Underwater Treadmill Training in Acute Complete Spinal Cord Injury: A Case Study

by

Zeke Grissom

A thesis presented to the Honors College of Middle Tennessee State University in partial fulfillment of the requirements for graduation from the University Honors College

Fall 2016

Underwater Treadmill Training in Acute Complete Spinal Cord Injury: A Case Study

by

Zeke Grissom

APPROVED:

Dr. Sandra L. Stevens
Exercise Science Department

Dr. Robert Sieg
Biology Department

Dr. Judith M. Iriarte-Gross
Honors Council Representative

Dr. John R. Vile
University Honors College Dean

Acknowledgement

I would like to acknowledge Dr. Sandra Stevens and all of the selfless work she has put into this project on my behalf. This thesis project has been a blessing to me, not just for the content of the study, but the chance it gave me to be mentored by someone so knowledgeable and caring. The time I have spent with Dr. Stevens has advanced my understanding of what research is, how to pursue it, and the significance it has on changing people's lives, including those doing the research.

Table of Contents

Abstract

Purpose: Determine the feasibility and effectiveness of Underwater Treadmill Training (UTT) in the acute phase of a traumatic spinal cord injury

Design: Case study

Participant: Nineteen-year-old female suffering complete spinal cord injury at T10, due to self-inflicted gunshot wound

Method: Six-month intervention involving resistance, overground, and underwater treadmill training

Results: Baseline to intermediate tests shows increases in all documented variables as well as observed increases in stamina, posture, gait and a decrease in dependence on assistance. Intermediate to post tests show slight progression in walking distance, decrease in daily steps, and a significant regression in lower body strength in conjunction with an increase in dependence on assistance, observed increase in fatigue, as well as posture and gait regression

Conclusion: This study faced many challenges to the participation and adherence to protocol, yet progress was still observed with no notable ill effects, supporting further study on UTT as a form of rehabilitation for a traumatic SCI in the acute phase

Introduction

Incidence and Prevalence of Spinal Cord Injury

As of 2015, the incidence of spinal cord injury (SCI) in the United States is 12,500 per year according to the National Spinal Cord Injury Statistical Center,[23] with motor vehicle crashes, violence, falls, or otherwise risky behaviors being the leading causes. Incidence is lowest in pediatrics and most common in late teens on into early twenties while decreasing thereafter with a secondary increase in the elderly.[2] Based on incidence rates and life expectancies of those living with SCI,[13] it is concluded that there are approximately 280,000 individuals in the U.S. living with SCI.[23]

Etiology of Spinal Cord Injury

Destruction of the neuronal pathways during a spinal cord injury can be expansive, especially in a complete SCI in which there is no functional movement below the site of injury. While the initial trauma causes extensive neuron damage, additional damage occurs as a result of the inflammatory response, termed spinal shock.[20] These lesions of the spinal cord may drastically alter the efficacy of neuronal input as previously connected interneuronal, motoneuronal, and propriospinal neuronal synapses are altered.[4] Even if some normal synaptic connection is maintained, the interpretation of signals will be skewed as the number of conferring inputs is lessened. Now with fewer inputs, each postsynaptic signal received is of greater magnitude in effect.[4] This disruption in signal can cause major losses in sensation, circulation, and voluntary motor control in body regions innervated by these distal pathways.[12] The extent of loss is mostly determined by what level of the spinal column the SCI is sustained (i.e. cervical, upper thoracic, lower thoracic, etc).[11]

Residual Impairment

One of the greatest challenges following SCI is maintaining a state of physical fitness. With this in mind, Stevens *et al* indicates that more than half of SCI individuals reporting a quality of life less than that of an able-bodied individual attribute it to his or her decreased level of physical activity.[14] Warburton describes physical fitness as "a physiologic state of well-being that allows one to meet the demands of daily living." [21] There is significant evidence suggesting a strong relationship between physical fitness and reduced risk of health related diseases and delayed mortality.[17] One of the major connections is the inverse relationship of physical activity and cardiovascular disease.[6] It has been shown that as little as one hour of walking per week is beneficial in the prevention of cardiovascular-related mortality in able-bodied individuals indicating that even minor improvements in physical activity can have a significant effect.[21]

Additionally, there is a 6% decrease in incidence of type 2 diabetes per 500 kcal (2092 kJ) in energy usage per week, especially in those who are at high risk of developing type 2 diabetes.[21] The effects of physical activity also extend into primary prevention of specific cancers such as colon cancer and breast cancer. Physically active men exhibited a 30%-40% reduction in the relative risk of colon cancer,[7, 21] while physically active women exhibited a 20%-30% reduction in the relative risk of breast cancer compared with their inactive counterparts.[10]

Studies indicate that daily physical activity is effective in slowing, preventing, or even reversing bone density loss as well.[6] These studies show that bone mineral density appears to be heavily affected by weight bearing exercise, specifically resistance exercise.[1]

Musculoskeletal fitness has become a focal point of health in the overall population.[6] An individual is reliant on musculoskeletal fitness to maintain any sort of overall fitness due to the body's need to be mobile. This is very apparent in the elderly in that although they might not exhibit common fitness markers such as cardiac output and oxidative potential, daily activity helps prevent a downward cycle of reduced musculoskeletal fitness leading to a cascade of increased inactivity and increased dependence which is similar to the conditions of a SCI individual.[21] Longitudinal studies have shown that individuals who can maintain muscular strength generally have fewer limitations and a lower dependence, which correlates significantly with delaying or even eliminating the onset of disability, chronic disease, and dependence.[19] Systematic reviews conclude that functional independence, mobility, glucose homeostasis, bone health, psychological well-being and overall quality of life are all positively affected by musculoskeletal fitness.[21] It is recommended that resistance and flexibility exercises be performed at least twice a week to maintain musculoskeletal fitness.[6]

Current Interventions

These recommended levels of physical activity can be difficult to achieve, even in able-bodied populations; for those with physical disabilities, it is even more challenging .[8, 9, 17] As a result, interventions that provide assistance to move the paralyzed lower extremities and facilitate walking have been developed. These forms of rehabilitation have been shown to be positively associated with improvements in quality of life.[14]

Typically in these interventions, the client's body is partially supported by a harnessing system.[3,5,22] Facilitation of stepping is accomplished by manual assistance from several trainers, robotic assistance, or electrical stimulation.[22] Each of these interventions have shown the capacity to improve physiological markers of fitness; however, there are problems associated with each method. The harnessing system can create pressure sores from the groin strap and may have a negative impact on cardiovascular responses to the increased physical demand. Robotic assistance such as computer-driven orthotics (CDO) have proven effective in retraining the individual without the pressure sores from harnessing; however, the magnitude of assistance from the device limits the energy exerted by the individual, leading to decreased fitness returns from activity, a significant concern in individuals with SCI.[22]

There is current research on the effectiveness of Underwater Treadmill Training (UTT) [15, 17] as an alternative to harness supported and robotic assisted training. UTT allows the participant to experience partial body-weight support similar to a harnessing system without the painful pressure sores and skin damage.[18] When nerve damage is sustained, the body experiences circulation issues to regions innervated by the spinal cord distal to the sight of injury, one reason why cardiovascular disease is a significant risk factor in SCI.[17] In accordance with this, the hydrostatic environment provided by the water also assists the body in blood circulation, [18] increasing cardiac output and lowering heartrate.[17] UTT also addresses sensory stimulation as the water immerses much of the body. The stimulation provided by the water impact and temperature, even if not "perceived" by the participant, can promote a form of nerve transmission that can supplement motor output.[18]

Currently, research is continuing to explore the results of Underwater Treadmill Training in this population during the chronic phase of recovery, the time period characterized by the absence of the initial spinal shock; [15, 17] however, little is known regarding the effects of this intervention during the acute phase of rehabilitation, a time period following post-incident, medical intervention in which spinal shock is still present. Therefore, the purpose of this study is to investigate the safety and effectiveness of UTT on restoration of gait following SCI during the acute phase of recovery. The investigation will focus on progression of gait restoration during six-months of underwater and over-ground training, initiated in the acute phase of recovery, following a T10 complete SCI, in a nineteen-year-old female. Due to encouraging results found in studies involving SCI in the chronic phase [15, 17] and the evidence to support some degree of injury resolution in the acute phase,[18] we hypothesize there will be similar results found for our participant as were found in chronic SCI participants. We hope that through this study we will be able to provide insight into future acute complete SCI studies and advance the knowledge of the effects and safety of UTT in hopes of one day making this intervention readily available to the general public.

Methodology

Operational Definitions

Acute: In SCI, generally referred to as the time period between 6-12 months post injury

Chronic: In SCI, generally referred to as the time period >12 months post-injury

Complete SCI: When there is a complete loss of function below the sight of injury

Distal: Reference to a point further from the central portion of the body. A relative term

Hydrostatic: The pressure of liquids at rest

Innervate:To supply a particular tissue with nerves

Interneuron: Serves as an intermediate between sensory and motor neurons

KAFOs: Knee, ankle, foot orthosis

Motoneuron: Transmits signals from the brain or spinal cord to muscles or glands

Neuron: Serves as a messenger in the body, conducting signals in the nervous system

Propriospinal neuron: a collection of neurons connecting both ascending and descending pathways at various levels along the spinal cord

Sensory neuron: Transmits sensory information from sensory receptors to the spinal cord or brain

Synapse: Region between two neurons that allows signals to be passed from presynaptic neuron to postsynaptic neuron

T10: The tenth level of the thoracic region of the spinal cord

Participant

This case study documents the progression of a 19 year old female who suffered a self-inflicted gunshot wound on May 26, 2015. Medical records indicated the participant sustained a T10 complete SCI, suggesting an injury in the mid to lower back with no functional movement below the site of injury. The participant was given an American Spinal Injury Association Impairment Scale (AIS) rating of A indicating no motor or sensory function below the level of injury. Additionally, she was diagnosed with borderline personality disorder in conjunction with evident family issues and substance abuse.

Quantitative Outcome Measures

Evidence suggests that preferred walking speed and lower extremity strength are associated with daily steps in natural environment.[16] Before intervention took place, we administered a pre-test that found baseline values for preferred walking speed, lower extremity strength, walking stamina, and daily step activity. Intermediate (12 week) and post tests were also administered, testing the same variables. Tests were compared to identify patterns of recovery.

Average Daily Step Activity

Average daily step activity is a measurement of walking activity in the participant’s natural environment. Values for average daily step activity are found by adding all of the reported steps taken in a week’s time span and dividing that by seven.

Walking Index for Spinal Cord Injury (WISCI)

A standardized scale of walking ability that incorporates the amount of physical and instrumental assistance needed by the participant during a ten meter walk. Levels range from zero to twenty, with zero requiring full physical and instrumental assistance and twenty requiring no assistance.

Walking Speed

We determined walking speed (m/s) using a 2 meter walking test. The participant walked a total of 4 meters at comfortable, self-directed pace. Only the central 2 meters were analyzed using two photoelectric cells (Brower Turning System); this allowed 1-meter respectively for potential acceleration and deceleration. The participant was allowed to utilize bilateral long leg braces (KAFOs; Appendix 1), a rolling walker, and manual assistance by three individuals to complete the test.

Six Minute Walk for Distance

Stamina was assessed by recording the total distance covered (m) on a flat surface during a six-minute time period. The participant was allowed to utilize bilateral long leg braces (KAFOs), a rolling walker, and manual assistance by three individuals to complete the test.

Lower Extremity Strength

Strength was measured as the peak force demonstrated during voluntary muscle contraction across the tested muscle groups using a J Tech Electronic Dynamometer. Measured in newtons, these values were then compared to the participant's weight (kg) to determine a force per mass unit ratio (N/kg).

Intervention

During the six-month training period, training was scheduled for 2 times a week[6] for approximately 1.5 hours. We allowed patient to choose 2 or 3 types of training from 3 different options to allow patient to experience some sense of control. With this being an exploratory study, we maintained the flexibility to adjust protocols as deemed appropriate as the study progressed.

Eccentron Training

Eccentron training (Appendix 2) is a form of eccentric resistive exercise that we utilized to restore muscle mass that was lost during inactivity. The machine works by applying force to the feet as the legs bend in the manner of a leg press; however, the goal of the exercise is to resist the pedals as they progress towards the body as opposed to actively moving the pedals away. This causes an eccentric contraction in the leg extensor muscles of the hips and knees. The patient passively rode the pedals for a one-minute warmup set, then actively resisted the pedals for three minutes, before a passive one-minute cool down. A calibration was conducted prior to training to determine appropriate load for each leg as well as proper seating position. A therapist manually added support to each knee to keep legs in proper alignment. Measurements were taken on observed peak resistance values per leg during active resistance and the average values per leg calculated by the computer program. Additionally, an exertion rating from 0 to 10 (0 great to 10 exhausted) was verbally given by the participant.

Overground Training

This is training in which the patient used assistance to walk overground in the lab, simulating a natural gait. There were three aspects of assistance utilized: utilization of bilateral long leg braces (KAFOs), manual assistance by therapist on each leg minimally assisting in leg control and knee locking, and use of walker or crutches. During overground walking, the patient utilized necessary assistance while walking overground approximately 35 feet at self-controlled pace for three walks. The patient often stood between walks with leg locking and some postural assistance from therapist for 1-2 minutes and then rested for 3-5 minutes. As observable progression ensued, backwards walking was added as well as increased distance and number of walks.

Underwater Treadmill Training

This is the basis of the study in which the participant was submerged in 46 inches of water and walked on a treadmill as we sought to reconnect neural pathways involved in gait, build muscle mass, and gain endurance (Appendix 3). Initial training consisted of three walks at 1.5 mph for five minutes followed by an additional five-minute walk at 0.5 mph in reverse. After training, an exertion rating from 0 to 10 (0 being great to 10 being exhausted) was verbally given by the participant. Additionally, during breaks which ranged from 3-7 minutes, body squats and other lower-extremity exercises in the water were encouraged.

Results

Quantitative Outcomes

Our participant attended a total of 18 out of roughly 48 total scheduled training session over a 24-week period, with the study being terminated due to lack of participation. Test data was collected on three occasions to document progression throughout the study. Fifteen training sessions were attended in the first half of the study while only three were attended in the latter half. At the week 12 intermediate test date, the participant reported an average of 2.68 daily steps (Figure 2), 1.82 steps more than the baseline of 0.86 (Figure 1). Testing showed a 16.67% increase in her two-meter speed trial (Figure 5) while showing a six-point increase in the WISCI score (Figure 6), even exhibiting a high comfort rating. A greater showing of stamina was exhibited as she walked 47.03% further (Figure 7). Finally, leg strength showed an overall 101.88% increase in total generated force through the legs (Figures 4).

From the intermediate test date to the post test date, the participant showed no change in her two-meter speed trial (Figure 5) or the WISCI score (Figure 6). The participant reported an average of 1.87 daily steps (Figure 3), a decrease of 0.81 steps from the intermediate date (Figure 2). An increase in stamina was shown as she walked 6.00% further (Figure 7). Finally, leg strength showed an overall 34.15% decrease in total generated force through the legs (Figure 4).

Qualitative Outcomes

We did not anticipate the impact of observed qualitative changes; however, as time went on, it became apparent that meaningful qualitative changes were occurring and journaling post-training sessions was implemented to document these qualitative observations.

Eccentron training, overground training, and underwater treadmill training showed no real change throughout the study. Training resistance fluctuated slightly throughout the training with no observable trend. The thing that did change with training was the observed exertion and execution. During the time period between the baseline test and the intermediate test, observers saw a decrease in dependence on assistance, increased posture and gait, as well as increased stamina and will to do more during the training. During the time period between the intermediate and post tests, we observed a much greater reliance on assistance while walking, similar to that of the beginning stages of training. This led to a slight decrease in posture and gait. Observed fatigue was also greater than that of the intermediate trail with diminished willpower.

Average Daily Step activity			0.86
Sedentary Time			99.50%
WISCI Score:	0	Required assistance of 2 people and walkers stabilization to ambulate 10 meters	
Comfort Level:	Comfortable		
Speed Trials: Pre-Test			
Normal Speed	0.06 m/s	Stood during rest breaks	
Rapid Speed	no rapid speed		

6 Minute Walk	20.73 meters

Leg Strength		
Force (N):		
	Right	Left
Hip Extension	22.24	17.79
Hip Flexion	31.14	26.69
Hip Abduction	15.57	8.90
Knee Flexion	13.34	20.02
Knee Extension	8.90	13.34
Dorsi Flexion	0.00	6.67
Plantar Flexion	6.67	4.45
Total Force	97.86	97.86

Figure 1. Pre-test Baseline Data. Data collected on November 24, 2015 to serve as baseline for the study. Reported average daily step activity was 0.86. Walking speed of 0.06 m/s was achieved while receiving a WISCI score of 0 in the 2 meter walk. 20.73 meters were covered in the 6 minute walk for distance. Weighing in at 46.04 kg, the participant generated a total of 195.72 N of force through her lower body (4.25 N/kg).

Average Daily Step activity	2.68
Sedntary Time	99.50%

WISCI Score: 6 — 1 person as an assist was able to take a few steps unassisted

Comfort Level: Very Comfortable

Speed Trials: Post-Test		
Normal Speed	0.072 m/s	Stood during rest breaks
Rapid Speed	0.094 m/s	

6 Minute Walk	30.48 meters

Leg Strength		
Force (N):		
	Right	Left
Hip Extension	57.83	35.59
Hip Flexion	71.17	68.95
Hip Abduction	31.14	26.69
Knee Flexion	17.79	17.79
Knee Extension	31.14	31.14
Dorsi Flexion	0.00	0.00
Plantar Flexion	0.00	0.00
Total Force	209.07	180.15

Figure 2. Week 12 Intermediate Test Data. Data collected on February 16, 2016 to serve as intermediate test for progression. Reported average daily step activity was 2.68 steps. Walking speed of 0.072 m/s was achieved while receiving a WISCI score of 6 in the 2 meter walk. 30.48 meters were covered in the 6 minute walk for distance. Weighing in at 45.36 kg, the participant generated a total of 389.22 N of force through her lower body (8.58 N/kg).

Average Daily Step activity	1.87
Sedntary Time	99.50%

WISCI Score: 6 1 person as an assist

Comfort Level: Very Comfortable

Normal Speed	0.069 m/s	Stood and sat during rest breaks
Rapid Speed	0.089 m/s	

6 Minute Walk	32.31 meters

Leg Strength		
Force (N):		
	Right	Left
Hip Extension	51.15	33.36
Hip Flexion	68.95	57.83
Hip Abduction	31.14	22.24
Knee Flexion	13.34	15.57
Knee Extension	35.59	28.91
Dorsi Flexion	4.45	0.00
Plantar Flexion	4.45	2.22
Total Force	209.07	160.14

Figure 3. Post-Test Data. Data collected on May 3, 2016 to serve as post-test for the study. Reported average daily step activity was 1.87 steps. Walking speed of 0.069 m/s was achieved while receiving a WISCI score of 6 in the 2 meter walk. 32.31 meters were covered in the 6 minute walk for distance. Weighing in at 45.59 kg, the participant generated a total of 369.20 N of force through her lower body (8.10 N/kg).

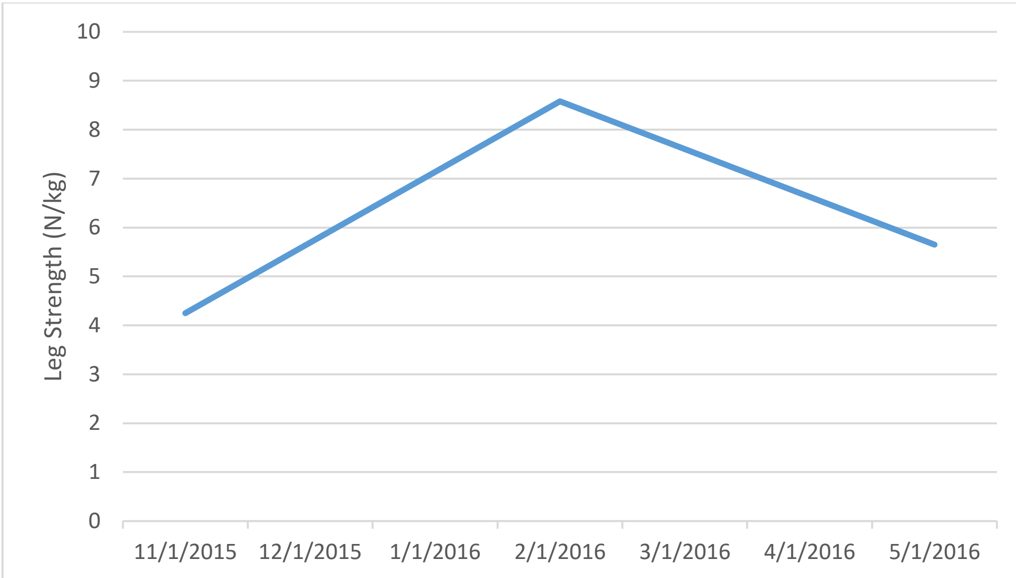


Figure 4. Leg Strength Progression. Shows linear progressions of total leg strength (N/kg) between test dates throughout the study. There was a 101.88% increase in leg strength between the baseline and the intermediate test, followed by a decrease of 34.15% between the intermediate and the post test.

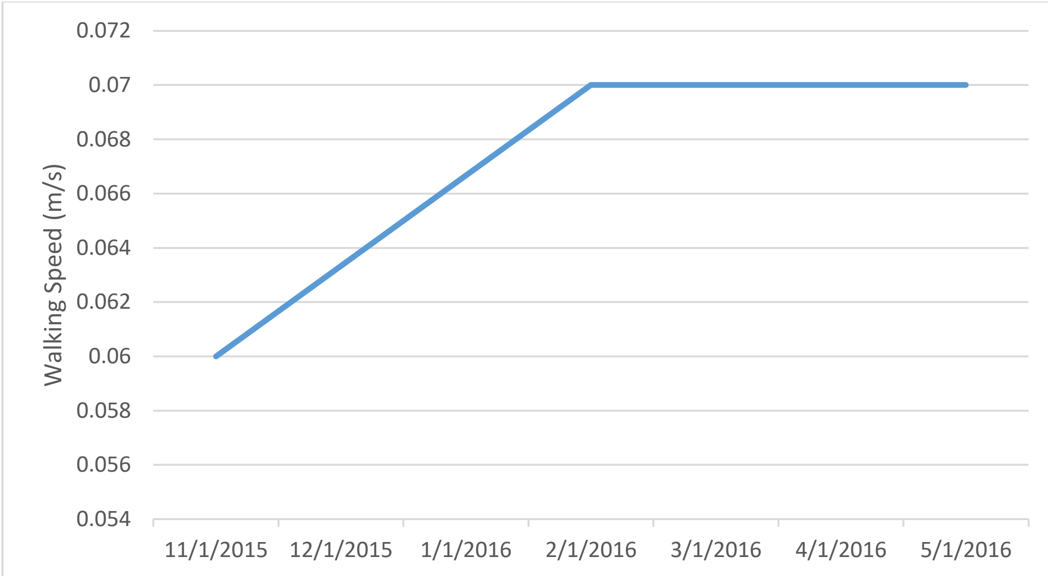


Figure 5. Walking Speed Progression. Shows linear progression of walking speed (m/s) between test dates throughout the study. There was a 16.67% increase in walking speed between the baseline and the intermediate test, followed by no change between the intermediate and the post test.

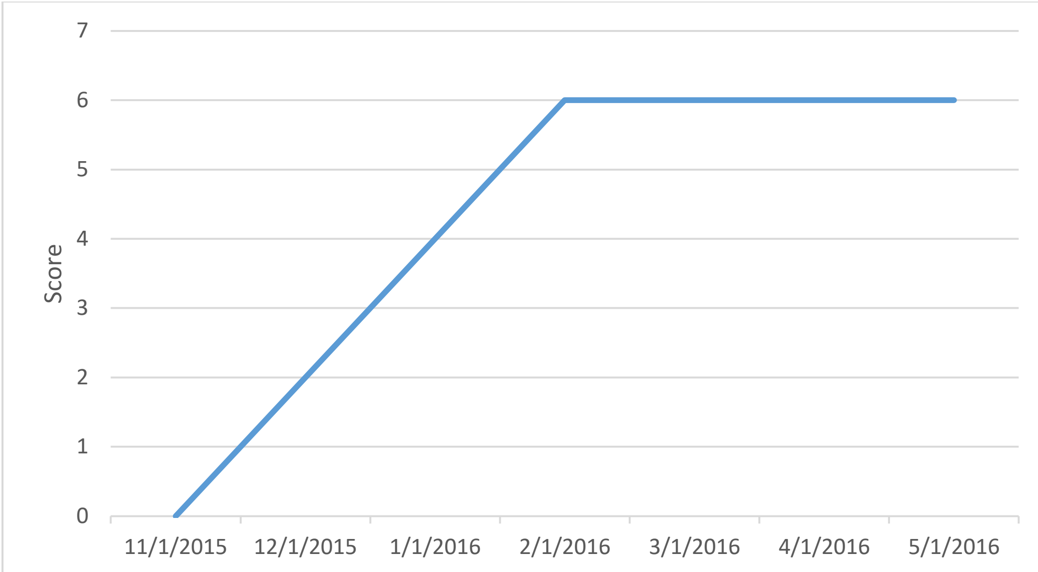


Figure 6. Walking Index Score for SCI Progression. Shows linear progression or WISCI scores between dates throughout the study. There was an increase in WISCI score increase of six between the baseline and intermediate test, followed by no change between the intermediate and post test.

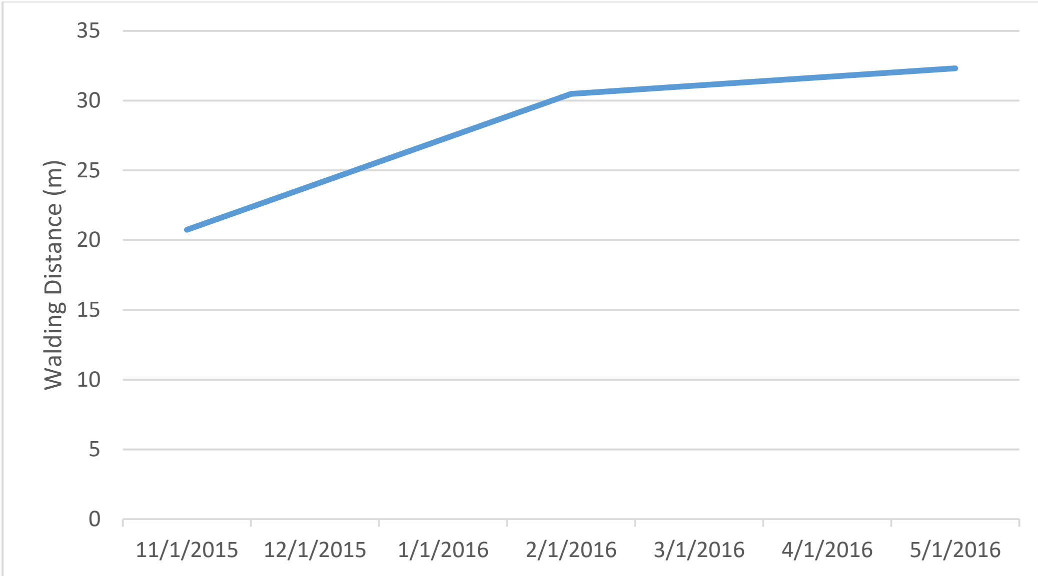


Figure 7. Walking Distance Progression. Shows linear progression of walking distance (m) between dates throughout the study. There was a 47.03% increase in walking distance between the baseline and the intermediate test, followed by a decrease of 6.00% between the intermediate and the post test.

Discussion

The purpose of this study was to determine the feasibility and effectiveness of UTT in the acute phase of a traumatic spinal cord injury of a nineteen-year-old female. Our results suggest that, transcending a plethora of external complications, there is an observable benefit to starting this form of rehabilitation in the acute phase of recovery with no apparent ill effects. Results showed that during the time period between the baseline and intermediate tests, the time in which the participant attended training fifteen times in twelve weeks, there were increases in all documented variables as well as observed increases in stamina, posture, gait and a decrease in dependence on assistance. The time period between the intermediate test and the post test, one in which the participant attended only three sessions in twelve weeks, showed only slight progression in walking distance, decrease in daily steps, and a significant regression in lower body strength. This was in conjunction with an increase in dependence on assistance, observed increase in fatigue, as well as posture and gait regression.

Although the participant's capacity to walk increased as indicated by gains shown in test data analysis, her performance did not change; she made little effort to walk in her natural environment at any point in the study as indicated by daily step values less than three as reported by the participant. This included several months when she had assistive devices loaned to her and available for use in her home.

Challenges

Despite the encouraging results seen in the first half of the study specifically, significant challenges were faced that very likely impaired the level of recovery achieved. Documentation cites the injury itself was due to a self-inflicted gunshot wound, suggesting a very serious case of depression was once exhibited by the participant (parent report) that was arguably still present throughout the time of the study. Psychological and emotional stress was high as she continued to adjust to her change in quality of life in this acute phase, even more significantly due to the nature of the injury itself. The participant was diagnosed with borderline personality disorder which Lieb et al. states is characterizes by "pervasive pattern of instability in affect regulation, impulse control, interpersonal relationships, and self-image."[26] The participant also showed substance abuse issues, further promoting a sense of depression (parent reference).

Where family support can be a positive influence in cases of traumatic injuries or depression in general,[24] the participant's family support was sub-par at best. There were tense situations exhibited among the participant and the accompanying family members, coupled with a lack of commitment in terms of transportation and behavioral support for the participant. It can be argued, the family as a whole continued in a state of denial of the new life for the participant, demonstrated through the outright refusal to take steps necessary to accommodate the participant's disability. The rehabilitation team made direct efforts in providing resources, direction, and encouragement to the family on how to better accommodate the disability and supplement progression outside of the lab, such as loaning assistive devices, scheduling appointments to receive KFAO's, standing frames, or even a walker; steps all of which were never taken, even with the availability of adequate financial resources.

External health complications with the lack of family support likely contributed to attendance at training sessions that was very sporadic, deficient, and ultimately the cause for study termination. Various reasons were given for cancellation, mostly just prior to the time of the appointment if not after, and few concerning the health of the participant.

Coming back from a nine week absence during the latter half of the training provided some interesting insight into the effectiveness of the study. After the absence, it was noted the assistance needed as well as posture in overground training had returned to that which was similar to the initial stages of the study. Stamina was also reduced in conjunction with an increase in visible fatigue.

The drastic decline in stamina and posture coupled with an increased level of assistance after the absence from the study has two possible implications. It suggests that the participant likely made little if any efforts to supplement her rehabilitation outside of what she was doing in the lab. This was supported by the lack of accommodations made that would assist in the before mentioned supplemental efforts. The decline also points to the direct effectiveness of the study even at such an early stage in recovery. Although there is potential for spontaneous recovery to take place in the first six months to one year post injury, some form of sustained, active rehabilitation is needed to promote the health benefits as illustrated by the progressive and regressive periods exhibited by the participant through the study.

Ideally, this study would have more consistency within the commitment of the participant. Our study was designed to be completely voluntary, so no incentive could be given to our participant to warrant a greater level of consistency short of improved quality of life as a result of the study itself. Although we allowed our participant a level of choice in what she did during her training session, it may have been better for the validity of the study to have mandated a greater level of consistency in the use of UTT;

however, at the end of the day, the importance of the study was to learn what we could from our given situation and actively seek an enhanced quality of life for our participant just as any healthcare provider desires. We found the level of participation in general a greater importance not only to this study, but also to the participant; the decision to put some sense of control over training into our participant's hands was directed towards the favorability of the study in the eyes of the participant, seeking increased participation.

Future Studies

This study was important in laying groundwork for future studies of SCI in the acute phase. This study supports the hypothesis that UTT is indeed an effective way to improve gait in a complete SCI while still in the acute phase, as indicated by the numerical and observational results. There were no observable adverse effects such as increased pain, musculoskeletal injury, bladder infection, etc experienced from initiating rehabilitation in the acute phase of recover six months post-incident. Because of these findings, further studies should seek to initiate rehabilitation earlier in recovery. One of the great challenges faced in recovering from a traumatic injury is the extensive muscle atrophy experienced from the period of inactivity. This forces any form of rehabilitation to spend time and energy trying to recover some of the lost muscle tone. Thus, the sooner rehabilitation can safely be implemented, the greater amount of effort can be directed towards synaptic stimulation and gait training. This would effectively push the window and extent of recovery forward, and may even lead to positive psychological effects through an increased sense of hope in the earliest stages in psychological adaptation.

Depression is considered the second most common condition faced in the general population of medical practice with roughly one out of every ten outpatients suffering from major depression, with those experiencing more than one medical condition and chronic pain, among other things, being at an increased risk. For those showing the strongest symptoms of depression coupled with an extended duration of illness or impaired function, such as a traumatic spinal cord injury, spontaneous recovery is highly unlikely making treatment necessary. Appropriate therapy can be effective in combatting the mild cognitive suppression, concentration impairment, as well as the psychomotor retardation that often accompanies depression. As these symptoms are resolved, the participant's quality of life is likely increased, leading to higher function and increased physical rehabilitation.[25] We would argue the form of rehabilitation performed in this study proved to be beneficial in addressing some of the stated concerns connected with the depression experienced by our participant. It was very apparent by those involved in the study, our participant's demeanor would drastically change throughout training on most days where she came to us looking mentally disconnected and observably drained. She would be very conserved, slumped over, in a defeated state; however, by the end of the training she would be talkative, perky, and hopeful. Additionally, there were many instances where family indicated our training was the only time our participant was happy, and this training was the only thing she looked forward to. As a result, these findings encourage subsequent studies to dig deeper into the psychological battle that is very evident in someone going through such a drastic change to quality of life. Greater attention directed towards psychological evaluations throughout the study that may point to a positive effect of UTT on confidence, mood, and self-assurance. If through careful study improvements can be made in the psychological side of rehabilitation, the challenges this study faced might be avoided or better resolved in future studies leading to more significant physical progression.

Conclusion

The importance of physical activity to the general health of an individual is well documented, thus any situation hampering an adequate level of activity can have collateral health implications that go beyond the direct effects of the condition. Our study of a nineteen year old female in the acute phase following a traumatic spinal cord injury sought to further the knowledge of how we are to combat this dilemma. With a sample size of one, no control group, or a concrete protocol, we cannot generalize our results to a larger population. This study faced many challenges to the participation and adherence to protocol, yet progress was still observed with no notable ill effects, supporting further study on UTT as a form of rehabilitation for a traumatic SCI in the acute phase with a larger sample size, consistent protocol, as well as an even earlier initiation.

References

1. Bolam, K. A., Van Uffelen, J. G., & Taaffe, D. R. (2013). The effect of physical exercise on bone density in middle-aged and older men: a systematic review. *Osteoporosis International*, *24*(11), 2749-2762.
2. Devivo, M. J. (2012). Epidemiology of traumatic spinal cord injury: trends and future implications. *Spinal Cord*, *50*(5), 365-372.
3. Dobbins, B., Barbeau, H., Deforge, D., Ditunno, J., Elashoff, R., Apple, D., et al. (2007). The evolution of walking-related outcomes over the first 12 weeks of rehabilitation for incomplete traumatic spinal cord injury: the muliticenter randomized spinal cord injury locomotion trial. *Neuro Rehabilitation and Neural Repair*, 21(1), 25-35.
4. Edgerton, V. R., Leon, R. D., Harkema, S. J., Hodgson, J. A., London, N., Reinkensmeyer, Tobin, A. (2001). Retraining the injured spinal cord. *The Journal of Physiology*, *533*(1), 15-22.
5. Fauad, K. & Pearson, K. (2004). Restoring walking after spinal cord injury. *Progress in Neurobiology*, 73, 107-126.
6. Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., Swain, D. P. (2011). Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Medicine & Science in Sports & Exercise*, *43*(7), 1334-1359.
7. Giovannucci, Edward, et al (1995). "Physical activity, obesity, and risk for colon cancer and adenoma in men." *Annals of Internal Medicine* 122.5: 327-334.
8. Haisma, J., Woude, L., Stam, H., Bergen, M., Sluis, T., & Bussmann, J. (2006). Physical capacity in wheelchair-dependent persons with a spinal cord injury: a critical review of the literature. *Spinal Cord*, 44, 642-652.
9. Haskell, W., Lee, I., Pate, R., Powell, K., Blair, S., Franklin, B., Macera, C., et al. (2007). Physical Activity and public health: Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Medicine and Science in Sports& Exercise*: *Special Communication*. 1423-1434.
10. Holmes, Michelle D., et al. (2005). "Physical activity and survival after breast cancer diagnosis." *JAMA* 293.20: 2479-2486.
11. Maynard, F. M., Bracken, M. B., Creasey, G. J. F. D., Ditunno, J. F., Donovan, W. H., Ducker, T. B., Waters, R. L. (1997). International standards for neurological and functional classification of spinal cord injury. *Spinal Cord*, *35*(5), 266-274.
12. Navarro, X., Vivó, M., & Valero-Cabré, A. (2007). Neural plasticity after peripheral nerve injury and regeneration. *Progress in Neurobiology*, *82*(4), 163-201.
13. Singh, A., Tetreault, L., Kalsi-Ryan, S., Nouri, A., & Fehlings, M. G. (2014). Global prevalence and incidence of traumatic spinal cord injury. *Clinical Epidemiol*, *6*, 309-331.

14. Stevens, S. L., Caputo, J. L., Fuller, D. K., & Morgan, D. W. (2008). Physical activity and quality of life in adults with spinal cord injury. *The Journal of Spinal Cord Medicine, 31*(4), 373-8.
15. Stevens, S. L., Caputo, J. L., Fuller, D. K., & Morgan, D. W. (2015). Effects of underwater treadmill training on leg strength, balance, and walking performance in adults with incomplete spinal cord injury. *The Journal of Spinal Cord Medicine*, *38*(1), 91-101.
16. Stevens, S. L., Fuller, D. K., & Morgan, D. W. (2013). Leg strength, preferred walking speed, and daily step activity in adults with incomplete spinal cord injuries. *Topics in Spinal Cord Injury Rehabilitation*, *19*(1), 47.
17. Stevens, S. L., & Morgan, D. W. (2014). Heart rate response during underwater treadmill training in adults with incomplete spinal cord injury.*Topics in Spinal Cord Injury Rehabilitation*, *21*(1), 40-48.
18. Stevens, S., & Morgan, D. W. (2010). Underwater treadmill training in adults with incomplete spinal cord injuries. *Journal of Rehabilitation Research & Development*, *47*(7), vii-vii.
19. Taylor, A. H., Cable, N. T., Faulkner, G., Hillsdon, M., Narici, M., & Van Der Bij, A. K. (2004). Physical activity and older adults: a review of health benefits and the effectiveness of interventions. *Journal of Sports Sciences*,*22*(8), 703-725.
20. Thuret, S., Moon, L. D., & Gage, F. H. (2006). Therapeutic interventions after spinal cord injury. *Nature Reviews Neuroscience, 7*(8), 628-643.
21. Warburton, D. E., Nicol, C. W., & Bredin, S. S. (2006). Health benefits of physical activity: the evidence. *Canadian Medical Association Journal*, *174*(6), 801-809.
22. Wirz, M., Zemon, D., Rupp, R., Scheel, A., Colombo, G., Dietz, V., et al. (2005). Effectiveness of Automated locomotor training in patients with chronic incomplete spinal cord injury: a multicenter trial. *Archives of Physical Medicine and Rehabilitation*, 86, 672-680.
23. National Spinal Cord Injury Statistical Center, Facts and Figures at a Glance. Birmingham, AL: University of Alabama at Birmingham, 2015.
24. Leach, L. R., et al. (1994). "Family functioning, social support and depression after traumatic brain injury." *Brain Injury 8.7*: 599-606.
25. Whooley, Mary A., and Gregory E. Simon. (2000). "Managing depression in medical outpatients." *New England Journal of Medicine* 343.26: 1942-1950.
26. Lieb, Klaus, et al. (2004). "Borderline personality disorder." *The Lancet* 364.9432: 453-461.

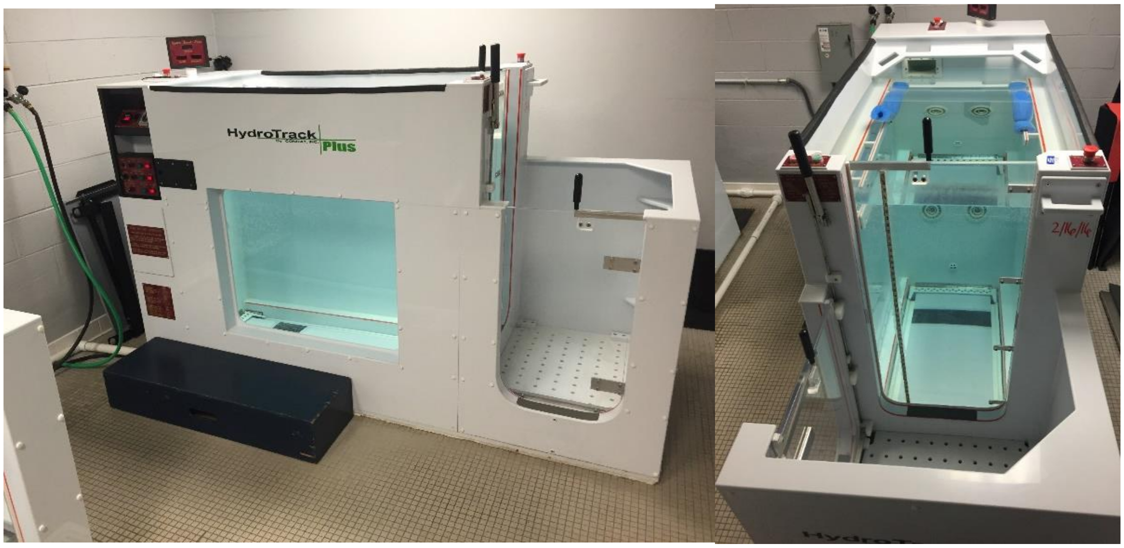
Appendices

Appendix 1. Knee Ankle Foot Orthoses (KAFO). Leg brace that crosses the knee and ankle joints terminating at the foot. Provides structural support to leg as well as optional leg extension assistance.

Appendix 2. BTe Eccentron Trainer. Participant sits and has feet strapped to pedals.

The computer records average values of resistance and observers record peak values during training.

a. **b.**



Appendix 3. Hydro Track Plus Underwater Treadmill. Participant enters apparatus by sitting in holding bay to the right. Holding bay is secured and water is allowed to fill the holding bay from the main tank until water level is even. Door to main tank is opened to allow participant to enter followed by securing main tank. Water is then pumped back into main tank to a desired level of 46.” Treadmill at bottom of main tank supplies training which is controlled by operator.