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BRIEF REPORT

Reducing Robotic Guidance During Robot-Assisted Gait Training Improves Gait Function: A Case Report on a Stroke Survivor

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Abstract

Objective: To test the feasibility of patient-cooperative robotic gait training for improving locomotor function of a chronic stroke survivor with severe lower-extremity motor impairments.

Design: Single-subject crossover design.

Setting: Performed in a controlled laboratory setting.

Participant: A 62-year-old man with right temporal lobe ischemic stroke was recruited for this study. The baseline lower-extremity Fugl-Meyer score of the subject was 10 on a scale of 34, which represented severe impairment in the paretic leg. However, the subject had a good ambulation level (community walker with the aid of a stick cane and ankle-foot orthosis) and showed no signs of sensory or cognitive impairments.

Interventions: The subject underwent 12 sessions (3 times per week for 4wk) of conventional robotic training with the Lokomat, where the robot provided full assistance to leg movements while walking, followed by 12 sessions (3 times per week for 4wk) of patient-cooperative robotic control training, where the robot provided minimal guidance to leg movements during walking.

Main Outcome Measures: Clinical outcomes were evaluated before the start of the intervention, immediately after 4 weeks of conventional robotic training, and immediately after 4 weeks of cooperative control robotic training. These included: (1) self-selected and fast walking speed, (2) 6-minute walk test, (3) Timed Up & Go test, and (4) lower-extremity Fugl-Meyer score.

Results: Results showed that clinical outcomes changed minimally after full guidance robotic training, but improved considerably after 4 weeks of reduced guidance robotic training.

Conclusions: The findings from this case study suggest that cooperative control robotic training is superior to conventional robotic training and is a feasible option to restoring locomotor function in ambulatory stroke survivors with severe motor impairments. A larger trial is needed to verify the efficacy of this advanced robotic control strategy in facilitating gait recovery after stroke.

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Gait impairment is one of the primary causes of disability after stroke with about 75% of stroke survivors living with some form of gait dysfunction.[1] Gait disruption not only creates a stigma for these patients, but also puts them at risk for fall-related injuries and for developing secondary cardiovascular, metabolic, and musculoskeletal complications. Unfortunately, even with the best standard of care, current therapeutic interventions have limited influence on the natural path of gait recovery after stroke.[2] Hence, there is a critical need for new interventions to effectively mitigate gait impairments after stroke, which could also ameliorate the physical, social, and economic consequences of stroke.

Robotic therapy is becoming increasingly popular for gait rehabilitation after stroke.[3] While there are a number of advantages favoring the use of robotic rehabilitation (eg, ability to reduce physical burden on the therapist, ability to provide a large volume of movement therapy in a safe environment, ability to objectively monitor patient performance and progression), current evidence suggests that clinical outcomes using robotic interventions are not

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Table 1 Baseline subject characteristics

Impairment	Motor	Fugl-Meyer = 10/34
		Isometric KE strength = 55% of nonparetic leg
		Isometric KF strength = 14% of nonparetic leg
	Sensory	Intact touch, discrimination, and proprioception
	Cognition	Intact; Mini-Mental State Examination = 29/30
	Vision	No double vision, hemianopia, or visual neglect
	Language	No aphasia or apraxia
Gait function	Ambulation level	Independent community ambulation with the aid of a stick cane and ankle-foot orthosis
	Velocity	Self-selected walking speed = .68m/s
		Fast walking speed = .93m/s
	Endurance	6-minute walking distance = 251m
	Characteristics	Stiff-knee gait with minimal circumduction
Comorbidities	Diabetes	Under control with medications
	Hypertension	Under control with medications

Abbreviations: KE, knee extension; KF, knee flexion.

superior to conventional therapy in ambulatory stroke survivors.[4] One key factor for this may be the use of robotic control strategies that provide substantial assistance while performing movements. Such assistance from the robots would minimize active involvement of patients in the therapeutic process, and may promote a slacking phenomenon, where patients rely on the robots to perform movements instead of actively initiating and performing movements themselves.[5]

To overcome this limitation, researchers have proposed that therapists use an assist-as-needed paradigm, where the robot provides assistance only when needed (eg, when considerable deviation from normative gait trajectory is recorded) and does not hinder the subject's movement during other times.[5-7] Recently, a broadly similar robotic control strategy was developed for the gait rehabilitation robot Lokomat.[8,9] This robotic control strategy takes into account the patient's intention and voluntary effort (ie, patient-cooperative) rather than simply imposing predefined gait trajectories. While the preliminary results appear to be promising in subjects with mild motor impairments,[10,11] it is not clear whether such benefits can also be realized in individuals with severe motor impairments. Moreover, the added benefits of such advanced controllers, as opposed to conventional position controllers, are not known. In this article, we assessed the feasibility and benefits of reduced robotic guidance training (in comparison with full robotic guidance) on a chronic stroke survivor with severe lower-extremity motor impairments (Fugl-Meyer scale score of 10 out of 34) using a single-subject crossover design.

Methods

Participant

For the purpose of this study, we recruited a 62-year-old man with right temporal lobe ischemic stroke resulting in left-sided hemiparesis. He was enrolled in the study 10 months after the onset of stroke. The details of baseline subject characteristics are provided in table 1. At the time of recruitment, the subject had severe motor impairments as characterized by a lower-extremity Fugl-Meyer motor score of 10 on a scale of 34.[12] However, his ambulatory function was preserved, and he was walking in the community with the help of a stick cane and an ankle-foot orthosis. The subject also had normative cognitive function based on the Mini-Mental State Examination score (29 on a scale of 30). Before participating in the study, the subject provided written informed consent by signing a form that was approved by the Northwestern University Human Subjects Research Institutional Review Board.

List of abbreviations:
BWSTT body weight-supported treadmill training

Design and intervention

We tested the benefits of cooperative control training (ie, reduced robotic guidance) using a crossover design. The subject underwent 12 sessions (3 times per week for 4wk) of conventional robotic training (full robotic guidance) followed by 12 sessions (3 times per week for 4wk) of reduced robotic guidance training using a gait rehabilitation robot called the Lokomat.[a] A 2-week break period was provided between the 2 training paradigms. The subject walked for about 45 to 60 minutes during each training session (excluding rest periods and setup time). Clinical outcomes were evaluated before the start of the intervention, immediately after 4 weeks of full robotic guidance training, and immediately after 4 weeks of reduced guidance training (fig 1A).

Conventional robotic control training

When the subject underwent standard robotic training, the legs of the Lokomat moved the subject's legs along a predetermined gait trajectory (position-controlled). The predetermined gait trajectory was based on the gait patterns programmed into the robot, which are patterns based on the kinematics exhibited by healthy subjects. The robot was least compliant in this mode and deviated minimally from its reference trajectory even if the patient attempted to deviate from the programmed path. The subject was instructed to walk along with the robotic legs and was provided with visual feedback of his walking patterns via a large whole body mirror that was placed in front of the subject. Progression was achieved by reducing the body-weight support and increasing the speed of the treadmill.