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Using Mirrors for Visual Feedback During Early Strengthening Following a Non-Traumatic Spinal Cord Injury: A Case Report

Abigail Drexler
University of Iowa

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Abigail Drexler

DPT Class of 2018
Department of Physical Therapy & Rehabilitation Science
The University of Iowa

Abstract

Background: Non-traumatic spinal cord injuries (NTSCI) occur commonly due to causes such as spinal cord degeneration, vascular disease, tumors or inflammation. These injuries can lead to loss of motor function and sensory impairments affecting patients' abilities to complete Activities of Daily Living (ADLs) and return to independence. **Purpose**: The purpose of this case report is to describe the use of a mirror for feedback with early strengthening in a NTSCI patient with impaired sensation and muscle weakness in bilateral lower extremities. **Case Description:** A 38-year-old female with a T7 hemangioma resection, T5-6 laminectomy, and T5-T9 posterior spinal fusion was seen in a sub-acute inpatient rehabilitation facility for three weeks for lower extremity strengthening, balance training, gait training, and endurance training. **Outcomes**: The patient improved Functional Independence Measure (FIM) scores, specifically in areas of bed-to-chair transfers, locomotion, and stairs. Scores improved from total assistance to modified independence for transfers and ambulation and to max assistance for stairs. **Discussion**: Using a mirror for feedback to improve lower extremity strengthening and to decrease the co-activation of agonist and antagonist muscle groups can be an effective and low-cost solution in the inpatient rehabilitation setting for patients with a NTSCI.

Keywords: Spinal cord injury; non-traumatic; mirror therapy; neurology; physical therapy; rehabilitation; NTSCI; level of assistance

Background

Approximately 12,000 new cases of traumatic spinal cord injury occur each year in the United States, while another 3,000 new cases of spinal cord impairments are due to disease or congenital anomalies.[1] Frequent causes of non-traumatic spinal cord injury (NTSCI) include degeneration of the spinal cord, vascular disease, benign or malignant tumors, and inflammation.[1] NTSCIs tend to occur more frequently in older individuals related to their increased likelihood of comorbidities.[1] A study in the Netherlands looked at length of stay and functional outcomes after NTSCI and determined the length of stay was related most to the cause of the NTSCI with an average length of stay in the rehab center of 86.2 days.[1] However, a 2005 United States study determined the average length of stay to be 50 days between the acute setting (12 days) and inpatient rehabilitation setting (38 days).[2] Another study evaluated the effects of gender on outcomes with an incomplete NTSCI in the elderly population. This study found an average length of stay for patients with malignant spinal tumors in the inpatient rehabilitation setting to be 17.5 days for men and 18.3 days for women.[3]

The effects of NTSCI can lead to loss of motor function, sensory impairments and bladder or bowel involvement depending on the level of lesion and area of the spinal cord affected.[2] One type of sensory input that can be impaired following a NTSCI is proprioceptive input. Proprioception is defined as an individual's ability to determine body segment position and body movement in space based on signals traveling from muscle, joint and skin receptors to the brain.[4] Motor learning and motor adaptation to environments that are changing rely on adequate feedback in the form of proprioception.[2] Proprioception, two-point discrimination, and vibration sense is relayed to the cerebral cortex in the brain using the dorsal column-medial lemniscus pathway from the spinal cord.[5] Therefore, if the dorsal aspect of the spinal cord is disrupted due to a spinal cord injury, it is likely for patients to have proprioception impairments in addition to impairments in two-point discrimination and vibration sense.[2] Initially, the rehabilitation process following a spinal cord injury focuses on regaining as much function as possible, but muscle weakness in an incomplete spinal cord injury may be prominent enough to require the use of gravity-eliminated exercises with tools such as skateboards, powder boards, and air splints.[2]

An individual's visual system is responsible for helping to integrate perceptual development by providing information about body positioning and spatial relationships to other people or objects.[2] In a 2017 study, it was found that when proprioception is impaired, ambulatory individuals with a spinal cord injury rely more on vision to cross over obstacles since their position sense has been altered.[6] While vision can help with aspects of movement quality, when other feedback systems like proprioception are impaired the visual system remains less efficient and requires increased concentration to achieve fluid movement.[2]

Research has recently integrated more feedback in the form of augmented reality to target both motor dysfunction and neuropathic pain for individuals with incomplete spinal cord injuries. Villiger found in 2013 found that walking speed, balance, and neuropathic pain all improved following a four week, 16-20 session intervention with a virtual reality simulation of a person's lower limb use.[7] While effective, virtual reality treatment may be costly and impractical for clinical application in the sub-acute setting after an incomplete spinal cord injury.

The purpose of this case study is to describe the use of mirrors for visual feedback in a patient with impaired proprioception and sensation during the initial strengthening period following a spinal tumor resection in a spinal cord injury patient.

Case Description

The patient was a 38-year-old female who presented to a sub-acute rehabilitation facility for treatment following a T7 hemangioma resection, T5-6 laminectomy, and T5-T9 posterior spinal fusion. Her pertinent past medical history included a thoracic spinal tumor resection in 2005 and smoking 10+ cigarettes per day. Eleven months prior to her admission at an inpatient rehabilitation facility, she started to note bilateral lower extremity weakness and paresthesia.

She was treated conservatively with serial Magnetic Resonance Imagining (MRI) and physical therapy with the focus on maintaining lower extremity strength and function. Her symptoms progressed four weeks before surgery, requiring the use of a walker. A wheelchair was needed soon after for mobility due to decreased strength and sensation. She also reported having had difficulty sensing the need to void urine and was straining to urinate at that four-week time mark prior to surgery. The patient then presented to the emergency department where she was admitted for a spinal tumor resection. Pre-operatively in the emergency department, the patient was reported to have +1 to 2/5 manual muscle strength in bilateral lower extremities as well as diminished sensation bilaterally, her left presented with more deficits than her right lower extremity. Six days following surgery, the patient was discharged from an acute setting and admitted to the inpatient rehabilitation facility where she reported no change in lower extremity strength, sensation or incontinence since surgery.

The physical therapy examination revealed no upper extremity impairments and lower extremity passive range of motion was within functional limits. Manual muscle testing (MMT) of bilateral lower extremities revealed moderate to severe weakness bilaterally (Table 1). MMT is a commonly used method to determine impairments in muscle strength. Reliability ranges from 0.68 to 0.98 with individual muscle groups and ranges from 0.57 to 1 for a total MMT score.[8]

Neurological screening revealed normal tone bilaterally to passive range of motion, however the patient reported extensor tone at night and in the morning. Clonus was present in bilateral ankles with 3-4 beats on each side. Light touch was impaired in bilateral lower extremities in all dermatomes. Proprioception was impaired in the right lower extremity at the great toe but intact in the left lower extremity.

The patient had good static sitting balance but delayed righting and protective reactions when provided with perturbations. She required moderate assistance to transfer from supine to sit (with bilateral lower extremities), minimal contact assistance for sit-to-supine (for bilateral lower extremities and trunk positioning), and moderate assistance for scooting, sit-to-stand, and stand-to-sit activities. She required total assistance for toilet transfers (Table 2). For mobility, the patient required moderate assistance of two individuals to ambulate. Using a front wheeled walker, she was able to walk 15 feet during her initial evaluation. Her gait was described as shuffling with a wide base of support. She had difficulty with right foot and toe clearance and ambulated with maximal weight bearing through bilateral upper extremities on the front-wheeled walker. The patient reported having bilateral ankle foot orthoses (AFO), which were obtained within the last few months at outpatient physical therapy, but she had not worn them within the last month due to lower extremity edema and because she was not ambulatory in the month prior to admission.

To look at performance of activities of daily living (ADLs), a Functional Independence Measure (FIM) was administered by the inpatient rehabilitation team. Items on the FIM evaluated by physical therapy and pertinent to physical therapy goals included a transfer between the bed and chair, locomotion via wheelchair and ambulation, and stairs. Tables 2 and 3 detail the items administered for the FIM and scoring criteria. The patient required total assistance, a score of 1, for the bed-to-chair or wheelchair transfer because she required two people to safely transfer using a stand-pivot transfer method. For locomotion, the patient required total assistance, scoring a 1, as she ambulated a short distance of about 15 feet, but required two helpers and only performed less than 25 percent of the activity independently. The patient scored a 5, which indicates supervision/set up, for wheelchair mobility as she required set-up to get into the chair but was otherwise able to navigate the chair for the designated 150 feet distance independently. The activity of stairs was not assessed because therapy staff deemed the task unsafe to perform.

The patient expressed personal goals of being able to walk short distances such as to and from the bathroom with a walker independently in her home. She also wanted to be able to care for her two young children with day-to-day tasks.

Table 1. Manual Muscle Testing (MMT) results at initial evaluation.

	Left lower extremity	Right lower extremity
Hip flexion	3+/5	3/5
Hip abduction	2-/5	2-/5
Hip adduction	2/5	2-/5
Knee flexion	2-/5	2-/5
Knee extension	4/5	4/5
Ankle dorsiflexion	3+/5	1/5
Ankle plantarflexion	1/5	1/5

Table 2. Functional Independence Measure (FIM) scoring criteria used at admission and discharge.[9]

Rating	Description
(1) Total Assistance	Performs <25% of the activity independently, requires assistance from a helper or two helpers
(2) Maximal Assistance	Performs >25% but less than 50% of the activity independently, requires assistance from a helper
(3) Moderate Assistance	Performs >50% but less than 75% of the activity independently, requires assistance from a helper
(4) Minimal Assistance	Performs >75% of the activity independently but requires assistance from a helper
(5) Supervision or set up	Performs 100% of the activity independently but requires help in setting up or supervision for safety to complete the activity
(6) Modified Independence	Performs the activity without a helper but may require use of a device such as a walker, bed railings, etc.
(7) Complete Independence	Performs the activity safely and in a timely manner without an assistive device or a helper

Table 3. FIM items evaluated at admission and discharge. Bolded items are scored by a physical therapist in this rehabilitation setting.[9]

1. Eating
2. Grooming
3. Bathing
4. Upper body dressing
5. Lower body dressing
6. Toileting
7. Bladder management
8. Bowel management
9. **Bed to chair to wheelchair transfer**
10. Toilet transfer
11. Shower transfer
12. **Locomotion (ambulatory and/or wheelchair)**
13. **Stairs**
14. Cognitive comprehension
15. Expression
16. Social interaction
17. Problem solving
18. Memory

Intervention

The patient was seen for three hours of therapy a day, half of which was physical therapy and half of which was occupational therapy. She was seen at least five days a week. For purposes of this case study the interventions most related to use of a mirror for feedback will be discussed, however a summary of other interventions is also included as the treatment evolved beyond this initial stage once proper activation of muscle groups was achieved.

On the first day of physical therapy intervention in the inpatient rehab setting, the patient attempted supine and side-lying exercises using a powder board due to impaired muscle contractions and fatigue in positions where overcoming gravity was required. A powder board is a tool placed under an extremity while in the supine position or between bilateral extremities in side-lying to reduce the amount of friction between the patients' extremity and the mat surface on which patients are typically laying. Baby powder can be added to the top of the board to reduce friction. Otherwise, a skate can be attached via straps to an extremity to roll over the board surface. Therefore, a powder board and a roller skate was attached to each lower extremity for this patient to provide both a gravity eliminated and friction eliminated environment. After verbal cues and maximum assistance to perform activities such as hip flexion, hip abduction, hip adduction, knee flexion and extension, the patient reported that she was unable to feel whether her lower extremities were performing the movement correctly. Due to positioning in supine and side-lying, the patient was unable to easily visualize whether her muscles were contracting appropriately to perform the desired strengthening activity. Therefore, a full-length mirror was adjusted so that her bilateral lower extremities could be visualized. Once a mirror was added on the first day, the patient required only minimum to moderate assistance to complete lower extremity strengthening exercises using a powder board and roller skate. She continued to have co-contraction of agonist and antagonist muscles, but to a lesser degree than she had without visual feedback. The strengthening exercises completed were supine hip flexion and hip abduction, hook lying hip abduction and adduction with minimal assist for the left leg and moderate assistance for the right leg. She also completed side-lying bilateral hip and knee flexion together, hip and knee extension performed together and a forward bicycle motion. Minimal assistance was provided for all side-lying activities to achieve full range of motion. Fifteen repetitions were performed for each exercise. This number was chosen because the patient was fatigued and could no longer perform additional repetitions with quality motion or without increased assistance.

On the second day of rehabilitation, the patient appropriately decreased co-activation of antagonist and agonist muscle groups with supine and side-lying exercises in a gravity and friction eliminated environment. The patient first attempted the exercises without a mirror, but she was unable to accurately perform the movements without the visual input. So again, visual feedback from a full-length mirror was provided to the patient. Supine exercises performed included bilateral hip flexion, hip abduction and adduction, hip extension and knee extension, as well as backwards and forwards bicycle motions. Verbal and tactile tapping cues were provided occasionally throughout 15 repetitions or until fatigue for each exercise.

On the third day of inpatient rehabilitation, the patient continued to require a mirror for visual feedback but required less physical assistance to complete full sets of the exercises. Exercises were similar as those listed for days one and two.

Days four through eight of rehabilitation involved therapeutic exercise and strengthening which progressed similarly as days previously. She continued to require visual input from a mirror but assistance with the exercises and need for verbal corrections decreased with each subsequent day. The majority of assistance was required at end range of motion. For example, on day seven, the patient could only perform 50% of full hip abduction range of motion in a supine position with the use of the powder board and skate. During these days, core strengthening activities such as posterior pelvic tilts and partial range of motion bridges were also added to her daily exercises due to diminished core stability. A mirror was also provided for these core exercises because they required a lot of verbal and tactile cueing. Supine and side-lying stretching was initiated on day five because increased spasticity was noted in bilateral lower extremities. Stretching included bilateral hamstring, gastrocnemius, and hip extensor muscles.

On day nine of inpatient rehabilitation, the patient progressed to supine and side-lying strengthening exercises without use of a skate for bilateral lower extremities due to improvements in strength but still required use of a mirror for feedback to complete the specific exercises correctly.

By days ten, eleven, and twelve of inpatient rehabilitation, the patient had progressed beyond supine and side-lying exercises, and was now able to perform sitting (with assistance) and standing strengthening exercises (with use of upper extremities for balance support).

Other interventions performed with the patient included ambulation with a front-wheeled walker and the application of bilateral AFOs. Initially, on day two of rehabilitation, the patient required use of a sock over the front of her right foot in addition to bilateral AFOs due to decreased toe clearance. The patient ambulated with a front-wheeled walker, progressing to longer distances and less assistance. Balance activities such as static standing progressed to dynamic standing with functional reaching. Standing balance activities occurred while using her front-wheeled walker or a counter for stability with one upper extremity.

The patient completed 5-10 minutes about every other day starting on day five on a NuStep to improve endurance and bilateral coordination, but required assistance to keep her feet on the footplates and thighs in a neutral position due to lack of hip adduction strength. A Nustep is a recumbent bike that allows an individual to use both legs and arms in a reciprocal pattern. The length of time and level of difficulty can be adjusted. The patient also worked on bed mobility such as transferring from supine to sitting at the edge of bed, requiring moderate assistance to position her left knee for a log roll method. Having a mirror available was helpful in coordinating rolling to the right, particularly, because she had limited proprioception and awareness of the position of her left leg.

Outcomes

The patient was discharged from the inpatient rehabilitation setting to her home with her family 19 days after admission. She received a total of 16 days of therapeutic intervention with physical and occupational therapy providing about one and a half hours each of therapy per day.

MMT was not re-assessed beyond the initial evaluation due to improvements in functional strength in all areas such as transfers, ambulation, and ability to perform exercises against gravity by discharge.

A FIM was administered again at discharge with the following results most related to physical therapy intervention: bed to chair or wheelchair transfer improved from a rating of total assist (1) to complete independence (7). The ambulation score improved from total assistance (1) to modified independence (6) because she still required use of a front wheeled walker and right AFO. And finally, completion of stairs was scored as maximal assistance (2) as the patient required considerable assistance to complete four stairs safely, however this was an improvement since admission since stairs were not attempted. No data exists regarding minimally clinically important difference (MCID) for the FIM in spinal cord injury patients as much of the focus in the literature has been completed for stroke patients.

Another measure of outcome from the sub-acute inpatient rehabilitation stay is the change in assistance needed for ADL's pertinent to physical therapy, such as supine-to-sit and sit-to-stand transfers. These activities are directly related and use specific muscles targeted in the strengthening exercises performed throughout the patient's length of stay. Supine-to-sit required total assistance at admission and the patient reached a level of modified independence by discharge. The patient required moderate assistance for a sit-to-stand transfer at admission and reached a level of modified independence by discharge (Figure 1).

Other outcome measures may have been considered for this patient population. For example, the Spinal Cord Independence Measure (SCIM) is a measure similar to the FIM in that it looks at an individual's ability to complete ADLs but is specific to those with a spinal cord injury, whereas the FIM can be applied to all diagnoses for the inpatient rehabilitation sub-acute setting. The SCIM was not evaluated for this patient but may have been indicated as she had a non-traumatic spinal cord injury. The SCIM III inter-rater reliability ranges between 0.64 and 0.95. The construct validity has been performed and compared the SCIM to the FIM scores with an r=0.79 to 0.80.[10]

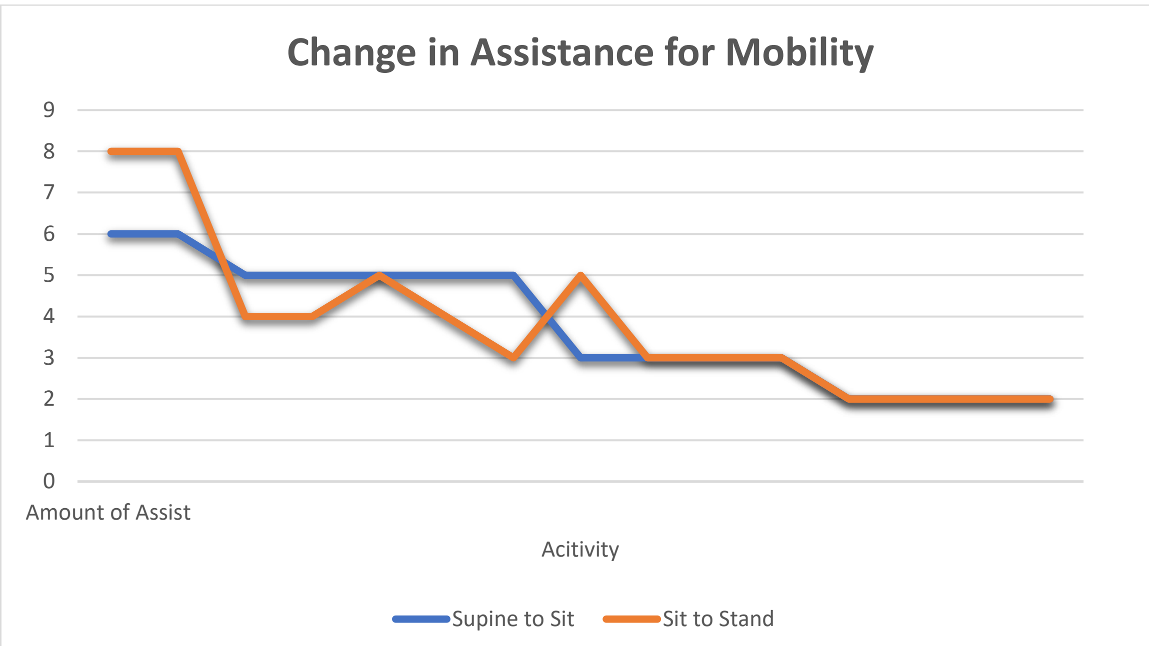

Figure 1. Amount of assistance required for mobility tasks supine-to-sit and sit-to-stand from admission to discharge. Total assistance (8), max assistance (7), moderate assistance (6), minimum assistance (5), contact guard assistance (4), supervision (3), modified independence (2), independence (1).

Discussion

The patient presented to an inpatient rehabilitation setting with complaints largely of decreased strength limiting her independence with ADLs such as ambulation, getting in and out of bed, and with managing her bowels and bladder due to a non-traumatic spinal cord injury. The intervention of using a mirror as feedback for early strengthening provided a low-cost method to improve specific muscle strength in supine and side-lying positions where visualization of the patient's bilateral lower extremities was difficult. On the first day of sub-acute rehabilitation, when visual feedback was provided via a mirror, the patient required less physical assistance to perform strengthening exercises, though her weakness and co-activation of muscle groups was severe enough that she also required use of a powder board and roller skate, which provided a gravity and friction eliminated environment.

Mirror visual feedback is commonly used to address phantom limb pain following limb amputation and for improvement in hemiparesis deficits after a stroke.[11] Recent studies on various feedback techniques in the non-traumatic spinal cord injury patient population has been looking at augmented reality[7] or force-plate feedback,[12] with virtually no studies involving mirror feedback. Improvements in function from force-plate feedback may be associated with fine-tuning any residual proprioceptive and sensory input following an incomplete spinal cord injury. Mirror feedback may similarly be beneficial for patients with impaired proprioception and sensation for re-learning how to perform specific tasks, such as activating specific muscles, given their new-normal feedback loop.

The type of feedback provided to a patient is also important to consider as the feedback may help or hurt their long-term success with an activity. Research by Sigrist indicates that feedback may facilitate compensatory mechanisms to overcome the loss of motor function rather than enhancing motor learning.[13] Concurrent feedback, feedback that is provided in real time, may be most important in the acquisition phase of a skill but no longer helpful once reaching the performance stage.[13] The mirror was used as a form of concurrent feedback, adjunct to both tactile and verbal cues, while the patient performed strengthening exercises. While strengthening exercises may not be viewed as a skilled or a functional activity, they do have a motor learning component. Strengthening exercises for this patient were indicated since functional activities such as sit-to-stand, bed mobility, and ambulation were challenging without adequate muscle strength, coordination, or substantial assistance. In this case, concurrent feedback via the mirror for supine and side-lying muscle strengthening was also beneficial related to the limitations in length of stay dictated by insurance coverage. Providing an extrinsic method with the mirror for getting feedback about the quality of movement seemed relevant to provide within the very first days of rehabilitation due to these insurance time constraints.

The patient demonstrated improvement in her functional strength by discharge, as she initially required total or moderate assistance but achieved a status of modified independence in activities of sit-to-stand and bed mobility (Figure 1). A minimal clinical important difference (MCID) value does not appear to exist in the literature regarding level of assistance for functional mobility goals such as sit-to-stand or for bed mobility in the spinal cord injury population. Moving supine-to-sit for this patient appeared to trend in a predictable pattern from requiring more assistance to less assistance whereas sit-to-stand transfers resulted in more day to day variability in the level of assistance required. The relatively consistent pattern of decreasing assistance needed with bed mobility may have occurred due to visual feedback from a mirror in beginning stages of therapy or also potentially related to a consistent environment for practice. With sit-to-stand transfers, though, factors such as fatigue level and different therapists reporting level of assistance may have impacted the higher variability observed in day to day trends for sit-to-stand level of assistance. In summary, the variability observed in assistance level in this patient for the sit-to-stand and bed mobility suggests a possible MCID for improvement in functional mobility. A larger difference or a change of at least two levels of assistance may be required for sit-to-stand transfers whereas only a one level change in assistance may be required for supine-to-sit bed mobility. Future studies with a larger sample size are needed to test this preliminary suggested MCID for mobility assistance scoring.

Future research is indicated to look at the effectiveness of using mirrors as a feedback method in the non-traumatic incomplete spinal cord population in comparison to costlier and time consuming methods such as augmented reality. This case suggests mirrors may provide a cost-effective approach for providing feedback in situations of impaired proprioception and sensation. It may also be beneficial to evaluate whether mirror feedback would be effective in situations of neurogenic pain in this population, though the patient in this case reported no pain.

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