Spring 2015

Implementation of a Comprehensive Treatment Program for a Patient with TBI to Address Balance and Gait Deviations: A Case Report

Robert de Lara
Governors State University

Follow this and additional works at: http://opus.govst.edu/capstones

Recommended Citation

de Lara, Robert, "Implementation of a Comprehensive Treatment Program for a Patient with TBI to Address Balance and Gait Deviations: A Case Report" (2015). All Capstone Projects. 120.
http://opus.govst.edu/capstones/120

For more information about the academic degree, extended learning, and certificate programs of Governors State University, go to http://www.govst.edu/Academics/Degree_Programs_and_Certifications/

Visit the Governors State Physical Therapy Department

This Project Summary is brought to you for free and open access by the Student Capstone Projects at OPUS Open Portal to University Scholarship. It has been accepted for inclusion in All Capstone Projects by an authorized administrator of OPUS Open Portal to University Scholarship. For more information, please contact opus@govst.edu.
Implementation of a Comprehensive Treatment Program for a Patient with TBI to Address Balance and Gait Deviations: A Case Report

By

Robert de Lara
B.S., The University of Iowa, 2007

CAPSTONE PROJECT

Submitted in partial fulfillment of the requirements

For the Degree of Doctor of Physical Therapy

Governors State University
University Park, IL 60484

2015
ABSTRACT

Background and Purpose. The purpose of this retrospective case report is to describe physical therapy interventions provided to improve the balance and ambulation of a 20-year-old patient with apparent lower extremity foot drop and fatigue 20 months post severe traumatic brain injury secondary to a motor vehicle accident.

Case Description. The patient initially had decreased active and passive range of motion in bilateral ankles, decreased BERG balance test scores, and decreased ambulation distance without the use of an assistive device. Treatment interventions included balance and ambulation training program that incorporated stretching and joint mobilizations, balance exercises, and endurance training.

Outcomes. Following 13 sessions of skilled physical therapy over a 19-day period, the patient exhibited mild improvement with ankle dorsiflexion, improved ambulation speed by 900%, improved Six-Minute Walk test ambulation distance by 250 feet, and improved BERG balance test score by 7 points. The patient was also capable of ambulating 295 feet in a crowded, public area with moderate assistance. Discussion. More research is needed to determine how mental fatigue impacts patients with acquired brain injury and impairments related to hypertonicity, balance, and ambulation distance beyond household distance (>150 feet).
INTRODUCTION

Acquired brain injury (ABI), particularly of traumatic etiology, is one of the leading causes of death and lifelong disability in North America, particularly in children and adolescents.\(^1,2\) In the United States, the incidence of traumatic brain injury (TBI) resulting in hospitalization is estimated to be approximately 600.7 per 100,000 population as of 2010.\(^3\) Moreover, in regards to gender, it is estimated there are 25.4 male related deaths secondary to TBI compared to 9.0 per 100,000 population for females.\(^4\) The Centers for Disease Control and Prevention indicate that from 2003-2004, TBI prevalence had reached a peak in males from age 15-24 with 126.6 hospitalizations per 100,000 population.\(^3\) Latest data from the CDC in 2010 indicate a prevalence of 81.2 TBI related hospitalizations per 100,000 among the same age group.\(^3\)

Within the TBI rehabilitation community there appears to be an increasing awareness that sound evidence for treatment effectiveness is in short supply, although evidence based practice is an increasingly important element of clinical practice.\(^5\) Evidence based practice provides guidelines for effective care to improve rehabilitation outcomes. In fact, current evidence supports a multi-disciplinary approach of combined physical therapy, occupational therapy, and speech therapy has been shown to significantly improve balance and

\[^{1}\text{de Lara}\]
ambulation deficits associated with symptoms of decreased attention and increased fatigue post TBI.⁶ Though the duration of TBI therapy can be quite long and costly, a multi-disciplinary approach can in fact reduce the time required for improved function and independence, thereby decreasing the necessity for additional therapy sessions upon discharge.

Return to ambulation is a common goal among patients with acquired TBI. Previous descriptive studies of adolescents with TBI provide a myriad of influences to consider in developing a predictive model for ambulation recovery.⁷ In a study conducted by Teasell, it was found that the presence of extracranial injuries, lower-extremity injuries, and the type of brain injury have been related to poor mobility and ambulation outcomes in adolescents with TBI.⁶ Moreover, it has been shown that the more severe the injury (defined as the amount of time the child is unconscious following injury), the less likely an adolescent with TBI will achieve full recovery of physical function.⁶ Hypertonicity, a commonly reported neuromuscular impairment following a TBI in children and adolescents, also has been reported to influence a patient’s ability to ambulate after injury.⁷

The return to independent ambulation represents a major milestone in the recovery of physical functioning following TBI in adolescents. Community based rehabilitation centers also make this a
primary goal because it allows young adults to return home without restrictions in mobility. The aim of this retrospective study was to determine effective evidence based interventions that correlated to improved ambulation and balance for an adolescent with TBI within a community based rehabilitation environment, and the associated carry over to functional ambulation.

**EVALUATION**

**History**

The patient was a 20-year-old male who was involved in a high-speed motor vehicle accident that resulted in a right tibia and fibula fracture and a severe TBI (defined as unconscious for over 6 hours and a Glasgow Coma Scale of 3 to 8). The patient’s family was not present for the initial evaluation. Immediately following 1-month acute hospitalization and a 4-month stay in an inpatient rehabilitation unit, the patient was admitted to a community based rehabilitation center where skilled physical therapy, occupational therapy, and speech therapy are provided 5 days per week. The patient has been living in the community based rehabilitation center for the past 15 months. For the purposes of this report, physical therapy services occurred 20 months after the initial injury.
Prior to his injury, the patient was a senior in high school with average academic performance and unremarkable prior medical history. He spent his leisure time attending school and playing basketball. The patient resided with his mother and brother in a large, urban area in a two-floor home requiring no supervision from his mother or brother.

The patient resided in a two-floor community based rehabilitation center, with the patient’s bedroom, kitchen, and living area on the main floor. Physical therapy was provided in the basement of the home, which was accessed either by 14 stairs or via an elevator. Assistive technology used included a custom, solid, non-articulating Ankle Foot Orthosis (AFO) on his right involved lower extremity. The AFO had trim lines to the metatarsal heads of the right lower extremity, and was made of plastic. The patient used a rolling walker to ambulate independently indoors and a standard, steel, manual wheelchair with stand by assistance for community ambulation secondary to fatigue.

Functionally, the patient was independent with dressing, bed mobility, transfers, and toilet usage. The patient required minimum to moderate assistance for bathing and meal preparations. At the time of treatment, the patient did not operate a motorized vehicle, and is
transported by the rehabilitation center staff for medical appointments and social outings.

The patient’s medications included one 10 mg tablet per day of Citalopram, which is a prescription antidepressant drug classified as a serotonin reuptake inhibitor, and was used to treat depression. Dantrolene was given to the patient 3 times per day, and was used as a prescription muscle relaxant to treat muscle spasticity. The patient received daily one 5g tablet of the prescription drug Methylphenidate to address an apparent attention deficit disorder. Lastly, the over the counter antihistamine Cetirizine was given as needed to address allergies in addition to Q-Pap (acetaminophen), which was used to treat pain. Both of these medications were taken as needed.

Physical therapy services were provided to increase walking tolerances without the use of an assistive device, safety with ambulation, and fall prevention and recovery. The patient was highly motivated to improve walking distances without the use of an assistive device and to improve his gait pattern. The patient ambulated with a “shuffling” gait pattern, with decreased stride length (left stride was longer than the right stride).

It is expected that in the next 11 months the patient will be discharged to his two-floor home, located in a highly urban
environment. The patient’s family has a culture where it is typical for the children to live with the parents past high school, and the patient has a desire to spend more time with family after discharge. It is anticipated by the therapy team that the patient will be living with his mother and his older brother requiring distant supervision indoors, however the patient has goals of reaching independent ambulation.

**Systems Review**

Reportedly the patient had typical cardiovascular function and integumentary consistency. However, Musculoskeletal and Neuromuscular impairments were observed in gross range of motion (ROM) for bilateral dorsiflexion, gross strength, static and dynamic balance in sitting and standing, gait while wearing his right AFO, and transfers from sitting to standing and standing to sitting. Based on the observed impairments in gait, hypertonicity, balance, and safety during transitions and ambulation, the appropriate tests and measures were selected.

**Clinical Impression**

The patient was an excellent candidate for physical therapy interventions based on his relative young age at the time of his accident, personal motivation, family support system, and progress.
made since his initial injury. At the time of initial admission into the community rehabilitation center, the patient was non-ambulatory and required moderate assistance for bed mobility, maximum assistance for transferring from bed to wheelchair, and maximum assistance for bathing and meal preparations. 15 months after initial admission, the patient presented with independent bed mobility, all transfers, and mild assistance for bathing and meal preparations. Based on this level of improvement since admission to the community rehabilitation center, it is anticipated that the patient will improve his ambulation distance without the use of an assistive device while wearing his right AFO.
Tests and Measures

Table 1. Ankle Passive Range of Motion, Active Range of Motion, and Manual Muscle Testing

<table>
<thead>
<tr>
<th>Day Number</th>
<th>Left Ankle Dorsiflexion</th>
<th>Right Ankle Dorsiflexion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PROM</td>
<td>AROM, MMT</td>
</tr>
<tr>
<td>Initial Evaluation</td>
<td>-2 deg</td>
<td>-5 deg 4/5 MMT</td>
</tr>
<tr>
<td>Day 4</td>
<td>0–3 deg</td>
<td>0 deg 4/5 MMT</td>
</tr>
<tr>
<td></td>
<td>*available ROM</td>
<td>*available ROM</td>
</tr>
<tr>
<td>Day 8</td>
<td>0–2 deg</td>
<td>0 deg 4/5 MMT</td>
</tr>
<tr>
<td></td>
<td>*available ROM</td>
<td>*available ROM</td>
</tr>
<tr>
<td>Day 15</td>
<td>0–8 deg</td>
<td>0–4 deg 4/5 MMT</td>
</tr>
<tr>
<td></td>
<td>*available ROM</td>
<td>*available ROM</td>
</tr>
<tr>
<td>Day 19</td>
<td>0–10 deg</td>
<td>0–3 deg 5/5 MMT</td>
</tr>
<tr>
<td></td>
<td>*available ROM</td>
<td>*available ROM</td>
</tr>
</tbody>
</table>

Range of Motion

Active range of motion (AROM) and passive range of motion (PROM) were measured in supine on the mat table for ankle dorsiflexion with an extended knee as described by Reese and Bandy, and ranged from -15 degrees to 10 degrees. AROM and PROM were collected twice a week, at the beginning of the therapy session. This was performed for the duration of 3 weeks (19 days). A summary of range of motion can be found in Table 1. In a well-documented study, Boone et al. reported that the intertester reliability for AROM was
lower than the intratester reliability for weekly measurements of the upper and lower extremities. Moreover, Boone et al. found that the reliability of lower extremity AROM (r = 0.58) to be quite low and suggested that when more than one tester measures the same motion, changes in AROM should exceed 5 degrees in upper extremity measurements and 6 degrees in lower extremity measurements to document "improvement".

Smith and Walker demonstrated higher intratester reliability (r = .90) than intertester reliability (r = .70) for knee and elbow AROM in healthy elderly persons. In a later study, Walker et al. reported greater variability between testers than within testers for AROM measurements of the upper and lower extremities of elderly subjects. The student in physical therapy conducted all ankle dorsiflexion measurements for the duration in which data was collected to ensure internal consistency.

**Manual Muscle Testing**

Manual muscle testing for ankle dorsiflexion was measured in the supine position. The patient presented with foot drop secondary to a right tibia and femoral fracture. The right ankle presented with plantar flexion hypertonicity that limited the amount of dorsiflexion, and produced a hard endfeel. The left ankle presented a similar endfeel.
The manual muscle tests were performed as described by Hislop and Montgomery and ranged from 4/5 to 5/5 bilaterally for available range of motion with ankle dorsiflexion. Bilateral manual muscle testing data for ankle dorsiflexion was collected twice a week for 3 weeks, and the results are summarized in Table 1.

Wadsworth et al. found that the intrarater reliability of data obtained with manual muscle testing for various upper and lower-extremity muscles was good, with test-retest reliability coefficients ranging from .63 to .98 (P<.05) and with the paired t-test revealing no significant test-retest mean differences between manual muscle tests (P>.05). Although its predictive validity has been debated in the literature, manual muscle testing is a metric frequently recorded by physical therapists across all settings.
Table 2. BERG Balance Score and Six-Minute Walk Test Results

<table>
<thead>
<tr>
<th>Day Number</th>
<th>BERG Balance Score (56 pts. possible)</th>
<th>Six-Minute Walk Test Right AFO and Min-Mod Hand Held Assistance (Distance - feet, Blood Pressure - mmHg, Pre and Post Oxygen Saturation - %100, Pre and Post Heart Rate – beats per minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Evaluation</td>
<td>32/56</td>
<td>200 feet BP = 118/70 Pre SpO2 = 98%. Pre HR = 63 BPM Post SpO2 = 97%. Post HR = 76 BPM</td>
</tr>
<tr>
<td>Day 4</td>
<td>247 feet BP = 110/72 Pre SpO2 = 96%. Pre HR = 65 BPM Post SpO2 = 95%. Post HR = 72 BPM</td>
<td></td>
</tr>
<tr>
<td>Day 8</td>
<td>250 feet BP = 108/80 Pre SpO2 = 98%. Pre HR = 64 BPM Post SpO2 = 93%. Post HR = 72 BPM</td>
<td></td>
</tr>
<tr>
<td>Day 10</td>
<td>39/56</td>
<td>Not Measured</td>
</tr>
<tr>
<td>Day 15</td>
<td>320 feet BP = 116/72 Pre SpO2 = 98%. Pre HR = 65 BPM Post SpO2 = 98%. Post HR = 74 BPM</td>
<td></td>
</tr>
<tr>
<td>Day 19</td>
<td>39/56</td>
<td>1. *295 feet (outdoors) 2. 450 feet BP = 118/78 Pre SpO2 = 97% Pre HR = 104 BPM Post SpO2 = 98% Post HR = 138 BPM</td>
</tr>
</tbody>
</table>

BERG Balance Test

The patient completed the BERG balance test a total of 3 times over 3 weeks, with 8 days passing between each re-test. The test was conducted on a closed course within the therapy gym of the community based rehabilitation center. The BERG balance test is a clinical test of a person’s static and dynamic balance, consisting of 14
simple balance related tasks.\textsuperscript{15} It is used to assess balance impairment for activities such as reaching, bending, transferring, and standing. Across 14 functional tasks, points are assigned (0-4 points), with a score of 56 points being a maximum score.\textsuperscript{15} In regards to classifications, a score from a range of 0-20 was classified as a “high fall risk”, a score range from 21-40 was classified as a “medium fall risk”, and a score from 41-56 was classified as a “low fall risk”.\textsuperscript{15} The patient’s scores ranged from 32/56 to 39/56 and are summarized in Table 2. Details on the 14 functional tasks and the patient’s respective scores are represented in Table 5.

Specifically regarding the TBI population, Newstead \textit{et al.} evaluated 5 patients with TBI using the BERG balance test, with a mean age of 24.4 years of age.\textsuperscript{15} Newstead \textit{et al.} would find “excellent” test-retest reliability (ICC = 0.986) and a standard error of measurement of 1.65.\textsuperscript{15} Regarding the minimal detectable change, Flansbjer \textit{et al.} found the minimal detectable change to be 4.13 points for the BERG balance test in a research study among chronic stroke patients.\textsuperscript{16} This value for minimal detectable change was found to be most appropriate as the patient was 20 months post TBI. In regards to validity, for patient’s 6 months post injury, Ditunno \textit{et al.} found a Spearman’s rho value of 0.89 ($p < 0.001$), which was classified as “excellent”.\textsuperscript{17}
Six-Minute Walk Test

A 50-foot walkway (100 feet = 1 lap) was set up in the physical therapy gym to conduct the Six-Minute Walk test. The patient was instructed to walk as far as possible in 6 minutes, and that the test would be “exhausting”. The patient was told to slow down or take rest breaks as needed, but to resume walking as soon as he was able. No words of encouragement were provided to the patient during the examination, but minor cues for safety were provided when the patient was at risk for falling. For the duration of the test, the patient was provided minimum-moderate “hand held” assistance, in which the patient ambulated without the use of an assistive device. As the patient had an involved right lower extremity with apparent foot drop, the patient utilized a right AFO and hand held assistance in his left hand while performing the test. Blood pressure (systolic/diastolic, mmHg), oxygen saturation (% saturation), and resting heart rate (beats per minute, BPM) were recorded before the test, and oxygen saturation, heart rate, Borg dyspnea, and rate of perceived exertion scores were recorded after the test.¹⁸

The Six-Minute Walk test was conducted a total of 6 times over 3 weeks, with two instances of the test being performed on the last day in which data was collected for physical therapy treatment (see Table 2). With the exception of one administration of the test, all tests were
performed indoors on a part tile/part rubberized surface located inside the physical therapy gym.

Standards for administration of the test require a straight 100-foot walkway, however a 50-foot walkway was created in the therapy gym due to space constraints. It is important to note that the 5th performance of the test was administered on the last day (day 19) of recorded physical therapy treatment outdoors at a public event, on a concrete surface. Distance was measured using a Garmin Forerunner 620 GPS watch and the Garmin Fit Application for iOS smartphone devices. The 6th administration of the test was then conducted on the same day (day 19), in the therapy gym. Ambulation distances ranged from 200 feet to 450 feet and are summarized in Table 2.

In a study conducted by Mossberg, 23 participants, at least 12 months post acquired TBI and an average age of 36 years, were evaluated using the Six-Minute Walk test. Mossberg would find an "excellent" test re-test reliability (ICC = 0.94) for the Six-Minute Walk test. In another research study, Moseley et al. evaluated 10 participants with acquired TBI using the Six-Minute Walk test. Participants were on average 56 days post acquired TBI, and the test was administered in various clinical and public settings. In regards to validity, Moseley et al. found "poor to adequate" correlation with a 10 meter (32.8 feet) walk test in various environments: poor correlation
when tested in car park of a metropolitan shopping center (ICC = 0.06) and inside shopping center (ICC = 0.18), but “adequate” correlation when tested in clinical environment (ICC = 0.37).\textsuperscript{18}

**Table 3. Borg Dyspnea Scale and Rate of Perceived Exertion**

**Reported Scores**

<table>
<thead>
<tr>
<th>Day Number</th>
<th>Borg Dyspnea Scale (6-20)</th>
<th>Rate of Perceived Exertion (0-10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Evaluation</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Day 4</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>Day 8</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Day 15</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td>Day 19</td>
<td>13</td>
<td>3</td>
</tr>
</tbody>
</table>

**Borg Dyspnea Scale**

The Borg dyspnea scale is a psychophysical measure in which a subject reports symptoms associated with a physical activity. The Borg dyspnea scale rates dyspnea on a scale of 6-20, corresponding to a heart rate range of 60-200.\textsuperscript{20} A score sheet was provided to the patient with descriptors for every odd number between 6-20, and ranged from “very, very light” to “very, very hard”. These descriptors added a quality of tangibility to the Borg Dyspnea scale for a patient under fatigue post endurance testing. The Borg dyspnea score was collected post Six-Minute Walk tests that were conducted in the therapy gym, for a total of 5 instances over the course of 3 weeks.
After performance of the Results of the patient’s reported RPE scores ranged from 2-7 and are summarized in Table 3.

Scores for the Borg dyspnea scale tend to increase linearly with HR and VO\(_2\), as exercise intensity increases and has been shown to correlate with CO\(_2\) production, lactate accumulation, and body temperature.\(^{21}\) Based on a retrospective analysis, Cazzola et al. found a minimal clinical important difference of 1 unit to be relevant with \(r = 0.88.\)^{21} In a study conducted by Kendrick et al. that assessed the degree of dyspnea in patients with COPD and asthma, the researchers were able to demonstrate that the scale was effective in evaluating dyspnea.\(^{22}\)

**Rate of Perceived Exertion**

Developed by Gunnar Borg, the rate of perceived exertion (RPE) is a widely used indicator to monitor and guide exercise intensity.\(^{20}\) The RPE was collected post Six-Minute Walk tests that were conducted in the therapy gym, for a total of 5 instances over the course of 3 weeks. The patient viewed a visual scale that ranged from 0 – 10 (0 being “nothing at all” and 10 being “Extremely Strong - Maximal”), and would subjectively rate his level of exertion during the exercise test.\(^{20}\) Results of the patient’s reported RPE scores are summarized in Table 3.
Borg’s RPE is based on a subjective feeling of exertion and fatigue during exercise, and it is used to assess and regulate exercise intensity. The theoretical premise of RPE is that a person will give a numerical value on a scale from 0 to 10, representing a verbal expression of effort during exercise. In a study conducted by Karavatas et al., the overall Pearson $r$ between RPE and HR was 0.58 and an $r^2$ value was 0.31.\textsuperscript{23} This is to say only 31% of the RPE variability can be attributed to differences in HR.\textsuperscript{23} Karavatas’ findings support the findings of the meta-analysis by Chen et al., who reported an overall RPE-HR criterion-validity coefficient of 0.62 and $r^2$ of 0.34.\textsuperscript{24} This is to say that that HR and RPE reported scores are not as strongly correlated as previously thought, however RPE can still be used to assess exercise intensity.\textsuperscript{25}

**Evaluation Summary and Clinical Impression**

At the time of initial evaluation for this case study, the patient was 20 months post motor vehicle accident. The combined physical demand of ambulating without an assistive device, maintaining balance, and endurance required with ambulation amount to an array of related challenges that prohibit the patient from ambulating farther distances without an assistive device. This hypothesis is supported by
the results of the initial examination, in which the patient scored low values for the Six-Minute Walk test and Berg Balance test.

**Diagnosis and Prognosis**

The patient was appropriate for skilled physical therapy based on his functional goal to progress ambulation distance while wearing his right AFO, but without the use of an assistive device - as this was the patient’s prior level of function before his motor vehicle accident. The patient has an overall goal of independent household ambulation upon discharge from the community rehabilitation center in 11 months, however Physical Therapy anticipates distant supervision from the patient’s family for household ambulation at discharge. Signs and symptoms of the patient are consistent with balance and endurance impairments secondary to TBI. Identified impairments include deficits in active range of motion, strength, balance, and endurance as limiting the patient’s ambulation without an assistive device.

The patient benefits from having strong personal motivation to return to function, an encompassing family support system, and having incurred his injury at a relatively young age. Prognosis of the patient was that he will be able to independently ambulate and maintain his balance on level surfaces and ambulate up/down stairs inside of his mother’s two-floor home upon discharge in 11 months.
with distant supervision. The plan of care covered in this retrospective case study encompasses a 19 day period, with the patient’s discharge date anticipated to be 11 months after the 19th day.
## INTERVENTION

### Table 4. Summary of Interventions Performed

<table>
<thead>
<tr>
<th>Day Number</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1, 2, 3, 4, 6, 8, A, B</td>
</tr>
<tr>
<td>2</td>
<td>3, 5, 7</td>
</tr>
<tr>
<td>3</td>
<td>2, 3, 4, 5, 6, 10</td>
</tr>
<tr>
<td>4</td>
<td>3, 5, 7</td>
</tr>
<tr>
<td>5</td>
<td>1, 2, 3, 4, 8, 9, B</td>
</tr>
<tr>
<td>6</td>
<td>No Therapy</td>
</tr>
<tr>
<td>7</td>
<td>No Therapy</td>
</tr>
<tr>
<td>8</td>
<td>1, 2, 3, 4, 6, 8, B</td>
</tr>
<tr>
<td>9</td>
<td>3, 5, 7</td>
</tr>
<tr>
<td>10</td>
<td>1, 2, 3, 4, 6, 10, A</td>
</tr>
<tr>
<td>11</td>
<td>3, 5*, 7, 9</td>
</tr>
<tr>
<td>12</td>
<td>No Therapy**</td>
</tr>
<tr>
<td>13</td>
<td>No Therapy</td>
</tr>
<tr>
<td>14</td>
<td>No Therapy</td>
</tr>
<tr>
<td>15</td>
<td>1, 2, 3*, 4, 6*, 8, 9, B</td>
</tr>
<tr>
<td>16</td>
<td>3*, 5*, 7</td>
</tr>
<tr>
<td>17</td>
<td>1, 2, 3*, 4, 5*, 6*</td>
</tr>
<tr>
<td>18</td>
<td>No Therapy**</td>
</tr>
<tr>
<td>19</td>
<td>6*, 9, 10, A, B</td>
</tr>
</tbody>
</table>

1 = Stretching  
2 = Joint Mobilizations  
3 = Parallel Bar Ambulation  
4 = Balance Recovery and Training  
5 = Hip Flexion Exercises  
6 = Gait Training  
7 = Treadmill Training  
8 = Dorsiflexion Strengthening  
9 = Education and HEP  
10 = Community Outing  
* = Modification to Intervention  
** = Pt. MD Appointment  

**Outcome Measures**  
A = BERG Balance Test  
B = 6 Minute Walk Test

The patient’s goal was to improve walking distance without the use of an assistive device, with the overall goal of supervised to independent household ambulation upon discharge in 11 months. In addition to improved
ambulation distance, family goals for the patient were to improve safety and recovery from a loss of balance or fall.

The patient was seen in an interdisciplinary, community based rehabilitation center receiving speech therapy, occupational therapy, and physical therapy 5 days per week pending the patient’s medical appointments. In addition to skilled therapy, the patient received on average 2 hours of physical and mental activities with Life Skilled Technicians. Skilled physical therapy sessions were one-on-one sessions lasting 45 minutes in length, and occurred 5 times per week. These activities included playing cards, making puzzles, board games, and seated range of motion exercises. With the exception of 2 days, the patient attended all physical therapy sessions during the weekdays, amounting to a total of 13 treatment sessions over the duration of 19 days. A summary of the treatment days is represented in Table 4.

**Stretching**

Stretching consisted of the student physical therapist (SPT) manually stretching bilateral gastrocnemius muscles while lying supine at the mat table using the contract-release methods of 20 seconds, performed 2-3 times. This progressed to the patient performing a gastrocnemius stretch while lying supine on the mat table, having a fully extended knee, and using both hands to hold a gait belt around the plantar surface of the foot. The
patient’s soleus muscles were not stretched during therapy sessions, but were a part of the patient’s home exercise program. The patient also stretched his bilateral quadriceps and iliopsoas musculature while lying supine at the mat table with one side of the body off of the table. This was performed for 20 seconds, 2-3 times per side or as tolerated by the patient. Stretching during the therapy session occurred in 6/13 treatment days over a period of 19 days.

**Joint Mobilizations**

The patient’s limited ankle range of motion contributed to the patient’s shuffled gait pattern (right strider shorter than the left stride). To improve range of motion, grade III and grade IV posterior glides were performed to the patient’s bilateral talocrural joints while lying in supine on the mat table for 60 seconds. This was repeated 2 times per side. The patient also received a single 60 second long-axis distraction at bilateral talocrural joint. Joint mobilizations during the therapy session occurred in 7/13 treatment days over the 19-day period.

**Parallel Bar Ambulation**

Parallel bar ambulation was utilized for active stretching and safe practice of ambulation, lasting 3-5 minutes depending on the patient’s level of fatigue as stated by the patient or determined by the SPT. Incorporation
of dual motor tasks and distractions inside the parallel bars was incorporated to improve motor control while ambulating outside the parallel bars, similar to the methods described by Tappan et al.\textsuperscript{25}

Exercises implemented by the SPT included stepping forwards and backwards with reciprocal movements, and sidestepping with upper extremity synchronization (feet apart and arms apart followed by feet together and arms together). Verbal and tactile cues were provided for coordinated contralateral arm swinging with the lower extremity for walking forwards and backwards. In regards to sidestepping, the patient practiced clapping his hands with each sidestep. Music was used to help facilitate coordination, and was weaned off by week 3. Coordinated arm swinging was facilitated inside the parallel bars in order to progress the patient toward a more natural gait pattern, while sidestepping with clapping was administered to improve upper and lower extremity coordination.

In all cases, use of a gait belt and stand by assistance or contact guard assistance was provided depending on the patient’s level of fatigue. Regarding fatigue, if the patient reported a moderate-high level of fatigue or was not capable of maintaining a consistent step height, the SPT terminated performance of the exercise. Parallel bar ambulation during the therapy session occurred in 12/13 treatment days over the 19-day period.
Balance Recovery and Training

Recovery from a loss of balance was addressed with various balance exercises with the intention of improving stepping responsiveness and ankle, knee, and hip strategies to maintain balance with less upper extremity support. The first exercise involved the patient standing inside the parallel bars without an assistive device, as he attempted to recover from moderate challenges of force in the anterior-posterior and posterior-anterior direction, which was applied by the SPT. Use of a gait belt and contact guard assistance was provided to the patient, and the patient received moderate verbal and tactile cues moving his lower extremity to recover from a loss of balance. Tactile cues included tapping the patient’s lower extremity to encourage stepping forward or backward. This was performed for 3-5 minutes depending on the patient’s level of fatigue, requiring a single rest period over the duration of 3-5 minutes of balance recovery training.

The patient also performed double-legged squats while standing on compliant and non-compliant surfaces, while reaching for a ball with bilateral upper extremities. 2 sets of 5 repetitions were performed. In all balance activities, the patient was provided contact guard assistance and progression was made by decreasing the amount of rest time between sets, depending on the patient’s apparent level of fatigue. Apparent level of fatigue was determined by the SPT using the patient’s decreased form and performance.
of the exercise. Balance training occurred in 11/13 treatment days over the 19-day period.

**Hip Flexion Exercises**

Hip flexion exercises were performed to accommodate for the lack of range of motion with ankle dorsiflexion, which is important for proper heel strike during the gait pattern. Performing hip flexion exercises allowed for the patient to compensate for his decreased ankle range of motion and encouraged a higher step height for improved safety with ambulation. Hip flexion exercises were performed at the parallel bars with bilateral upper extremity support to improve endurance, hip flexion, and foot clearance associated with the patient’s right foot drop during ambulation. The patient performed forward step-ups to a 10-inch step with a red TheraBand (1.87 lb. resistance at 50% elongation) tied around each of the patient’s ankles. Two sets of 10 repetitions were performed for this exercise, stretching the red TheraBand to approximately 50% of its length. Progression of this exercise involved utilizing 3 lb. ankle weights in lieu of red Theraband on day 11 through day 19, which was based on improved performance of the exercise, observation of decreased upper extremity support, and decreased level of fatigue. This intervention was performed in 6/13 treatment days over the 19-day period.
Gait Training

In order to improve ambulation distance and endurance without the use of an assistive device, the participant practiced ambulation with “hand held assistance”, which consisted of the patient holding onto the arm of the SPT with his left hand and while wearing his solid, non-articulating AFO on his right lower extremity. Prior to day 1 of the case study, attempts were made previously by Physical Therapy to instruct the patient to use a cane (progressing the patient from his rolling walker). However, it was reported that after numerous attempts to instruct cane ambulation, the patient was not capable of performing the proper sequencing for cane ambulation, as it was determined by Physical Therapy that cane sequencing was in fact limiting the patient’s progression in ambulation. Therefore, hand held assistance was utilized to progress the patient toward improved household ambulation with his right AFO and no assistive device.

The patient received minimum to moderate hand held assistance as he ambulated inside the therapy gym, on level surfaces, and over obstacles 1 inch and 4 inches in height. The patient received moderate to maximum verbal and tactile cues for step height, step length, dorsiflexion, and gait speed. Verbal cues were given for proper gaze, maintaining attention, and speed. Tactile cues were provided to the back of the patient’s leg for proper step length and height.
Gait training was progressed to the patient ambulating while grasping an aluminum dowel on day 15. The aluminum dowel was parallel to the floor, and the patient used an overhand grip and wide distance between both of his hands for upper extremity support.

Gait training exercises were performed for 10-15 minutes in 7/13 treatment days over the 19-day period. Day 19 involved gait training at a boardwalk during a located at public beach, with hand held assistance. In all gait-training activities, the patient received contact guard to stand-by-assistance, based on the patient’s level of fatigue. Rest periods were provided based on patient’s stated level of fatigue or as determined by the SPT based on inconsistent step length, step height, respiratory rate, and patient safety.

**Treadmill Training**

To address endurance, gait training on a treadmill was performed for 10-20 minutes, which depended on the patient’s level of fatigue and his ability to ambulate with proper dorsiflexion/no dragging of the toes. Treadmill training did not occur on days in which gait training exercises were performed or a Six-Minute Walk test was administered. The patient ambulated on the treadmill with no incline, at 0.58-0.63 meters per second receiving moderate to maximum verbal and tactile cues for step height, step length, dorsiflexion and gait speed. If the patient was not able to ambulate
with proper dorsiflexion, the exercise was discontinued. Treadmill training was administered in 5/13 therapy sessions over the 19-day period.

**Dorsiflexion Strengthening**

Improvement for foot drop in the right lower extremity was addressed with dorsiflexion strengthening in the improved range, after joint mobilizations and stretching to bilateral ankles. Two sets of 10 repetitions were performed, which involved the patient lying in supine at the mat table with a yellow Theraband (3 lb. resistance at 100% elongation) around his ankle. TheraBand was held in place by the SPT as the patient performed concentric ankle dorsiflexion, stretching the TheraBand to approximately 100% of its length. This was performed for both the right and left ankles in conjunction with ankle stretching and joint mobilizations, as previously discussed, in 4/13 therapy sessions over the 19-day period.

**Education and Home Exercise Program**

Updates and review of the patient’s Home Exercise Program (HEP) were provided to the patient at initial evaluation, day 5, day 11, day 15, and day 19. The HEP involved the patient using a gait belt to stretch bilateral gastrocnemius muscles while long sitting in full knee extension in his bed. This was performed for 30 seconds and 2 repetitions. Similarly, this exercise was also performed for bilateral soleus muscles with the knee flexed. The
patient performed both exercises independently in the morning and evening before bed.

The patient was also instructed that the same exercise could be performed using a step stool or by standing staggered with one foot in front of the other, with a rolling walker positioned in front of a wall. Proper removal of the right AFO was reviewed on each of these days in order to properly perform the stretching exercise.

On day 15, the HEP was changed to include 2 sets of 10 repetitions of posterior pelvic tilts while lying in supine, which was to be performed in the morning and evening before bed. Additionally, the nursing staff was informed to allow the patient to eat lunch, a period of 20 minutes, while sitting on a balance ball. Both of these exercises were added to the HEP to address an apparent anterior pelvic tilt present during ambulation.

**Community Outing**

Once a week, the patient engaged in a community outing in which speech therapy, occupational therapy, and physical therapy were performed via a functional group activity in the public. Community outings were 3-5 hours in duration and occurred on day 3, day 10, and day 19 (Tab. 4). Outings included a picnic in the park with sports activities, a car wash with washing and drying of the facility cars, and a trip to the beach. On day 3 and day 10, the patient participated in both a one-on-one physical therapy
treatment session inside of the gym and in the respective community outing activity. On day 19 the patient did not participate in one-on-one physical therapy, and only participated in the community outing (Tab. 4).

OUTCOMES

Range of Motion and Manual Muscle Testing

The patient’s progression of ankle range of motion is outlined in Table 1. A positive range for left ankle PROM dorsiflexion was attained by day 4, with a peak range of 0-10 degrees by day 19. AROM for left ankle dorsiflexion reached positive values by day 15, with a peak range of 0-4 degrees by day 15.

PROM for right ankle dorsiflexion did not reach a positive value, but reached a peak value of -5 degrees on day 4. Similarly, AROM for right ankle dorsiflexion did not reach a positive value, with a peak value of -9 degrees measured on day 4 and day 19.

Manual muscle testing for left ankle dorsiflexion was initially measured to be 4/5 at initial evaluation, and reached 5/5 by day 19. Manual muscle testing for right ankle dorsiflexion was measured to be 5/5 for available range of motion at initial evaluation, and maintained at this level through day 19. The patient’s right ankle plantar flexion hypertonicity was the limiting factor for preventing the patient from reaching full range of motion,
though an improvement in muscle strength was noticed in the available range of motion.

The patient would likely benefit from botox injections to the right ankle and an articulating right AFO to address the limited range of motion, and these recommendations are further discussed in the discussion portion of the case report. Despite minor improvement, the patient was observed to have an improved swing phase during ambulation.
BERG Balance Test

Table 5. BERG Balance Test Activities and Scores

<table>
<thead>
<tr>
<th>Item</th>
<th>Item Description</th>
<th>Score (0-4)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial Evaluation</td>
<td>Day 10</td>
<td>Day 19</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Sitting to Standing</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Standing Unsupported</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Sitting Unsupported</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Standing to Sitting</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Transfers</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Standing with Eyes Closed</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Standing with Feet Together</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Reaching Forward with Outstretched Arms</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Retrieving Object from Floor</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Turning to Look Behind</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Turning 360 Degrees</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Placing Alternate Foot on Stool</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Standing with One Foot in Front</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Standing on One Foot</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total Score</strong></td>
<td><strong>32</strong></td>
<td><strong>39</strong></td>
<td><strong>39</strong></td>
<td></td>
</tr>
</tbody>
</table>

Over 19 days, the patient completed three instances of the BERG balance test (Tab. 2). A summary for the activities performed during the BERG balance test and the patient’s respective scores are represented in Table 5. The patient scored a 32/46, 39/56, and 39/56 at initial evaluation, day 10, and day 19 respectively (Tab. 2 and Tab. 5).

Referencing Table 5, improvements were made in sitting to standing, standing to sitting, reaching forward with outstretched arms, retrieving objects from the floor, turning to look behind, and standing with one foot in front of the other. In all instances, the patient improved his score by 1 point.
from initial evaluation to the second performance of the test on day 10. No improvement was made between the second and third instance of the test on day 10 and day 19 respectively.

The 1 point improvement for sitting to standing was defined by the patient progressing from standing with the use of his hands at initial evaluation, to standing without the use of his hands by day 10 and day 19. Similarly, improvements in standing to sitting transfers was defined by progressing from utilization of his hands for the transfer at initial evaluation, to minimal use of his hands measured at day 10 and day 19. Reaching forward with outstretched arms, the patient was capable of reaching 1.75 inches with his arms at 90 degrees while standing unsupported and maintaining his balance. This progressed to reaching 6 inches at day 10 and 9 inches at day 19, resulting with a 1 point improvement in the BERG balance test. Regarding picking up objects from the floor, the patient was capable of picking up a pencil from the floor under supervision resulting with a score of 3 points at initial evaluation. By day 10 and day 19, the patient was capable of performing the task safely and easily scoring 4 points for the task. At initial evaluation, the patient was capable of turning 360 degrees under close supervision and stand by assistance, resulting with a score of 1 point. At day 10 and day 19, the patient was capable of performing the task independently, but requiring a time of greater than 5 seconds. This resulted with a score of 2 points for the task. Lastly, the patient was not capable of
performing 2 alternating steps onto a footstool without losing his balance or moderate assistance, resulting with a score of 0 points. At day 10 and day 19, the patient was capable of performing greater than 2 alternating steps, but less than 4 alternating steps, resulting in a score of 1 point for the task.

Interventions were provided to address safety concerns with ambulation inside of the house without the use of an assistive device. The scores on the patient’s BERG balance assessment across 3 administrations of the BERG balance test indicate that the patient improved his ability to balance during several functional tasks.

Functionally, it was observed that the patient had improved use and coordination in his ankles, knees, and hips when challenged with balance activities, gait exercises, or activities as described by the BERG balance assessment. For example, the patient had an improved ability to bend from his ankles and waist when reaching forward for items. It is foreseeable that this is a functional task that the patient will likely perform while ambulating within his house at discharge (i.e. picking something off the floor). This is therefore is consistent with the patient and family’s current goal of improved ambulation without an assistive device, with the end goal of supervision to independent household ambulation upon discharge 11 months after day 19.
Six-Minute Walk Test, BORG Dyspnea, and Rate of Perceived Exertion

Figure 1. Six-Minute Walk Test Scores and Walking Speed

The Six-Minute Walk test was administered a total of 5 instances across 19 days and the results are summarized in Table 2. In all performances of the Six-Minute Walk test the patient wore his solid, plastic right AFO. Additionally, the patient received minimum-moderate hand held assistance on the patient’s left and right hand. The patient would begin each instance of the Six-Minute Walk test with minimum hand held assistance on the patient’s left side. This would progress to the patient asking the SPT to provide hand held assistance on the patient’s right side secondary to left arm fatigue. In all performances of the Six-Minute Walk test, the patient required moderate hand held assistance during the last 1-2 minutes of the Six-Minute Walk test. The specific point at which hand held assistance
switched arms or level of assistance increased for each instance of the Six-Minute Walk test was not recorded.

Figure 1 represents a cumulative record for patient’s ambulation distance and associated walking speed. Represented on the left Y-Axis is the cumulative record of ambulation distance. The X-Axis represents the days at which the test was performed. Represented on the right Y-Axis is average ambulation speed in meters per second.

Walking speed was calculated by dividing the total distance ambulated (Tab. 2) by the time, 6 minutes. By Day 19, the patient progressed from a speed of 0.012 meters per second at initial evaluation to ambulating at a speed of 0.12 meters per second. This represents a 900% change in ambulation speed from initial evaluation to day 19, however the ability of the patient to maintain this speed consistently and without hand held assistance is questionable.

Ambulation speed and ambulation distance appear to be consistent, with the greatest improvement in ambulation distance and speed occurring at day 15 and day 19.
Figure 2 represents a cumulative record for the patient’s ambulation distance with the associated pre-heart rate and post-heart rate values. Referencing Figure 2, the greatest changes in ambulation distance occurred between day 8 and day 15, and between day 15 and day 19. On day 15, the patient ambulated a distance of 320 feet, resulting in an improvement of 70 feet from day 8. On day 19, the patient ambulated a distance of 450 feet, resulting in an improvement of 130 feet from day 15. The associated heart rate values are represented in Figure 2, with a peak post-test heart rate value of 138 beats per minute (BPM) across all 5 administrations of the test (Tab. 2).
Figure 3 represents a cumulative record for the patient’s Six-Minute-Walk test ambulation distance in conjunction with the patient’s reported Borg dyspnea scores. On a scale from 6-20, the patient reported a peak score of 15 on day 15 (Tab 3.) with an associated ambulation distance of 320 feet (Tab 2.). Regarding a change in reported dyspnea scores, the greatest level of change occurred between day 8 and day 15, in which a 4 point change in reported dyspnea scores were recorded. Interestingly, the patient reported a score of 13 on day 19, the day in which the patient ambulated the farthest distance and exhibited the greatest change in ambulation distance.

Reported scores for dyspnea appear to be inconsistent with ambulation distance, as reported values increased and decreased in subsequent administrations of the Six-Minute-Walk test.
Figure 4 represents a cumulative record for the patient’s Six-Minute-Walk test ambulation distance in conjunction with the patient’s reported RPE scores. Unlike the reported dyspnea values, from initial evaluation through day 15, the patient’s reported RPE values increase linearly with increased ambulation distance as represented in Figure 4, reaching a peak value of 7/10 on day 15. However, the patient reported his second lowest value, a score of 3/10, for RPE on day 19, the day in which the patient ambulated the farthest distance and had the highest values for pre and post-heart rate measurements (Tab. 2 and Fig. 1).

Lastly, the patient performed the Six-Minute Walk test in a public setting, a city walking path that was adjacent to a beach during a public
event. This occurred on day 19, prior to the patient’s performance of the Six-Minute Walk test inside of the therapy gym. With maximal visual and auditory distractions, the patient ambulated 295 feet with moderate hand held assistance (Tab. 2).

Six-Minute Walk test ambulation speed, ambulation distance, recorded heart rate values, reported Borg dyspnea and RPE values are indeed consistent with the goals of the patient and family. These goals being for the patient to improve ambulation distance without the use of an assistive device, with the overall goal of supervised to independent household ambulation upon discharge in 11 months (discharge is anticipated to occur 11 months post day 19). This was further demonstrated by performance of the Six-Minute Walk test outdoors while at a public event. These outcomes indicate a measurable progression in ambulation distance, and the associated level of fatigue the patient endures.

**DISCUSSION**

This treatment approach was consistent with evidence based research structured to improve ambulation and balance associated with adolescents with severe TBI. In a study conducted by Dumas et al., 95 children and adolescents with TBI were evaluated in an inpatient setting to identify predictors for return to ambulation at discharge from an inpatient rehabilitation setting. Children and adolescents who achieved ambulation at
the time of discharge were at least 8 times more likely to have had a history of no lower-extremity hypertonicity on admission to the inpatient rehabilitation facility. Since the absence of lower-extremity hypertonicity was by far the strongest predictor of recovery, emphasis on stretching bilateral gastrocnemius, in addition to ankle joint mobilizations, were provided to the patient. Although the patient was not able to achieve a positive active range of motion for right ankle dorsiflexion (Tab. 1), it is possible that the improved range of motion contributed to the increased ambulation distance during the Six-Minute-Walk test. Perhaps the patient will continue to improve his ambulation distance with an increase active range of motion for right dorsiflexion.

At the time of the case study, the patient had not received botox injections to his right ankle. It is possible that botox injections can improve the patient’s right ankle range of motion, however botox injections to the ankle have shown to not significantly improve step length or velocity with patients who have slow walking velocity (<0.49 meters per second).

A 7 point improvement in the BERG balance test occurred between initial assessment and day 19 (Tab. 1). Functional balance was observed to have improved, as the patient was gradually permitted to ambulate from his bedroom to the dining and living area without his rolling walker with stand by assistance of the nursing staff. Reportedly, the nursing staff made statements that the patient had an improved ability to transfer from
standing to sitting and required a decreased level of assistance during bathing. Although the decreased level of assistance for bathing is not measured by the BERG balance test, the reported decreased level of assistance during transfers can be tied directly to the recorded improvements of the BERG balance test (Tab. 5). Lastly, it was observed by the SPT that the patient had improved use of his ankles and hips when performing reaching activities, during ambulation, and other functional tasks with a noticeable coordination at these two joints. These observed improvements are further supported by the patient’s improvement in the BERG balance test (Tab. 5).

A 250 feet improvement in ambulation distance occurred between initial evaluation and day 19 (Tab.1 and Fig. 1). Mossberg et al. determined that the measured ambulation distance from the Six-Minute-Walk for patients with TBI provided good correlation with measured peak oxygen volume and consumption (VO$_2$ Max).\textsuperscript{19} Although VO$_2$ Max was not specifically measured at any point during the case study, the improved ambulation distance can likely be associated with improved VO$_2$ Max and therefore improved endurance. Interestingly, the Mossberg study showed that the inclusion of heart rate data during the Six-Minute-Walk test had only a minor added benefit to the correlation to measured VO$_2$ Max.\textsuperscript{19} Heart rate and reported BORG dyspnea values appeared to have little correlation to ambulation distance (Fig. 2 and Fig. 3), although the patient’s reported RPE
values correlated well with ambulation distance (Fig. 4). In summary, reported RPE values and ambulation distance from the Six-Minute-Walk test are likely the best predictors for improved endurance in a patient post severe TBI.

Ambulation speed progressed from 0.012 meters per second at initial evaluation to 0.12 meters per second at day 19, indicating a 900% change. Ambulation speed has been shown to be used as an accurate predictor for outcomes such as functional status, discharge, and need for rehabilitation. The white paper by Fritz and Lusardi determined that a gait speed less than 0.6 meters per a second classifies patient as likely dependent with activities of daily life and limited community ambulation, but likely able to be discharged home. The patient’s ability to maintain the peak ambulation speed of 0.12 meters per a second is questionable, and moreover, measuring ambulation speed without hand held assistance would be more functionally for the patient upon subsequent testing.

Weaknesses of the study involve the interventions not taking into account the mental and attention deficits associated with TBI. The patient’s mental and attention deficits were evident in that the patient frequently stated inconsistent performance of his HEP, as he attributed it to a high level of fatigue at the end of the day or to simply “forgetting” to perform his HEP. Consistent performance of the patient’s HEP would have potentially produced
greater improvements in ankle range of motion, as soleus stretching was not performed during therapy sessions by the SPT.

In regards to dual task training as it relates to addressing attention deficits, at day 19 the patient ambulated a lower recorded distance of 295 feet in a public setting, which can likely be attributed to the high levels of visual and auditory stimulus in the environment. Mental and physical fatigue are impairments commonly associated with severe TBI, and was apparent with the patient in this case study. Another limitation of this case study is that incorporating visual and auditory stimulus during gait training or more functional gait training outdoors in the community would have likely lead to a higher performance of the Six Minute Walk test outdoors. Although mental fatigue was not specifically addressed in the interventions provided by physical therapy in this case study, future studies could address functional ambulation by utilizing graded amounts of verbal and visual distractions throughout ambulation and endurance training, as depicted in a retrospective study conducted by Tappan et al. Addressing the mental and physical fatigue could also lead to better compliance in the patient’s safety and HEP performance, as previously discussed.

Lastly, another limitation of the study is the inherent fact that TBI is unique to each patient, and application of the interventions from this study would not be appropriate to the spectrum of TBI patients. Application of this case study to adults for example, would not be appropriate. However, in
regards to adolescents with severe TBI and hypertonicity/foot drop in the lower extremity, the interventions and treatment plan provide a solid framework for treatment to be built upon. Though the patient’s family is willing to ambulate with hand held assistance, long-term the patient would potentially benefit from an articulating AFO to improve his gait pattern. In a study by Radtka et al. the examiner’s results would find that an articulated AFO was found to produce more normal dorsiflexion during terminal stance phase and increased ankle power generation at pre-swing phase of the gait cycle. This is pertinent to the patient, as the patient ambulated in a shuffling gait pattern with no dorsiflexion at terminal stance phase. It would be important for the patient to consider all options of botox injections and/or a right articulated AFO, and for the patient’s orthopedic doctor to communicate with the community rehabilitation center to provide the best combination of assistive technology and therapy.

In conclusion, this retrospective case report demonstrated effective interventions to improve ambulation, endurance, and balance for a patient post severe TBI with apparent foot drop and hypertonicity. As confirmed with previous studies, the BERG balance test and Six-Minute-Walk test were shown to be a useful predictor for balance during functional tasks and endurance, in addition to hypertonicity and ambulation speed potentially limiting ambulation independence. It is recommended that in anticipation for discharge, that future therapy sessions with the patient include graded dual
task training, increasing the amount of auditory, physical, or mental stimulus while performing both gait and balance exercises. Cooperation with Speech Therapy and Occupational Therapy could yield better functional outcomes, as it has been shown to improve functional ambulation in patients with TBI.\textsuperscript{6}\ Future therapy sessions with the patient should also monitor gait speed with and without the use of hand held assistance, as it will help better predict the patient’s anticipated level of independence.\textsuperscript{27} A coordinated effort with the patient, the rehabilitation team, and the patient’s medical doctors will be necessary in order for the patient to reach the goal of supervised to independent household ambulation at discharge.
REFERENCES


27. Fritz S, Lusardi M. White paper: "walking speed: the sixth vital sign". 
28. Radtka SA, Skinner SR, Johanson ME. A comparison of gait with solid 
and hinged ankle-foot orthoses in children with spastic diplegic 