergone bilateral Achilles tendon lengthening at 6 years of age, along with bilateral distal hamstring lengthening, rectus femoris transfer to gracilis, and gastrocnemius lengthening at age 26 years. Although he could walk without assistance using a single cane and bilateral ankle-foot orthoses (AFOs), his gait gradually deteriorated.

The patient's gait disturbance mainly stemmed from bilateral lower limb spasticity and weakness; muscle tightness was not apparent during the physical

examination. According to the Medical Research Council (MRC) scale, hip flexor strength was grade 3, knee extensor and ankle dorsi-/plantar-flexor strength were grade 4, and knee flexor strength was grade 2. Spasticity scores of hip flexors, knee flexors, and knee extensors were 1+ bilaterally according to the Modified Ashworth Scale (MAS). Ankle planar flexor spasticity was 3 on the MAS. Ankle clonus was positive on both sides, and he had a spastic gait with excessive lumbar lordosis. The patient had been taking baclofen (20 mg twice a day) to reduce spasticity and was performing home-based exercises regularly.

Because intensive treatment was expected to improve his gait disturbance, the patient was provided with a training program that involved robot-assisted gait training in combination with physiotherapy; this protocol was based on a previous meta-analysis of patients affected by stroke [5]. The daily training session included 30 minutes of robot-assisted walking using an exoskeleton-type gait robot with partial body weight support (Walkbot_S; P&S Mechanics, Seoul, Korea), 30 minutes of gait training on the ground, and 30 minutes of upper extremity exercises with functional training. He underwent 25 training sessions during a 6-week period.

The gait robot replicated a normal gait pattern on a treadmill by controlling movements of the hip, knee, and ankle joints on both sides. The speed of the robot-assisted walking was increased from 1.2 to 1.8 km/h at each session. The amount of body weight support was gradually lowered from 25% to 0% during the course of the training sessions.

Clinical and functional assessments and gait analysis were performed 1 day before and 3 days after the training program. Clinical and functional assessments included the MRC scale for muscle strength, MAS, functional ambulation category, 10-meter walk test (average of 3 trials), 6-minute walk test (6MWT), timed up and go (TUG), and Berg Balance Scale (BBS). The patient was instructed to use bilateral AFOs and a single cane while performing the standing and locomotor function tests.

Gait analysis was performed using a 3-dimensional optical motion capture system with EVa Real-Time software (Motion Analysis Corp, Santa Rosa, CA). Spatiotemporal parameters and kinetics and kinematics of the hip, knee, and ankle joints in the sagittal, coronal, and transverse planes were measured while the patient walked barefoot along an 8-meter walkway using a single cane at a comfortable speed.

Muscle strength of the lower extremities did not change, except in the knee flexors, which improved from grade 2 to 3 on the MRC scale after the training. The MAS scores were unchanged in hip flexors, knee flexors, and extensors on both sides, whereas in both ankle plantar flexors, the MAS scores reduced from 3 to 2.

Functional assessments showed some improvements in walking speed and balance after training (Table 1). The patient's 10-meter walk test and TUG results showed a decrease in time by 1.7 seconds (13.5%) and 3.3 seconds (13.9%), respectively. The patient's BBS showed 4 points (10.3%) of improvement. Alternatively, walking endurance measured using the 6MWT showed a slight decrease by 13 meters (5%) after the training. Functional ambulation category showed no change.

In the gait analysis, spatiotemporal gait parameters showed a decreased cadence, speed, step width and length, and duration of swing phase after the training (Table 2). Gait kinematics and kinetics showed no remarkable change before and after the training (data not shown). Severe gait abnormalities, including a compensated Trendelenburg gait pattern, excessive flexed position of the hip joints, and decreased knee and ankle range of motion, were observed in both analyses. Left hip extension moment during stance phase and hip rotation improved toward a normal pattern, whereas pelvic obliquity and left hip abduction during left stance phase were slightly worse after the training.

Discussion

To our knowledge, this is the first case report that has examined the effect of robot-assisted gait training on walking in a patient with HSP. Contrary to our expectations, no remarkable improvement in gait biomechanics was observed, despite some functional improvement. Nevertheless, the findings provide information about the effect and therapeutic target of physical therapy in patients with HSP.

In late-onset HSP (after age 6 years), gait disturbance usually worsens insidiously over many years [3]. Physical therapy has been used in patients with HSP for symptomatic improvement of lower extremity strength, gait, and cardiovascular condition. However, evidence of effectiveness is still lacking. Because it is difficult to alleviate gait disturbances in patients with HSP by using conventional physical modalities, novel therapeutic approaches deserve consideration.

Table 1

Outcomes of the functional assessments before and after the training program

Functional Assessments	Before	After
FAC	3	3
10MWT,* s	12.6	10.9
6MWT, m	249	236
TUG, s	23.8	20.5
BBS	39	43

FAC = functional ambulation category; 10MWT = 10-meter walk test; 6MWT = 6-minute walk test; TUG = timed up and go; BBS = Berg Balance Scale.

* Mean value of 3 trials. The patient used bilateral ankle-foot orthoses and a single cane during the tests.

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