Land and Aquatic Based Physical Therapy Interventions to Improve Mobility and Independence on a Pediatric Patient After a Near-Drowning: a Case Report.

A Capstone Project for PTY 768
Presented to the Faculty of the Department of Physical Therapy
Sage Graduate School

In Partial Fulfillment
of the Requirements for the Degree of
Doctor of Physical Therapy

Erica Gabriel
May, 2010

Approved:

Gabriele Moriello, PT, PhD, MS, GCS
Research Advisor

Marjane Selleck, PT, DPT, MS, PCS
Program Director, Doctor of Physical Therapy Program

SAGE GRADUATE SCHOOL

I hereby give permission to Sage Graduate School to use my work,

Land and Aquatic Based Physical Therapy Interventions to Improve Mobility and Independence on a Pediatric Patient After a Near-Drowning: a Case Report.

For the following purposes:

- Place in the Sage Colleges Library collection and reproduce for Interlibrary Loan.
- Keep in the Program office or library for use by students, faculty, or staff.
- Reproduce for distribution to other students, faculty, or staff.
- Show to other students, faculty or outside individuals, such as accreditors or licensing agencies, as an example of student work.
- Use as a resource for professional or academic work by faculty or staff.

Erica Gabriel May 2010

I represent to The Sage Colleges that this project and abstract are the original work of the author, and do not infringe on the copyright or other rights of others.

Land and Aquatic Based Physical Therapy Interventions to Improve Mobility and Independence on a Pediatric Patient After a Near-Drowning: a Case Report.

Erica Gabriel May 2010

Land and Aquatic Based Physical Therapy Interventions to Improve Mobility and Independence on a Pediatric Patient After a Near-Drowning: a Case Report

Erica Gabriel

Abstract

Background and Purpose: There is currently a lack of research on physical therapy interventions, specifically the combination of aquatic and land therapy, for younger individuals with hypoxic brain injury. The purpose of this case report was to discuss the variety of treatments and successful outcomes reached with an adolescent male post hypoxic brain injury. *Case Description:* The individual for this case report was an 18 year old male diagnosed with a hypoxic brain injury due to a near-drowning in 1997. In 2008 he required supervision in sitting, minimal/moderate assistance to transfer, and moderate assistance to ambulate with a gait trainer 400'. His primary means of mobility was in a manual wheelchair propelled by an adult. *Methods:* He received physical therapy land sessions 2x/week for 30 minutes that consisted of transfer training and traditional overground gait training. Furthermore, he received an hour of aquatic therapy 1x/week that consisted of lap walking and stretching. *Outcomes:* By 2009, this individual made significant improvements in his gross motor skills. Most notably he progressed out of the gait trainer and was able to ambulate 920 feet with only contact guard assistance. For short distances, about 10 feet, he was able to ambulate with only close supervision. He demonstrated better ability to motor plan around obstacles and transfer from sit to standing independently. *Discussion:* The combination of land and aquatic therapy can produce successful outcomes for an adolescent male post hypoxic brain injury. During motor skill acquisition, repeating a movement continuously and under varying circumstances leads to procedural learning. Through procedural learning, activation and changes of neurons in our brain take place and enhance neuroplasicity. Tasks that may be difficult or unsafe on land can be preformed safely in the aquatic environment. The natural resistance of the water assists with strength training and balance which can carryover to help improve overall motor function on land. Then during land therapy, repetition of the actual task can be preformed

Introduction

Near drowning is a significant cause of disability in children. Between 2007-2008, the Center for Disease Control and Prevention reported 5,214 unintentional nonfatal drowning injuries in males, a shocking 929 of those were children between the ages of 5-14.[1] Nonfatal drownings can lead to brain damage resulting in long-term disabilities such as memory dysfunction, learning problems, and permanent loss of basic functioning. Such disabilities occur secondary to hypoxic-ischemic brain injury. Hypoxia refers to actual deprivation of oxygen supply to the tissues, while the term ischemia is used to describe a condition in which there is insufficient blood flow to the brain to meet its metabolic demand. The process of ischemia leads to cerebral hypoxia. During near drowning episodes, there is an overproduction of carbon dioxide which decreases the activity of the heart.[2] As the cardiovascular system begins to shut down, cerebral blood flow decreases resulting in ischemia and an elevation in extracellular glutamate.[3] Glutamate is a key molecule responsible for cellular metabolism, but at increased levels, it is believed to be directly linked to neuronal damage and hypoxic injury.[3,4]

Individuals post brain injury can experience a wide variety of adverse effects, especially motor impairments. A study by Gagnon et al,[5] examined children with mild traumatic brain injury and their scores on the Bruininks Oseretsky Test of Motor Proficiency, a normative referenced clinical standardize assessment tool. Compared to the published normative values for this test, the children with brain injury scored significantly lower in domains of balance, response speed and running speed on agility testing, yet significantly higher in domains of upper extremity coordination and visual motor control.[5]

Children with brain injury also demonstrate some motor deficits similar to individuals with cerebral palsy. Cerebral palsy itself can be caused from a perinatal hypoxic brain injury that results in motor deficits.[6] Muscle strength, neuromuscular activation, and motor unit recruitment all help grade the forces generated by muscle contractions to produce normal movement. Individuals with cerebral palsy often exhibit decreased activation of all available motor units resulting in muscle weakness and poor activation.[7] Due to this loss of selective muscle control, they have a very difficult time with gross motor functioning.[8] The effects of cerebral palsy on the body's ability to control muscle coordination is impaired[9] and these children can also display dysfunctions of sensory organization[9], a necessary component to developing postural control and proper gait mechanics.[10]

Another common result of brain injury is decreased cognitive functioning. Research has documented that traumatic brain injury often results in difficulty with selective attention, non-verbal fluency, recall of verbal information, and the ability to process visual and tactile information.[11] Other research also documents difficulty with spatial learning and memory,[12,13,14] as well as executive functioning.[15] When cognitive function is impaired, motor development is often adversely affected[16], which can impact rehabilitation.

Along with motor and cognitive impairments, individuals with brain injury can experience a vast assortment of emotional side effects. Individuals after brain injury are at very high risk for developing depression.[17] Neuropathological changes after a brain injury can effect the areas of the brain responsible for controlling emotions, including the prefrontal cortex, limbic system, and basal ganglia. Major depression has been shown to occur in about one quarter of persons with a traumatic brain injury.[18] Incidences of depression have been shown to impede achievements of optimal functional outcomes during rehabilitation.[19]

There are many rehabilitation options for people after brain injury. Physical therapy is a dynamic profession that can help to restore, maintain, and promote optimal physical function, wellness, and quality of life. Traditional physical therapy interventions can include transfer and gait training, range of motion and stretching, aquatics, and wheelchair/assistive device assessments.

Gait training is a skilled intervention many therapists utilize when working with individuals post brain injury. A study by Brown et al,[20] found that physical therapy interventions using conventional over the ground gait training helped improve gait patterns including velocity, step width, and step length for people post traumatic brain injury.[20] Additionally, the study reported that traditional over the ground gait training was more effective than bodyweight supported treadmill training for improving gait symmetry.[20] Many people with brain injury exhibit slower walking velocity,[21] and decreased step and stride length.[22] With conventional gait training, physical therapists may be able to improve some of these gait deficits in this population.

Following a brain injury, individuals often experience changes in muscle tone. Any central nervous system lesion can lead to muscle shortening, often termed spasticity.[23] There are many therapy interventions that can be utilized to help reduce spasticity including range of motion/stretching, proper positioning, and orthotics. Providing a stretch directly to the muscle depresses the muscle spindle activity[24] and reduces the possibility of developing contractures.[25, 26] Range of motion and stretching to aid in the prevention or reduction of contractures is very important to decrease pain associated with contracture development and resultant difficulties with functional mobility.[27]

Proper seating and positioning is important in the management of spasticity, especially for those individuals who spend long periods of time in a wheelchair or other seated device. Increased muscle tone can create postural instability, joint contractures, and limit upper extremity functioning.[27] A trained physical therapist can help develop the best positioning option for an individual with spasticity to help reduce these problems. The use of orthotics can also help control levels of spasticity. Recent literature has found that the sensory feedback provided by the orthosis helps to alter or reduce muscle tone.[28,29] Three main principles that allow for this mechanism of action are inhibition of primitive reflex activity, pressure that is placed over a muscle insertion, and the mechanical stabilization of the joint that allows for an active and static prolonged stretch.[30] By combining these interventions, a trained physical therapist can develop an appropriate regimen for a person with a brain injury to help reduce or prevent spasticity.

Aquatic therapy is a unique physical therapy intervention that can expand the depth and scope of our treatment. Aquatic rehabilitation has been cited throughout many sources as a useful treatment for people with neurological conditions.[31,32,33] Creating a specialized rehabilitation program in the water for individuals with a brain injury can help improve their level of physical fitness as well as their functional capacity.[31] After successful outcomes with an aquatic therapy program, individuals with brain injury have demonstrated higher levels of physical self-concept and self-esteem levels[32], as well as improvements in their overall mood.[33]

The unique properties of water, such as buoyancy and hydrostatic pressure, allow for gradation of exercise and treatment. The buoyant effects of water help offset the downward pull of gravity, thus providing a percentage of weight relief.[34] As a result, a variety of exercises can be performed in the aquatic environment safely and with greater ease. The principles of buoyancy allow a gradual transition from limited weight bearing in the water to eventual full weight-bearing on land. Hydrostatic pressure is defined as the force exerted on the body by the water molecules once immersed. As a result of hydrostatic pressure, an equal amount of pressure is felt across the body and this tactile input can help provide a greater sense of proprioceptive feedback.[35] The natural resistance created in the water has been shown to help dampen the involuntary spastic movements and/or tremors often associated with neurological impairments and the slow-motion effect as a result of resistances allows extra time for controlled movement.[34,35] The feeling of hydrostatic pressure and the resistance of the water will help to support individuals with balance deficits[34] which may provide a sense of confidence in people that typically have a fear of falling while ambulating or exercising. Hydrostatic pressure has also been shown to decrease pain and edema[34, 35] which in turn will help improve range of motion and flexibility. In addition, the warm temperature of the water can be therapeutic and can help relax hypertonic muscle activity.[36]

There is currently a lack of evidence based literature on the topic of physical therapy interventions for younger individuals with hypoxic brain injury due to near drowning. Furthermore, there is no research on the combination of aquatic and land therapy in those children with brain injury. The purpose of this case report was to discuss the variety of treatments and successful outcomes reached with an adolescent male post hypoxic brain injury.

Methods

Case Description

The individual for this case report was an 18 year old male with a diagnosis of hypoxic brain injury secondary to a submersion injury in 1997. Prior medical history included a diagnosis of fetal alcohol syndrome, attention deficit hyperactive disorder with mental retardation, and controlled asthma. He attended a full time school program in a self-contained classroom 5x/week, where he participated in adapted physical education 2x/week for 50 minutes. He also received occupational therapy and physical therapy 2x/week and speech 3x/week for 30 minutes.

He was alert and oriented to his surroundings and interacted with others through reaching, touching, and eye gaze. There was no documentation of any reports of pain. He was non-verbal but used a Mac switch, rocker switches, pictures, yes/no symbols, and facial expressions to convey his needs. His primary means of mobility was through a manual wheelchair propelled by an adult. During transportation to and from school he required a wheelchair lift and a 1:1 aide on the bus. He wore bilateral solid ankle-foot orthoses that were reported to be worn at all times to encourage proper foot position and alignment.

This individual was selected for this case report for many reasons. From 2008 to 2009 he made terrific gains in mobility towards independence. In 2008 he required supervision in sitting, assistance for all transfers, and a gait trainer for ambulation. By 2009, he was able to sit independently, transfer with only close supervision, and ambulate with only contact guard/close supervision. Over the course of the year, this individual received both land and aquatic based therapy.

Examination

Examination information was obtained from the child's Individual Education Program (IEP). The physical evaluation portion of the IEP was conducted by a trained, licensed physical therapist. Outcome measurements including range of motion, muscle tone, strength, and overall function were included in the IEP. Standard range of motion testing using a universal goniometer revealed decreased right and left knee extension (-30 degrees on the right, -20 degrees on the left) for this individual. Other range of motion testing was performed through visual observation and determined to be within functional limits. Muscle tone testing was performed throughout and it was determined that he exhibited generalized low muscle tone. Overall this individual demonstrated a decrease in muscle strength as evident by his delays in gross motor skills.

According to this individual's 2008 annual IEP review, he demonstrated a wide variety of motor impairments. Overall, he exhibited decreased processing time of movement influenced by motor planning and body awareness deficits. He showed slowed equilibrium and postural reactions in sitting, as well as a poor ability to grade upper and lower extremity movements for accuracy. He was independent from supine and prone, and could creep using reciprocal arm motions, yet tended to advance the lower extremities together forward. He could independently maintain sitting on the floor with a wide base of support, often in a ring sit or side sit position. He was able to rise from the floor independently using his upper extremities to stabilize himself at firm support, such as a table. When there was no stable surface to use, he required contact guard/minimal assist from the therapist to rise to stand. In standing, he demonstrated fair balance skills and slowed protective reactions. His primary means of mobility was through a manual wheelchair propelled by an adult. He required maximum assistance to weight shift in the wheelchair and minimum assistance through a stand-pivot transfer to rise to stand. To ambulate, he used a gait trainer with a pelvic saddle and trunk support along with two hand held assistance of the therapist to steer the device and provide necessary anterior trunk support. When on level surfaces, he required only minimal assistance. On uneven terrain or inclines, he required moderate assistance to ambulate. He ambulated with a crouched gait pattern and no heel strike. At this time, he was able to ambulate 400 feet and was unable to navigate stairs and curbs.

Outcome Measures

In December of 2004, The Individuals With Disabilities Education Act (IDEA) law was created to ensure services to children with disabilities throughout the United States.[37] Part B of this act governs how a state or public agency provides special education and related services to youth ages 3-21 with disabilities. IDEA regulations require that any eligible child have a written statement developed that explains the child's present levels of academic achievements and functional performance, a list of measurable annual goals, and a description of the child's progress.[37] This document is known as the child's IEP. The IEP has two general purposes: to set reasonable academic-based goals for a child and to state the services that the school district will provide for the child. A multidisciplinary team of professionals evaluate the child and determine eligibility for services based on their observations and the child's performance on standardized testing. An IEP typically includes statements about how the child's disability affects his or her involvement and progress in the classroom. It includes any special education and related services the child needs, as well as how often each service will be provided, where they will be provided, and how long each session will last. It also states any supplementary aids and/or assistive devices that will be needed to support the child in the school environment. Finally, an IEP contains annual goals for the child developed by the team of professionals and the parents. A child's IEP must also be reviewed annually thereafter to determine whether the established goals are being achieved and to be revised as appropriate. Currently there is no research on the reliability and validity of the IEP.

Range of motion is a term used to describe the flexibility available at any single joint (Reese). A joint's range of motion is usually measured by the number of degrees from the starting position to its position at the end of its available full range of movement. A double-armed goniometer was used to measure the amount of joint motion and muscle length of the knee in the supine position. Many studies have shown that goniometric measurements have a high reliability (r = .88-.99, ICCs = .97-.98) and validity.[38,39,40] All other joint ROM was visually estimated. The American Academy of Orthopedic Surgeons[41] once reported that visual estimation of joint flexibility was equivalent to goniometric measurements.

Muscle tone refers to the amount of resistance in a resting muscle when passively stretched.[42] When muscle tone is normal, there is minimal resistance during passive range of motion. Increased resistance to stretching is called hypertonia, whereas an abnormally low resistance to stretch is termed hypotonia. Tone testing was performed with the individual in supine and the resistance of the muscles to passive movement by the therapist was assessed. It was determined by a trained physical therapist that this individual had low muscle tone. The muscles of individuals with hypotonia are much slower to initiate a muscle contraction in response to a stretch stimulus. Furthermore, individuals with low tone often have difficulty with maintaining a muscle contraction for a long period of time.[42] A study by Gregson et al.,[43] examined the reliability of tone assessment to passive movement compared to the modified Ashworth scale in acute stroke patients. The researchers found marked variability in the assessment of posture (ICC=.22-.50 for interrater and .29-.55 for intrarater comparisons) but fair responses to passive movement compared to the modified Ashworth scale. There was good interrater reilability (ICC=.79-.92) and intrarater reliability (ICC=.72-.86), except when examining the ankle, which was poor (ICC=.59).

Muscle strength can be defined as a muscles capacity for exertion and endurance.[44] Strength testing can be performed in a variety of ways, including standard manual muscle testing or through pure observation of functional capacity. Performing a standard manual muscle test has been questionable for individuals with spasticity, impaired muscle length, and impaired selective motor control.[45] Furthermore, in order to perform the test, the person must be able to comprehend the task and comply with producing their maximal amount of effort.[45] For this individual, strength testing was observed through his abilities to move independently in different positions against gravity. It was determined by the licensed physical therapist that his strength was considered "functional", yet there was no definition for functional strength.

Evaluation and Prognosis

Overall, this individual demonstrated very significant motor impairments that led to his decreased level of function. He exhibited impaired strength and endurance, decreased range of motion for bilateral knee extension, decreased coordination, balance, proprioceptive processing, poor body awareness and overall low muscle tone. Furthermore, he demonstrated delays in motor planning and processing time which created difficulties in performing gross motor skills. As a result of the impairments above, this individual had many functional limitations. He was unable to transfer without assistance, unable to ambulate without the use of a supportive assistive device, unable to navigate stairs/curbs, and dependent on caregiver for all mobility while in a wheelchair. He also relied on assistance from his caregivers for all self care needs, including bathing, feeding, dressing, continence, and grooming. Many of the individual’s impairments also influenced his ability to socialize and participate in school activities.

To address his functional limitations and improve his levels of independence, long term goals were created within his IEP focusing on improving balance, ambulation skills, and functional mobility. At his annual review, two main goals were proposed: ambulating 50' with minimal two hand held assistance while wearing bilateral AFO's, and transfer from standing to sitting using his upper extremities on the armrests for support with contact guard assist of one with physical prompts at elbows for safety 5/5 trials. Despite many of the physical barriers that may have decreased the ability to reach such goals, this individual's prognosis was very good. A review of the literature by Carroll et al.,[46] found that a child's prognosis after a traumatic brain injury is good due to the faster resolution of symptoms compared to adults.[46] He was an extremely friendly and energetic young man. His positive attitude and motivation would play a huge part in achieving his goals and he had a wonderful support system at home that would carry over the treatments.

The plan of care was developed to carry out the goals listed above. It was determined that he would receive physical therapy services two times per week for 30 minutes in the school setting and one time per week in the aquatic environment for 30 minutes. Interventions consisted of stretching/range of motion, ambulation, balance training, endurance activities, strengthening, and functional mobility exercises.

Throughout 2008, this individual received land therapy to address his impairments and work towards his functional goals. Treatment sessions consisted of bilateral hamstring stretching for 30 second holds to improve lower extremity range of motion. Sit to stand transfers at different heights with verbal and manual cues to use his arms and push off of the hand rest were practiced. Static standing activities with one hand support at a table top with proprioceptive cues at the trunk were also performed. During treatments, ambulation in the gait trainer using upper extremity supports and a saddle seat to promote trunk stability was also done at an average distance of 400 feet. Moderate to maximum assistance was required by the physical therapist during ambulation to steer the walker and provide anterior trunk support. As he progressed with his gait skills, ambulation without the gait trainer was performed with 2 hand held moderate assistance of the therapist.

In 2007 he was first evaluated to begin pool therapy. It was decided that he would begin pool therapy 1x/wk for one hour sessions with goals of increasing ambulation and endurance, as well as maintaining range of motion. Throughout 2008, sessions included lap walk with moderate assistance while using a pool walker or arm floats. He also donned ankle weights to assist with lower extremity proprioception and foot placement during gait. Ambulation in the pool typically consisted of lap walking about 10 feet for about 15-20 trials. Lap walking included forward, backward, and side stepping. Manual stretching of bilateral lower extremities was also performed in the pool while he was supported floating in supine. Stretches were held for 30 seconds and performed to his quadriceps, hamstrings, and gastroc-soleus complex. When he first began pool therapy, he was transferred into the water using a pool chair.

Outcomes

By 2009 this individual began to make significant improvements in his gross motor skills. One of his most notable achievements was his progression with ambulation. He also made gains in his abilities to sit independently, transfer, and during pool therapy.

At one time, this individual relied on a gait trainer to ambulate, explore his environment, and interact with peers. By 2009, he progressed out of the gait trainer to walking overground with 2 hand held moderate assist of the therapist. As his skills continued to grow, he advanced to one hand held assist by the therapist and eventually only contact guard assistance. Currently, he is able to ambulate short distances, about 10 feet at a time, with only close supervision and no assistive device. His endurance for walking has drastically improved as well. The farthest distance on record that he has ambulated is 920 feet with contact guard assistance on a variety of surfaces. Although not measured objectively, observations by a licensed physical therapist stated that his overall walking velocity, cadence, and step length has increased as well. As he continued to progress in therapy, practice walking on ramps and inclines, as well as curbs and stairs was done with moderate assist of the therapist along with verbal and manual cues to use one handrail. He was also better able to motor plan around obstacles while walking which is necessary for safety and interacting with his peers. He continues to use a manual wheelchair, propelled by an adult, as his primary means of mobility.

This individual also demonstrated improvements in his sitting balance and ability to transfer. In 2008 this individual required supervision in sitting and assistance during transfers. By 2009 he was able to sit independently to interact with peers during school. He was able to transfer from sitting in a chair with armrests to standing with only contact guard assistance. It was documented, however, that on occasion he rose to standing completely independent. This inconsistency of transferring independently appears to be related to his motivation to move, rather than an impairment in gross motor ability.

By 2009, this individual also made significant gains in pool therapy. Initially, he was transferred into the pool using a standard pool chair. Currently, he is able to ambulate up and down the ramp of the pool, about 25 feet, with only one hand held assistance of the therapist for safety. While in the water, he no longer requires ankle weights or a flotation walker. He is able to ambulate independently forward, backward, and sideways while in water. He demonstrates increased trunk control and stability against the waves of the water and is able to navigate around other people and floats well.

Discussion

Physical therapy provides treatment to individuals to develop, maintain, and restore maximum movement and function by using a multidimensional approach. There has been little research on the combination of land and aquatic therapy and its implications to people with brain injuries. The use of land therapy alone can include gait training exercises and research has shown that traditional over the ground gait training is an effective method to improve ambulation skills and functional status.[20] Aquatic therapy alone has been shown to increase levels of physical fitness and functional capacity,[31] as well as ones physical self-concept and self-esteem for individuals with brain injury.[32] When used together, land and aquatic therapy were shown to make significant improvements for this individual of this case study. He demonstrated progress in his sitting balance, transfer skills, ambulation, and his overall functional independence.

Several improvements were made as a result of the interventions conducted in this case. One of the most significant advancements was in his ambulation skills. In 2008, he used a gait trainer with a pelvic saddle and trunk support along with two hand held assistance of the therapist to ambulate for 400 feet on level surfaces only. This individual was able to progress to walking overground with only contact guard assist of the therapist and ambulate short distances, about 10 feet at a time, with only close supervision and no assistive device. Furthermore, his endurance for walking drastically improved as well. He is now able to ambulate 920 feet with contact guard assistance over a variety of surfaces. He is also better able to motor plan around obstacles while walking which is necessary for safety and exploring his environment. Another significant improvement was made in this individual's functional ability to transfer. At one time, he was unable to transfer without assistance, however, he is currently able to transfer from sit to stand independently.

The combination of land and aquatic therapy resulted in very successful outcomes for this person. To interpret these results, it is important to understand the fundamental processes underlying the learning and performance of complex movements. The term "motor learning" has been used to describe the internal process that reflects a person's current capability for acquiring or modifying movement. The field of motor learning has traditionally referred to the study of how "normal" individuals produce a particular movement. In contrast, the term "recovery of function" is a term used to represent the reacquisition of movement skills lost after an injury. For these individuals, there have been many theories of how these learners begin to understand the basic coordination and problem solving of complex motor patterns. Nondeclarative, or implicit forms of learning, are often used to describe how individuals gain new skills. There are three divisions of implicit learning; nonassociative, associative, and procedural learning. Nonassociative learning often occurs when an individual is given a single stimulus repeatedly and begins to habituate to it. Associative learning refers to how a person learns to detect causal relationships. Procedural learning is a term to describe when the motor tasks can be performed automatically without attention or conscious thought. During motor skill acquisition, repeating a movement continuously under varying circumstances would typically lead to procedural learning.[47]

To understand how the results of this case study reaped such successful results, it is key to know the implications of implicit learning, specifically procedural learning. Furthermore, it is important to understand how procedural learning can lead to neuroplasticity. Neuroplasticity is the ability of neurons to change their function and/or chemical structure.[48] Memory of a task requires the synthesis of new proteins and the growth of synaptic connections. With repetition of movement, through procedural learning, the synthesis and activation of proteins alter the neuron's excitability and promote the growth of new synaptic connections.[49] Studies have shown that after repetitive performance of a particular sequence of movements, we are able to memorize and execute the task without external guidance.[50] When developing a treatment protocol for individuals after brain injury, it is essential to incorporate task-specific practice to enhance motor learning and long-lasting cortical reorganization in the brain.[51,52] A study by Lee et al.,[53] also reported that in order to improve the generalization value of therapy results, there should be variability within the practice setting and a "learning landscape" should be created. All of this research helps to support the principle that including repetitions of task specific patterns in a variety of different settings provides the best overall therapeutic benefit to increase motor learning and neuroplasticity.

A combination of land and aquatic therapy uses many of the components needed for recovery of motor function. One great benefit of land therapy is that it allows you to practice the actual task repeatedly to improve procedural learning and neuronal connections. During land therapy, problem solving tasks such as walking through an obstacle course or transferring from different surfaces can also be added to enhance learning. Utilizing aquatic therapy allows an individual to intensify his learning experience by changing the environmental setting. Ambulating in the water requires the use and coordination of different muscles. By incorporating aquatic therapy into the treatment sessions, it allows the learner to perform the task under different circumstances, enhancing their procedural learning capability as well as neuroplasticity.

It is also important to discuss the gains this individual made in his sitting balance and transfer ability. Due to his decreased cognitive status, it was difficult and unsafe to instruct him on strengthening or balance exercises while on land. The aquatic environment provided a safe and unique atmosphere to practice strength training, balance, and endurance. The natural resistance created by walking through the water helped to strengthen his lower extremities and abdominals. When practicing static standing in the water, he constantly had to balance the coactivation of flexors and extensors throughout his body to prevent himself from falling. The waves created in the water also provided a challenge for him while trying to maintain his balance. Lastly, because the water provided such a safe environment, he was able to ambulate for almost a full hour of the treatment session, thus enhancing his endurance.

There were many limitations to this case study that should be considered when evaluating the successful outcomes and its implications to physical therapy practice. As the research has shown, standardized testing is a reliable and valid method to examine the physical status of patients. The documentation obtained for this case study, including the child's IEP and physical therapy evaluation, did not contain many forms of standardized testing. An IEP is a widely used and accepted document to explain the impairments and functional limitation of an individual to qualify them for services. Therefore, more studies on the reliability and validity of this document need to be done to ensure that it is appropriate to be used for future research.

Due to the cognitive impairments of the individual for this case report, norm-referenced standardized testing was not included in his IEP. Instead, observation of functional ability was used to qualify him for services and measure his improvements with therapy. More research still needs to be done to confirm that observation provides good interrater/intrarater reliability. Goniometry was used to assess the lower extremities, however all other joints were deemed within functional limits purely by observation. Future testing should include all joint range of motion measurements to allow for proper outcome assessments. There was also no valid assessment of strength used. It was listed as simply "functional" by a physical therapist after observations of his mobility. There is a cognitive aspect to performing strength testing that is required by the person to follow directions, therefore it may have been difficult to do any standard manual muscle testing in this case. Research has shown that a dynamometer can be used to quantify isometric strength in hip flexors, quadriceps, plantar flexors, and triceps brachii following traumatic brain injury.[54] Future research should include using this form of strength testing. The information obtained for this case report also did not include any formal scale to assess his level of spasticity. Research has documented that the Modified Ashworth Scale is a reliable measurement of tone.[55,56] This scale measures resistance during passive soft-tissue stretching and rates the amount of spascity on a 4-point scale. Further research with appropriate tone testing should be done to truly assess the progress gained with using a combination of land and water-based therapy.

There were also some limitations to the interventions that the individual received. Land therapy frequently consisted of transfers and gait training under the same conditions. For example, transfers were not practiced from different surface heights or a variety of chairs/mats. Ambulation was often performed with the same gait trainer or manual contact, in the same environment, and on the same flat surfaces. Although this is all great for repetition of the task, it does not provide the necessary variability with practice while on land. Another option for land therapy that could have been utilized is body weight support treadmill training. Research has shown that treadmill training offers the advantages of task-oriented training with numerous repetitions of stepping under the supervision/assistance of a trained physical therapist.[57]

Another limitation to the interventions performed was the lack of variability in activities while in the aquatic setting. Session always consisted of the same activities, lap walking and stretching. Once again the repetition of lap walking is beneficial for procedural learning, however it does not provide the person with much variability in muscle activation or coordination. For example, in the aquatic environment, this individual would be able to perform strength training that he may not be able to complete on land. Exercises in the water, such as squats, step ups, lower extremity movements in all planes (flexion, extension, abduction, adduction), and/or kicking could all have been included in his treatment sessions to improve his strength necessary for walking. Furthermore, swimming in the pool may have also helped increase his endurance.

This case study offers many implications for clinicians working with individuals post brain injury. First, a thorough evaluation of the client, including appropriate range of motion, strength, tone testing, and functional capacity, is necessary to evaluate the progress of the person and success of the plan of care. When the individual demonstrates impairments that can be addressed using traditional land therapy and from the unique properties of water, he/she may be a candidate for a combination of treatment. It is important to continuously monitor the person and re-evaluate the plan of care to ensure the best care is given to the individual.

References

1. Centers for Disease Control and Prevention, National Center for Injury Prevention and Control Web-based Injury Statistics Query and Reporting System (WISQARS) [online]. (2008) [cited 2008 March 23]. Available at http://www.cdc.gov/injury/wisqars/index.html

2. Jerusalem E, Starling EH. On the significance of carbon dioxide for the heart beat. *J Physiol.*1910;40(4):279-294.

3. Wheeler DS, Wong HR, Shanley TP. *Pediatric Critical Care Medicine: Basic Science and Clinical Evidence*. 6th ed. Springer; 2007.

4. Rothman SM. Glutamate and the pathophysiology of hypoxic-ischemic brain damage. *Ann Neurol*. 2004;19(2):105-111.

5. Gagnon I, Forget R, Sullivan SJ, Friedman D. Motor performance following a mild traumatic brain injury in children: an exploratory study. *Brain Inj*. 1998;12(10):843-853.

6. Perlam JM. Intrapartum hypoxic-ischemic cerebral injury and subsequent cerebral palsy: medicolegal issues. *Pediatrics.* 1997;99(6)851-859.

7. Rose J, McGill K. Neuromuscular activation and motor-unit firing characteristics in cerebral palsy. *Dev Med Child Neurol*. 2005;47(5):329-336.

8. Ostensjo S, Carlberg EB, Vollestad NK. Motor impairments in young children with cerebral palsy: relationship to gross motor function and everyday activities. *Dev Med Child Neurol*. 2004;46(9):580-589.

9. Nashner LM, Shumway-Cook A, Marin O. Stance posture control in select groups of children with cerebral palsy: deficits in sensory organization and muscular coordination. Exp Brain Res. 2004;49(3):393-409.

10. Long T, Toscano K. *Handbook of Pediatric Physical Therapy*. 2nd ed. Baltimore, MA. Lippincott, Williams & Wilkins. 2002.

11. Mathias J, Beall J, Bigler E. Neuropsychological and information processing deficits following mild traumatic brain injury. *J Int Neuropsychol Soc*. 2004;10(2):286-297.

12. Hamm RJ, Dixon E, Gbadebo DM, Singha A, Jenkins LW, Lyeth BG, et al. Cognitive deficits following traumatic brain injury produced by controlled cortical impact. *J Neurotrauma*. 2009;9(1)11-20.

13. Skelton RW, Bukachl CM, Laurance HE, Thomas K, Jacobs J. Humans with traumatic brain injuries show place-learning deficits in computer-generated virtual space. *J Clin Exp Neuropsychol*. 2000;22(2):157-175.

14. Rimel R, Giordani B, Barth J, Boll T, Jane J. Disability caused by minor head injury. *Neurosurgery*. 1981;9(3);221-228.

15. McDowell S, Whyte J, D'Esposito M. Working memory impairments in traumatic brain injury: evidence from a dual-task paradigm. *J Neuropsych*. 1997;35(10):1341-1353.

16. Diamond A. Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. *Child Dev*. 2000;71(1):44-56.

17. Seel RT, Kreutzer JS, Rosenthal M, Hammond FM, Corrigan JD, Black K. Depression after traumatic brain injury: a national institute on disability and rehabilitation research model systems multicenter investigation. *Arch Phys Med Rehabil.* 2003;84(2):177-84.

18. Fedoroff JP, Starkstein SE, Forrester AW, Geisler FH, Jorge RE, Arndt SV, et al. Depression in patients with acute traumatic brain injury. *Am J Psychiatry*. 1992;149(9):918-923.

19. Rosenthal M, Christensen B, Ross T. Depression following traumatic brain injury. *Arch Phys Med Rehabil*. 2004;79(1):90-103.

20. Brown T, Mount J, Rouland B, Kautz K, Barnes R, Jihye K. Body weight-supported treadmill training versus conventional gait training for people with chronic traumatic brain injury. *J Head Trauma Rehabil*. 2005;20(5):402-415.

21. Ochi F, Esquenazi A, Hirai B, Talaty M. Temporal-spatial feature of gait after traumatic brain injury. *J Head Trauma Rehabil*. 1999;14(2):105-115.

22. Kuhtz-Buschbeck J, Stolze H, Golge M, Ritz A. Analyses of gait, reaching, and grasping in children after traumatic brain injury. *Arch Phys Med Rehabil*. 2003;84(3):424-431.

23. Gracies JM. Pathophysiology of impairment in patients with spasticity and use of stretch as a treatment of spastic hypertonia. *Phys Med Rehabil Clin N Am*. 2001;12(4):747-768.

24. Kaplan N. Effect of splinting on reflex inhibition of sensorimotor stimulation in the treatment of spasticity. *Arch Phys Med Rehabil*. 1962;43(1):565-569.

25. Harburn K, Potter PJ. Spasticity and contractures. *Phys Med Rehabil State Art Rev*. 1993;7(1):113-132.

26. Bakheit AM. Management of muscle spasticity. *Crit Rev Phys Rehabil Med*. 1996;8(1):235-252.

27. Barnes M, Johnson GR. *Upper Motor Neuron Syndrome and Spasticity: Clinical Management and Neurophysiology.* 2nd ed. Cambridge NY. Cambridge University Press. 2008.

28. Lima D. Overview of the causes, treatment and orthotic management of lower-limb spasticity. *J of Prosthet Orthot*.1990;2(1):33-39.

29. Bronkhurst AJ, Lamb GA. An orthosis to aid in reduction of lower-limb spasticity. *Clin Orthot Prosthet*.1987;41(2):238.

30. Lohman M, Goldstein H. Alternative Strategies in tone-reducing AFO design. *J Prosthet Orthot*. 1993;5(1):1-4.

31. Driver S, O'Connor J, Lox Curt, Rees K. Evaluation of an aquatic program on fitness parameters of individuals with a brain injury. *Brain Inj*. 2004;18(9):847-859.

32. Driver S, Rees K, O'connor J, Lox C. Aquatics, health-promoting self care behaviors and adults with brain injuries. *Brain Inj.* 2006;20(2):133-141.

33. Driver S, Ede A. Impact of physical activity on mood after TBI. *Brain Inj*. 2009;23(3):203-212.

34. Oeverman S. Why aquatic therapy. *Brain Inj*. 2005;5(2):64-67.

35. Prentice W, Voight M. *Techniques in Musculoskeletal Rehabilitation*. 1st ed. McGraw-Hill Medical. 2001.

36. Kesiktas, Parker, Erdogan, Gulsen, Bicki, Yilmaz. The use of hydrotherapy for the management of spasticity. *Neurorehabil Neural Repair*. 2004;18(4):268-273.

37. U.S Department of Education, Office of Special Education programs' (IDEA). http://idea.ed.gov/explore/home. Accessed January 1, 2010.

38. Rothstein JM, Miller PJ, Roettger R. Goniometric reliability in a clinical setting: elbow and knee measurements. *Phys Ther.* 1983;63(10):1611-1615.

39. Allington NJ, Leroy N, Doneux C. Ankle joint range of motion measurements in spastic cerebral palsy children: intraobserver and interobserver reliability and reproducibility of goniometry and visual estimation. *J of Ped Orthopaedics B*. 2002;11(3):236-239.

40. Gogia PP, Braatz JH, Rose SJ, Norton BJ. Reliability and validity of goniometric measurements at the knee. *Phys Ther.* 1987;67(2):192-195.

41. American Academy of Orthopedic Surgeons. http://www.aaos.org/research/research.asp. Access on January 20, 2010.

42. Lundy-Ekman L. *Neuroscience: Fundamentals for Rehabilitation*. 3rd ed. St. Louis, MI. Saunders Elsevier. 2007.

43. Gregson J, Leathley M, Moore A, Sharma A, Smith T, Watkins C. Reliability of the

tone assessment scale and the modified ashworth scale as clinical tools for assessing poststroke spasticity. *Phy Med Rehabil*. 1999. 80(9):1013-1016.

44. Merriam-Webster's Medical Dictionary. Springfield, MA. Merriam-Webster Inc. 2006.

45. Damiano D, Dodd K, Taylor N. Should we be testing and training muscle strength in cerebral palsy. *Dev Med Child Neurology*. 2004;44(1):68-72.

46. Carroll L, Cassidy D, Peloso P, Borg J, Holst H, Holm L, Paniak C, Pepin M. Prognosis for mild traumatic brain injury: results of the WHO collaborating center task force on mild traumatic brain injury. *J Rehabil Med*. 2004;43:84-105.

47. Shumway-Cook A, Woollacott M. *Motor Control: Translating Research into Clinical Practice*. 3rd ed. Philadelphia, PA. Lippincott, Williams & Wilkins. 2007.

48. Woolf CJ, Salter MW. Neuronal plasticity: increasing the gain in pain. *Science*. 2000;288(5472):1765-1769.

49. Johansson BB. Brain plasticity in health and disease. *J of Med*. 2004;53(4):231-246.

50. Tanji, Shima. Role for supplementary motor area cells in planning several movements ahead. *Nature*. 1994;371(6496):413-416

51. Bayona B. The role of task-specific training in rehabilitation therapies. *Top Stroke Rehabil*. 2005;12(3):58-65.

52. Classen L. Rapid plasticity of human cortical movement representation induced by practice. *J of Neurophysiol*.1998;79(2):1117-1123.

53. Lee T, Swanson L, Hall A. What is repeated in a repetition? Effects of practice conditions on motor skill acquisition. *Phys Ther*. 1991;71(2):150-157.

54. Morris D. Aquatic neurorehabilitation. *Neuro Report*. 1995;19(3):22-29.

55. Blackburn M, Vliet P, Mockett S. Reliability of measurements obtained with the Modified Ashworth Scale in the lower extremities of people with stroke. *Phys Ther*. 2002;82(1):25-34.

56. Bohannon R, Smith M. Interrater reliability of a modified ashworth scale of muscle spasticity. *Phys Ther*. 1985;67(2):206-207.

57. Hese S, Bertelt, Jahnke, Schaffrin, Baake, Marlezic, et al. Treadmill training with partial body weight support compared with physiotherapy in nonambulatory hemiparetic patients. *Stroke*. 1995;26(6):976-981.