Outcomes Following Treadmill Training with Partial Body Weight Support of an Individual with a Traumatic Brain Injury and Multiple CVAs.

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Doctor of Physical Therapy

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Abstract

Purpose: The purpose of this case report was to document outcomes of 16 weeks of body weight supported treadmill training (BWSTT) on the range of motion, muscle strength, cardiovascular parameters, transfers, and functional mobility. **Methods:** The participant was a 38 year old female who acquired a traumatic brain injury and multiple cerebral vascular accidents 3 years ago. She was seen 2 times per week for a total of 16 weeks for BWSTT. Outcome measures utilized in this study included passive range of motion measurements, circumferential measurements, manual muscle testing, video analysis, and functional assessments. The participant's weight was recorded prior to, throughout and following the intervention. **Outcomes:** At the conclusion of the 16 week intervention, the participant showed minor improvements on all outcomes measures. The participant had an increase in total amount of weight loss, as compared to pre and post intervention. Anecdotal improvements were made in the participant's quality of life and a decrease of the family's caregiver burden. **Discussion:** The participant's improvements suggest that BWSTT may be beneficial in improving overall functional abilities even when recovery of walking ability is not achieved. The participant's improved balance and upper extremity function, along with reduced effort required to complete transfers, also suggests that the intervention may have had a positive effect on the participant's trunk control. She was able to respond to the cardiovascular demands of BWSTT to increase her energy expenditure enough to stimulate greater weight loss.

Background and Purpose

Bhambhani et al[1] define traumatic brain injury (TBI) "as a condition that includes intracranial injury, loss of consciousness, skull fracture or posttraumatic amnesia." There are approximately 1.4 million people who sustain a TBI annually in the United States, and this number is greatly under-estimated as it only reflects people who have been properly screened and sought medical treatment.[2] The most common causes of TBI are motor vehicle accidents, violence, sports injury and falls and it is most common among males between the ages of 18 and 24. It is the most significant cause of trauma related disability in the United States.[3] As healthcare continues to improve, the survival rates and life expectancies for people with TBI increases. With increased survival, comes a higher lifetime healthcare cost. It is estimated that the lifetime costs of those who survive TBI, including healthcare and lost productivity, is $60 million.[4] With all of the complications associated with TBI, these people may be at a higher risk for developing secondary health conditions including hypertension, coronary artery disease, diabetes mellitus, and obesity.

There are several physical, cognitive, and psychosocial limitations associated with TBI. Impairments include decreased strength, range of motion, proprioception, increased muscle tone and spasticity. It is also noted that people with TBI often have impaired balance, posture, coordination, decreased attention, and changes in behavior. A decrease in the quality of movement can lead to decreased participation in higher level balance activities, gait training, and sports and leisure activities.[1,5,6] Duong et al[7] found through manual muscle testing that participants with motor strength of less than 3/5 and moderate to severe incoordination were more likely to need assistance with mobility and self-care. They also noted that sitting balance is necessary for feeding, dressing, bathing, transfers and wheelchair mobility, and that standing balance is needed for walking and maintaining an upright posture.

Individuals who have sustained a TBI have several impairments which decrease their ability to exercise or have an active lifestyle. A recent study found that 41% of community dwelling individuals with TBI are non-exercisers as compared to 25% of healthy able-bodied people.[8] Mossberg et al[9] found that individuals with TBI have peak aerobic capacities 65-74% of the normal values. They also found fatigue is the most common complaint among this population. Physical and cognitive reasons for persons with TBI to have decreased activity include decreased strength, range of motion, endurance, impulse control, motivation, compliance, inattention, and disrupted memory.[10] In addition, neuroendocrine changes reportedly occur in 10-28% of individuals with TBI along with reports of changes in eating habits and appetite.[7] Hibbard et al.[11] found women reported a weight gain post injury. They also found there were changes in eating habits and appetite post injury. These changes in eating habits coupled with a more sedentary lifestyle can be harmful to an individual's health.

In the general population a sedentary lifestyle can be detrimental to an individual's health. People who are sedentary are at a higher risk for obesity, high blood pressure, chronic heart disease, osteoporosis, blood clots and certain types of cancer.[1,9] A sedentary lifestyle directly causes weakness, decreased flexibility, and decreased endurance.[9] Regular exercise can reduce the prevalence of all these risk factors. The parameters for increasing cardiorespiratory fitness in the seemingly healthy population using moderate activity which is defined as activity occurring 5 days per week, 40-59% VO_2 reserve, and 20-60 minutes each session.[12] Studies show that regular exercise improves strength, increases endurance, and can increase maximal oxygen consumption (VO_2 max).[13] Exercise plays an important role in helping an individual maintain functional mobility.

Individuals with moderate to severe TBI have a low tolerance for sustained physical activity combined with an increased energy expenditure during activity, so they often experience premature fatigue.[1] There are several factors from the time of injury through the rehabilitation process that contribute to a decrease in a person's cardiorespiratory capacity. Initially these people spend several days on bed rest and later experience several barriers to exercise. Bed rest can have a detrimental effect on the cardiovascular system in as little as 24 hours. Long-term bed rest is likely to result in an increase of resting and sub-maximal heart rate, and a decrease of lung volume and capacities.[14] Individuals with TBI have decreased accessibility to exercise. Therefore, they become predisposed to a sedentary lifestyle and the increase of risk factors associated with it. Unsupervised exercise may be unsafe for this population because of balance impairments or the effects of medication.[9] With these impairments come an increase in oxygen costs for any physical activity including walking.[13]

Individuals with TBI have many impairments that limit their ability to exercise or participate in many activities which can lead to a decrease in cardiorespiratory capacity. The American College of Sports Medicine[10] recommends that people with a brain injury should participate in activity 3 to 5 times a week at 40-70% peak oxygen uptake for 20-60 minutes. It has been shown that cardiorespiratory training in the healthy population will help increase stroke volume and decrease resting heart rate; it is hypothesized that the same effects would occur in people with brain injury. Individuals with TBI have a lower oxidative rate than their healthy counterparts and fatigue 2-6 times faster. Bhambhani et al[15] found that prolonged inactivity can greatly decrease aerobic fitness and is associated with an increase of percentage of body fat and reduction of lean body mass in the healthy population. Therefore, individuals with TBI are likely to experience similar deficits after their injury.

Body-weight supported treadmill training (BWSTT) in adults was first described by Seif-Naraghi and Herman.[6] Researchers noticed that cats with spinal cord injuries could have normal gait patterns if their hindquarters were supported by a harness while walking on a treadmill[16]. It is thought that central pattern generators (CPGs) are responsible for this spontaneous movement. The CPG is stimulated by the reflexive movement of the lower extremities when placed on a moving treadmill and stimulates reciprocal walking. BWSTT utilizes a harness to fully support the individual and unweight a percentage of their body weight while walking on a treadmill. The constant movement of the treadmill cues the person and stimulates a more normal gait pattern. The harness system allows the physical therapist to facilitate a normal symmetrical gait pattern in a secure environment where the person is able to concentrate on the quality of gait.[17] Individuals are also able to concentrate on the frequency of stepping, which will increase muscle contraction and oxygen demand, which will help to increase the aerobic capacity.[12]

A case series by Wilson and Swaboda[2] described outcomes of gait ability of an acute and chronic participant with TBI. The partial weight bearing training was used for 1 hour, 2 days a week for 8 weeks. Both participants showed an improvement in gait quality at the end of the 8 weeks. Researchers reported moderate gains in gait ability as measured by the Standing Balance Scale and Functional Ambulation Category. However, when measured using the Missouri Assisted Gait (MAG) scale more remarkable gains were noted. Seif-Naraghi and Herman[6] found similar findings in their case series. Two participants with chronic TBI were placed on a partial weight bearing training program for 3-4 months. Improvements in both participants were noted by an increase in time on the treadmill, speed of the treadmill and functional ability. A decrease in physical support by the therapists and support needed from the weight bearing apparatus were also noted as improvements for the participants. Both studies support BWSTT as a means of improving gait in participants post TBI, both acute and chronic.

A randomized control trial by Brown et al[18] examined the effectiveness of BWSTT as compared to traditional over-ground gait training. Twenty were included in the study; all had sustained their injury 7 years prior to the study, making spontaneous recovery a low possibility. Each participant received their respective intervention twice a week for 14 weeks and walked about 15 minutes during a 30 minute session. Researchers found that BWSTT caused no significant change in comparison to traditional over ground training. Limitations to this study include the procedural placement of the BWSTT harness, the small sample size, and the duration of the intervention. In this study, the harness was placed just below the greater trochanter possibly limiting hip extension. It is theorized that stretch to the hip flexors stimulates the central pattern generators, so the CPGs may not have been stimulated to their full capacity. Research shows that there is a greater carryover of gait if participants are slowly weaned off BWSTT, which did not occur in the current study. The researchers decided that a longer duration of the intervention would have facilitated better carryover.[18]

In another randomized control trial by Wilson et al,[19] 38 participants post TBI received either traditional gait training or traditional gait rehabilitation supplemented with BWSTT twice a week. The study showed no significant gains in the group that was receiving BWSTT as compared to traditional over ground gait training. A limitation of the study is the small sample size, and the outcome measures used may not have been sensitive enough to detect small gains made in gait, especially in people with TBI.

In an unpublished case report by Moriello et al,[20] BWSTT was used to improve gait and transfers in a participant with an anoxic brain injury. The participant participated in the intervention once a week for 14 weeks and each individual treatment was no more than 15 minutes. At the end of the study the participant showed improvements in gait and transfers. The researchers felt that BWSTT offers a unique opportunity to better stimulate the central pattern generators in the spine which is necessary for the reciprocal movement used in gait. It was also felt that as the motor pathways through the central pattern generators are stimulated, the motor control for the task of walking would be simplified, as the task is relearned, for people with anoxic brain injury.

There are many studies that discuss the use of BWSTT for gait training in people with TBI. Some research supports the use of BWSTT for exercise to help increase cardiorespiratory capacity as measured by VO_2 max, heart rate and oxygen saturation.[17] Research has focused on using BWSTT as a method for gait training, since this is often a goal of patients with TBI. There is little research available addressing the use of BWSTT as a mode of increasing a participant’s functional ability. Most studies that are available focus on the sub-acute phase of rehabilitation as this is thought to be within the rehabilitation window. It has been shown that the sooner rehabilitation is started the better the outcomes will be for regaining function.[21] The purpose of this case report was to document outcomes of 16 weeks of BWSTT on the participant’s range of motion (ROM), muscle strength, trunk control, cardiovascular parameters, quality of movement, functional mobility, and weight loss.

Methods

Case Description

The participant was a 38 year old female who acquired a TBI following a fall down a flight of stairs in 2005. Medical imaging following the TBI revealed she also acquired multiple cerebral vascular accidents (CVAs) in the past which affected the occipital lobe. The participant and her family were unaware of the multiple CVAs. Following the injury, she spent 71 days in a hospital and was then transferred to a rehabilitation center for subacute rehabilitation and long term care until 2006. Since leaving the rehabilitation center she has been living with her parents and her young daughter. An aide comes to their home to assist with activities of daily living. She currently attends an Adult Day Care program every weekday where she receives physical therapy 3 times per week. In therapy, they work on transfers, standing in the parallel bars, balance, ROM, and patient education. She also receives aquatic therapy 1 day per week during the spring and summer months at which she currently ambulates the width of the pool with assistance.

The participant had a Baclofen pump inserted into her abdomen in May 2008 with the dose adjusted twice since. The family has not noted significant changes in the participant's lower extremity spasticity overall, except when she first transfers from sit to supine. The participant had cortical blindness secondary to multiple CVAs that affected the occipital lobe, with greater impairments on the right as compared to the left. Her memory was impaired, although she was able to learn new things with repetition. She had a neurogenic bladder and wore an indwelling catheter and had a history of urinary tract infections. As reported by the participant's family she had a history of substance abuse, but has been clean for 7 years. The participant also had an onset of hypertension in the hospital following her TBI but has had no problems since.

The participant's diagnosis falls within the Physical Therapy Preferred Practice Pattern 5D: Impaired motor function and sensory integrity associated with nonprogressive disorders of the central nervous system-acquired in adolescence or adulthood.[22] She was recommended by her primary physical therapist to participate in the BWSTT research as a means to improve her gait and transfer abilities. Written consent was given by the participant's mother and the participant assented to the study. This study was approved by The Sage Colleges' Institutional Review Board.

Examination

The initial evaluation was completed at The Sage Colleges by the physical therapist heading the research project. This individual has 21 years experience working with people with neurological diagnoses. The initial evaluation was completed just over 3 years following the date the participant acquired the TBI. The evaluation utilized the standard tests of physical therapy put forth by the Guide to Physical Therapist Practice.[22] The systems review revealed that the participant's blood pressure, heart rate, and oxygen saturation level were within normal ranges. Her initial weight was 247 pounds as recorded at her Adult Day Care. The participant's cognitive level falls within the Ranchos Los Amigos Cognitive Functioning VI. She demonstrated the ability to follow simple directions and showed goal-directed behavior but depended on external cues. The participant was legally blind and demonstrated signs of cortical blindness. She could see large objects placed about 1 foot in front of her, although sometimes she could see further. The participant reported low back pain secondary to sitting in her wheelchair for long periods of time. Precautions include fear of movement and seizures. She had 1 seizure during her hospital stay immediately following her injury; she has not experienced any since.

Stereognosis was intact in bilateral hands. Tactile localization was intact in the right upper extremity (UE) with a 4.56 monofilament and in the left UE and bilateral lower extremities (LE) using a 6.65 monofilament. Position sense and kinesthesia were intact in the right ankle and the left great toe but not the right great toe. She reported sensations of numbness and tingling in bilateral LEs. Bilateral bicep, brachioradialis and patellar monosynaptic stretch reflexes (MSRs) were normal.

The Modified Ashworth Scale was utilized to assess the participant's tone. She received a Grade 0 throughout when tested in supine except the right elbow flexors and extensors received a rating of Grade +1. Babinski reflex was positive on the right and clonus was noted bilaterally. Passive range of motion (PROM) measurements were within normal limits except for bilateral shoulder flexion, shoulder abduction, shoulder external rotation, hip flexion, hip abduction, knee flexion, ankle dorsiflexion and left hip external rotation. See Table 1 for a complete list of initial measurements. Circumferential measurements were recorded to note any changes in distal leg mass. See Table 2 for a complete list of initial measurements.

Manual muscle testing (MMT) revealed decreased strength in all extremities; especially bilateral hip flexors, hip abductors, hip adductors, knee flexors, and ankle dorsiflexors. Refer to Table 3 for specific measurements obtained at each joint. UE coordination was impaired bilaterally and LE coordination was unable to be assessed due to severe decrease in muscle strength bilaterally. See Table 4 for specific values.

Unsupported static sitting balance was rated 3-/5. Participant's sitting posture revealed trunk shortening on the left, elongation on the right, left head tilt, increased weight bearing on left buttock, and a neutral pelvis with hands resting on knees. Standing balance was poor and she demonstrated minimal weight bearing through bilateral lower extremities. She required total assist of 3 to stand for 5 seconds. The participant scored a 2 on the Trunk Impairment Scale (TIS).[23] At the time of the initial evaluation she was wheelchair dependent for mobility, dependent in activities of daily living (ADL's) and instrumental activities of daily living (IADLs), and non-ambulatory. The participant scored an 18 on the Motor Functional Independence Measure (FIM).[24] She was fully independent with mobility, ADLs, and IADLs prior to her injuries.

Outcome Measurements

The participant was evaluated prior to the onset of the intervention, once every 4 weeks, at the end of 16 weeks and again 5 months following the termination of the intervention by the physical therapist leading the research project. Outcome measures utilized in this study included PROM measurements, circumferential measurements, MMT, pulse oximetry, video analysis of standing and sit to stand transfers, the Motor FIM, TIS, and MAG. PROM measurements of bilateral upper and lower extremities were taken using a standard goniometer.[25] Measurements were obtained with the participant in supine; one researcher held the extremity while a second obtained the measurement. ROM measurements obtained with a standard goniometer are both valid and reliable.[26] Goniometric measurements have been shown to be highly reliable in the clinical setting for measuring active flexion or extension at the elbow and knee joints. Intratester reliability was high (r= .91 to .99) and intertester reliability was high except for knee extension (r= .88 to .97).[27-28]

Circumferential measurements were taken bilaterally in supine with a tape measure in order to note changes in leg mass.[29] The measurements were taken at 5", 8" and 9.5" above the most distal portion of the medial malleolus. Circumferential measurements obtained in this manner have been shown to have a high reliability (ICC= .72 to .97).[30-31] MMT was performed with the participant in supine. The modified position was used secondary to the participant's poor seated balance. The manual muscle testing system that utilizes a 0 to 5 scale has been shown to be a reliable assessment tool.[7] Pulse oximeter accuracy varies even among the same models. Research suggests that a pulse oximeter that utilizes a finger probe, as was done in this study, is more accurate than one that utilizes an ear lobe probe. Pulse oximeters have been suggested to be accurate when used in nonsmokers with an oxygen saturation level of greater than or equal to 85%. Research suggests that a pulse oximeter should be validated with arterial blood sampling prior to its use.[32]

Video analysis was used to evaluate the participant's quality of transfers. She was recorded from a frontal view each time in order to maintain consistency. Video analysis was also used to evaluate the quality of her standing in the parallel bars. She was recorded from the front, back and side views. Video analysis has been shown to be a reliable tool utilized when examining the properties of gait.[33-34] A second physical therapist was chosen to view and analyze the video of the participant in order to eliminate bias. The examiner has been a practicing physical therapist for 10 years with 8 years experience working with the neurological population. She has 4 years experience utilizing BWSTT with patients. This individual has her Doctorate in Physical Therapy (DPT) degree and is a board certified neurological specialist. The video analysis form was created by one of the participating researchers. The form looks at the expected movements during sit to and from stand transfers, and standing. The form also breaks down specific elements of each movement the video examiner should look for during analysis. See Appendix A.

The Motor FIM was utilized to monitor changes in the participant's motor function throughout the study. The FIM was designed for individuals in in-patient rehabilitation and is utilized to measure ADL and functional ability. The Motor FIM measures independence with self-care, sphincter control, transfers, and locomotion. Each item receives a rating of 1 to 7 with 1 being "total assistance" and 7 being "complete independence". The Motor FIM is composed of 13 items; lowest earned score is 13 and the highest is 91.[35] The FIM has been shown to be an assessment tool that is appropriate for use with individuals with TBI. The Motor FIM has shown a high reliability at 1 year post TBI (ICC= .75-.92).[24]

Trunk stability was monitored and assessed using the TIS. The TIS was developed as a tool to assess motor impairments of the trunk in those with stroke. The 3 subscales that compose the TIS are static sitting balance, dynamic sitting balance, and coordination. TIS score ranges from 0 to 23. A higher score indicates better performance. Interobserver reliability and test-retest values for the TIS total score was 0.96-0.99. Internal consistency, defined by Cronbach alpha coefficients, ranged from 0.65 to 0.89.[23]

The MAG was used to analyze the progression of ambulation on the BWSTT. The MAG is based on the developmental sequence of gait and it has been suggested that the re-development of gait following a TBI parallels the development of gait in an infant. The MAG examines specific elements of gait including initiation of leg swing, hip rotation/obliquity, foot clearance, step length, hip abduction and the patient's ability to respond to verbal cues. Reliability and validity have not been measured.[2]

The participant's weight was recorded prior to, throughout, and following the BWSTT intervention. At 1 month intervals the participant's weight was measured while suspended in a Hoyer lift. This procedure was done at her Adult Day Care.

Evaluation/Prognosis

Participant's functional status is severely limited secondary to cognitive impairments, fear of movement, impaired vision, Motor FIM score of 18, wheelchair dependence for mobility, maximum to total assistance for all transfers and wheelchair propulsion, impaired strength, impaired motor control, impaired coordination, impaired endurance and impaired balance. The participant required maximal to total assistance for all bed mobility, supine to and from sit with total assistance, sit to and from stand with total assistance and total assistance of 3 in order to stand.

The participant's prognosis for ambulation was poor secondary to the fact that the participant had been non-ambulatory since her injury in 2005; and since she presented with severely decreased strength throughout bilateral lower extremities. She had no active contraction of any lower extremity flexors. She also presented with an overall decrease in endurance, motor control deficits, severe deficits in equilibrium reactions, moderate deficits in protective extension reactions, and a Motor FIM score of 18. The participant's prognosis for improving all transfers was fair secondary to severe weakness of bilateral lower extremities, fear of movement, poor sitting and standing balance, impaired motor control, and a TIS score of 2. Participant's prognosis for weight loss and change in cardiovascular status was fair secondary to decreased endurance and being sedentary as a result of dependence for all wheelchair mobility and transfers. The goals set forth by the evaluating physical therapist, the participant's parents and the participant were to improve her ability to perform transfers, to assist more with ADLs and IADLs, and to work on and improve the participant's ambulation.

Plan of Care

The participant was seen 2 times per week for a total of 16 weeks for BWSTT using the Lite Gait System I 250 and standard treadmill. Treatment sessions took place at The Sage Colleges. The duration of each individual treatment session was dependent upon the participant’s tolerance to treatment and progression occurred accordingly. The first 16 sessions consisted of 2 bouts of BWSTT; the first bout lasting approximately 10 minutes and the second bout lasting between 4 to 9 minutes. For the remaining 14 treatment sessions she completed 3 shorter bouts, lasting approximately 5 minutes each. This change led to improved performance and response to treatment by the participant as well as improved tolerance by the researchers to assist with her gait.

She was secured in a tight fitting harness in supine at the start of each session with the assist of 2 researchers. The range for amount of unweighting for each BWSTT bout was recorded from the BySym scale on the Lite Gait system at each treatment session. Unweighting was determined by full foot contact with treadmill, without knee hyperextension as determined by the head therapist. The amount of unweighting allowed for facilitation to be as close to a normal gait pattern as possible. Two researchers guided the participant’s lower extremities throughout the phases of gait. Manual contacts were applied to the participant’s posterior knee in order to provide total assist with knee flexion/leg advancement during the swing phase of gait as well as at the top of the participant’s foot to assist in dorsiflexion/heel strike. A third researcher provided manual contacts to the pelvis at the iliac crests in order to maintain correct alignment of the pelvis and position on the treadmill. Approximately 2 months after the start of the intervention, ace wraps were wrapped around the base of the metatarsals and anchored around the proximal tibia bilaterally to assist with dorsiflexion and to maintain the foot in a neutral position. Verbal cues were given to the participant 75-85 percent of the time during each treatment session. Verbal cues were meant to encourage participation from the participant throughout the gait cycle, as positive reinforcement, and as a means of motivation.

Treadmill speed and duration of the treatment were based on the participant's tolerance in terms of participation and level of fatigue. The ability of the researchers to correct gait deviations and the investigators tolerance level were determinants as well. The participant's cardiovascular response was measured by heart rate (HR), oxygen saturation levels were monitored with a pulse oximeter and blood pressure (BP) was taken at the start of each treatment session and after each bout. Participant rated her shortness of breath on a scale of 0 to 10 following each bout of exercise; starting on research day 14. See Table 5 for measurements.

Outcomes

At the conclusion of the 16 week intervention (31 visits total), the participant showed minor improvements in PROM, muscle strength, bed mobility, transfer status, sitting balance and standing endurance in the parallel bars. She also exhibited a significant amount of weight loss.

Improvements were made in PROM, specifically in bilateral hip flexion, bilateral hip abduction and bilateral ankle dorsiflexion. At the 5 month follow up, the participant maintained PROM of bilateral hip flexors and abductors, but there was a slight decline in bilateral ankle dorsiflexion PROM. Improvements were made in muscle strength of the bilateral hip extensors, bilateral hip abductors, right hip adductors, bilateral knee extensors and bilateral ankle plantar flexors. However, no changes in LE flexor strength were noted. She also showed improvements in bilateral UE strength and functional use of her arms. See

Tables 6 and 7 for specific PROM and MMT measurements at initial evaluation, discharge and 5 month follow up. Circumferential measurements of bilateral LEs showed a decrease in girth measurements from initial evaluation to the 5 month follow up. See Table 8 for the changes in circumferential measurements.

The participant still required maximum to total assistance with all phases of bed mobility, but has shown minor improvements in her ability to roll to both sides. Prior to the intervention, she required maximum assistance to roll to either side in bed once her hand was placed on the bedrail. She is now able to independently place her left arm on the bedrail and pull to roll to the left with maximum assistance. When rolling to the right, she still requires assistance to place her arm on the rail, but then can pull and roll with maximum assistance. There was no change in her ability to scoot in supine or in sitting at the edge of the mat during the 16 weeks. During sit to supine transfers on the mat, the participant was able to lower herself down onto her right elbow and lift bilateral lower extremities through half the range from the floor to the mat, but the remaining aspects of the transfer requires maximum assistance. This is an improvement as she initially required total assistance to perform the transfer. When transferring supine to sit, the participant continues to require total assistance to roll into side lying and push up into the sitting position.

Some improvements in function were noted, but her ability to assist with transfers was inconsistent due to fatigue. The participant required total assistance of 1 when performing a stand pivot transfer to and from her wheelchair to the mat, which did not changed over the 16 weeks. Sit to stand transfers require maximum assistance of 1, but the majority of the assistance was needed for the anterior weight shift to decrease the amount of weight on the buttocks. Once the weight was taken off, she was able to assist up to 90% for the rest of the transfer. This is a change as initially she required total assistance throughout the entire transfer. At the start of the intervention, she was visibly fearful when completing transfers. Her family now reports a decrease in her anxiety during transfers, as she no longer becomes fearful or emotional when completing them. Her family also reports that bed mobility and transfers have become easier and more efficient since the intervention; she is now able to reach for the bedrail without assistance and no longer requires total assistance for a sit to supine transfer. Her ability to ambulate did not change over the intervention and 5 month follow up, as she is still non-ambulatory. At discharge, the participant's Motor FIM score increased from 18 to 20 and she can now brush her own hair, wash her upper body, unzip her coat, and don mittens. See Table 9 for a summary of her functional status at initial evaluation and discharge.

The participant's sitting balance also improved over the course of the intervention. At initial evaluation, she required minimum to moderate assistance to maintain the sitting position at the edge of the mat. She now has the ability to sit unsupported for up to 1 minute with close supervision once she is placed in the sitting position. Her dynamic sitting balance also improved as she is able to raise one UE to wave to the therapist while maintaining her balance, which she was unable to do at the initial evaluation. Sitting balance and posture varied from day to day depending on level of fatigue. Her equilibrium reactions are still impaired and she is slow to react to any change in sitting balance. Protective extensor reactions are present but are also slowed, especially on the right UE. The participant did not show any improvements on the TIS with a score of 2/23 at initial evaluation and discharge, indicating poor static and dynamic balance, as well as poor coordination during sitting.

Standing balance remained poor from the initial evaluation to discharge. The participant originally required total assistance of 3 to stand for 5 seconds with UE support without wearing bilateral ankle foot orthoses (AFOs). In standing, the participant had limited weight bearing through the LEs and shifted anterior causing her to stand on her toes. By the end of the intervention, she only required total assistance of 1 to stand for up to 30 seconds, but still demonstrated poor balance.

The participant's endurance and quality of standing in the parallel bars improved over the course of the intervention. At initial evaluation, she was able to stand in the parallel bars with moderate assistance of 1 while wearing bilateral AFOs for 16 seconds. At discharge, she was able to stand for 1 minute 20 seconds in the parallel bars with moderate assistance of 1 and bilateral AFOs. The level of fatigue again greatly influenced her ability to stand for long periods of time.

During the sit to stand transfer at initial evaluation, the participant's starting position revealed her head and shoulders shifted to the left side with decreased forward and anterior motion of the pelvis during the initiation of movement phase. As she moved into the seat unloading phase, her upper body was still shifted to the left and the movement was not fluid. She was unable to achieve full hip flexion when leaning forward, which caused her to push posterior to her center of mass. She also used her left UE more than the right during this phase. As she moved into the ascending phase, her posture remained the same as the previous phase with her weight more posterior and displaying unequal weight bearing through the UEs and LEs. Once in the standing position and the stabilization phase, the participant showed hyperextension of the hips, trunk and neck. Her weight was also unevenly distributed, with more weight bearing through the left UE and LE.

Upon examination of the sit to stand portion of this transfer at discharge, some visible changes occurred. The initiation of movement phase showed an improvement in sitting posture, as she is now able to maintain her head and shoulders closer to midline. In the seating unloading phase, she displayed enhanced anterior and upward weight shifting, but full range of motion was still not achieved. Her weight was still slightly posterior when transitioning, but at discharge she ascends more anterior during this phase when compared to initial evaluation. She also showed improved hip flexion during the transition, equal weight bearing through all extremities and the movement is more fluid and continuous. Once in the standing phase, there was less hyperextension of the hips, trunk and neck, more equal weight on through the extremities and more co-activation of the abdominals and extensors to maintain her posture.

The participant also made improvements in the stand to sit portion of the transfer. Prior to the intervention, she maintained an extended posture during the initiation of movement phase. During the descending phase of the transfer, she showed decreased eccentric muscle control, unequal weight distribution on LEs and movements were not coordinated. The participant did not achieve any hip flexion during this phase, causing her center of mass to be too far posterior. In the seat loading phase, she exhibited decreased control and coordination of the transfer. Her neck and trunk were flexed to the left side in the stable sitting position.

Several changes in the stand to sit portion of the transfer have occurred from initial evaluation to discharge. The participant was unable to achieve a flexed posture during the initiation phase; however she now exhibits less trunk hyperextension and more co-activation of the trunk musculature at this point of the transfer. In the deceleration phase, there is more equal weight bearing noted in all extremities and she demonstrates improved eccentric muscle control. In addition, the movement is more fluid, there is improved hip flexion and better posture of the head and trunk. The seat loading and stabilization phases showed improvements in the fluidity of the transfer and her ability to maintain a posture closer to midline.

Video of the participant standing in the parallel bars was acquired from a lateral and posterior view. Video at initial evaluation displayed neck, trunk, hip and knee hyperextension. Video also showed that the participant leaned too far posterior, had minimal abdominal activation and external support was needed to maintain the standing position. There was also unequal UE and LE weight bearing during standing.

The participant was able to make improvements in standing post BWSTT intervention. She exhibited no hip and neck hyperextension, less lordosis, increased use of abdominal muscles, increased co-activation of the trunk and decreased recurvatum of the left knee. Analysis also indicated less neck side flexion to the left, shoulders more equally aligned, more equal weight distributed on UEs, pelvis more equally aligned and closer to equal weight bearing on LEs.

The MAG scale was used to assess the progress of gait during treadmill training. At the start of the intervention, the participant was partial weight bearing and needed assistance with full range of motion on the treadmill indicating a score of 1 bilaterally on the MAG. By the end of the 16 weeks the participant scored a 2 bilaterally, which indicates an improvement in the ability to assist with gait on the treadmill. Partial weight bearing was still indicated with a score of 2 on the MAG scale, but assistance was needed with initiation of swing and completion of the stance phase of gait. The participant also improved in her ability to walk on the treadmill at faster speeds than at the beginning of the intervention. Figure 1 shows the change in treadmill speed over the 16 weeks.

Some cardiovascular changes were also noted over the 16 weeks. At initial session, the participant increased her HR post exercise seven beats per minute when compared to her baseline resting HR. During the last session, she was able to increase her HR 27 beats per minute when compared to the baseline resting rate. Table 11 and Figure 2 depict the percent change in HR over the 16 week intervention. The percent change in HR from initial session to discharge was 18.46% to 36.99%.

A 5 month follow up was conducted at the participant's home post intervention. There were no changes in bed mobility from discharge to follow up, but her family reports that she is now able to assist with undressing the LE on the left side. Supine to and from sit transfers still require total to maximum assistance to perform. No changes were noted in her ability to perform a stand pivot transfer wheelchair to and from bed as she still requires total assistance. However, she has retained the ability to assist with the sit to stand portion of the stand pivot transfer. Sitting balance and functional mobility were not assessed during the 5 month follow up. The participant still remains dependent for all wheelchair mobility, but the family reports she is working on manually propelling her chair with bilateral upper extremities in physical therapy. The participant remains at a Motor FIM score of 20, indicating the ability to brush her hair, wash her upper body and brush her teeth with supervision after set up is completed by someone else. She requires moderate assistance with upper body dressing and can zip her tops as well as unbutton them. She requires total assistance with all lower body dressing.

The participant lost a total of 32 pounds over the course of 1 year. During the intervention, the participant had an increase in total amount of weight loss as compared to pre and post intervention. Refer to Table 10 and Figure 3 for complete weight loss. Pre-intervention the participant lost an average of 1.66 lbs over 4 months. During the intervention she lost an average of 3.12 lbs over 4 months and post intervention average of 2.74 lbs over 4 months.

Discussion

The purpose of this case report was to document outcomes of 16 weeks of BWSTT on the participant's range of motion (ROM), muscle strength, trunk control, cardiovascular parameters, quality of movement, functional mobility, and weight loss. A number of studies[2,6,19,36] have previously shown the positive effect of BWSTT on improving gait in individuals with TBI. However, there is less evidence of the benefits for those who are not expected to recover functional gait, particularly concerning cardiovascular parameters and weight loss. Additionally, evidence has found that BWSTT may be an alternative method for aerobic exercise training in individuals who are unable to perform traditional aerobic exercises.[16,37-41] The outcomes from this case study support that BWSTT is effective in increasing ROM, strength, trunk control, cardiovascular parameters, quality of movement, functional mobility, and weight loss in an individual with a chronic TBI. Despite the lack of change in the participant's ambulation status, she was able to make progress toward improving her overall function.

The participant was able to make gains in both PROM and strength during the course of the intervention. The specific improvements seen in PROM of hip flexors, hip abductors and ankle dorsiflexors are most likely a result of the upright and repetitive motion involved with treadmill walking. Even though the intervention did not create a maximal stretch of these muscles, the muscle activation and increased blood flow during exercise may have allowed the greater range to occur. During movement, the Golgi tendon organs mediate muscle activity in response to tension by sending signals to the spinal cord in order to excite or inhibit as specific muscle.[21] As this cycle is stimulated during walking, the active leg muscles contract and relax in a rhythmic manner that may allow for improved control of muscle length. The rhythmic motion of walking also produces a contraction of the LE extensors in weight bearing followed by relaxation, to allow the swing phase of gait. This reciprocal demand may also act as a contract-relax stretch of the LE extensors to promote increased PROM.[42,43] Additionally, there may have been an effect on her LE spasticity as a result of BWSTT. Wilson and Swaboda[2] also reported a reduction in LE spasticity and increased LE strength as a result of BWSTT, possibly due to the increased sensory input from repetitive weight bearing joint loading leading to adaptations of motor control.

The participant was able to increase strength in her hip extensors, hip abductors, knee extensors, and ankle plantarflexors. BWSTT allows functional use of these muscles during the gait cycle. The majority of improvement in the participant’s ability to contribute to walking on the treadmill was in the stance and terminal stance phases of gait; where these muscles are activated. This is supported by the participant’s improvement on the MAG scale as she only needed assistance for initiation of swing and achieving full hip extension with partial weight bearing through body weight support.[2] At the 5 month follow up, the majority of strength gains made during training were not maintained potentially due to the lack of continued muscle activation.

The participant was unable to improve her ability to activate her LE flexors through this intervention. The exact location of her brain damage is unknown, but it is suspected that her presenting deficits are a direct correlation to the areas of her brain affected by her TBI. As a result, the participant was unable to initiate the stepping motion necessary to take even a few steps in the parallel bars that had been anticipated by the researchers.

It is unknown if further gains could have been made with a longer intervention period. It has been shown that it is more difficult to recover function through rehabilitation when the time since injury is more prolonged. The best response of neuroplasticity for recovery of function occurs with early rehabilitation using task-specific protocols at a high intensity.[6,21] Gray[44] did show that individuals who were slow-to-recover after severe TBI were able to continue to make gains many years after injury even with out formal rehabilitation and suggests that with the appropriate rehabilitation program even greater gains could be made. In terms of gait, Katz et al[45] determined that those who were not independent ambulators at 4 months after injury only had a 9% chance of recovering the ability to walk independently. This supports what was seen in the present case report, however, improvements were made by the participant in other functional areas.

Improvements in PROM, strength, and ability to assist with gait on the treadmill may have had an influence on the participant’s gains in completing functional tasks. Although she still requires maximal to total assistance to complete all transfers and bed mobility tasks, she was able to increase her effort in rolling, sit to supine transfers, sit to stand transfers, stand pivot transfers, and standing balance. The increase in her leg strength, specifically in extensors, allows for greater recruitment of her muscle strength when performing transfers and standing.

The participant in the current study did not make as significant gains as the participant in an unpublished case report by Moriello et al[20] in amount of assistance needed in transfers and gait. The participant in the previous case had an anoxic brain injury (ABI). Even though it has been suggested that ABI results in more diffuse damage and poorer prognosis, it was shown by Shah et al[46] that this was not supported. Individuals with ABI tended to have a shorter length of stay in inpatient rehabilitation as they regained functional mobility at a faster rate than those with TBI. ABIs tend to produce more cognitive impairments; whereas individuals with TBI often have greater physical impairments.[46] The participant in the previous study had severe motor apraxia and difficulty initiating movement, while strength and ROM were grossly within normal limits with a few exceptions. He was also able to sit unsupported prior to the intervention, showing that his underlying impairments were mainly involving motor planning and coordination.[20] The current participant has more significant physical impairments with less cognitive impairments and did not show significant changes in the level of assistance needed and continues to be non-ambulatory. The participant of the current case report had greater physical involvement as a result of her TBI. She had significant loss of functional mobility, strength, ROM, balance, and vision. She also required the use of a Baclofen pump to manage spasticity, especially in her LEs. As a result of these variations in presentation, it is not surprising that the participant with an ABI was able to make considerable gains. The repetition provided by BWSTT may have a greater impact on improving motor control and motor learning than regaining neurological innervation, at least in a short-term intervention such as this. The participant in this case study did not have any active use of her LE flexors suggesting a more profound injury to specific areas of her brain and due to the chronic nature of her TBI made it more difficult for neuroplasticity to occur in order to regain the function of walking.[21]

Even though the level of assistance did not improve as much as the individual in the previous case report, there were changes in sitting and standing balance, UE function, and Motor FIM score. These changes may have been due to improvements in trunk control. She did not show any improvements on the TIS, although suspected gains in trunk strength and control were observed. The participant was able to increase both sitting and standing balance, which are influenced in part by trunk control. Her posture and stability in both positions was visibly better as shown by video analysis. The participant showed improved alignment, maintained posture closer to midline, and moved with increased fluidity and control. She utilized more equal weight bearing bilaterally and greater co-activation of her trunk through out these tasks. Prior to the intervention she required the assistance of 3 to stand for 5 seconds and was able to reduce the assistance to 1 to stand for 30 seconds after the intervention. The most significant change in standing was in the parallel bars where the participant was able to increase time in standing from 16 seconds at initial evaluation to 1 minute and 20 seconds after the intervention. Also, she is now able to maintain sitting balance for 1 minute with close supervision while prior to the intervention she could only maintain static sitting momentarily. Anecdotally, she has begun to incorporate dynamic balance challenges and showed improved equilibrium reactions in sitting that she was unable to do prior to the intervention.

It appears that the TIS was not to the level of sensitivity needed to detect changes in trunk control seen in the participant. The first set of items on the TIS involves movement of the LEs to change her base of support requiring a higher level of activity than this participant was able to complete.[23] The participant was able to move her UEs as a dynamic challenge to sitting balance, yet she is still reliant on her LEs as part of her base of support because she continues to lack strength in her trunk and exhibits slowed postural and equilibrium reactions.

It has been shown that impaired sitting and standing balance can negatively impact mobility and the ability to complete ADLs, however research also supports the use of BWSTT for improving both balance and trunk control.[6,7,16,47] Both Mudge et al[47] and Visintin et al[16] support a potential cross-over effect from gait training to balance due to the increased demand during gait. It was shown that BWSTT might have a greater impact on balance, as measured by the Berg Balance Scale, than treadmill walking alone in individuals with stroke. Improvements in balance were still present at 3 months after intervention was completed.[16] This suggests that controlling the amount of unloading is integral in maintaining proper gait response and practice in order to make the desired gains in function. Although Mudge et al[47] were not able to show improvements in the Trunk Control Test after BWSTT, a significant increase in the lateral reach test, particularly in the participant's involved side, post-intervention suggests that there is a positive effect from BWSTT on sitting balance and trunk control. It was suggested that the upright postural support from the harness and increased proprioceptive information through weight bearing might influence these responses.

The portions of her transfers that improved may be related to her improved trunk control. Her increased ability to lean forward in her wheelchair to prepare for transfers, dressing, and other ADLs shows her gain of control and fluidity of movement. She is also able to assist with sit to supine transfers by controlling her trunk motion down onto the mat and initiating the upward movement of her legs. Additionally, her sitting posture at the completion of the stand pivot transfer is more stable and she is able to maintain this position. Prior to the intervention, the participant needed to be manually placed in an upright sitting posture.

Another aspect that may be related to her improvement in trunk control was an increase in UE function. At discharge, her Motor FIM score increased from 18 to 20 and she was able to complete more ADLs including brushing her hair, washing her upper body, unzipping her coat and donning mittens. She was also able to reach for the bedrail during rolling and wave her hand during sitting. These improvements were maintained at the 5 month follow up and the participant was observed while actively raising both UEs overhead, exhibiting functional active ROM. Although, a cause and effect relationship can not specifically connect the participant's UE functional improvement with the intervention, it is possible her improvement in trunk control and posture are a factor. Mudge et al[47] found improved lateral reach in 1 person with stroke following an intervention using BWSTT. It is also known that trunk posture, stability, and alignment are important in creating the base needed to complete dynamic movements of the limbs and that activation of postural muscles supporting the trunk allow for smooth and directed movement of the arms.[48] Gillen et al[48] found that a neutral alignment of the trunk provided the most beneficial condition for efficient functional performance of the UE's, especially in the nondominant UE. It was also shown that postural influences were greatest in completing fine motor, accuracy, and strength tasks. This suggests that if the participant was able to make improvements in trunk control and posture as a result of the intervention, she would be able to complete greater functional tasks using her UEs.

Another study by Ploughman et al[49] found UE performance in those with chronic stroke improved following a single bout of BWSTT. The authors proposed that the rhythmic movement of treadmill walking with fixed UEs as the participants held the handrails may have relaxed the participant's UE tone and subsequently increased UE function. Additionally, the authors suggested that the treadmill walking might have served as a warm up for the arms to prepare for later tasks. Even though the participant in the present study was encouraged to walk without use of the handrails, she felt more comfortable holding them and did so for the majority of the intervention. Due to her participation in occupational therapy during the intervention, there is no way of identifying which intervention produced her improvements. However, she has been receiving occupational therapy for maintenance of function as a result of the length of time since her injury, suggesting that the improvements made during the intervention may have been related to the BWSTT.

Most studies exploring the benefit of BWSTT in individuals with TBI, spinal cord injury (SCI) and stroke have shown that it produces an increase in endurance.[17,36,39-41] This is the first study to explore the effect of BWSTT on cardiovascular parameters in an individual with TBI who is not expected to regain functional gait. Previous studies have supported the use of BWSTT to improve gait speed, maximum ambulation distance, activity tolerance, and cardiovascular response as measured by HR, however, all involved participants could at least ambulate with some level of assistance.[8,17,36,39,40] In the present study, the participant was able to show favorable changes in cardiovascular parameters, particularly HR, which suggests that her cardiovascular system made some adaptations to the increase in exercise demands. Also, as other studies have shown, the participant was able to work at greater treadmill speeds as the intervention progressed which represents increased exercise tolerance.

These are expected responses to exercise training, especially in someone who may be deconditioned. However, the intensity was not high enough to produce any cardiovascular training effects such as reduced resting HR or decreased HR at a constant workload.[13,17,39,50]

Those with moderate to severe TBI have been shown to have a low tolerance to physical activity, higher energy expenditure, lower aerobic capacity, and earlier fatigue. Higher functioning individuals with TBI were able to improve all of these factors with supervised circuit training or aerobic training programs, showing that it is possible for individuals with TBI to benefit from aerobic training.[1,9,13,15] The HR response to increased intensities seen in this study suggests that those same benefits might be achieved in individuals with TBI who have lower functional capacities. However, since aerobic capacity was not directly measured it cannot be confirmed.

In addition, it is important to consider the other benefits of BWSTT that may be favorable to individuals with TBI, even those who are not functional ambulators. Any form of aerobic exercise will reduce the risk for coronary heart disease, hypertension, obesity, diabetes, and other comorbidities related to a sedentary lifestyle.[9] BWSTT allows individuals who have difficulty using traditional exercise methods to exercise for longer durations and higher intensity in an upright position with delayed fatigue and increased safety promoting the potential for greater training gains.[17,36,38,39] BWSTT can improve glycemic regulation through an increase in glucose storage and more effective glucose utilization in individuals with incomplete SCI.[51] Most significantly, Ditor et al[38] showed that 4 months of BWSTT was able to improve peripheral vascular function by increasing resting femoral artery compliance as measured by Doppler ultrasound imaging in individuals with motor-complete SCI. The authors did point out that femoral artery compliance might be beneficial in reducing the risk of thrombus formation, development of pressure sores by improving tissue perfusion, and decreased risk of vessel wall damage.[38] This suggests that further cardiovascular benefit can be attained regardless of ambulatory status when using BWSTT.

This case study is also the first to suggest that BWSTT can be effective in facilitating weight loss. Previous studies[8,15,52] have shown no immediate effect and even weight gain after exercise training in individuals with acute TBI. It was suggested that the increase in body mass as a result of the BWSTT intervention might have been due to an increase in muscle bulk or increased appetite from exercise training, especially since caloric intake was not controlled during any of the intervention periods. In the current case study, the participant’s family had initiated a dietary weight loss program prior to the intervention with some progress made. Weight loss accelerated during the course of the BWSTT intervention. The combination of controlled caloric intake and exercise has been shown to be the most successful plan for weight loss.[50] This implies that BWSTT allows for enough increase in energy expenditure to have a positive effect on weight loss, however further research would be needed to explore the desired intensity and frequency of training.

Although the participant was not able to decrease her level of assistance needed for functional mobility tasks, her increased strength, increased ROM, decreased weight and increased trunk stability allow her to be an active participant in these tasks as opposed to requiring her family to do all of the work. Duong et al[7] reported that reduced strength along with decreased sitting and standing balance at discharge from acute rehabilitation indicated the need for greater assistance. These differences in functional ability and assistance persisted even at 1 year following injury. It was suggested that strength less than 3/5 on MMT indicated a greater need for assistance. The LE strength gains made by the participant in this study may have lead to increased participation in functional mobility tasks, but since she was not able to surpass the cutoff score proposed by Duong et al[7] throughout her LEs, it is not surprising that her level of assistance was not changed.

All of the participant's improvements as a result of the intervention suggest that in addition to her functional gains, her family may experience decreased caregiver burden. Although caregiver burden was not objectively measured, the participant's family reported greater ease and efficiency when completing transfers, bed mobility, and ADLs after BWSTT. For example, initially the participant required total assistance to complete a sit to stand transfer, while after the intervention she needed assistance to complete the forward weight shift and then could participate in the majority of the remaining transfer motion. This additional assistance contributed by the participant, as well as her weight loss, leads to less physical work done by her family members. Watson et al[53] stated that evaluation of caregiver burden had a significant association with deficits in social cognition, communication, self-care, locomotion, and transfers. Deficits in cognition and self-care were found to result in the highest caregiver burden score. It is valuable for the participant's family to be reporting greater ease with daily care and the participant's ability to complete more UE ADLs independently.

Reduction in caregiver burden is not only important for the family's physical health, but also psychosocial health. There is a high incidence of stress, depression and anxiety, among other issues, in caregivers of individuals with TBI.[54] Although the most significant influence of increased burden is cognitive and personality changes, level of physical disability is also very influential.[7,53,54] Therefore, any reduction in physical disability or ease of care would most likely have a positive effect on caregiver burden.

A positive influence on quality of life appeared as a result of the intervention, but it was also not objectively measured. The participant verbally expressed her eagerness and anticipation for each session because she enjoyed being on the treadmill. Prior to her injury, the participant was dedicated to fitness and regularly visited the gym. She often mentioned that being on the treadmill again made her feel as if she was back at the gym. It is also suggested that exercise has psychological effects in addition to physical effects such as, increased sense of self-worth, feelings of well-being, and possibly social contact.[8] Hellweg and Johannes[41] suggested that physiotherapy after TBI improves general state of health and reduces depression. As many individuals with TBI experience depression and the negative psychological effects of disability, incorporating physical activity in any way possible would be beneficial.

Another positive result of the BWSTT in this study was the reduction of the participant's fear and anxiety during transfers. Initially, the participant was very fearful during all transfers, but after intervention she became much more confident and did not need any reassurance. It is suspected that her improved strength and trunk control make the participant feel more in control and stable during transfers.

There were several limitations to this study. With a case study, cause and effect relationships are not clearly defined making it difficult to link the intervention with the outcomes observed. Another limitation is the lack of objective measures to evaluate caregiver burden and quality of life. Even though the participant did not reduce her assistance needed to perform transfers, the participant's family verbally expressed increased ease in performing self-care tasks and transfers after the intervention. This suggests that the participant's improvements in strength, trunk control and weight loss may have reduced their caregiver burden in a way that was significant to their quality of life and safety, but neither were assessed. Adding objective measures of both caregiver burden and quality of life would improve the strength of the outcomes of BWSTT in non-ambulatory individuals in future research.

As stated previously, the TIS was not sensitive enough to detect change for this participant. Anecdotally, improvements in trunk control were observed in sitting by her ability to maintain balance with small dynamic arm movements and correction of trunk movement, however she was unable to increase her score on the TIS. The TIS required stationary sitting to be maintained while the base of support of the LEs was changed by passively and actively crossing the participant's legs. The tasks required on the TIS were too challenging for this participant, however she may have shown improvement using another measure involving dynamic motion of her upper extremities, such as a lateral reach test.

It would have also been beneficial to further standardize the treatment protocol. The amount of unweighting used each session was not fixed or progressively changed in a systematic manner, making it difficult to asses the amount of change in the participant's ability to assist on the treadmill and support more of her own weight. Establishing a protocol for progressive weight-bearing that has been utilized in other studies[6,17,36,39] might have been useful to assess her ability to actively assist with the gait cycle. Also, due to the fact that the participant was showing improvements, a longer intervention could have shown even greater gains in strength, PROM, weight loss and balance, as well as possibly showing changes in areas that did not show improvement in this case study.

Monitoring the cardiovascular effects of the intervention could have also been improved. Rating of perceived exertion was implemented late in the intervention and seemed to provide some additional information on the participant's response. However, since it was not used throughout the intervention and reliability with this patient was unclear, the feedback could not be included in the assessment. Additionally, more frequent measurement of HR and BP would have provided more accurate feedback of cardiovascular response. It may be useful to know how long the participant was able to maintain her HR elevated above resting and at what intensity this occurred. It can be suggested, through her peak HR response, that greater treadmill speeds increased the participant's HR, but it is unknown if this HR was maintained for the length of each bout of treadmill training. Pre- and post-intervention measurements of maximal oxygen consumption could have been used to assess progress more concretely.

This study has posed a number of opportunities for further research, particularly in the cardiovascular benefits of BWSTT in individuals with TBI who are not functional ambulators and the potential influence on weight loss. As many studies[2,6,19,36] have shown, BWSTT can improve cardiovascular endurance in individuals with TBI, however they also improved gait speed and distance able to ambulate. It has yet to be determined if BWSTT can decrease the risk of comorbidities associated with a sedentary lifestyle, as well as increase quality of life, in groups requiring more assistance to exercise. Also, due to the decreased ability to actively participate in treadmill walking, the optimal intensity of BWSTT for these individuals to see cardiovascular benefits is still needed.

It is promising to see such significant gains in UE function after BWSTT. Although there may have been additional factors, such as occupational therapy, the results suggest that increased trunk control can influence UE function as a result of BWSTT. Further research is needed to explore the possible crossover effect and what true relationship exists between UE function and trunk control, increased endurance, decreased spasticity, or other factors.

Another benefit may develop from further exploration of the possible connection between weight loss and caregiver burden as a result of the decrease in physical demand. This is the first case study to document outcomes using BWSTT for weight loss in individuals with TBI. There has been little research published on the use of exercise in individuals with TBI for weight loss. Previous studies[8,15,52] were unable to show a positive effect due to the lack of control of caloric intake and the use of individuals with acute TBI. In the future, the exploration of exercise, weight loss, and BWSTT using a larger sample of individuals with TBI would determine if this is an effective intervention for this population. Since many individuals with TBI are at greater risk for obesity due to decreased physical activity, this would be extremely valuable for future intervention.[11,15]

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Table 1 . Passive range of motion(degrees)

Motion	Right Week 1	Left Week 1
Shoulder Flexion	0-165°	0-165°
Shoulder Extension	WNL	WNL
Shoulder Abduction	0-155°	0-165°
Shoulder Internal Rotation	WNL	WNL
Shoulder External Rotation	0-60°	0-55°
Elbow Flexion	WNL	WNL
Elbow Extension	WNL	WNL
Wrist Flexion	WNL	WNL
Wrist Extension	WNL	WNL
Fingers	WNL	WNL
Hip Flexion	0-90°	0-90°
Hip Abduction	0-25°	0-40°
Hip Internal Rotation	WNL	WNL
Hip External Rotation	WNL	0-35°
Knee Flexion	0-120°	0-120°
Knee Extension	WNL	WNL
Ankle Dorsiflexion	0°	0°
Ankle Plantarflexion	WNL	WNL
Ankle Inversion	WNL	WNL
Ankle Eversion	WNL	WNL

*WNL: Within normal limits.

Table 2. Lower extremity circumferential measurements (inches)

Inches above medial malleolus	Right Week 1	Left Week 1
5"	12.38"	12.00"
8"	15.25"	15.00"
9.5"	16.00"	15.75"

Table 3. Muscle Strength (Manual Muscle Test)

Motion	**Right** Week 1	**Left** Week 1
Shoulder	*	3+/5
Elbow	3+/5	4-/5
Wrist	3+/5	4-/5
Grip	4-/5	4/5
Hip Flexion	0/5	0/5
Hip Extension	3-/5	3-/5
Hip Abduction	1+/5	2-/5
Hip Adduction	1+/5	1+/5
Knee Flexion	0/5	0/5
Knee Extension	2-/5	2-/5
Ankle Dorsiflexion	0/5	0/5
Ankle Plantarflexion	2-/5	2+/5
Ankle Inversion	0/5	2-/5
Ankle Eversion	0/5	0/5

* : able to move against gravity through ¾ - full range with slight flexor synergy noted

Table 4. Coordination

Upper Extremity	Right Week 1	Left Week 1
PT finger to participant nose*	2/4	3/4
Finger opposition*	2/4	2/4

Bilateral lower extremities unable to test secondary to severe decrease in muscle strength

***Nonequilibrium Coordination Tests: 5 point scale**

4 Normal performance demonstrated.

3 Movement is accomplished with only slight difficulty.

2 Moderate difficulty is demonstrated in accomplishing activity; movements are arrhythmic, and performance deteriorates with increased speed.

1 Severe difficulty is noted: movements are very arrhythmic; significant unsteadiness, oscillations, and/or extraneous movements are noted.

0 Patient unable to accomplish activity.

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<u>Table 5.</u>		**Session 2**	**Session 3**	**Session 4**	**Session 5**	**Session 6**
Amount unweighted (lbs)	165-205	190-205	162-205	180-210	165-211	150-205
Speed (mph)	0.4-0.5	0.4-0.7	0.5-0.6	0.4-0.9	0.4-0.9	0.5-0.9
Total Treadmill Time (min)	14:35	18:05	15:00	19:03	18:16	17:30
	Session 7	**Session 8**	**Session 9**	**Session 10**	**Session 11**	**Session 12**
Amount unweighted (lbs)	150-210	115-216	*	135-215	136-220	106-215
Speed (mph)	0.6-1.2	0.6-0.9	*	0.7-1.0	0.7-1.1	0.7-1.0
Total Treadmill Time (min)	19:04	15:11	*	9:54	15:30	17:38
	Session 13	**Session 14**	**Session 15**	**Session 16**	**Session 17**	**Session 18**
Amount unweighted (lbs)	120-220	138-215	114-200	107-222	99-229	111-215
Speed (mph)	0.7-1.2	0.8-1.0	0.8-1.2	0.8-1.2	1.0-1.6	1.0-1.6
Total Treadmill Time (min)	16:02	15:00	17:34	16:08	15:04	15:11
	Session 19	**Session 20**	**Session 21**	**Session 22**	**Session 23**	**Session 24**
Amount unweighted (lbs)	111-228	104-205	89-213	98-220	114-231	101-223
Speed (mph)	0.8-1.5	1.0-1.4	1.0-1.6	1.0-1.4	1.2-1.6	1.0-1.4
Total Treadmill Time (min)	15:08	15:02	15:03	15:20	12:02	15:08
	Session 25	**Session 26**	**Session 27**	**Session 28**	**Session 29**	**Session 30**
Amount unweighted (lbs)	**	**	*	66-213	83-212	90-220
Speed (mph)	1.2-1.6	1.0-1.2	*	1.0-1.6	1.2-1.7	1.2-1.5
Total Treadmill Time (min)	15:03	12:01	*	15:52	15:01	14:59
	Session 31					
Amount unweighted (lbs)	**					
Speed (mph)	1.2-1.9					
Total Treadmill Time (min)	15:01					

***Sessions 9 and 27 were cancelled.**
****Measurements unable to be obtained secondary to equipment failure.**
Sessions 1-16: 2 bouts of BWSTT
Sessions 17-31: 3 bouts of BWSTT

Table 6. Passive range of motion (degrees) at initial evaluation, discharge and follow up.

	Right			Left		
Motion	Week 1	Week16	Follow up	Week 1	Week16	Follow up
Shoulder Flexion	0-165°	0-165°	0-165°	0-165°	0-165°	0-165°
Shoulder Extension	WNL	WNL	WNL	WNL	WNL	WNL
Shoulder Abduction	0-155°	0-155°	0-155°	0-165°	0-165°	0-165°
Shoulder Internal Rotation	WNL	WNL	WNL	WNL	WNL	WNL
Shoulder External Rotation	0-60°	0-60°	0-60°	0-55°	WNL	WNL
Elbow Flexion	WNL	WNL	WNL	WNL	WNL	WNL
Elbow Extension	WNL	WNL	WNL	WNL	WNL	WNL
Wrist Flexion	WNL	WNL	WNL	WNL	WNL	WNL
Wrist Extension	WNL	WNL	WNL	WNL	WNL	WNL
Fingers	WNL	WNL	WNL	WNL	WNL	WNL
Hip Flexion	0-90°	0-112°	0-111°	0-90°	0-113°	0-125°
Hip Abduction	0-25°	WNL	0-30°	0-40°	WNL	0-20°
Hip Internal Rotation	WNL	WNL	0-18°	WNL	WNL	WNL
Hip External Rotation	WNL	WNL	WNL	0-35°	0-35°	WNL
Knee Flexion	0-120°	0-120°	0-120°	0-120°	0-120°	0-120°
Knee Extension	WNL	WNL	WNL	WNL	WNL	WNL
Ankle Dorsiflexion	0°	0-3°	0-1°	0°	0-4°	0-3°
Ankle Plantarflexion	WNL	WNL	WNL	WNL	WNL	WNL
Ankle Inversion	WNL	WNL	WNL	WNL	WNL	WNL
Ankle Eversion	WNL	WNL	WNL	WNL	WNL	WNL

*WNL: Within normal limits

Table 7.Muscle strength (manual muscle test) at initial evaluation, discharge and follow up.

	Right			Left		
Motion	Week 1	Week 16	Follow up	Week 1	Week 16	Follow up
Shoulder	*	*	**	3+/5	4-/5	4/5
Elbow	3+/5	4-/5	4-/5	4-/5	4+/5	5/5
Wrist	3+/5	4-/5	4-/5	4-/5	4+/5	5/5
Grip	4-/5	4/5	4+/5	4/5	5/5	5/5
Hip Flexion	0/5	0/5	0/5	0/5	0/5	0/5
Hip Extension	3-/5	4-/5	3/5	3-/5	4-/5	3-/5
Hip Abduction	1+/5	2-/5	1/5	2-/5	2-/5	2-/5
Hip Adduction	1+/5	1+/2-/5	1+/5	1+/5	1+/5	1/5
Knee Flexion	0/5	0/5	1/5	0/5	0/5	1/5
Knee Extension	2-/5	3+/5	2-/5	2-/5	3+/5	2-/5
Ankle Dorsiflexion	0/5	0/5	0/5	0/5	0/5	0/5
Ankle Plantarflexion	2-/5	3+/5	2+/5	2+/5	4-/5	2-/5
Ankle Inversion	0/5	0/5	0/5	2-/5	1/5	1+/5
Ankle Eversion	0/5	0/5	0/5	0/5	0/5	0/5

* : able to move against gravity through ¾ - full range with slight flexor synergy noted

**: able to move against gravity through full range with slight flexor synergy noted

Table 8. Circumferential measurements (inches) at initial evaluation, discharge and follow up.

	Right			Left		
Inches above medial malleolus	Week 1	Week 16	6 Months	Week 1	Week 16	6 Months
5"	12 3/8	12 1/4	12 1/4	12	12	11 7/8
8"	15 1/4	15	14 1/8	15	14 3/8	14 1/8
9 1/2"	16	15 1/2	14 3/8	15 3/4	15 3/4	14 1/2

Table 9. Functional status and level of assistance at initial evaluation and discharge

Activity	Week 1	Week 16
Rolling	Max A bilaterally	Max A bilaterally
Scooting in supine	Total A	Total A
Scooting on edge of bed	Total A	Total A
Sit to supine transfer	Total A	Max A
Supine to sit transfer	Total A	Total A
Sit to stand transfer	Total A	Max A of 1; unless fatigued
Stand pivot transfer	Total A	Total A
Standing in parallel bars	Mod A of 1 with bilateral AFO's for 16 seconds	Mod A of 1 with bilateral AFO's for 1 minute 20 seconds
Gait	Non-ambulatory	Non-ambulatory

Definitions

Mod A: patient expends between 50 and 74% of the effort to complete the activity

Max A: patient expends between 25 and 49% of the effort to complete the activity

Total A: patient expends less than 25% of the effort to complete the activity

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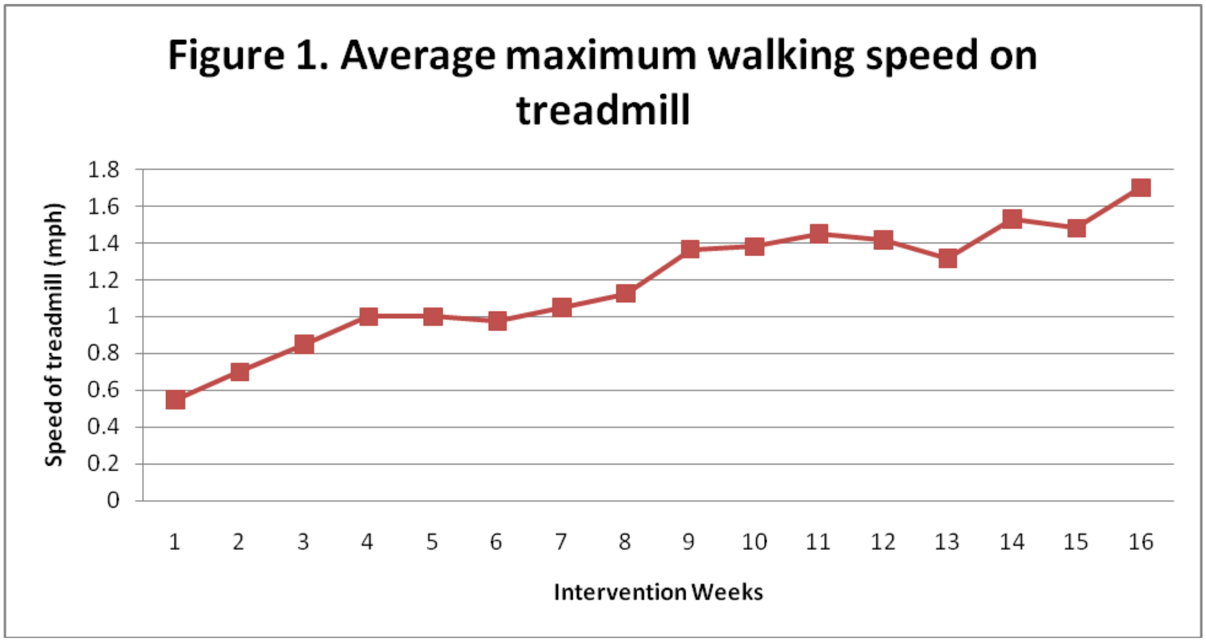
Table 10. Trend of weight loss

Date	Weight(lbs)
5/2/08	247
6/2/08	245.4
7/2/08	248.6
8/5/08	240.4
9/2/08	238.2
10/1/08	233.2
11/2/08	230.8
12/1/08	228.6
1/5/09	223.4
2/2/09	220.8
3/5/09	218.6
4/6/09	215

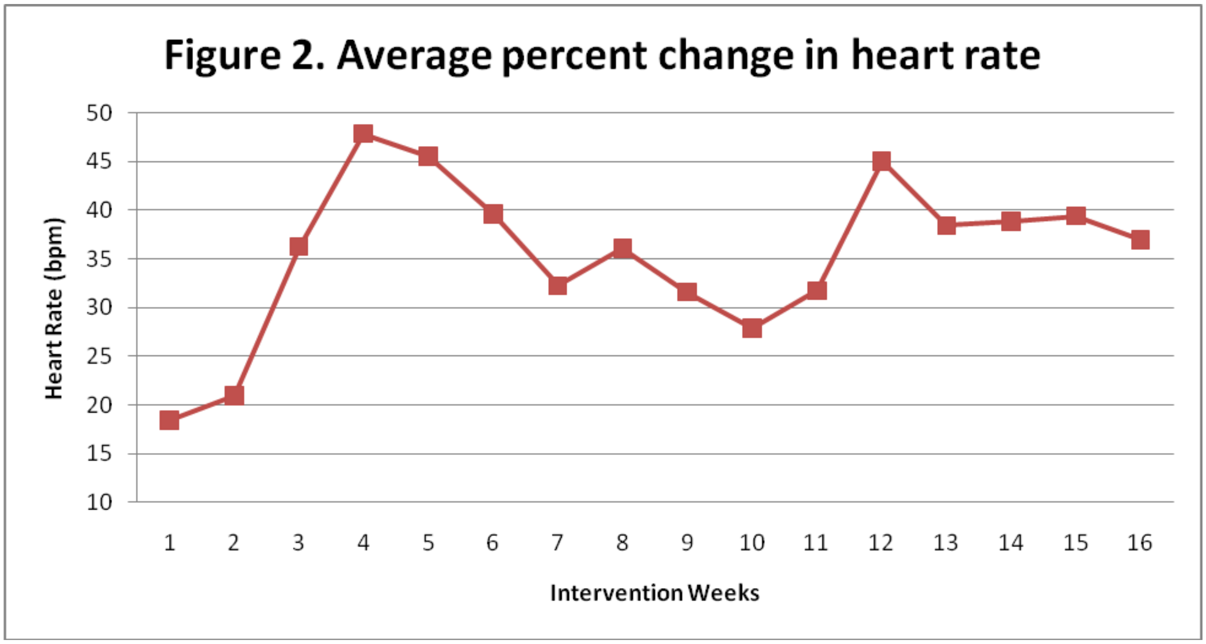
Table 11. Percent change in heart rate

Week	Average resting HR	Average change in HR	Percent change in HR(%)
1	74.5	13.75	18.46
2	71.5	15	20.98
3	65.5	23.75	36.26
4	70.5	33.75	47.87
5	79	36	45.57
6	74.5	29.5	36.9
7	77.5	25	32.26
8	73.5	26.5	36.05
9	76.5	24.17	31.59
10	76.5	21.33	27.88
11	73.5	23.335	31.75
12	72.5	32.665	45.06
13	78.5	30.17	38.43
14	78	30.33	38.88
15	74	29.17	39.42
16	73	27	36.99



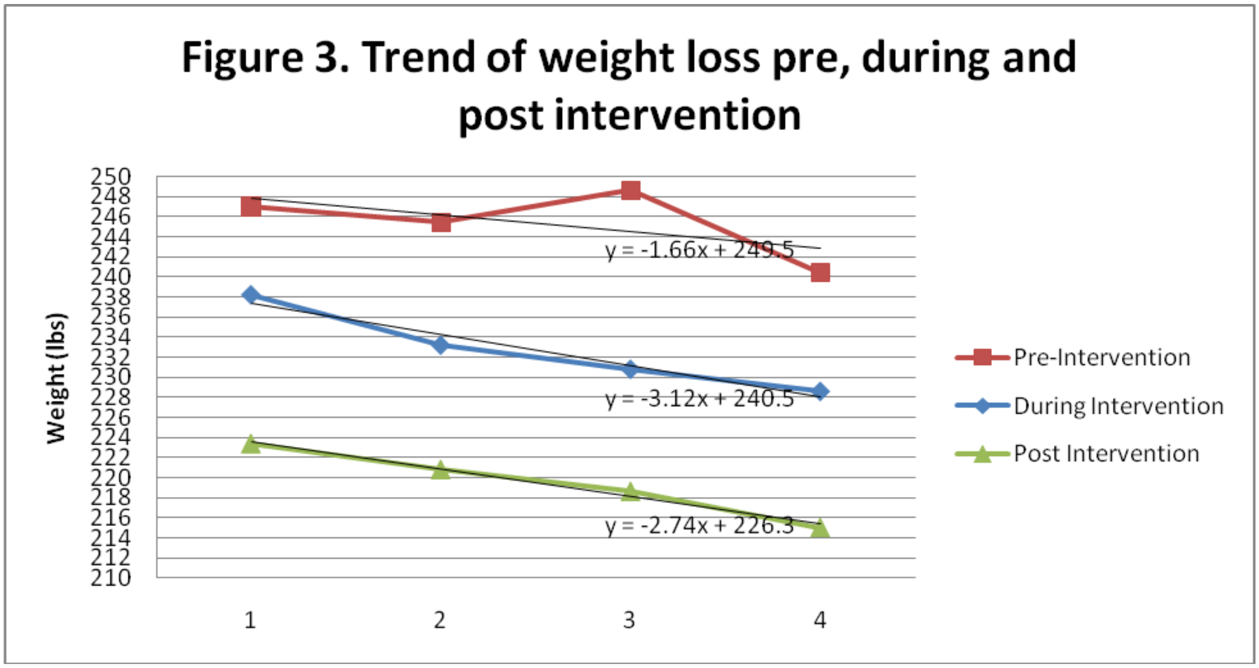
*Average treadmill speed was calculated by averaging the speed of each bout of exercise per session.

*Each week contained two sessions that were averaged to acquire the maximum treadmill speed for each week.



* Average percent change in heart rate was calculated by averaging the change in heart rate of each bout of exercise per session, subtracting from baseline heart rate and multiplying by 100.

*Each week contained two sessions that were averaged to acquire the percent change in heart rate for each week.



*Weight was recorded at the participant's adult day center at the beginning of each month from May 2008-April 2009.

Appedix A: Transfer Analysis Forms[55-60]

Transfer Analysis Form: Sit to Stand

		Complete Transfer (100%)					
	Sitting	Initiation of Movement (24% of motion)	Seat Unloading (7% of motion)	Seat Off	Ascending (39% of motion)	Stabilization (27% of motion)	Standing
Expected Movement		**Flexion Momentum Phase:** • Initiation of head movement • Trunk and pelvis rotate anteriorly into trunk flexion forward • Thighs and lower legs remain stationary • BOS in buttocks • Forward momentum generated in upper body	**Momentum Transfer Phase:** • Buttocks lifted from seat of chair • Momentum of upper body transferred to total body for upward and anterior motion • BOS moves from buttocks to feet and vertical acceleration begins • Maximum hip flexion occurs first, followed by max trunk flexion then max head extension • Phase ends with max ankle dorsiflexion		**Extension Phase:** • Vertical acceleration continues and converts to vertical deceleration at about 45% completion of movement • Phase ends with full hip and knee extension	**Stabilization Phase:** • End of vertical motion with full hip and knee extension • Stabilization in standing occurs (some sway may be noted) • Erect stance maintained	
What to Look For During Motion	• Are knees and feet aligned forward about hip-width apart • Is trunk upright and resting against back of chair • Postural alignment and head position? • Assistance or external support needed?	• Is the movement fluid? • Do both sides move together? • Do the above movements occur and in the correct order? • Are knees and feet aligned forward about hip-width apart? • Is trunk flexion creating momentum? • Postural alignment and head position? • Assistance or external support needed?	• Is the movement fluid? • Do both sides move together? • Do the above movements occur and in the correct order? • Does weight bearing appear equal bilaterally as the BOS shifts to feet? • Are knees and feet aligned forward about hip-width apart? • Is there visible muscle activation of lower extremities? • Does forward momentum transfer into upward acceleration? • Postural alignment and head position? • Assistance or external support needed?		• Is the movement fluid? • Do both sides move together? • Do the above movements occur and in the correct order? • Does upward acceleration transition into controlled deceleration toward end of motion? • Are hips and knees fully extended at completion of motion? • Postural alignment and head position? • Assistance or external support needed?	• Is the movement fluid? • Do both sides move together? • Do the above movements occur and in the correct order? • Are hips and knees fully extended at completion of motion? • Is the majority of motion controlled with minimal postural sway and minimal exertion to maintain upright stance? • Postural alignment and head position? • Assistance or external support needed?	See Stabilization Phase

Transfer Analysis Form: Stand to Sit

		Complete Transfer (100%)					
	Standing	Initiation of Movement (15% of motion)	Decending (27% of motion)	Seat Contact	Seat Loading (7% of motion)	Stabilization (51% of motion)	Sitting
Expected Movement		**Flexion in Standing Phase:** • Initiation of movement • Transition to stooped posture • Begins with the start of hip flexion	**Descending Phase:** • Vertical downward acceleration of body mass occurs and changes to deceleration at about 26% completion of transfer • Trunk flexion, hip flexion, knee flexion and ankle dorsiflexion occurs • Ends with maximum hip flexion and buttocks touching seat of chair		**Seat Loading and Extension in Sitting Phase:** • Initiates with seat contact • Weight transfers from legs and feet to buttocks • Trunk extension occurs • Ends with maximum hip extension in sitting with upright posture and back touching back of chair	**Stabilization Phase:** • Trunk and sitting balance adjustments occur • Maintenance of upright sitting posture	
What to Look For During Motion	• Postural alignment and head position? •Assistance or external support needed?	• Is the movement fluid? • Do both sides move together? • Do the above movements occur and in the correct order? • Are knees and feet aligned forward about hip-width apart? • Is motion controlled eccentrically? • Postural alignment and head position? • Assistance or external support needed?	• Is the movement fluid? • Do both sides move together? • Do the above movements occur and in the correct order? • Is motion controlled eccentrically with downward acceleration transitioning smoothly to deceleration? • Are knees and feet aligned forward about hip-width apart? • Does max hip flexion occur just before seat contact? • Postural alignment and head position? • Assistance or external support needed?		• Is the movement fluid? • Do both sides move together? • Do the above movements occur and in the correct order? • Is the motion controlled eccentrically? • Are knees and feet aligned forward about hip-width apart? • Is there a smooth transfer of weight onto buttocks from feet and legs? • Does the trunk fully extend to upright sitting at end of motion? • Assistance or external support needed?	• Is the movement fluid? • Do both sides move together? • Do the above movements occur and in the correct order? • Is upright sitting maintained with minimal support? • Are knees and feet aligned forward about hip-width apart? • Is the majority of motion controlled with minimal postural sway and minimal exertion to maintain upright sitting? • Postural alignment and head position? • Assistance or external support needed?	See PreviousPhase

Transfer Analysis Form: Standing

	Lateral View	Anterior View	Posterior View
Expected Movement	• Landmarks aligned laterally fall slightly anterior to lateral malleolus, slightly anterior to axis of knee joint, through greater trochanter just posterior to hip joint, through majority of lumbar and cervical spine, through shoulder point and through ear • Normal curves visible: Cervical and lumbar lordosis, Thoracic kyphosis • Neutral pelvis • Hip and knee joints extended to neutral position • Neutral position of ankle	• Landmarks aligned from posterior views are midline of head, entire spine through sacrum • Shoulders, scapula, hips/pelvis can be equally bisected along midline • Ears, shoulders, scapula, hips/pelvis, knees and malleoli of ankles are level bilaterally • Thighs, knees, lower legs and feet are evenly spaced with equal weight bearing through legs	• Landmarks aligned from anterior views are midline of head (bisecting eyes, nose and mouth), sternum/rib cage • Shoulders, hips/pelvis can be equally bisected along midline • Ears, eyes, shoulders, hips/pelvis, knees and malleoli of ankles are level bilaterally • Thighs, knees, lower legs and feet are evenly spaced with equal weight bearing through legs • Feet and knees facing forward
What to Look For During Motion	• Legs and feet are aligned, only one side visible from lateral view. • Co-activation of trunk and legs maintains postural control and normal muscle tone to maintain upright standing with minimal sway and minimal exertion. • Postural alignment and head position? • Assistance or external support needed? • Any visible discomfort as a result of maintaining position? • Length of time upright standing is maintained?	• Co-activation of trunk and legs maintains postural control and normal muscle tone to maintain upright standing with minimal sway and minimal exertion. • Postural alignment and head position? • Are landmarks symmetrical bilaterally? • Assistance or external support needed? • Any visible discomfort as a result of maintaining position? • Equal weight bearing through lower extremities? • Length of time upright standing is maintained?	• Co-activation of trunk and legs maintains postural control and normal muscle tone to maintain upright standing with minimal sway and minimal exertion. • Postural alignment and head position? • Are landmarks symmetrical bilaterally? • Assistance or external support needed? • Any visible discomfort as a result of maintaining position? • Equal weight bearing through lower extremities? • Length of time upright standing is maintained?