



Two-week intensive locomotor training improves balance and mobility of a person with chronic incomplete C4 tetraparesis

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Abstract

Background: Literature supports the achievement of meaningful functional outcomes following long duration intensive locomotor training (LT). However, these long duration protocols may not be feasible in the current reimbursement environment. The purpose of this case report was to determine if similar functional gains can be achieved through a shorter duration, high intensity training in a person with chronic motor-incomplete C4 tetraparesis.

Case presentation: The patient was a 61-year-old male with a chronic incomplete spinal cord injury (iSCI) level C4 ASIA Impairment Scale (AIS) D (16 months). The intervention was initiated after 13 months of traditional outpatient physical therapy.

Discussion: Course of 10 sessions over two weeks of 90-minute intensive locomotor training comprised of body weight supported treadmill training (BWSTT) with manual assistance, overground training, and independent community integration. Improvements in the Berg Balance Scale, Timed Up and Go, independent walking distances, and self-reported quality of life were noted.

Conclusion: A patient with chronic (>1 year) SCI AIS D improved in walking ability and balance after two weeks of intensive locomotor training. The outcomes followed a similar trend seen with long duration protocols.

Keywords: Balance, motor-incomplete spinal cord injury, locomotor training

Background

Current research shows that in individuals with incomplete spinal cord injuries (iSCI), locomotor training leads to improved balance and walking and mitigates secondary health conditions related to decreased mobility and falls from impaired balance [1-3]. Experts at the Christopher and Dana Reeve Foundation NeuroRecovery Network (NRN) developed a standardized treatment protocol to maximize functional gains in participants with iSCI using locomotor training (LT) with three elements: body weight supported treadmill training (BWSTT), immediately followed by over ground training, and community integration. Outcomes of the training demonstrated statistically significant improvements in balance and walking after long durations (20-251 sessions) of LT [1-4].

Of the three elements in LT, safe environment and access to the patient's body for manual assistance makes BWSTT the

most commonly used method for balance and ambulation rehabilitation in patients with iSCI with American Spinal Injury Association Impairment Scale (AIS) C and D [5,6]. AIS levels can be found in **Table 1**. Ample research has demonstrated improvements in walking function after BWSTT in this population [1,5-14]. BWSTT allows for high step volume ideal for repetition needed for motor learning. Additionally, results of these studies support the concept that spinal cord circuitry, separate from supraspinal centers, respond to afferent stimuli resulting in a stepping pattern, similar to studies using other mammals [1,15-17].

The second element of the NRN protocol includes overground training to assess carryover from BWSTT and identify functional gait impairments [1,2]. A clinical trial by Field-Fote et al., [5] demonstrated greater improvements in functional walking with overground training when compared to treadmill training in

Table 1. American Spinal Injury Association Impairment Scale (AIS)*.

A	Complete
B	Sensory incomplete: sensory but not motor function is preserved below the neurological level and includes the sacral segments S4-S5
C	Motor incomplete: motor function is preserved below the neurological level, and more than half of key muscles below the neurological level have a muscle grade less than 3 strength
D	Motor incomplete: motor function is preserved below the neurological level, and at least half of key muscles below the neurological level have a muscle grade of 3 or more strength
E	Normal

*From: International Standards for Neurological Classification of Spinal Cord Injury. Available at: http://www.asia-spinalinjury.org/learning/ASIA_ISCOS_high.pdf. Accessed on April 21, 2016.

participants with iSCI C/D. The final element integrates task specific training to promote functional walking in a real world environment (community integration) [1,2,18-20]. Individuals practice and improve walking performance by learning to generate and control motor output when initiating steps in real life situations that are both cognitively and physically challenging [5,18-22].

There is a need for shorter, intense bouts of physical therapy designed to maximize functional gains similar to clinical trials with longer treatment duration, and reduce the impact of secondary conditions, minimizing health care costs. The purpose of this case report was to determine if functional gains attained through long duration intensive locomotor training (LT) could be achieved through short duration, high intensity training for a patient with a chronic motor-incomplete C4 tetraparesis.

Case presentation

Patient history

The 61-year-old male patient sustained fractures to cervical vertebrae two through four in a mountain biking accident 16 months ago. The medical diagnosis was SCI level C4 with tetraparesis AIS C.

After the accident, the patient was in acute care for two weeks before transferring to acute rehabilitation, where he completed 63 days of inpatient rehabilitation. He had completed approximately 13 months of outpatient physical therapy, with focus primarily on ambulation with assistive devices, endurance, and whole body strengthening and stability. The locomotor intervention began after a scheduled one-month therapy hiatus. This provided an advantage in that the changes could possibly be linked to the intervention rather than previous therapy. The patient was taking oral Baclofen daily, since initiation of outpatient therapies, for management of increased tone secondary to the SCI.

Prior level of function was independent in all activities

including regular walking and bike riding. Current functional level was ambulation one mile daily with wife using bilateral ankle foot orthotics (AFOs) and Lofstrand crutches. The patient's goals for this intervention were to improve strength, increase stamina, become a more proficient walker, and improve balance and stability.

Examination

Examination of impairment, activity limitations, and participation restrictions were conducted the week prior to the intervention. The patient had spasticity present in all extremity motions on the Modified Ashworth Scale, [23] the greatest was a score of four in right ankle plantar flexors. Proprioception [24] was intact in bilateral great toes, ankles, knees, hips, wrists, and elbows, and impaired in bilateral middle fingers. The AIS score was ASIA D with an upper-extremity (UE) motor score of 43/50 and lower-extremity (LE) motor score of 40/50, with higher motor scores on his left side, UE>LE.

The outcome measures chosen are recommended for patients with SCI [25]. Berg Balance Scale (BBS) is composed of 14 items and measures static and dynamic balance, quantitatively assessing fall risk [26]. He scored 30/56, indicating medium fall risk (21-40 BBS). The mean BBS score for tetraplegia is 50.7 (7.5 range=31 to 56) [27]. Six-Minute Walk Test (6MWT) assesses endurance by measuring the max distance that a person can walk in six minutes [28]. The patient walked 121.92 meters (400 feet) at 0.34 meters per second (mps) (0.76 miles per hour) on 6MWT with Lofstrand crutches. Normative data for patients with SCI American Spinal Injury Association (ASIA) D show a mean of 382.39 meters. Timed 10-Meter Walk Test (10MWT) records the time it takes an individual to ambulate the middle 10 meters in a 20 meter area [29,30]. This assesses comfortable and fast gait speed, while minimizing effects of endurance [30]. The patient walked at 0.32 mps at chosen speed, and 0.44 mps on 10MWT at fast speed with Lofstrand crutches. The normative data for chosen speed is a mean of 1.37 mps for individuals with chronic SCI AIS D [31]. The 60-second Sit-to-Stand (STS-60) tests the number of repetitions of sitting down and standing up that an individual can achieve in 60 seconds [32]. STS-60 is a measure of LE strength and force-generating capacity [33]. The patient did 10 repetitions with UE support. The Timed Up and Go (TUG) tests basic functional mobility and risk of falls [30-34]. The patient scored 45.8 seconds with Lofstrand crutches.

The World Health Organization Quality of Life (WHOQOL-BREF) assesses quality of life within the context of an individual's culture, value systems, personal goals, standards and concerns [35]. It is highly recommended for use with chronic SCI AIS C/D [25,36]. Scores in four domains are reported between 0-100, with a higher number indicating a higher quality of life [35]. WHOQOL-BREF domain scores were: Physical Health: 60.7, Psychological Health: 87.5, Social Relationships: 75, Environment: 81.3. The patient indicated scores consistent with normative data for individuals with chronic stroke

in the domain of physical health (mean score of 60.5), and a higher quality of life score for psychological health (59.8), social relationships (mean 62.1), and environment (67.9) [37].

Evaluation and physical therapy diagnosis

The patient was appropriate for intensive locomotor training according to a literature review indicating that inclusion criteria of incomplete SCI, ASIA classification of C or D, upper motor neuron involvement, SCI occurring in the past three years, and ambulating speed of less than 0.8 mps [38].

Patient presented with inability to ambulate independently in the community due to impaired balance, decreased endurance, slow gait speed, muscle weakness, UE and LE tone, decreased motor control and controlled mobility which make him a fall risk.

Intervention

The intensive locomotor training intervention consisted of 10 sessions, five times per week for two weeks (Table 2). Before each day of intervention baseline heart rate (HR) and blood pressure (BP) were obtained, followed by passive range of motion (PROM) to B LE and doffing of bilateral AFOs.

The intervention was replicated as closely as possible each day. The first task consisted of 40 minutes of BWSTT without UE support, primary physical therapist and physical therapy student assisting with LE advancement and weight shifting (Table 3). Heart rate and Borg Rating of Perceived Exertion (RPE) [39] were obtained every 3 minutes. Standing rest breaks were granted upon patient's request or when the primary physical therapist determined that the patient was not able to maintain proper gait mechanics. Breaks were recorded for time, though the 40 minute clock continued. Unweighting via LiteGait™

(Tempe, AZ) recorded as minimal, moderate, or maximal by feeling tension on the straps. The second task was 30 minutes of over ground activities in a 15.24 meter (50 foot) hallway on low ply carpet, five minutes each of six activities: walking with cognitive (counting) challenge, backwards walking, lateral stepping, slalom course through cones, stepping over 1.5x3.5 inch hurdles, and fast walking. Total session time was 90-110 minutes per day, including donning/doffing harness before and after treadmill, and transitioning between tasks (Table 3). The third task was independent daily activity 30 minutes community ambulation supervised by the patient's spouse (Table 4). A pedometer for step tracking was worn on the patient's right shoe; the number was multiplied by two for accurate step count.

The tasks were not changed for the purpose of consistency and repeatability during this intervention. Progress was determined by performance on each task. For the first task, tolerance to increased speeds while maintaining optimal mechanics, and decreased HR and reported RPE throughout task was considered progress. Progress in the second task was determined by increased distance covered in each task, and the patient's ability to perform optimal mechanics. For the third task, increased steps taken in 30 minutes in a variety of

Table 2. Intensive Locomotor Training Protocol.

Task	Time	Task Details
Task 1: BWSTT*	40 mins	Constant walking at speeds 0.48–0.94 mps
Task 2: Over ground activities with Lofstrand crutches	30 mins total time	5 mins Walking with cognitive (counting) challenge
		5 mins Backwards walking
		5 mins Lateral stepping
		5 mins Slalom course through cones
		5 mins Stepping over 2wx4h inch hurdles
	5 mins Fast walking	
Task 3: Community ambulation	30 mins	Community ambulation with Lofstrand crutches and bilateral AFOs**. Supervised by spouse. Step # recorded via pedometer.

*BWSTT: Body weight supported treadmill training

**AFOs: Ankle foot orthotics

Table 3. Body weight supported treadmill training program.

	Week 1		Week 2	
	Day 1	Day 5	Day 8	Day 12
Body weight support	Min	Mod	Mod	Mod
Walking time (m:s)*	33:20	37:42	39:27	38:40
Speed range (mps)	0.48-0.49 mps	0.89 mps	0.89 mps	0.89 mps
Distance (km)	0.90	2.17	2.12	2.24

m:s= minutes:seconds; mps= meters per second; km= kilometer

*Total time for task 1 was recorded for 40 minutes. Treadmill time was stopped if the patient took a standing rest break.

Table 4. Community Ambulation Log.

Day	Total steps/day	Steps during Task 3: Community Ambulation	Activity time (minutes)	Location
1	Pedometer was not recording at the hip		40	Home Depot
2			30	Home Depot
3	2508	1408	30	Neighborhood
4	2732	1388	30	Neighborhood
5	1900	288	30	Church
*6	940	456	30	Shopping
*7	2256	1868	42	Community
8	1772	952	30	Neighborhood
9	2192	488	40	Neighborhood
10	2048	938	35	Neighborhood
11	2100	1368	30	Indoors
12	2200	1420	30	Indoors

*Weekend day

environments was considered progress.

Outcomes

Impairment and activity level post-testing were administered in the week following the intervention. The patient's spasticity was present in all extremity movements on Modified Ashworth Scale, which were generally higher than pre-test. Proprioception was intact, except for bilateral middle fingers. AIS classification was ASIA D with an upper extremity (UE) motor score of 46/50 and lower extremity (LE) motor score of 47/50. The patient scored 40/56 on the BBS, indicating medium fall risk (21-40). A score of 41 would indicate a low fall risk [26]. He walked 150.67 meters at 0.42 mps with bilateral Lofstrand crutches on the 6MWT. The patient improved by 28.75 meters (23.58%), however, this did not meet the MDC of 45.8 meters [40]. Scores for Timed 10MWT were 0.29 mps at chosen speed with bilateral Lofstrand crutches (0.03 mps slower than pre-test), and 0.49 mps at fast speed (0.05 mps faster than pre test). Fast speed did not meet the minimal detectable change (MDC) of 0.163 mps [41] or 0.13mps [42]. The 60-second Sit-to-Stand improved by five repetitions (50%). TUG was 30.5 seconds with Lofstrand crutches, decreased time by 15.3 seconds (33.41% faster), and exceeded the MDC of 10.8 seconds [40]. WHOQOL-BREF domain scores increased in Physical Health, Social Relationships, and Environment, and stayed the same in Psychological Health. **Table 5** shows a summary of the outcomes.

Gait analysis pre intervention showed excess hip flexion with use of Lofstrand crutches, and impaired stability of right knee during stance phase of gait, slow gait speed. Post intervention showed excess hip flexion with use of Lofstrand crutches, and increased stability of right knee during stance phase of gait.

The patient met goal for decreased fall risk as shown by

improved BBS score by 10 points and TUG by a 15.3 second decrease. Improved ambulation was evident by increased maximum gait speed on 10MWT by 11.36% using Lofstrand crutches, and improved LE motor score by greater than one point in more than one muscle group, an overall seven point increase. While the patient met the goal of increasing walking distance on the 6MWT, it did not meet the MDC. The patient subjectively reported, "My legs are stronger, knee control is better, I walk more without my AFOs. And walk longer." "This has helped me in all areas."

Discussion

Prior to the intervention, gait and balance deficits impeded the patient's ability to ambulate long distances and safely negotiate the environment due to increased risk of fall. The patient's goal of "walking better" was directly targeted through intensive LT consisting of BWSTT, overground gait training, and community integration. The design of this intervention aimed to boost functional mobility in a short time frame in order to resume traditional outpatient physical therapy at a higher functional level. The intervention resulted in statistically significant improvement in balance (33% increase BBS and TUG) and sit-to-stand (50% increase), as well as individually meaningful improvements in gait speed and mobility (increased 23% 6MWT, and 11% 10MWT). Additionally the patient reported improved quality of life (WHOQOL-BREF increased 19% overall).

A study by the NRN found that intensive LT participants demonstrated improvements in BBS (average of 9.6 points); 6MWT distance (average 63 m); 10-MWT speeds (average 0.20 m/s) [22]. However, this study included participants as early as 32 days post injury, within the one year window of rapid recovery. A single patient case study with a 25-year-old male with chronic iSCI D using NRN standardized protocols

Table 5. Outcome measures.

Measure	Pre- intervention	Post-intervention	Point Change	Percent Change	MDC for SCI (if available)
Berg Balance Scale (BBS) ⁴⁷	30/56	40/56	+10	+33.33%	+7 for elderly
Six-minute walk test (6MWT) ⁴⁹	121.92 meters (0.34 mps)	150.67 meters (0.42 mps)	+28.75 meters	+23.58%	45.8 meters (150ft)
Timed 10-Meter Walk Test (10MWT) Chosen speed	0.32 mps	0.29 mps	-0.03 mps	9.38% slower	0.254 mps or 0.13mps
Timed 10-Meter Walk Test (10MWT) Fast speed	0.44 mps	0.49 mps	+0.05 mps	11.36% faster	0.163 mps or 0.13mps
60-second Sit-to-Stand	10 repetitions with UE	15 repetitions with UE	+5 repetitions	+50.0%	Not found
Timed Up and Go (TUG)	45.8 seconds	30.5 Seconds	-15.3 seconds	33.41% faster	10.8 seconds
World Health Organization Quality of Life (WHOQOL-BREF)					
Physical	60.7	75	+14.3	+23.6%	Not found
Psychological	87.5	87.5	0	0%	--
Social	75	91.7	+16.7	+22.3%	--
Environment	81.3	90.6	+9.3	+11.4%	--

for LT [23] conducted 100 sessions at five days per week for 90 minutes each visit. Participants demonstrated improvements in 6MWT (111% increase), and gait speed (23.5% increase).

Although the patient improved by smaller percentages than the patient in the Morrison [2] case study, results of this intervention were consistent with that of Harkema et al., [3] demonstrating improvements in walking ability, and balance. High frequency/duration is possible in a research setting, though many patients with chronic SCI do not have the annual insurance benefits or personal financial resources to cover such a large duration of exercise. As demonstrated in this report, intense bouts of short duration training can lead to both statistically significant and meaningful functional gains. Health care costs can be minimized while allowing for transition back to traditional outpatient physical therapy at a higher functional level. The findings have potential significant clinical implications as the short duration protocol described demonstrated a trend toward the same outcomes as the established longer duration protocols. That means that the patient was able to achieve similar functional improvements in shorter period of time, and with less treatment visits. Additional studies are needed to investigate if the gains are maintained in the long term following the shorter duration protocols.

Limitations

Alternative hypotheses for the positive outcomes of the intervention could be that natural healing is unpredictable and may still be occurring 2 or 3 years after the injury [43]. Learning and neuroplasticity happens in the brain even without rehabilitation [44,45]. Variations in hypertonicity may have affected the reliability of the pre and post test outcome measures. The patient reported difficulty with ambulation using Lofstrand crutches while experiencing increased hypertonicity in UEs. Additionally, it may have been beneficial to record RPE and HR during the functional outcome measures in order to determine the intensity of the patient's performance to compare pre and post-test intensity.

It is not possible to state a cause and effect relationship between patient's improvements and the intervention due to (n=1). No generalizations to the broader population of individuals with incomplete spinal cord injury can be made from this case report due to (n=1).

Future research is recommended with a clinical trial using a larger sample size of ambulatory patients with motor-incomplete SCI and a control group receiving the same number of sessions of intensive locomotor training in a less frequent time frame (two to three visits per week) for 10 sessions. Additionally, research should be done into the most effective treatment duration for locomotor training to boost functional outcomes while reducing health care costs.

Conclusion

Literature shows that intensive locomotor training as standardized by the NRN in individuals with motor iSCI demonstrate

statistically significant improvements in balance, gait speed and mechanics. Modeling after existing intervention protocol by the NRN, our intervention was reduced to ten visits to determine if improvements in gait and balance would be seen in a clinically relevant timeframe. The patient demonstrated improvements in balance and gait mechanics, as well as an improvement in his UE and LE motor scores on the AIS. Additionally, the patient reported improved walking ability and quality of life. Achieving significant and meaningful gains in a shorter time frame could save in health care costs, making them more accessible for all individuals with chronic iSCI C/D.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

Authors' contributions	AEL	JCW	KB	GBL	RTL
Research concept and design	✓	✓	--	--	--
Collection and/or assembly of data	✓	✓	✓	--	--
Data analysis and interpretation	✓	✓	--	--	✓
Writing the article	✓	--	--	✓	✓
Critical revision of the article	✓	--	--	✓	✓
Final approval of article	✓	✓	✓	✓	✓
Statistical analysis	✓	✓	--	✓	✓

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