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CASE REPORT

RESTORATION OF WALKING FUNCTION IN AN INDIVIDUAL WITH CHRONIC COMPLETE (AIS A) SPINAL CORD INJURY

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Objective: **The prognosis for further recovery of motor function 2 years after complete spinal cord injury is poor. This case report describes recovery of walking function in an a 33-year-old man two years post T7 spinal cord injury American Spinal Injury Association (ASIA) Impairment Scale (AIS) A following intensive physical therapy and robotic locomotor training.**
Design: **Case report.**
Methods: **The subject engaged in an intensive clinic-based physical therapy program and research-based robotic locomotor training study over a 7-month period. Physical therapy was initiated 4 months prior to entry into the research study, and targeted trunk control, upper extremity strength, and upright mobility. On initial entry into the robotic locomotor training study the subject's AIS A classification was substantiated. Initial, interim, and follow-up tests of sensation, strength, sitting balance, spasticity, and mobility were performed.**
Results: **Lower extremity motor scores improved from 0/50 to 4/50, bilateral hip flexors increased from grade 0/5 to 2/5, warranting injury re-classification from AIS A to C. Intensive physical therapy combined with robotic locomotor training was associated with restoration of short distance walking function with lower extremity braces and a walker.**
Conclusion: **To our knowledge, this is the first report of an individual with chronic spinal cord injury AIS improving in over-ground walking ability following intensive physical therapy and robotic locomotor training. The presence of a neurophysiologically discomplete lesion probably permitted training of operational neural pathways and enabled the development of useful voluntary movement.**

Key words: complete spinal cord injury; locomotor training; discomplete spinal cord injury; robotic training.

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INTRODUCTION

The prognosis for recovery of motor function after complete spinal cord injury (SCI) is poor (1). The American Spinal Injury Association (ASIA) Impairment Scale (AIS) provides the standard for neurological classification of AIS A–E SCI (2). Fewer than 1% of individuals classified as AIS A (complete SCI) one month after injury learn to walk again (1). However, evidence in non-disabled individuals (3) and in individuals with SCI (4) suggests that spinal neural circuitry has the capacity for activity-dependent plasticity. Post-mortem human and animal studies have established that the spinal cord is rarely completely severed after blunt trauma (5). In individuals with AIS SCI A, neurophysiological tests, which record surface electromyography responses to reinforcement maneuvers, vibration, and withdrawal reflex suppression, have demonstrated evidence of translesional motor connections, characterizing these lesions as "discomplete" (6). Presence of "discomplete" neurophysiological markers in 43 of 67 persons classified with SCI AIS A or B (6) suggests that these individuals probably were neurophysiologically incomplete; training of these operational neural pathways may promote useful voluntary movement (7).

This case report describes recovery of locomotor function subsequent to intensive physical therapy and robotic locomotor training in an individual 2 years post T7 AIS A SCI.

CASE REPORT

A 33-year-old man entered our robotic locomotor training (RLT) study 29 months post SCI. His rehabilitation services had been discontinued at 8 months post SCI due to plateau of function. At 25 months post-SCI, he begun an intensive out-patient physical therapy program, which continued during his RLT. Written consent was obtained for exchange of medical information, release of physical therapy records and participation in the RLT study, which was approved by the University of Miami Institutional Review Board for Human SubjectsResearch.

Review of the subject's initial clinical physical therapy evaluation indicated SCI T7 AIS A and lower extremity spasticity during position changes. Functional test results indicated poor sitting balance, and moderate assistance was required for wheelchair transfers. An intensive physical therapy program to improve trunk strength, sitting balance and mobility, and wheelchair transfers was initiated. The program included exercises for trunk and pelvis re-training, upper extremity

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strengthening, and sitting balance activities during 1-hour sessions, 2–3 times per week, as well as a home exercise program. Functional outcome measures included trunk and lower extremity manual muscle tests, unsupported sitting balance duration, standing ability, and walking ability. As the patient's trunk strength, unsupported sitting balance and independent transfers improved, the difficulty of the program was progressed to include standing in a tilt table, sit-to-stand transitions, and gait training in parallel bars.

Initial evaluation at our research laboratory using the standard ASIA examination (2) revealed a neurologic motor and sensory level of T7, Lower Extremity Motor Score (LEMS) of 0/50, no sacral sensation, and a zone of partial sensory preservation to T12 for pin prick and light touch; a classification of AIS A was assigned. The individual was able to rise to standing from the seated position independently with a rolling walker using upper extremity strength and lower extremity extensor spasticity for minimal lower extremity weight-bearing. He was not able voluntarily to initiate hip flexion for stepping with either leg; forward over-ground progression using the walker was accomplished with using trunk mechanics to lift the pelvis and advance the limb, while weight-bearing on his upper extremities and relying on fluctuating extensor spasticity for lower extremity weight support. RLT was initiated using the Lokomat (Hocoma, Inc., Switzerland), a computer-controlled, treadmill-based motorized robotic gait orthosis, 3 times per week for 12 weeks. Outcome measures included ASIA sensory scores, LEMS, the Pendulum Test of quadriceps spasticity (9), clinical tests of functional independence (FIM) (10) and spasticity (Ashworth (11), Spasm Frequency (12) and Severity (13)). A total of 33 40-min training sessions with body weight consistently supported at 80% were completed. During the first 10 training sessions, treadmill speed was gradually increased from 0.8 km/h to 3.2 km/h (0.5 to 2.0 mph), provided appropriate gait kinematics were demonstrated, then maintained at 2.0 mph during all subsequent training sessions. The individual was encouraged to "step with the robot" during walking.

RESULTS

For this individual, functional abilities improved over the course of his physical therapy and RLT programs (Table I).

Table I. *Impairment, functional, and robotic locomotor training outcome measures*

Date	Sensation	Trunk/LE strength	LE spasticity	Sitting balance	Sit to stand	Standing	Walking
21 Sept 2006	Absent below T8	0/5 Abdominals 0/5 Paraspinals 0/5 Psoas 0/5 Gluteals 0/5	Min right LE flexor withdrawal	Unable	Unable	Unable	Unable
15 Nov 2006			Increasing extensor tone	5 s	// bars Min assistance	// bars Min assistance	// bars 3 m (10 ft) Mod assistance
4 Dec 2006					// bars Independent	// bars Independent uses LE tone	// bars 3m (10 ft) pelvic rotation PT assistance swing phase
Enrollment in robotic locomotor training program							
19 Jan 2007 Pre-tests	AIS score Touch 76/108 Prick 70/108	LEMS 0/50	Pendulum test Right: 64.85° Left: 58.46°	Sitting balance	Rolling walker Mod assistance	Rolling walker Mod assistance	Rolling walker Unable
14 Feb 2007				30 s			
2 Mar 2007	Absent below T12	LEMS 2/50 Abdominals 1+/5 Paraspinals 1+/5 Hip flexors 1/5 Gluteals 1+/5		60 s		// bars 20 s unsupported	
28 Mar 2007	Deep pressure in gluteal area and posterior thighs	LEMS 4/50 Abdominals 2+/5 Paraspinals 2+/5 Hip flexors 2–/5 Gluteals 2+/5					Rolling walker 6 m (20 ft) Max assistance × 2
16 April 2007 Post-tests	AIS Score Touch 76/108 Prick 70/108	LEMS 3/50	Right: 107.18° Left: 118.89°				
27 April 2007 Follow-up		LEMS 4/50					// bars 3 m (10 ft) × 6 independent

LE: lower extremity; LEMS: lower extremity motor score; // bars: parallel bars; PT: physical therapist; Min: minimal, Mod: moderate; Max: maximal.

Improvements in walking function and motor control of the trunk, pelvis and lower extremities resulted in the ability to walk over-ground for bouts of 6 m (20 feet) using a rolling walker, with the maximal assistance of 2 people, maintain unsupported sitting balance for 60 seconds, and perform sit-to-stand transitions independently. Bilateral hip flexor LEMS improved from 0/5 to 2/5. He was fitted with bilateral knee-ankle-foot orthoses and continued progressive gait training.

Table I shows the initial and final locomotor training outcome measures. The ASIA sensory score showed no change, the LEMS increased from 0/50 to 4/50. The Pendulum Test (9), demonstrated an increased first swing excursion of 42° on the right and 60° on the left; indicating a reduction in quadriceps spasticity in both legs. The FIM (10) and spasticity tests (Ashworth (11), Spasm Frequency (12) and Severity (13)) showed no change.

DISCUSSION

Prior reports of individuals with chronic complete SCI who convert from classification of AIS A to C are limited to a single case study of an individual with a C2 AIS A injury (14). Over a 3-year period, the individual exhibited substantial sensory recovery. In this case, restoration of movement was exhibited for right wrist and elbow extension; warranting re-classification from AIS A to C. However, these improvements were not sufficient to alter the individual's daily functional abilities. Prior reports of locomotor training in individuals with SCI classified as AIS A and B have not resulted in recovery of over-ground walking function (7, 8).

In the present case, intensive physical therapy targeting task-specific practice combined with robotic locomotor training resulted in restoration of some walking function, improved sitting balance and reduced spasticity. The difference in these results suggests that the combination of intensive physical therapy and robotic locomotor training is more effective than locomotor training alone in improving functional abilities in individuals with chronic AIS SCI A. Evidence suggests that the training activity must be intensive and task-specific (15) in order to drive the neuroplastic changes required for restoration of targeted functional skills.

Studies indicate that spinal reflex circuitry exhibits activity-dependent plasticity (3, 4, 7, 8, 16). Findings of training-related modulation of stretch reflex magnitude in people who were trained to either increase or decrease their reflex output (3), and similar results in individuals with SCI (4) indicate that spinal neural circuitry has the capacity for activity-dependent plasticity. The spinal cord is able to generate complex, rhythmic behaviors in the absence of both supraspinal and proprioceptive information (for review see Field-Fote (16)); these central pattern generating circuits contribute to locomotor function (7, 8) and respond to training. The rhythmic input evoked by a moving treadmill is a form of sensory input that may be a useful adjunct to training spinal neural mechanisms. The type of training used, training intensity, frequency, and task-specificity are important factors that contribute to motor performance outcomes. The evidence that spinal neuronal organization is susceptible to influence from sources other than supraspinal centers is important in the rehabilitation of individuals with SCI.

In conclusion, to our knowledge, this is the first report of an individual with chronic AIS SCI A improving in over-ground walking ability following participation in a program of intensive physical therapy and locomotor training. The controlled reciprocal movements of robotic locomotor stepping may provide sufficient afferent cues to stimulate appropriately timed lower-extremity electromyography activity (7, 8), access operational neural pathways (6), enhance locomotion (17) and enable the production of functional movement in individuals classified as AIS SCI A. Caution must be employed when extrapolating these findings to all individuals with AIS SCI A. This individual's lesion probably was neurophysiologically "discomplete" and therefore benefited from training of operational neural pathways. For this particular individual's damaged spinal cord, the combined effects of intensive task-specific training provided sufficient afferent input and descending voluntary activation to promote neural plasticity, resulting in improved functional abilities. These results may not be generalizable to all individuals with chronic AIS SCI A. Limitations of the ASIA in assessing completeness of SCI include qualitative grading of voluntary motor function in 10 muscles exclusive of thoracic levels, variability in scoring conscious sensory function, and extensive individual variability in preserved function after SCI (1). Further research is required to elucidate the extent to which other people with chronic AIS SCI A may benefit from a similar intervention program.

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