BRIEF REPORT

NeuroRecovery Network Provides Standardization of Locomotor Training for Persons With Incomplete Spinal Cord Injury

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ABSTRACT. Morrison SA, Forrest GF, VanHiel LR, Davé M, D'Urso D. NeuroRecovery Network provides standardization of locomotor training for persons with incomplete spinal cord injury. Arch Phys Med Rehabil 2012;93:1574-77.

Objective: To illustrate the continuity of care afforded by a standardized locomotor training program across a multisite network setting within the Christopher and Dana Reeve Foundation NeuroRecovery Network (NRN).

Design: Single patient case study.

Setting: Two geographically different hospital-based outpatient facilities.

Participants: This case highlights a 25-year-old man diagnosed with C4 motor incomplete spinal cord injury with American Spinal Injury Association Impairment Scale grade D.

Intervention: Standardized locomotor training program 5 sessions per week for 1.5 hours per session, for a total of 100 treatment sessions, with 40 sessions at 1 center and 60 at another.

Main Outcome Measures: Ten-meter walk test and 6-minute walk test were assessed at admission and discharge across both facilities. For each of the 100 treatment sessions percent body weight support, average, and maximum treadmill speed were evaluated.

Results: Locomotor endurance, as measured by the 6-minute walk test, and overground gait speed showed consistent improvement from admission to discharge. Throughout training, the patient decreased the need for body weight support and was able to tolerate faster treadmill speeds.

Conclusions: Data indicate that the patient continued to improve on both treatment parameters and walking function. Standardization across the NRN centers provided a mechanism for delivering consistent and reproducible locomotor training programs across 2 facilities without disrupting training or recovery progression.

Key Words: Rehabilitation; Spinal cord injuries.

LOCOMOTOR TRAINING using partial body weight support over a treadmill with manual assistance improves recovery of walking in persons with motor incomplete spinal cord injury (SCI).[1-6] The improvements observed in walking function include increased speed,[1-3] distance,[3,4] level of independence,[1,5,6] and time spent in the community.[1] Maintenance of such improvements has been documented for 6 months to 6.5 years posttraining.[4,5,7,8]

The Christopher and Dana Reeve Foundation NeuroRecovery Network (NRN) integrated specialized centers to provide standardized activity-based rehabilitation for individuals with motor incomplete SCI in outpatient rehabilitation settings. Seven NRN centers have undergone extensive training to standardize the locomotor training intervention, as well as the measurement of outcomes. All 7 centers use the same equipment to execute the treatment protocol. In addition, each center populates a national database to allow the NRN to analyze session parameters and outcome data. In keeping with the *International Classification of Functioning, Disability and Health* outcome assessments collected are in the body functions and structures, activity, and participation domains.[9]

Standardization of treatment interventions and outcome measurements is important for demonstrating the efficiency and efficacy of therapy involved in current or future clinical trials.[10] Standardization of functional outcome measures allows for health care professionals to directly measure the efficacy of different rehabilitation treatments, as well as to allow effective communication among health care professionals throughout an individual's continuum of care.[11]

The purpose of this case study is to illustrate the continuity of care afforded by a standardized treatment protocol across a multisite network setting. Continuity of care was determined by evaluating whether the patient showed steady progression in treatment parameters as well as walking function across 2 different clinical sites within the NRN. The patient in this case study was chosen because he was the first patient within the NRN who received services at the 2 different sites.

METHODS

In order to standardize all testing and training protocols, the NRN directors facilitate yearly education to all staff in locomotor training theory, manual facilitation techniques, progression in treadmill, overground and community environments, and outcome measurement among all sites of the NRN. Each

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List of Abbreviations

AIS	American Spinal Injury Association Impairment Scale
ASIA	American Spinal Injury Association
NRN	NeuroRecovery Network
SCI	spinal cord injury

site also participates in monthly conference calls to discuss and review protocols, as well as reinforce the standardization of all protocols through the use of video case studies.

Each locomotor training session has 3 components and occurs 3 to 5 times per week. The first component is step/stand retraining. Step/stand retraining involves walking and standing on a treadmill in a controlled environment using body weight support with verbal and manual facilitation led by a physical therapist. Up to 3 additional staff members assist with manual facilitation of the leg movements and trunk, as well as control the body weight support and treadmill parameters. The second component consists of overground training to evaluate the transfer of current capacity of the patient's neuromuscular system to mobility, posture, and walking skills over level ground. The final component, community integration, provides instruction for the patient to perform his/her daily activities in the home and community environment. Patients continue in the program as long as they progress in any of the 3 components of training.

The admission criteria for the NRN include persons who have a nonprogressive SCI above the 11th thoracic level with an American Spinal Injury Association (ASIA) Impairment Scale (AIS) grade of C or D. The patient for this case study was a 25-year-old man who sustained an SCI after falling 10.7m on January 15, 2007. He entered the outpatient NRN locomotor training program at the Kessler Institute for Rehabilitation on September 11, 2007 with an admitting diagnosis of C4 tetraplegia and AIS grade D. His ASIA upper extremity motor score was 50 (out of 50) and his ASIA lower extremity motor score was 50 (out of 50). (The upper extremity motor score is derived from adding the scores of the following 5 muscle groups bilaterally on a scale of 0 to 5: elbow flexors, wrist extensors, elbow extensors, long finger flexors, and abductor on the fifth digit. The lower extremity motor score is derived from adding the scores of the following 5 muscles bilaterally on a scale of 0 to 5: hip flexors, knee extensors, ankle dorsiflexors, long toe extensors, and ankle plantarflexors. His sensory score was 86 (out of 112) for light touch and 80 (out of 112) for pin prick for a total ASIA sensory score of 166 (out of 244). On NRN admission, he could walk without an assistive device, but demonstrated difficulty walking as a result of right lower extremity hypertonicity (per NRN protocol, patients are not to receive any antispasticity medication or injections). The observed clinical gait deviations included the following: (1) decreased right heel strike, (2) right toe drag at the initiation of swing phase, (3) decreased right knee flexion during swing, (4) increased circumduction of right lower extremity during swing, and (5) decreased right hip extension during terminal stance on the right. This patient's walking function was more advanced than most individuals admitted to the NRN; however, his primary recovery goal was to return to his previous occupation in the military, which required jogging and running safely on all surfaces, stopping/starting to walk unexpectedly, and quickly changing directions on command. The patient participated in the intense outpatient NRN locomotor training program 5 days per week for 1.5 hours per treatment session. Each session included training on a TheraStride body weight support treadmill system,[a] overground training, and community ambulation skills and integration. Per the NRN protocol, each 60-minute treadmill session addressed step/stance retraining using manual facilitation techniques and step/stand adaptability to promote independence.

The patient participated in the above protocol for 40 sessions at the Kessler Institute for Rehabilitation. The patient then requested to transfer his NRN locomotor training to Atlanta, Georgia, because of his family residing in Atlanta. He was subsequently discharged from the Kessler Institute for Rehabilitation on November 15, 2007 and was admitted to Shepherd Center on December 14, 2007. He received the same NRN protocol for an additional 60 sessions and was discharged on March 31, 2008. The patient was discharged because he had met the recovery goals of his rehabilitation as well as he, in the best professional judgment of the physical therapist and physician, would not have improved any further in walking function with continued treatment sessions. Throughout the 100 treatment sessions at both facilities, locomotor training was the only therapy intervention this patient received.

Standardized clinical outcome assessments were performed by an NRN trained physical therapist during initial and discharge evaluations at each center. The 10-meter walk test was performed using a straight walkway 14-m long. The patient was asked to walk as fast as he could, and the time he took to walk the middle 10-m was recorded in seconds.[12] The 6-minute walk test was performed using standardized verbal instructions.[12] The patient walked as far as he could for 6 minutes without resting using a 30.48-meters straight walkway marked by cones at each end. The distance walked for the 6 minutes was recorded. Training intensity was measured across 100 sessions using the amount of body weight support required, the average treadmill speed during each training session, and the maximum treadmill speed tolerated during each session. All applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed.

Analysis

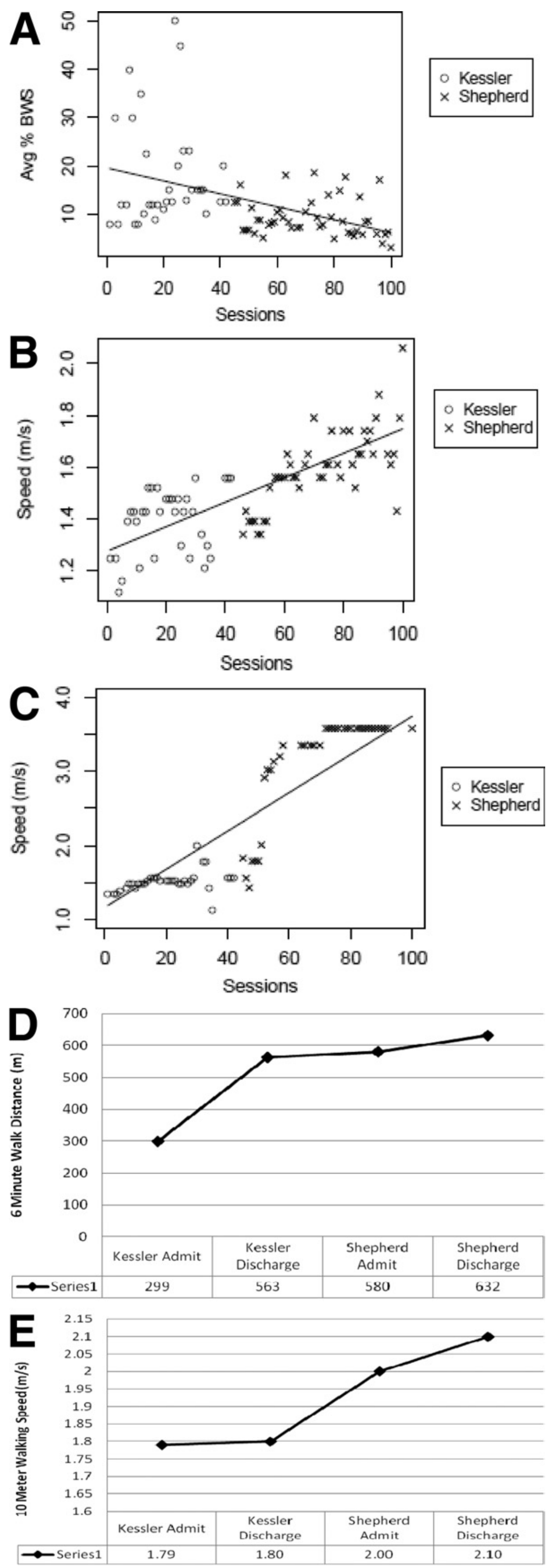
A recursive cumulative sum test[13] was applied to test the standardization of therapy and uniformity of recovery in treadmill speeds (average and maximum) and percent body weight support over time between centers. The recursive cumulative sum test can be used to identify structural shifts (shifts and/or changes in slope) in a time series, and hence evaluate whether the patient's change in centers resulted in a change in recovery. To estimate the rate of improvement of this patient in treadmill speed and percent body weight support over time, a generalized least-squares model with an autoregressive error structure of order 1 was fit, to account for the time series nature of the data.

RESULTS

Over the 100 sessions, the body weight support decreased from the patient requiring 30% of his body weight support during step training to requiring 3% body weight support (fig 1A). The average treadmill speed per treatment session also showed an improvement over the 100 sessions ranging from 0.98m/s to 2.06m/s (fig 1B). Lastly, the maximum treadmill speed tolerated during each treatment session increased from 1.4m/s at the Kessler Institute for Rehabilitation to 3.58m/s at the Shepherd Center (fig 1C).

The patient attended 100% of the scheduled treatment sessions. The only interruptions of care included the 1-month delay between discharge from the Kessler Institute for Rehabilitation and admission to the Shepherd Center (time requested to move his belongings), as well as 14 days during the holidays. No adverse events were noted throughout all 100 sessions. On admission to the NRN at the Kessler Institute for Rehabilitation, the patient's 6-minute walk test was 299m and improved to 632m by discharge from the NRN program at the Shepherd Center (fig 1D). Walking speed, as determined by the 10-meter walk test, increased from 1.79m/s at admission to the Kessler Institute for Rehabilitation to 2.1m/s at time of discharge from Shepherd Center (fig 1E).

While figure 1A shows deviation in average training speed across the 2 sites, the recursive cumulative sum test[13] was



established so that there were no significant changes in treadmill speed (P=.09) and body weight support (P=.29) across sessions. The intercept from the generalized least-squares model was 1.28 (1.20, 1.35), and the slope was 0.0047 (0.004, 0.006). The rate of improvement of average speed was significant (P<.0001). Importantly, the recursive cumulative sum test identified a significant (P=.03) structural shift in the data at the switch from the Kessler Institute for Rehabilitation to the Shepherd Center, that is, the average speed significantly shifted downward at the switch (although the rate of improvement did not significantly change). For maximum speed (see fig 1C), the linear regression intercept was 1.02 (0.35, 1.69), and slope was 0.027 (0.016, 0.038). The rate of improvement of maximum speed was significant (P<.0001). Further, the recursive cumulative sum test showed no evidence (P=.44) of a structural change, that is, either a shift in the line of best fit or a change in the slope. For body weight support, the linear regression intercept was 19.6 (16, 23.1), and the slope was −0.13 (−0.19, −0.07). The rate of decrease in body weight support was significant (P<.0001), and the recursive cumulative sum test (P=.37) showed no shift or change in slope.

The patient's stated goals were also achieved. At the time of the Shepherd Center discharge, the patient was able to run overground (with and without a 6.804-kg backpack) and was able to stop, start, and change direction quickly. He was also able to perform other high-level activities such as combat rolls, crawling, and jumping. All of these skills allowed him to return to his previous employment. There were no observed gait deviations at the time of the Shepherd Center discharge.

DISCUSSION

This case study presented data from 2 NRN locomotor training sites. At both NRN sites the standardized locomotor training progressions consisted of bouts of step and stand adaptability, and bouts of step and stand retraining, average training, treadmill speeds, and body weight support for 100 sessions of locomotor training therapy. The steady incline in the average treadmill training speed with steady decline in body weight support demonstrated the progression of 1 hour, locomotor training sessions. While there were steady increases in average and maximum treadmill speed and increases in body weight loading on the treadmill over time, our analyses showed no statistically significant shift in treatment dosage (for treadmill training speed or body weight support) across both NRN sites. This clearly demonstrates the standardization of locomotor training therapy across sites.

The infrastructure of the NRN through meetings, conference calls, and data screening processes allowed for our patient to experience standardized, activity-based locomotor training across 2 geographically different centers. This standardization of performing outcome measures, treatment paradigms (training dosing, intensity and duration of locomotor training), treatment progression, and equipment allow for a continuity of treatment progression, within and across the 2 geographically distant centers. While at the Kessler Institute for Rehabilitation,

Fig 1. (A) Results of average body weight support per session, (B) average treadmill speed per session, and (C) maximum treadmill speed, (D) 6-minute walk test, and (E) 10-meter walk test across 100 treatment sessions delivered by 2 rehabilitation centers (Kessler Rehabilitation Institute and Shepherd Center). Note that for 1A, the body weight support intercept was: 19.6 (16.0, 23.1); body weight support slope: −0.13 (−0.19, −0.07). Recursive cumulative sum test: *P*=.37. Abbreviation: BWS, body weight support.

the patient walked between a maximum speed of 1.3m/s to 1.8m/s, whereas at the Shepherd Center the maximum speed peaked aggressively to 3.6m/s. The linear regression analysis for average speed and maximum speed demonstrated a consistent and significant rate of improvement over the 100 training sessions in these treadmill walking measures. The initial decrease in average treadmill speed at Shepherd Center did not affect overall rate of improvement in treadmill walking speed.

Lam et al,[14] using meta data analysis for incomplete SCI data (C2-L1; <12-mo postinjury), calculated the smallest change or smallest real difference in overground walking measures that represent a real (clinical) change beyond 0, with 95% confidence.[15] These smallest real difference values indicate how well an outcome measure would be able to detect a clinically relevant change.[15] A change (or smallest real difference) of 45.8m was found to detect significant clinical change in the 6-minute walk test, and a change of 0.05m/s was found to detect significant clinical change on the 10-meter walk test. Based on Lam's[14] data and calculations, both sets of discharge walking data at the Kessler Institute for Rehabilitation and the Shepherd Center show a positive change for walking distance and a trend toward a gain in speed, which are both clinically relevant.[15]

The positive linearity of the average walking speed and decrease in body weight support showed the consistency in the training protocol, and the overground walking/running abilities demonstrated the gains in functional ability for the individual. This continuum of progression would have been difficult to substantiate if the patient received care by a non-NRN center at either of the 2 time frames. The quality of the information the physical therapist received in regards to functional status and treatment planning between facilities would have been reduced because of the high probability that the facilities would use different outcome measures and/or treatment protocols. This diminished transference of information may have contributed to a further interruption of care and/or reduction in performance until new treatment protocols are established. However, these consequences did not occur for this patient. Efforts to standardize other activity-based assessments and treatment protocols may be valuable.

Study Limitations

Limitations of this case study from a clinical outcome perspective are: (1) the lack of information on the spatial temporal parameters; (2) the lack of improvement or ceiling effect shown for balance and walking ability; and (3) the patient was highly functional at the time of admission to the NRN and therefore it is difficult to discern if progression was because of natural recovery or the treatment intervention. Limitations of establishing a similar network, such as the NRN, include: (1) incorporating locomotor training using body weight–supported treadmill systems can be financially difficult for some facilities; however, such programs have been shown to be financially feasible,[16] and (2) the cost of the personnel and travel expenses for the twice a year training, as well as the monthly calls.

CONCLUSIONS

This case study is an example of how treatment interventions can be standardized across centers to provide consistent and reproducible services to a patient who was involved in a locomotor training program. The NRN is a good example of how to provide standardized interventions and outcome measurements for a locomotor training program for persons with motor incomplete SCI. The standardization of delivering a treatment program and measuring outcomes provides a mechanism for collecting baseline data for future research, while allowing the continuum of care to be recorded and tracked.

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