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Locomotor Training and Virtual Reality-based Balance Training for an Individual with Multiple Sclerosis: A Case Report

George D. Fulk, PT, MSPT

ABSTRACT

Background and Purpose: Impaired walking ability, balance, and fatigue are common problems for people with multiple sclerosis (MS). The purpose of this case report is to describe the use of plan of care that included locomotor training using both a body weight support (BWS) with a treadmill (TM) and overground walking as well as a virtual reality (VR)-based balance intervention to improve walking ability, balance, and endurance for an individual with MS. **Case Description:** The client was a 48-year-old female with a 10-year history of MS. Her main goals were to improve walking ability, balance, and endurance. She presented with impaired gait, balance, motor function, and increased fatigue. Locomotor training using a BWS/TM system and overground and VR-based balance interventions were implemented 2 days a week for 12 weeks. **Outcomes:** The client demonstrated improvements in gait speed, gait endurance, and balance postintervention and maintained the improvements at a 2-month follow up. **Discussion:** This case report is the first to report on the use of locomotor training with BWS/TM system and overground and VR-based balance interventions for a client with MS. The plan of care was formulated based on the patient's goals and the available literature on the use of the interventions with other patients with neurologic conditions to provide an intervention that was task-oriented, skilled, and intensive.

Key Words: multiple sclerosis, locomotor training, body weight support, virtual reality, gait, balance

INTRODUCTION

There are approximately 400,000 individuals in the United States living with Multiple Sclerosis (MS).[1] Multiple Sclerosis is a chronic, progressive neurological disease with a clinical course that may result in severe disability. Common symptoms for individuals with MS include paresis, sensory impairment, spasticity, balance deficits, and fatigue.[2] These impairments often lead to gait disturbances and difficulty walking. Approximately 50% of individuals with MS will require assistance and/or an assistive device to ambulate short distances within 15 years of onset of the disease.[3] Between 50% and 60% of people with MS identify fatigue as the worst symptom that they experience.[4,5] Increased fatigue may affect the functional walking endurance of individuals with MS. It is therefore important to develop effective rehabilitation interventions to address gait, balance, and endurance in individuals with MS.

Different authors have compared the effectiveness of task-oriented physical therapy interventions to a facilitation-based approach to improve walking ability and balance in individuals with MS.[6,7] Both methods have been shown to improve functional mobility, walking speed, and balance.[6,7] However, neither approach was shown to be more beneficial than the other.[6,7]

Aerobic training utilizing an ergometer also has been evaluated with individuals with MS.[8,9] One group of researchers found that 3 to 4 weeks of lower extremity (LE) training in combination with in-patient rehabilitation produced significant improvements in aerobic threshold, health perception, and activity level compared to in-patient rehabilitation alone.[8] Rodgers and colleagues[9] found that a 6-month aerobic training program consisting of a combined upper extremity (UE) and LE ergometer had minimal effects on gait characteristics. After the training period, the subjects demonstrated a decrease in gait velocity, ankle dorsiflexion, and maximum hip extension.[9]

Locomotor training using a body weight support (BWS) and treadmill (TM) system is a task-oriented intervention that has shown promise in improving walking ability in individuals who have experienced neurological injuries such as a spinal cord injury,[10-13] Parkinson disease,[14] and stroke.[15-18] Locomotor training with a BWS/TM involves suspending the client in a parachute-like harness over a treadmill, which allows for a percentage of the client's weight to be relieved. Therapists are able to provide manual assistance to facilitate a normal walking pattern. This training modality allows for repetitive locomotor training throughout a complete gait cycle.

The use of virtual reality (VR)-based rehabilitation interventions has more recently been advocated as a potentially effective technique to improve function, gait, and balance in individuals with traumatic brain injury[19,20] and stroke.[21-24] Although both of these interventions—locomotor training with a BWS/TM system and VR based interventions—have shown promise with individuals with various neurological disorders, the literature has not reported on their use with individuals with MS. The purpose of this case report is to describe an intervention program consisting of locomotor training utilizing a BWS/TM system and overground and VR-based balance training with the goal of improving walking ability, balance, and endurance in a client with MS.

CASE DESCRIPTION

Examination

History

The client was a 48-year-old female with a diagnosis of MS. She had been diagnosed with MS 10 years earlier. The orders from the prescribing physician stated that the patient was being referred for physical therapy due to MS

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with lower extremity spasticity to improve ambulation. She reported that she was not going out as much with her family because she could not keep up with them and would become fatigued. However, she had not experienced an acute exacerbation of her symptoms at this time. She also stated that she was falling occasionally when doing yard work or walking on uneven surfaces. Her Expanded Disability Status Scale (EDSS)[25,26] score was a 2.5. The EDSS is a 10-point scale, with scores ranging from 0 to 10, for rating overall disability in individuals with MS. The EDSS focuses on walking ability as the primary indicator of disability.[2] She was taking the following medications: Avonex, Baclofen, and Zanaflex. The appropriate institutional review board approved this case study and the client provided informed consent.

Physical therapy tests and measures

The client was able to ambulate independently without an assistive device. Her self-selected gait speed, as measured over the middle 10 m of a 14 m walk, was 0.95 m/s and her gait endurance as measured over a 6-minute walk at her self-selected speed was 329 meters. Gait speed is a valid and reliable measure of walking ability in individuals with MS.[27-29] Although the 6-minute walk test has not been validated with individuals with MS, it is used with a variety of patient populations as a measure of walking endurance including those with cardiac disease,[30,31] pulmonary disease,[32] older adults,[33,34] stroke,[35-37] and brain injury.[35] Since a primary complaint of the patient was her inability to keep up with her family when walking in the community it was decided that the 6-minute walk test would be a clinically useful method of measuring her walking endurance.

Balance was assessed using a variety of different tests and measures. She demonstrated a positive Romberg with feet together with eyes closed. She could stand in this position for 6 seconds. Her Berg Balance Scale[38] (BBS) score was a 49/56. Although primarily used with geriatric clients and individuals with stroke, the BBS is a valid measure of balance for individuals with MS.[39-41]

The client's self-efficacy in her balance was assessed using the Activities-specific Balance Confidence (ABC) scale.[42] The ABC scale is a 16-item questionnaire that is administered through an interview. Total scores range from 0% (no confidence) to 100% (completely confident) in maintaining balance while performing 16 functional tasks. The ABC scale was originally designed to measure balance self-efficacy in community dwelling elders and has been shown to be valid and reliable with this population.[42] Although this outcome measure has not been used with people with MS, no comparable tool was found that had been validated with this population. The client's perception and confidence in her balance were one of the primary reasons the client sought out physical therapy services so it was decided that the ABC scale would be a clinically useful tool to measure this aspect of her balance. The client's initial score on the ABC scale was 73%.

Further balance testing was done using the sensory organization test (SOT) on the NeuroCom SMART Balance Master® (NeuroCom International, Inc., Clackamas, Ore). The platform posturography SOT of the Balance Master® has been shown to provide useful diagnostic information in patients with MS.[43] The SOT identifies impairments in the 3 primary sensory systems that contribute to balance: vestibular, vision, and somatosensory. The composite equilibrium score quantifies the center of gravity sway under the 6 different sensory conditions of the SOT: (1) normal vision with fixed support surface, (2) absent vision with fixed support surface, (3) sway referenced vision with fixed support surface, (4) normal vision with sway support surface, (5) absent vision with sway support surface, and (6) sway referenced vision and support surface. The client's initial composite equilibrium score was 65 and her sensory analysis vestibular score was 38. Both of these scores were less than the score achieved by 95% of age-matched individuals with no history or symptoms of balance dysfunction reported by the manufacturer (Table 1).

Fatigue was assessed using the abbreviated Modified Fatigue Impact Scale (MFIS) 5-item version.[44] The MFIS 5-item version contains 5 statements that describe how fatigue may impact an individual with MS. For example, one of the statements is "I have had trouble maintaining physical effort for long periods of time." The client was asked to rate how her fatigue has affected her during the past 4 weeks for each of the 5 statements on a 5-point ordinal scale with 0 equal to 'never' and 4 equal to 'almost always.' Scores range from 0 to 20, with a lower score indicating less fatigue. The MFIS was designed and validated specifically for individuals with MS.[5] The client's initial MFIS 5-item score was a 5/20.

The client's motor function in her UEs was within normal limits. The client exhibited impaired motor function in both of her LEs, with the left being more severely affected. The tone in her left knee extensors and plantar flexors was a 3 on the modified Ashworth scale[45] and it was a 2 in these same muscle groups in her right lower extremity. Muscle performance was measured using manual muscle testing procedures as described by Daniels and Worthingham.[46] These ranged from 5/5 to 3+/5 in the right lower extremity and 4/5 to 3-/5 in the left lower extremity. The client's sensation was tested as described by Schmitz[47] and was intact to light touch, pain, and proprioception in both lower extremities except for being impaired to light touch at the L5 dermatome in the left lower extremity. Passive range of motion (PROM) was grossly within functional limits in both lower extremities except for left hip extension was 5° from neutral.

The author, who had 9 years of experience working with clients with neurological disorders, performed all of the tests and measures during the client's first visit in the order presented above with the exception of the ABC scale, MFIS-5 item version, and the Balance Master® testing. The 2 questionnaires were administered at the end of the examination process on the first day and the Balance Master® testing was done during the client's second physical therapy session.

Table 1. Summary of Pre-, Post- and Follow Up Outcome Measures and Normative Values

Outcome Measure	Preintervention	Postintervention	2 Month Follow-up	Normative Values
Gait speed (10 meter walk)	0.95 m/s	1.15 m/s	1.16 m/s	1.02-1.37 m/s[53] 1.247 (0.144 SD) m/s[54]
Gait endurance (6 minute walk)	329 meters	410 meters	411 meters	573 meters[56] (low range 434 meters[56])
Berg Balance Scale	49/56	53/56	54/56	N/A
Activities-Specific Balance Confidence scale	73%	91%	86%	N/A
Composite Equilibrium score on SOT	65	75	67	80 (70)
Somatosensory Sensory Analysis Ratio on SOT	97	95	94	98 (90)
Visual Sensory Analysis Ratio on SOT	98	89	94	88 (74)
Vestibular Sensory Analysis Ratio on SOT	38	73	61	74 (55)
Visual Preference Sensory Analysis Ratio on SOT	100	97	82	98 (86)
Modified Fatigue Impact Scale 5-item version	5/20	0/20	2/20	N/A

m/s=meters/sec, SD=standard deviation, N/A=not available, SOT=sensory organization test. SOT normative data and population 5th percentile scores in parenthesis provided by manufacturer

Table 1 summarizes the relevant findings from the initial physical therapy examination.

Evaluation/Diagnosis/Prognosis

The data from the initial examination revealed impairments in endurance, motor function, strength, and PROM. Functional limitations were noted in the client's walking ability and balance. These findings agreed with the client's main concerns and reasons for seeking physical therapy services. Using the *Guide to Physical Therapist Practice*,[48] the client was classified in the neuromuscular practice pattern E—Impaired Motor Function and Sensory Integrity Associated With Progressive Disorders of the Central Nervous System.

Due to the chronic, progressive nature of MS the author and client discussed that although she may demonstrate improvement in walking ability, balance, and endurance over the course of her physical therapy she would likely still exhibit deficits in these areas after her treatment was completed. The client was very knowledgeable regarding the course of the disease and understood this. The primary goals established in conjunction with the client were to improve her gait speed, walking endurance, and balance.

The *Guide to Physical Therapist Practice*[48] presents a range of 6 to 50 visits in this practice pattern. Based on the client's availability, review of the existing literature,[7,14,18] and insurance constraints the number of treatment sessions was set at 24. The client came to therapy 2 times per week for 12 weeks.

The plan of care was developed in collaboration with the client to address the impairments and functional limitations identified by the initial examination. Three main types of interventions were provided to address these areas: locomotor training using a BWS/TM system and overground, a VR-based balance system, and a home exercise program (HEP).

Locomotor training using a BWS/TM modality and overground is a task-oriented intervention that is based on neurophysiological principles of walking.[49-51] There has been extensive and ongoing research primarily with individuals with SCI,[10-13] stroke,[15,16,18] and Parkinson disease[14] regarding its effectiveness. Although its use with individuals with MS has not been reported previously, the author thought that this intervention as part of the comprehensive plan of care might be beneficial for improving the client's walking ability because of its sound theoretical basis and effectiveness with individuals with other neurological disorders. Previous research with regards to other techniques to improve walking ability in individuals with MS has not shown one treatment approach to be more effective than another.

A VR-based balance intervention was chosen because the virtual environment provided a setting that encouraged and rewarded movement and was a method for practicing balance skills in a novel way. This intervention also made it necessary for the client to perform a cognitive task, ie, participate and interact with the game in the virtual world, while maintaining her balance.

A HEP was designed to supplement the interventions done in the clinic to ultimately improve the client's walking ability, balance, and endurance. The HEP consisted of riding a stationary combined UE and LE ergometer, LE and trunk strengthening exercises, and standing balance exercises.

Intervention

The interventions were provided by the author and when more than one person was necessary to provide the interventions physical therapist students who were in the second year of a 2 1/2-year program assisted. Each therapy session was approximately one hour long.

Locomotor Training

Locomotor training consisted of training in 2 environments: the BWS-TM environment, which was followed by overground walking. Initially a goal of a total of 15 minutes of walking in the BWS-TM environment and 10 minutes of overground walking was set. Locomotor training, in both environments, followed the principles developed by Behrman and Harkema[11,52]: (1) maximize weight bearing through the lower extremities and minimize or eliminate weight bearing through the arms; (2) provide sensory input consistent with normal walking; (3) promote trunk, limb, and pelvic kinematics associated with normal walking; (4) promote balance and upright control associated with normal walking; and (5) maximize the recovery and use of normal movement patterns and minimize the use of compensatory movement strategies. Another critical component was also included, educating the client to incorporate the strategies learned during the locomotor training into her everyday life.

Locomotor training in the BWS-TM environment consisted of having the client suspended in a harness over a TM using a Biodex Unweighting system (Biodex Medical Systems, Inc., Shirley, NY). In order to promote the principles described above to facilitate improvement in walking ability the following variables were manipulated in the BWS-TM environment: (1) amount of BWS, (2) TM training speed, (3) duration of walks during each session, (4) manual assistance and verbal cues. Initially, 20% BWS was provided while training on the TM, with a goal of 0% BWS by the end of the 12 weeks. The goal with treadmill speed was to train as close as possible to normal walking speeds for this client's age, 1.02 m/s to 1.37 m/s.[53] Three 5-minute walks were set as a goal for each session.

Initially, 3 trainers provided manual assistance while training in the BWS-TM environment. The team of trainers worked with the client during step training to promote a stepping pattern that closely resembled normal gait kinematics and sensory feedback associated with normal walking. The trunk/pelvic trainer provided manual assistance and verbal cues to maintain an upright trunk and head centered over the pelvis. This trainer also provided manual assistance at the pelvis to facilitate pelvic rotation and weight shifting during walking. The LE trainers provided manual assistance at the knees and ankles to facilitate stepping. The goal was to walk with improved gait kinematics without manual assistance.

Locomotor training overground consisted of gait training with the client on level surfaces in the clinic. The client held on to 2 crutches that were held parallel to the ground by 2 trainers, while one trainer stood behind the client to provide manual facilitation at the pelvis. The client would then walk overground while the 2 trainers swung the crutches back and forth to promote symmetrical arm swing. The third trainer, directly behind the client, provided manual cues to facilitate weight shifting and pelvic and lower trunk kinematics associated with a normal walking pattern. During each overground locomotor training session the client ambulated for 25 meters 4 to 6 times at her self-selected speed for a total distance between 100 and 150 meters.

During training in both environments, educating the client through verbal cues while training and discussion during rest periods was incorporated. The 5 training principles listed above were described to the client. A particular emphasis was placed on maintaining an upright head and trunk posture while walking, improving left LE kinematics during swing, and minimizing compensatory movement. As the training progressed less feedback was provided and the client was asked to provide an analysis of how the session went. The therapist and client also discussed how to incorporate what she was learning into her walking during everyday life.

Balance Training

Balance intervention consisted of training in a virtual environment using the Interactive Rehabilitation and Exercise Systems (IREX) developed by JesterTek (JesterTek, Inc., Port Jefferson, NY). With the IREX system the client stood facing a television screen and camera. The camera captured the client's image and projected it onto the television screen in front of her. The client then saw her image in the virtual environment on the screen in front of her. The system calculates the position of the client to determine if they have contacted an object in the virtual environment or uses the position of the client's extremities and trunk to control movement in the virtual environment. IREX contains various virtual scenes with objects to block and courses to navigate. The speed and location at which the virtual objects appear in the different virtual scenarios can be modified to make the intervention more difficult or easier. For example, one balance intervention used was called 'Formula Racing.' In this virtual environment the client saw herself in a racecar on a track (Figure 1). By shifting her weight from side to side she could 'steer' the car around the track while trying to avoid and pass other cars on the track. The speed at which other cars appear on the virtual racetrack can be changed. Another virtual training game incorporated into her treatment was 'Sharkbait.' In this virtual environment the client saw herself submerged in a deep-sea environment. By shifting her weight to the left and right and squatting up and down, the client moved within the virtual scene. The goal of the game was to capture stars by moving into them while avoiding other objects such as sharks and eels. This game facilitated weight shifting side to side within her base of support while flexing and extending her knees and hips at the same time.

Other virtual scenarios in the IREX system that were used as balance intervention were 'Snowboard' and 'Soccer.' These scenarios were chosen to promote weight shifting on to the client's left LE. While performing all of the VR balance interventions the client stood on a 5-inch piece of dense foam and a trainer stood behind the client to facilitate weight shifting to the left and for safety. The use of foam was selected to challenge the vestibular component of balance training. Each balance training session lasted approximately 20 minutes.