

CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

The Effects of Aquatic and Land-based Exercise on Balance and Gait in People Post  
Stroke

A thesis submitted in partial fulfillment of the requirements

for the degree of Masters of Science

in Kinesiology

By

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## DEDICATION

To God for giving me strength and opportunity to do this work

To my grandparents Late Mr. Amar Nath Motta, Late. Major Niranjan Nath Kuda and Late Mrs. Nirmla Kuda, my parents Mr. Bal Krishen Motta and Mrs. Usha Motta, my uncle Col. Surinder Nath Kuda, my sister Megha Motta, and my best friend Atif Zubair for all their love and encouragement

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## ABSTRACT

The Effects of Aquatic and Land-Based Exercise on Balance and Gait in People Post-Stroke

By

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Masters of Science in Kinesiology

The purpose of this study was to examine the effects of aquatic and land-based exercise on balance and gait outcomes in people post-stroke.

*Methods:* One person (1 male) participated in land-based exercise, two people (1 male and 1 female) participated in aquatic exercise, and one person (1 male) participated in home-based exercise. The aquatic and land-based participants received an 8-week exercise program, 3 training sessions, 3 times a week for 50 minutes. The home-based exercise participant was provided with an individualized exercise program which had the components similar to the other two protocols. The Biodex Balance Equipment was used to collect the participants' balance data and Biodex Gait Trainer was used to collect the participants' walking data. Pre-data was collected before the beginning of the exercise program followed by bi-weekly data collection. There were a total of five data collection points. The individuals participating in a aquatic exercise program performed the exercise in the therapeutic pool with a pool temperature range from 92-94 degrees Fahrenheit. The individual participating in land-based exercise program performed the exercise in the expansion room.

*Results:* The balance time series graph of the participant who took part in an 8-week land-based exercise program revealed a decrease in overall scores, medial-lateral index and anterior-posterior index. The time series graph of the participant (1) who took part in an 8-week aquatic exercise program revealed a decrease in overall score and anterior-posterior index. The balance time series graph of participant (2) who took part in an 8-week aquatic training programs revealed a decrease in overall scores, anterior-posterior index and medial-lateral index. The balance time series graph of the participant who participated in an 8-week home-based exercise program did not show significant improvement in overall scores, anterior-posterior index or medial-lateral index.

The gait time series graph of the participant who took part in an 8-week land-based training program showed significant improvement in coefficient of variation, step length, walking speed and cadence. However, they did not show improvement in ambulation index and the time they spent on each foot. The gait time series graph of the participant 1 who took part in an 8-week aquatic exercise program showed significant improvement in coefficient of variation, step length and walking speed. However, they did not show improvement in ambulation index, cadence or the time they spent on each foot. The gait time series graph of the participant 2 who took part in an 8-week aquatic exercise program showed significant improvement in ambulation index, the time they spent on each foot coefficient of variation, step length and walking speed. However, they did not show improvement in step length or cadence. The gait time series graph of the participant who took part in an 8-week home-based exercise program showed significant improvement in ambulation index, time they spent on each foot, cadence and walking

speed. However, they did not show improvement in step length or coefficient of variation.

*Conclusion:* The study results indicated that the individuals that participated in aquatic exercise and land-based exercise program showed remarkable improvements in their balance and gait outcomes compared to the individual participated in home-based exercise program.

## INTRODUCTION

Stroke is the second most common cause of death worldwide after ischemic heart disease and is a major health burden. It contributes to three percent of disability worldwide. In developing countries, two-thirds of deaths occur due to stroke (Warlow, Sudlow, Dennis, Wardlaw & Sandercock, 2003). Stroke survivors may suffer from cardiovascular deterioration, motor deficits, postural control issues, balance disturbances, muscular weakness, spasticity and a limited ability to walk. Physical activity is decreased in people post-stroke, contributing to depression (O'Sullivan & Schmitz, 2004).

Previous studies have indirectly suggested muscle weakness as a limitation in gait performance (Nadeau, Gravel, Arsenault & Bourbonnais, 1999). Nadeau et al. (1999) in their study concluded that the greatest limiting factor in gait speed is weakness of plantar flexors. Moreover, Milot et al. (2006), compared the walking pattern of seventeen hemiparetic participants with fourteen able-bodied individuals and found that the hemiparetic individuals demonstrated greater peak muscular utilization values than the able-bodied participants. Jonsdottir et al. (2009) reported decreased work production while walking due to reduced positive work at the ankle while walking at the comfortable speed and negative work at the ankle and hip while walking at fast speed in people post-stroke.

A main goal of rehabilitation for people post-stroke is to improve motor performance and functional abilities when performing ADLs (Carr & Shepherd, 2003). Rehabilitation allows them to walk independently with sufficient velocity and endurance (Yen, Wang, Liao, Huang & Yang, 2008). It has been reported that up to 80% of people

post-stroke are able to recover their ability to walk short distances, whereas the other 20% are not able to achieve the locomotor capacity that is essential for ambulation (Ross Bogey, 2007). In addition, people post-stroke require 50% to 100% more energy to walk at a self-selected speed as compared to age matched individuals (Ross Bogey, 2007). Treadmill walking with partial weight bearing helped improve gait patterns by reinforcing normal movement patterns by decreasing muscle spasms due to body weight (Petrofsky, Petrofsky & Bweir, 2004).

Due to the popularity of partial weight bearing in gait training, the aquatic environment is also gaining popularity for gait improvement. The four main properties of water: buoyancy, resistance, support and hydrostatic pressure, makes it easier for people with disabilities to exercise in water (Hale & Waters, 2007). As water provides stability, less energy expenditure and less muscle stress are required to maintain balance in the water while exercising. This reduces fear of falling in individuals when they exercise in water (Hale & Waters, 2007). Due to water density, the movements when performed in water are comparatively slower and more stable than when they are performed on land. (Bintzler, 2006). Increased resistance and water temperature create a more favorable environment to achieve treatment goals as compared to exercising on land (Bintzler, 2006).

Recent studies have shown water to be a more suitable and effective environment to exercise in individuals with a disability than land (Hale & Waters, 2007). Silva, Valim, Pessanha, Oliveira, Myamoto & Jones (2008), reported that pain level decreased more in the people with osteoarthritis of the knee who were given aquatic exercise group for 18 weeks as compared to land-based exercises. Chu et. al. (2004) compared the effects of an

8-week aquatic exercise program with those of an upper extremity function program on land on cardiovascular fitness, gait speed and maximal workload in people post-stroke. They concluded that cardiovascular endurance, maximal workload, gait speed, and paretic lower-extremity muscle strength in people post-stroke was significantly increased in individuals who participated in the aquatic exercise program.

Few studies have compared the benefits of aquatic and land-based exercise in people with different disabilities. They have found water to be more effective environment for exercise. However, no study has looked at the effects of aquatic and land-based exercise on gait and balance outcomes in people post-stroke. The purpose of this study was to determine the effects of aquatic and land-based exercise on balance and gait in people post-stroke. It was hypothesized that the individuals participating in aquatic and land-based exercise would demonstrate significant improvements in their gait and balance outcomes when compared to home-based exercise. It was also hypothesized that the individuals participating in aquatic-based exercise would demonstrate equal or better improvements in their gait and balance outcomes than the participants in the land and home-based exercise.

### **Clinical Significance**

No study has looked at the effects of aquatic and land-based exercise on gait and balance outcomes in people post-stroke. This study would help to develop evidence-based aquatic and land-based exercise for people post-stroke. Overall, this study was expected to provide scientific understanding of aquatic and land-based exercise on gait and balance outcomes with people post-stroke.

## **Hypotheses**

Hypothesis 1: People post-stroke participating in aquatic and land-based exercise programs would demonstrate significant differences in their gait and balance outcomes compared to those participating in the home-based exercise program.

Hypothesis 2: People post-stroke participating in aquatic and land-based exercise programs would demonstrate equal improvements in their gait and balance outcomes.

Hypothesis 3: People post-stroke participating in aquatic-based exercise program would demonstrate significant differences in their gait and balance outcomes compared to those participating in the land-based exercise program.



## **Delimitations**

The following delimitations and the assumptions were set to make this study a workable research problem.

1. All the participants were diagnosed as having a stroke (minimum 1 year post-stroke) by a neurologist, geriatrician or a rehabilitation specialist.
2. Participants recruited had no neurological conditions other than stroke, no open wounds, no surgery within last six months, and no coexisting orthopedic, cardiovascular, visual impairment or tremor effecting locomotion.
3. Only independent (with or without aids) ambulatory participants with no fear of water and no current participation in any aquatic or land intervention were recruited in the study in order to reduce the complications during the study.
4. Participants had bladder and bowel control and could understand verbal instructions and follow the instructor.
5. Pool temperature was controlled between 92 to 94 degrees Fahrenheit.
6. All the participants exercised for 50 minutes, three times a week for 8 weeks.
7. Practice trials were given to each participant during every data collection. Practice time was set to minimize familiarization time and fatigue.

## **Limitations**

The following limitations and assumptions were present in the study, which may be confounding to the dependent variables, as they could not be controlled.

1. It was assumed that the gait assessment from BIODEX GAIT TRAINER and the balance assessment from BIODEX BALANCE were accurate and reliable.
2. It was assumed that the participants put their maximum effort during the test trials.
3. It was assumed that the participants put their maximum effort during the aquatic and land-based exercise sessions.
4. It was assumed that the participant in the home-based exercise group followed the guidelines and the instructions of the researcher by exercising three times a week for eight weeks.

## **Independent and Dependent Variables**

### Dependent variables:

#### 1. Spatiotemporal gait variables

- Cadence (steps cycles/minute)
- Stride length (meters)
- Stride time (%)
- Coefficient of variation (%)
- Walking speed
- Ambulation index

#### 2. Balance

- Overall scores
- Anterior/posterior index
- Medial lateral index

### Independent variables

1. Aquatic exercise
2. Land-based exercise
3. Home-based exercise

## **Definition of Terms**

Pain: A general feeling of discomfort.

Fatigue: A feeling of tiredness without exercise.

Muscular Strength: The ability of a muscle to increase intra-muscular tension.

Muscular Endurance: The ability of a muscle to sustain the muscular contraction.

Home-based Exercise: Exercise program designed to perform at home.

Aquatic Training: Exercise performed in the water.

Land-based Training: Exercise performed on land.

Stretching Exercise: A therapeutic maneuver designed to lengthen (elongate) the pathologically shortened stretchers, and thereby increasing the range of motion (ROM)

Strengthening Exercise: Exercise designed to increase muscular strength.

Functional Activity: The ability to perform activities of daily living.

Involved Side: The side (right or left) affected by stroke.

Less Involved Side: The side (right or left) not affected by stroke.

Gait: Manner of walking.

Gait Cycle: Sequence of motion that occurs from one initial contact of heel to the next consecutive initial contact of the same heel while walking.

Cadence: Steps cycles taken by a person per minute while walking.

Stride Time: Time spent on each foot by a person while walking.

Stride Length: The length of the steps taken by a person while walking.

Walking Speed: Speed of a person while walking.

Coefficient of Variation: Variability in the participant's gait during each trial in gait analysis.

Ambulation Index: A rating scale used to assess mobility by evaluating the time and degree of assistance required to walk.

Balance: The process that maintains the center of gravity within the body's support base and requires constant adjustments that are provided by muscular activity and joint positioning.

Anterior-posterior index: Anterior-posterior sway performed to maintain the center of gravity and line of gravity within body's supported base.

Medial-lateral Index: Medial-lateral sway performed to maintain the center of gravity and line of gravity within body's supported base.

Overall scores: Comprises of anterior-posterior index and medial-lateral index.

## LITERATURE REVIEW

### Stroke

A stroke is also called a cerebrovascular accident. It is an acute onset of neurological dysfunction resulting in signs and symptoms that correspond to the involvement of focal areas in the brain. A stroke generally occurs due to abnormal blood circulation in the cerebrum. The common impairments in people post-stroke are changes in levels of consciousness, sensory, motor, cognitive, perceptual and language function. When the focal neurological deficits persist for 24 hours or more, then it is classified as a stroke (O'Sullivan & Schmitz, 2004).

A stroke occurs due to atherosclerosis where plaque is formed due to an accumulation of lipids, complex carbohydrates, fibrin and calcium deposits on the walls of the arteries which can lead to the narrowing of blood vessels. Strokes can be either ischemic or hemorrhagic. An ischemic stroke occurs when there is a lack of cerebral blood flow that deprives the brain of the oxygen and glucose necessary to function. This disrupts the metabolism in the cells and, thus, leads to brain injury and death of brain tissues. Hemorrhagic stroke occurs when there is bleeding in the extra vascular areas of the brain due to trauma or aneurysm. This increases intracranial pressure and restricts the blood flow to the distal areas of the brain. A congenital defect which leads to a stroke is arteriovenous malformation (AVM) in which the arteries and veins in the brain are stressed (O'Sullivan & Schmitz, 2004).

Strokes are the most common cause of disability in United States and are seen mostly in adults (O'Sullivan & Schmitz, 2004). Stroke is the second leading cause of

death in the world. Two-thirds of all deaths which occur in developing countries are due to stroke (Feigin, 2005). More than four million Americans are currently stroke survivors while 700,000 Americans experience their first stroke annually (Silver, Macko, Forrester, Goldberg & Smidth, 2000; Wade & Hewer, 1987). Ischemic stroke accounts for 61% to 81% of all strokes while hemorrhagic stroke accounts for 12% to 24% (O'Sullivan & Schmitz, 2004). Age also plays a significant role in the incidence of stroke. In the Caucasian population, three quarters of all first strokes occur after the age of 65 years (Warlow et al., 2003).

## Gait in Stroke

Gait incorporates the repeated movements of the limbs in sequence while maintaining stability (Perry, 1992). The gait cycle is divided into the swing and stance phases. The stance phase begins with initial contact of the foot and ends with the toe off, the swing phase begins at toe off and ends with the heel strike of the same foot. During the swing phase the foot is in the air (Perry, 1992). The stance phase constitutes 60% of the total gait cycle and the swing phase constitutes 40% of the total gait cycle (Kirtley, 2006). The stance phase is divided into the initial contact, loading response, mid-stance and terminal stance phases. The swing phase is divided into the initial-swing, mid-swing and terminal swing phases. One gait cycle is completed with one complete stride and one stride is completed with two consecutive initial foot contacts of the same foot (Kirtley, 2006).

Gait initiation is a unique and challenging task. It is a period that starts with an upright stance and ends with a steady-state gait (Kirtley, 2006). At the time of gait initiation each limb is responsible for performing its own work depending on the choice of the leading limb (Kirtley, 2006). In a study by Tokuno and Eng, it was reported that if gait was initiated by the weaker limb the impulses generated by antero-posterior forces on the weaker limb were almost non-existent (Tokuno & Eng, 2006).

Previous studies indirectly suggest that muscle weakness may limit gait performance (Nadeau, Gravel, Arsenault & Bourbonnais, 1999). Gait performance largely depends upon the strength of the more involved lower limb in people recovering from a stroke. Nadeau et al. (1999) examined the walking patterns of 17 adult volunteers



(14males and 13 females) at their comfortable gait speed and then at their maximal gait speed. They found that one of the greatest limiting factors in gait speed is the weakness of plantar flexors. After a stroke, weakness in specific muscles can cause a slower walking speed (Milot et al. 2006). The force generated by hip extensors, ankle planter flexors and hip flexors during walking is important to increase or maintain the forward velocity of the body (Milot et al. 2006).

Milot et al. (2006) compared the walking pattern of seventeen hemiparetic participants with fourteen able-bodied individuals and found that the hemiparetic individuals showed greater peak muscular utilization values than the able-bodied participants. Several other studies have evaluated the utilization of specific muscles in hemiparetic participants while walking. In 2006, Milot et al. evaluated the muscular utilization while walking at their self-selected speed and maximal velocities in seventeen hemiparetic individuals. They concluded that the highest level of effort is made by the weakest paretic muscle group while walking (Milot et al. 2006). In addition to muscular strength, balance and sensation also affect gait speed in people post-stroke. ( Milot et al. 2006).

Parvataneni et al. (2007) evaluated the walking patterns of twenty eight post stroke participants before and after a strength training intervention for ten weeks for three times per week and one hour per session. They found that by increasing the hip extensor work on both the sides in early stance phase, and plantar flexor thrust on the affected side, an individual can increase gait velocity.

Jonsdottir et al. (2009), compared the gait patterns of people post-stroke at their self-selected speed and fastest speed. They found that people post-stroke, when walked at

their faster speed had reduced work production as compared to walking at their self-selected speed, due to decrease in the positive work at ankle. People post-stroke demonstrated negative work at ankle and hip while walking at their fastest speed (Jonsdottir, 2009). Moreover, Jonkers et al. (2008) concluded that the power generation by impaired ankle, in addition to the saturation of hip power generation, limits the potential to increase the walking speed in lower functioning people post-stroke (Jonkers 2008).

Beaman et al. (2009) analyzed relative changes in paretic and non-paretic leg symmetry to assess the effect of speed on asymmetry. Forty-six participants post-stroke were asked to walk at their self-selected and fastest-comfortable speeds on an instrumented split-belt treadmill. The researchers concluded that the participants with greater step length asymmetry at their self-selected speed walked more slowly than at their fastest-comfortable walking speeds. However, fastest-comfortable walking speeds with step length symmetry at self-selected speed were negatively correlated (Beaman, 2009).

## Gait Rehabilitation Post-Stroke

When a stroke is diagnosed an individual should begin the rehabilitation program to prevent further complications as soon as possible. Mobilizing the individual and encouraging a resumption of the activities of daily living should be emphasized (Gresham, 1995). In addition to the maintenance of functional health patterns such as nutrition, and bladder and bowel control, the primary focus of rehabilitation in people post-stroke is to improve mobility and motor control (Gresham, 1995). Treadmill walking with partial weight bearing progressing treadmill walking with full weight bearing, is used as an important and reliable method for gait rehabilitation in stroke survivors (Carr & Shepherd, 2003). The use of over-ground walking for gait rehabilitation helps post-stroke individuals focus on maintaining balance while walking (Carr & Shepherd, 2003).

Various studies have been conducted to compare over-ground walking and treadmill walking to determine which of the two gait training methods work better for people post-stroke. Laufer, et al. (2001) determined treadmill training to be more effective in order to improve functional ambulation, stride length, percentage of paretic single stance period and gastronemius activity. They also reported that people post-stroke can tolerate treadmill training without using the weight support apparatus in their later phase of rehabilitation.

In contrast, Bayat, et al. (2005) stated that over-ground walking, when compared with treadmill walking, resulted in increased gait speed, lower cadences and longer stride lengths. In 2009, the faculty of Birgitta Langhammer Physiotherapy Programme and Johan K Stanghelle Sunnaas Rehabilitation Hospital evaluated spatial and temporal gait

characteristics and endurance in people-post stroke. Thirty nine people were randomly put in an outdoor walking group and treadmill walking group. The results demonstrated greater improvement in spatial and temporal gait characteristics of the participants in treadmill walking group compared to outdoor walking group.

Peurala, et al. (2007) analyzed the effects of gait therapy for people after acute stroke. Fifty-six people, eight days post-stroke, were randomly divided into a gait trainer exercise group, over-ground walking group and conventional treatment group.

Participants in the gait trainer exercise and over-ground walking groups practiced walking for three weeks (15 sessions) and also received additional physiotherapy. Results of the study demonstrated significant improvement in walking ability of the groups which practiced over-ground walking and gait trainer in addition to exercise therapy. Also, the researchers concluded that early intensive gait training resulted in better walking ability than did conventional treatment (Peurala, 2007).

Thus, both over-ground and treadmill gait training methods have been found to be promising modes of gait training for people-post stroke. However, the effectiveness of over-ground walking as compared to treadmill walking has been a long debated issue. The idea of partial weight bearing has given focus to aquatic intervention as a potential method of treatment in early phase of rehabilitation (Bintzler, 2006).

## Aquatic and Land-based Exercise

Recent research focuses on the benefits of exercising in water for different aspects of health. Waters, et al. (2007) examined the effects of a 12-week aquatic exercise program on gait and balance in older adults. The experimental group was instructed to do the aquatic exercise that consisted of warm up, aerobic exercise, balance exercise, strength exercise followed by a cool down. The control group was instructed to do home-based exercise. The researchers found aquatic exercises to be potentially beneficial for improving gait and balance in older people. Moreover, the participants in the experimental group also reported a greater range of perceived psychological and physical benefits after exercising in water when compared to home-based exercise group (Waters & Hale, 2007).

Water has more density than air which makes a person more stable in the water than on land. With the properties of water such as buoyancy, it is much easier to perform a movement in water compared to land. Movements performed repeatedly in water at a greater speed, due to increased resistance, improves muscular strength and endurance. The other physical benefits while performing exercises in water include improved pulmonary function, increased relaxation and increased circulation (Butler, 2002). Masumoto, et al. (2004) concluded that the muscle activation of paraspinal muscles was greater when the participants walked backwards against the water current due to the maximal voluntary contraction of paraspinal muscles in water.

Many researchers have compared the effects of aquatic and land-based exercise on healthy individuals as well as in people with disabilities. Douris, et al. (2003) compared aquatic exercise with land-based exercise for improving balance in older

adults. Participants were randomly assigned to land-based and aquatic group. Land-based group performed balance exercises on land and the aquatic exercise group performed balance exercises in the pool two times per week for six weeks. Results demonstrated significant improvements in both the groups (Douris, 2003).

Chu, et al. (2004) compared the effects of an 8-week aquatic exercise program with the upper extremity function program on land, on cardiovascular fitness, gait speed and maximal workload in people post-stroke. Participants in the experimental group were instructed to do aquatic exercises in chest-level water. Their exercise intervention included stretching for 10 minutes, 5 minutes of light aerobic warm-up, 30 minutes of moderate to high aerobic activities at the prescribed heart rate, followed by five minutes of light cool-down and 10 minutes of gentle stretching in water. Participants in the control group were instructed to do an upper extremity program. Their exercise intervention included upper extremity warm up for 5 minutes, circuit training that focused on the upper extremity strength and fine motor skills for 50 minutes followed by a five-minute cool down. The results showed significant increases in cardiovascular endurance, maximal workload, gait speed, and paretic lower-extremity muscle strength in people post-stroke who participated in the aquatic exercise program.

(Chu et al. 2004).

Greene, et al. (2009) compared the efficacy of water and land treadmill use for adults with obesity. The individuals participated in a 12-week training program. The intensity of exercise prescription for the participants in the underwater treadmill group and the land treadmill group was calculated by their %  $VO_{2max}$  and was recalculated every week to monitor their progress. The results demonstrated both underwater treadmill

and land treadmill were equally capable of improving aerobic capacity and body composition but the underwater treadmill training showed significant results in increasing leg muscle mass (Greene, 2009).

In 2004, Benelli and De Vito compared the heart rate and blood lactate responses in ten healthy young women after doing the same aerobic exercise routine in three different environments (on land, in shallow water and in deep water). They found that heart rate and blood lactate production was decreased in the participants who did the exercise in deep water (Benelli & De Vito, 2004).

Silva, et.al. (2008), conducted a study to compare the effects of water-based exercise and land-based exercise on pain management in people with osteoarthritis knee. Participants were randomly divided into two groups (water-based exercise group and land-based exercise group). Both of the groups did the intervention for 50-minute per session for three times a week for 18 weeks. Water temperature was maintained at 32 degree Celsius for the water-based exercise group throughout the intervention. The intervention for both groups included stretching exercises, strengthening exercises (isotonic and isometric) and gait training. Results showed significant decreases in the pain level in participants with osteoarthritis of the knee who participated in the water-based exercise program as compared to those in the land-based exercise program (Silva, 2008).

Water temperature may also help with pain reduction (Jentoff, 2001). Jentoft, et al. (2001) compared pool-based aerobic exercise and land-based aerobic exercises in women with chronic muscle pain. Eighteen female participants took part in the pool-based aerobic exercise and sixteen female participants participated in the land-based

structured exercise program. Both groups did the training for 20 weeks. The temperature of the pool was maintained at 34 degree Celsius for the pool-based exercise group. The results showed significant improvements in cardiovascular capacity, walking time and daytime fatigue in both the groups. However, participants who participated in the pool-based exercise also reported significant decrease in their chronic muscle pain level, anxiety and depression when compared to land-based exercise program (Jentoft, 2001).

Few studies have compared the benefits of aquatic and land-based exercise in people with different disabilities. Of these studies, water was found to be more suitable and effective environment for exercise. However, no study has compared the effects of aquatic and land-based exercise on balance and gait in people post-stroke. The purpose of this study was to determine the effects of aquatic and land-based exercise on balance and gait outcomes in people post-stroke.



## Aquatic versus Land-Based Exercise in People Post- Stroke

A person has less fear of falls in water due to its properties. Aquatic exercises also help an individual to focus more on the muscles responsible for proper and safer gait patterns. As a result, a person with a disability may feel more balanced and confident while walking in water (Bintzler, 2006). Many researchers have found water to be a more effective environment for exercise as compared to land for people with a disability (Waters & Hale, 2007). Silva et. al. (2008) reported a significant decrease in pain level of the people with osteoarthritis of the knee who participated in the aquatic exercise program as compared to the participants in the land-based exercise program. Jentoft et. al. (2001) found significant decreases in chronic muscle pain, anxiety and depression in the female participants who participated in the aquatic exercise. Chu et al. (2004), concluded that cardiovascular endurance, maximal workload, gait speed, and paretic lower-extremity muscle strength in people post-stroke increased significantly in individuals who participated in the aquatic exercise program as compared to the participants those in the land-based program (Chu, et al. 2004).

Thus, it was hypothesized that the people post-stroke participating in the aquatic exercise program would demonstrate significant differences in their balance and gait outcomes when compared to those part in the land-based and home-based exercise programs.

## METHODOLOGY

### Participants

This study involved five people post-stroke. Two people (1 male and 1 female) participated in land-based exercise, Two people (1 male and 1 female) participated in aquatic exercise, and one person (male) was in the home-based exercise group. One participant in land-based exercise, was excluded from the study for not being able to in the training sessions. Only four participants completed the study. The participants were recruited from a stroke support group from Northridge Medical Center, Northridge, California. They were randomly assigned to three groups: aquatic, land-based or home-based training programs.

The inclusion criteria were:

- Age 45-85years
- Minimum 1 year post stroke
- Ability to ambulate
- Ability to communicate
- No other neurological and/or orthopedic conditions
- No cardiac conditions
- Bladder and bowel control
- No surgery within last six months
- Medical clearance from a primary physician
- No current participation in any aquatic or land intervention

The exclusion criteria were:

- Acute medical conditions
- Any neurological condition other than stroke
- Fear of water
- Open wounds
- Inability to ambulate

### Setting

The study was conducted at the Center of Achievement/ Brown Center on the campus of California State University, Northridge. The aquatic-based exercise program was held in a main therapy pool (4 foot depth) where the water temperature was maintained between 92- 94 degrees Fahrenheit. The land-based exercise program was held in the expansion room. The home-based exercise program was carried out at the participant's home with a family member. Initial instruction and a program card were provided to the home-based exercise participant and their family member.

### Instrumentation

The Biodex Gait Trainer was used to collect participants' walking data and Biodex Balance Equipment was used to collect participants' balance data.

### Testing procedures

Two variables were tested with each participant: gait and balance. A total of five data collection points were included in the study. Pre-data were collected before the beginning of the exercise programs and then every alternate week during the exercise program. It was followed by the post data by the end of 8<sup>th</sup> week. The data collection procedures were explained to each participant and an informed consent form was obtained. After

receiving instructions the participants were escorted to the assessment room for data collection. The participants were given two practice trials to determine the level of instability and for familiarization on the Biodex Balance Equipment. The participants were then given a 2-minute rest period followed by the three data collection trials. After the balance data were collected the participants were again given a 2-minute rest period followed by the gait data collection. For the gait data collection the participants were given one practice trial (2-minute walk) on the Biodex Gait Trainer to determine their comfortable speed and for familiarization of the equipment. This was followed by a 2-minute rest period. After the 2-minute rest period the data were collected on the Biodex Gait Trainer using a 2-minute walk test.

Independent variables in this study were the training modes: aquatic exercise, land-based exercise and home-based exercise. The dependent variables in this study were : spatiotemporal gait variables (cadence (steps/minute), stride length (meters), stride time (%), coefficient of variation (%), walking speed, and ambulation index.

For balance, the dependent variables were: overall scores anterior/posterior index and medio-lateral index.

### Intervention

All of the interventions were carried out in Center of Achievement at California State University, Northridge. The exercise programs (aquatic, land-based and home-based) met three times a week for 50-minute per session over 8 weeks (excluding the 10 minute transition time). The exercise programs were divided into phases three phases. The first two phases were three weeks each and the third phase was two weeks (Table 1).

The individuals participating in aquatic exercise program performed the exercise in the therapeutic pool with a water temperature ranging from 92-94 degrees Fahrenheit. The aquatic exercise protocol started with a 5-minute lower extremity stretching routine followed by 15-minute lower extremity strengthening exercise. The participants were then asked to do 10 minutes of balance exercises followed by 10 minutes of pool floor walking and 10 minutes of treadmill walking. The exercise session ended with a 5-minute cool down (Table 2).

The participants in the land-based exercise program performed the exercises in the expansion room. The land-based exercise protocol started with a 5-minute lower extremity stretching followed by 15 minutes of lower extremity strengthening exercises. The participants were then asked to do 10 minutes of balance exercises followed by 10 minutes of parallel bar walking and 10 minutes of treadmill walking. The exercise session ended with a 5-minute cool down (Table 3).

The participant in the home-based program was provided with an individualized exercise program which had components similar to those of the other two protocols. The participant and the caregiver/family member were instructed on the implementation of the program with initial on-site orientation and guidelines. They received copies of pictures that demonstrated flexibility, strength, balance and mobility exercises of the lower extremities. The adherence to the program was monitored by weekly phone calls and logs kept by the research

Table 1

*Intervention Phases*

Weeks	Phase 1	Phase 2	Phase 3
1 <sup>st</sup> , 2 <sup>nd</sup> & 3 <sup>rd</sup>	<p><u>-Strengthening exercises:</u> with assistance</p> <p>- <u>Aquatic exercises:</u> No weight cuffs while pool floor walking and treadmill walking</p> <p>- <u>Land-based exercises:</u> No weight cuffs while parallel bar walking and treadmill walking</p> <p><u>-Balance exercises:</u> with assistance</p>		
4 <sup>th</sup> , 5 <sup>th</sup> & 6 <sup>th</sup>		<p><u>-Strengthening exercises:</u> with minimal to no assistance</p> <p>- <u>Aquatic exercises:</u> Light weight cuffs while pool floor walking and treadmill walking</p> <p><u>-Land-based exercises:</u> Light weight cuffs while parallel bar walking and treadmill walking</p> <p><u>-Balance exercises:</u> With minimal assistance</p>	
7 <sup>th</sup> , 8 <sup>th</sup>			<p>- <u>Strengthening exercises:</u> With light weight cuffs.</p> <p>- <u>Aquatic exercises:</u> medium weight cuffs while pool floor walking and treadmill walking</p> <p>- <u>Land-based exercises:</u></p>

			medium weight cuffs while parallel bar walking and treadmill walking <u>-Balance exercises:</u> with no assistance
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**Table 2***Land-Based Intervention Protocol*

Warm-up and Stretching (5-minute)	Stretching -Lower extremities: hamstring stretch, quadriceps stretch, calf stretch, adductor stretch, abductor stretch, plantar, dorsiflexor stretch, evertors and invertors stretch.
Strength (10 minutes)	-Hip joint: flexion, extension, abduction, adduction, internal and external rotation, and circumduction. -Knee joint: flexion and extension. -Ankle joint: planter flexion, dorsi flexion, eversion and inversion.
Balance Exercises (10 minutes)	- Sit to stand. - Standing with narrow base of support (with assistance).
Gait Training (20 minutes)	-Pool floor walking (10 minutes) and underwater treadmill walking (10 minutes).
Cool-down ( 5 minutes)	-Breathing exercises.



**Table 3***Aquatic Intervention Protocol*

Warm-up and Stretching (5-minute)	Stretching -Lower extremities: hamstring stretch, quadriceps stretch, calf stretch, adductor stretch, abductor stretch, plantar, dorsiflexor stretch, evertors and invertors stretch.
Strength (10 minutes)	-Hip joint: flexion, extension, abduction, adduction, internal and external rotation, and circumduction. -Knee joint: flexion and extension. -Ankle joint: planter flexion, dorsiflexion, eversion and inversion.
Balance Exercises (10 minutes)	- Sit to stand. - Standing with narrow base of support (with assistance).
Gait Training (20 minutes)	-Pool floor walking (10 minutes) and underwater treadmill walking (10 minutes)
Cool-down ( 5 minutes)	-Breathing exercises.

### Data analysis

The outcomes of the study were analyzed by performing visual analysis of progress based on time graph series.

First, it was hypothesized that the people post-stroke participating in aquatic and land-based training programs would demonstrate significant differences in their balance and gait outcomes when compared to the home-based exercise individual.

Second, it was hypothesized that the people post-stroke participating in aquatic and land-based training programs would demonstrate equal improvements in their balance and gait outcomes.

Third, it was hypothesized that the people post-stroke participating in aquatic exercise program would demonstrate significant differences in their balance and gait outcomes when compared to those participating in land-based training program.

### Human Subjects Review

This study was approved by the Institutional Review Board of California State University, Northridge. Potential risks for participants included fatigue, dehydration, falling on land, drowning and other water safety issues. These risks were minimized by close monitoring and active spotting by research assistants. Additionally, the safety of all the participants in the aquatic training program was ensured by the presence of a lifeguard on the pool deck. All the procedures, risks and benefits were explained to all the participants before they participated in the study. Informed consent (Appendix A) was obtained for each participant and they were permitted to withdraw from the study at any time during the course of the programs for any reason without penalty.

## RESULTS

The purpose of this study was to determine the influence of aquatic and land-based exercise on balance and gait outcomes in people post-stroke. A total of five people post-stroke participated in this study. Two people (1 male & 1 female) participated in land-based exercise, two people (1 male & 1 female) participated in aquatic exercise and one person (male) participated in the home-based exercise group. One participant from land-based exercise group was excluded and only four participants completed the study. All the profiles of the participants are listed in Table 4. Fatigue, lower extremity weakness, impaired walking and impaired balance were most common symptoms among all participants. One of the five participants had pain due to spasticity in addition to other symptoms. Participants were randomly divided into three groups: aquatic, land-based and home-based exercise groups. The aquatic and land-based group participated in an 8-week exercise program with the home-based group following a similar program at home.

All of the groups were tested on balance and gait parameters before the exercise programs began. These data were collected bi-weekly during the 8-week exercise program followed by the post data at the end of the 8<sup>th</sup> week. There was a total of five data collection points. The Biodex Gait Trainer was used to collect data for the gait parameters while the Biodex Balance Equipment was used to collect data for balance variables. The outcome of the study was analyzed by performing a visual analysis of progress based on a time graph series.

Table 4

*Participant information*

Index	Age	Gender	Primary symptoms	Involved side
1	75	Male	Fatigue, lower extremity weakness, Impaired walking, impaired balance	Right side
2	84	Male	Fatigue, lower extremity weakness, Impaired walking, impaired balance	Left side
3	47	Male	Fatigue, lower extremity weakness, Impaired walking, impaired balance	Right side
4	79	Female	Fatigue, lower extremity weakness, Impaired walking, impaired balance	Left side

It was hypothesized that the people post-stroke participating in aquatic and land-based training programs would demonstrate significant differences in their balance and gait outcomes when compared to the in home-based exercise participant.

It was hypothesized that the people post-stroke participating in aquatic and land-based training programs would demonstrate equal improvements in their balance and gait outcomes.

It was hypothesized that the people post-stroke participating in the aquatic training program would demonstrate significant differences in their balance and gait outcomes when compared to those in the land-based training program.

The time series graph revealed significant differences in balance and gait outcomes between the pre and post training programs for aquatic, land-based and home-based exercises.

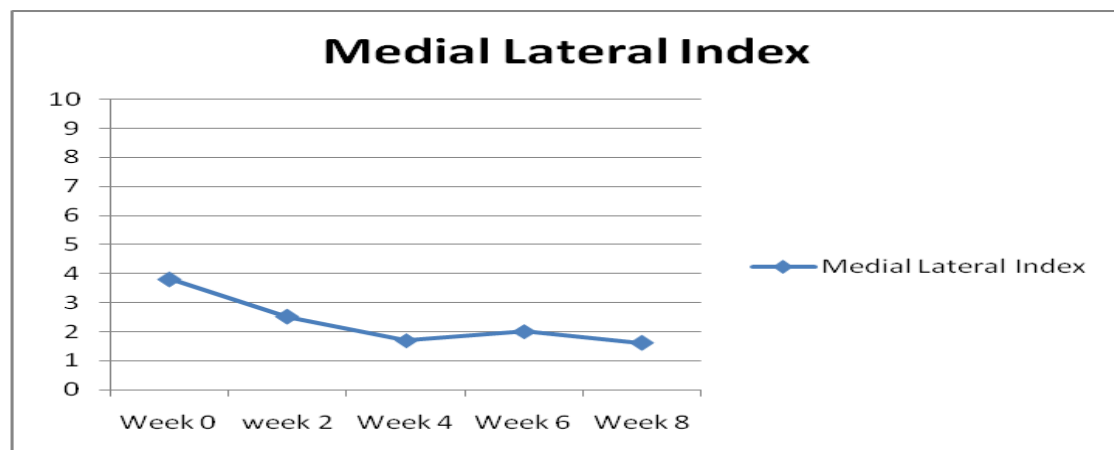
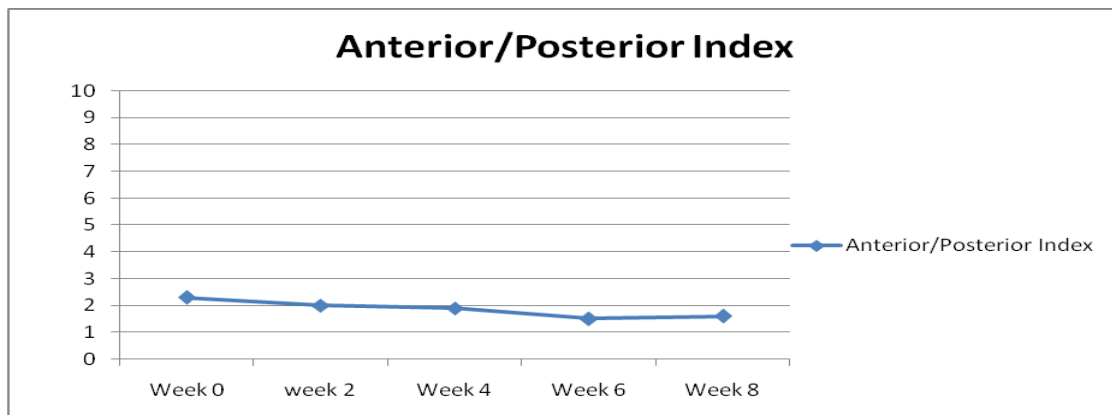
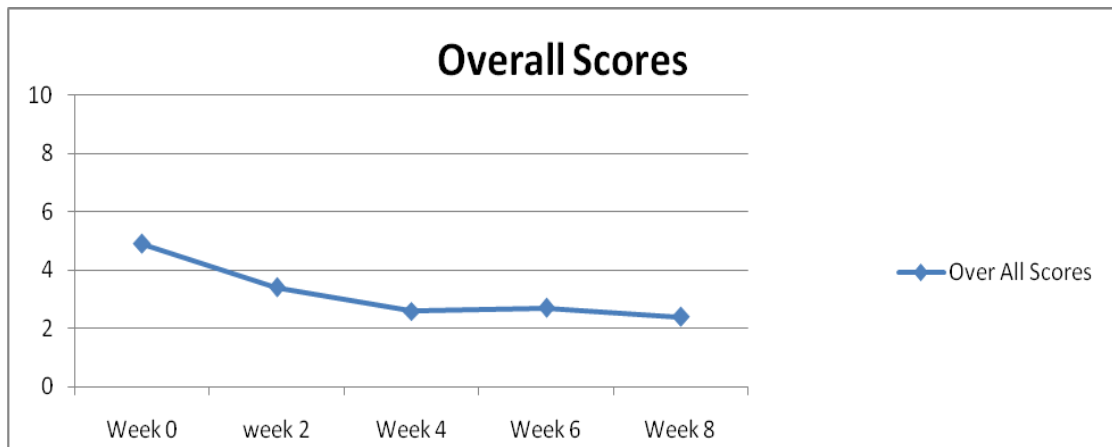
## **Balance Outcomes**

*(Land-based exercise participant 1)*

The time series graphs of the participant who took part in an 8-week land-based exercise program revealed a decrease in overall scores, anterior-posterior index, and medial-lateral index (Figure 1a, 1b, 1c).

## Balance

*(Land-based exercise participant 1)*



*Figure 1a, 1b, 1c*

## **Balance Outcomes**

*(Aquatic-exercise participant 1)*

The time series graphs of the participant (1) who took part in an 8-week aquatic exercise program revealed a decrease in overall score and anterior-posterior index.

However, no improvement was found in the medial-lateral index (Figure 2a, 2b, 2c).



## Balance

(Aquatic exercise participant 1)

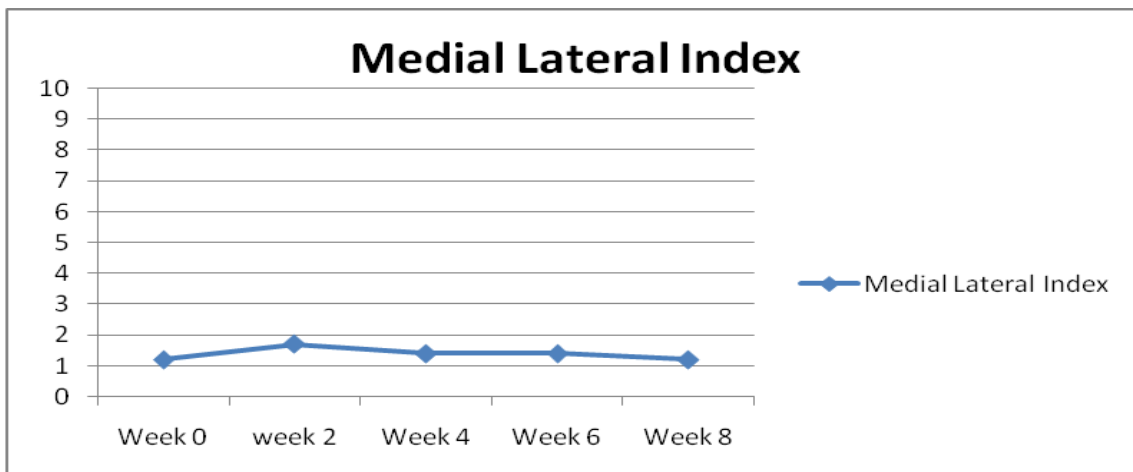
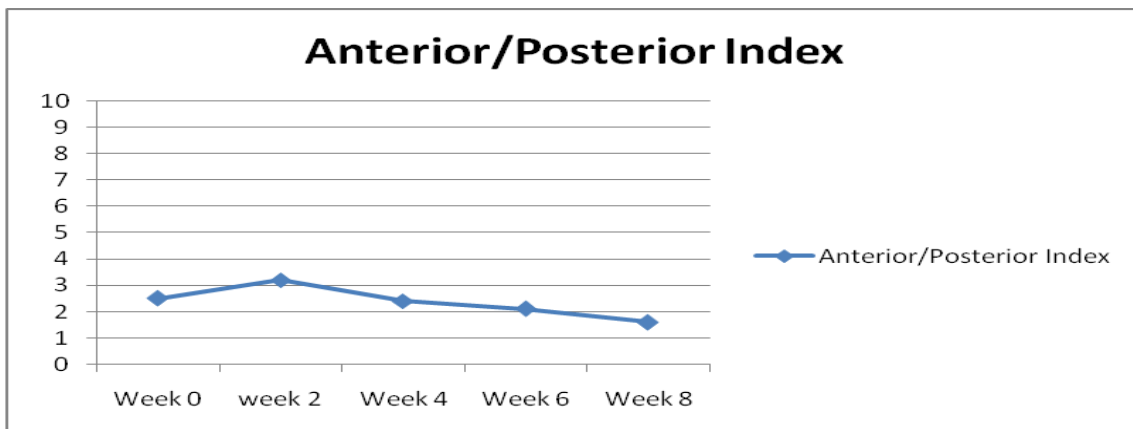
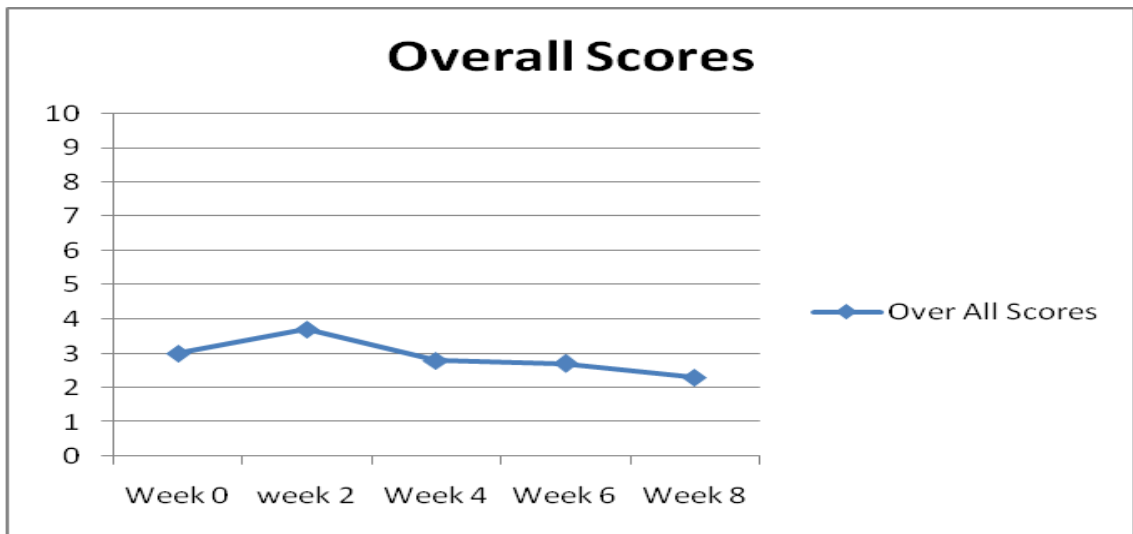


Figure 2a, 2b, 2c

## **Balance Outcomes**

*(Aquatic exercise participant 2)*

The time series graphs of participant (2) who took part in an 8-week aquatic training programs revealed a decrease in overall scores, anterior-posterior index, and medial-lateral index (Figure 3a, 3b, 3c).

## Balance

(Aquatic exercise participant 2)

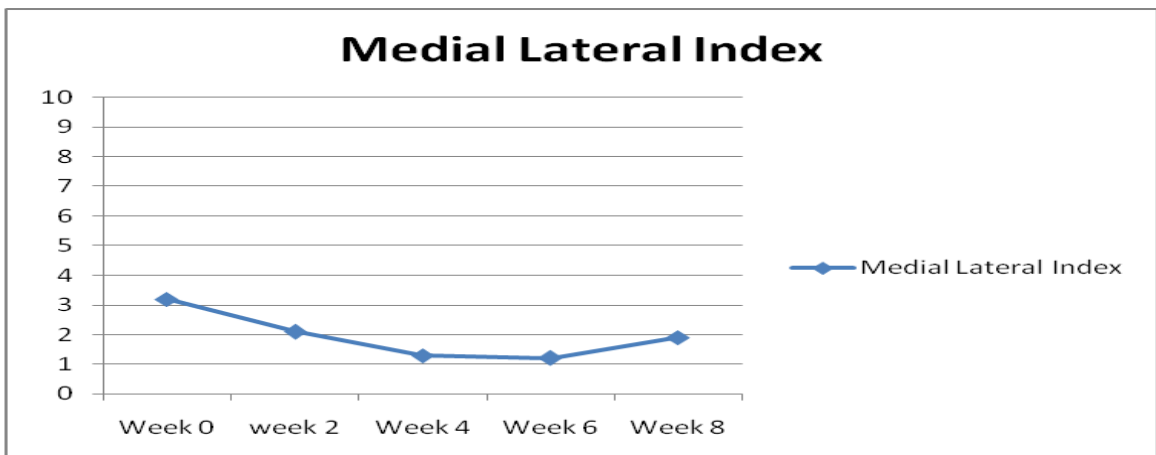
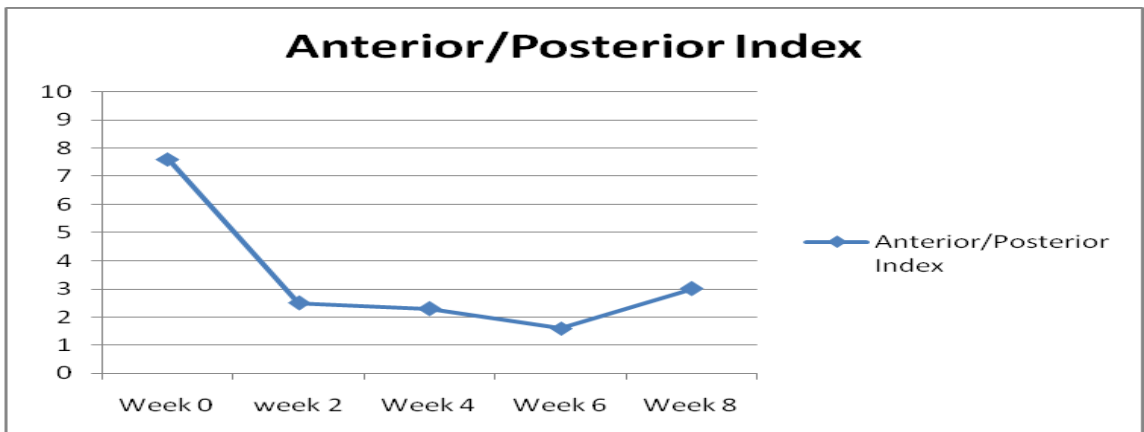
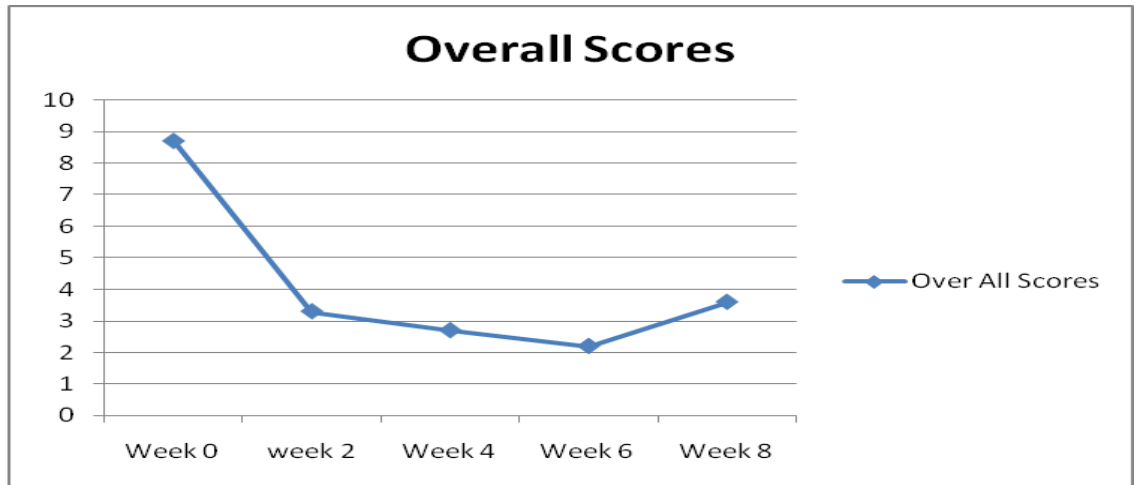


Figure 3a, 3b, 3c

## **Balance Outcomes**

*(Home-based exercise participant)*

The time series graphs of the participant who participated in an 8-week home-based exercise program did not show significant improvement in overall scores, anterior-posterior index or medial-lateral index (Figure 4a, 4b, 4c).

## Balance

(Home-based exercise participant)

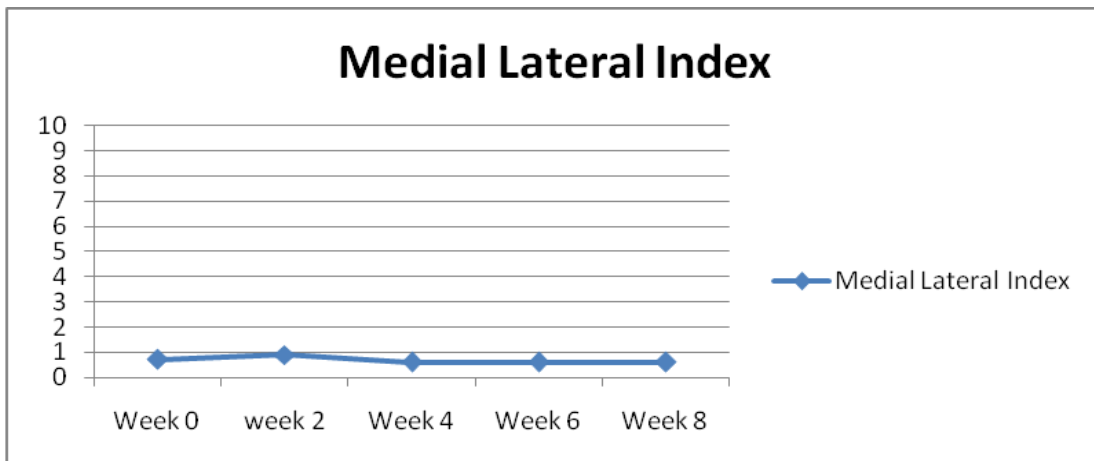
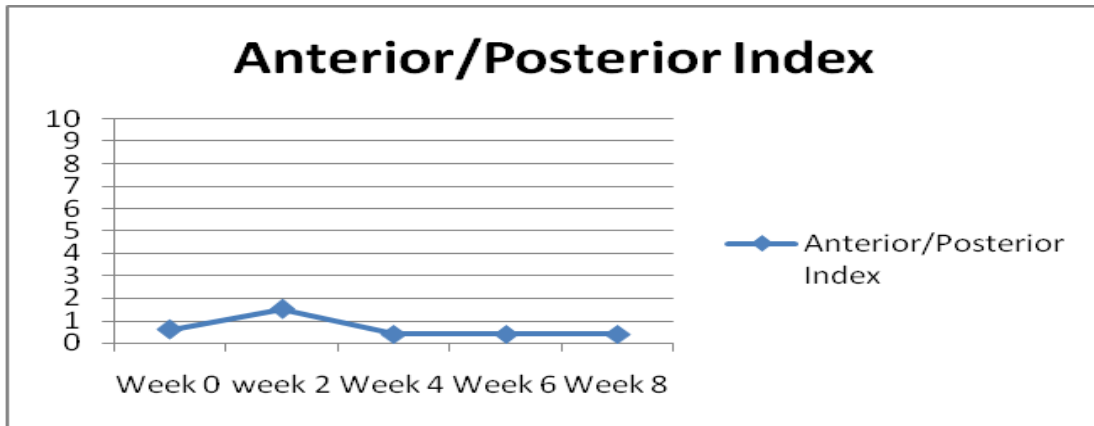
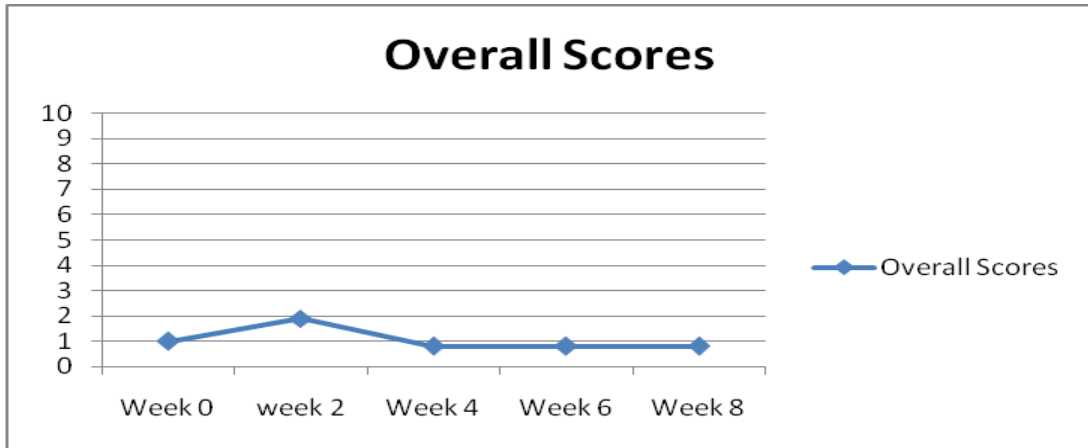


Figure 4a, 4b, 4c

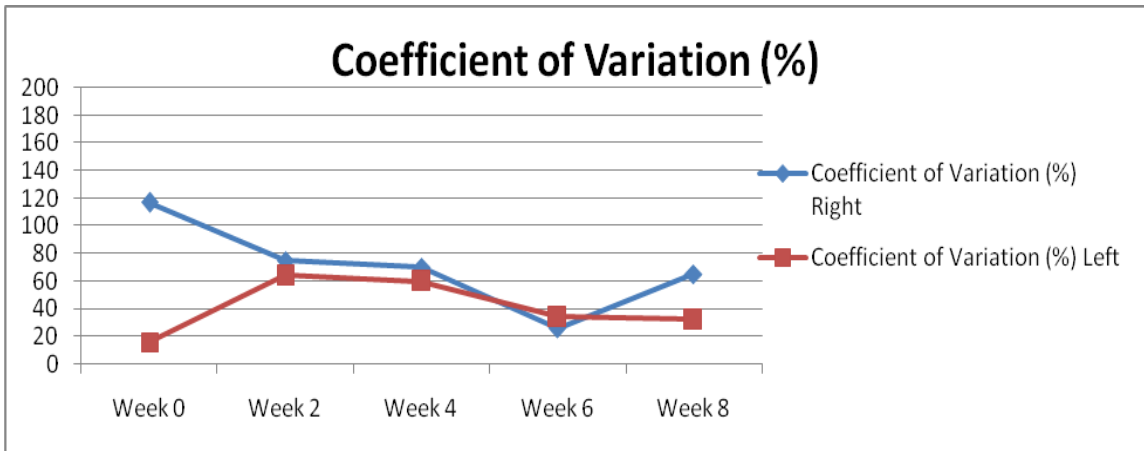
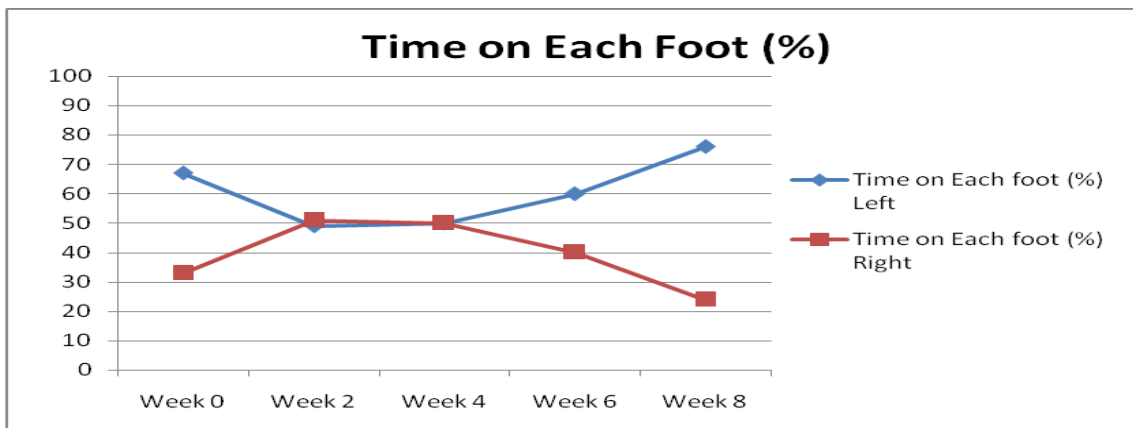
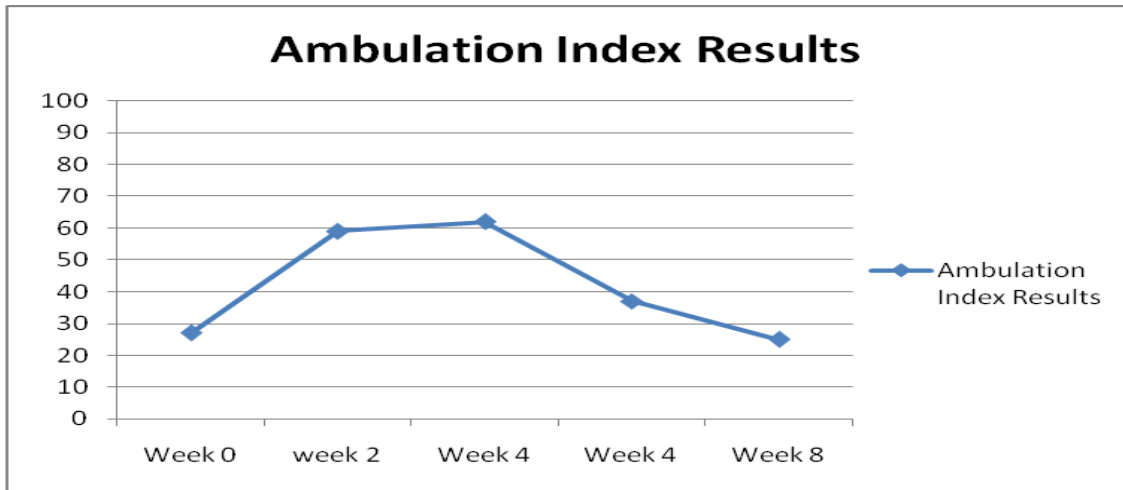
## **Gait Outcomes**

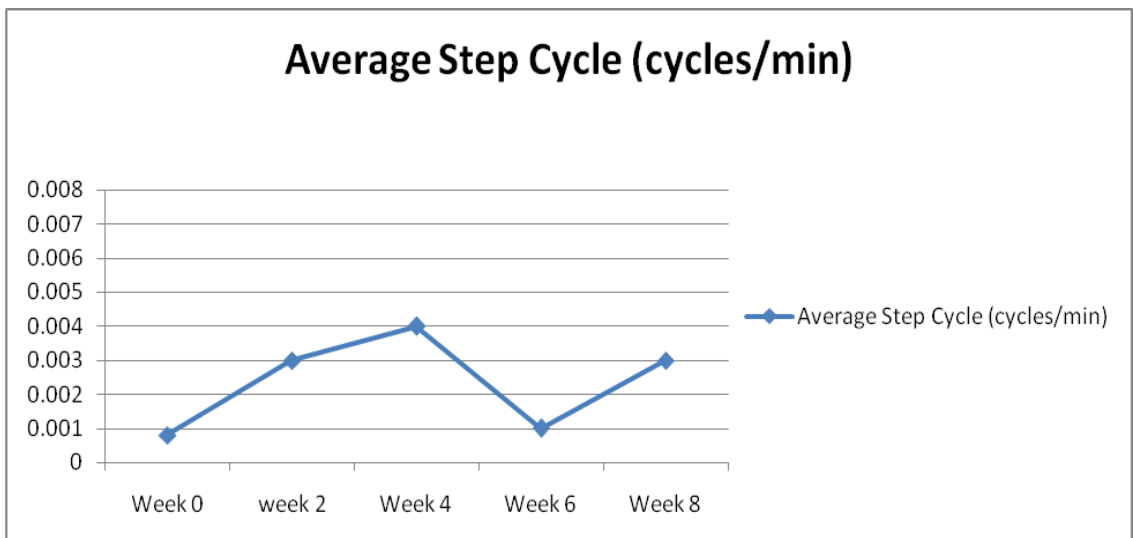
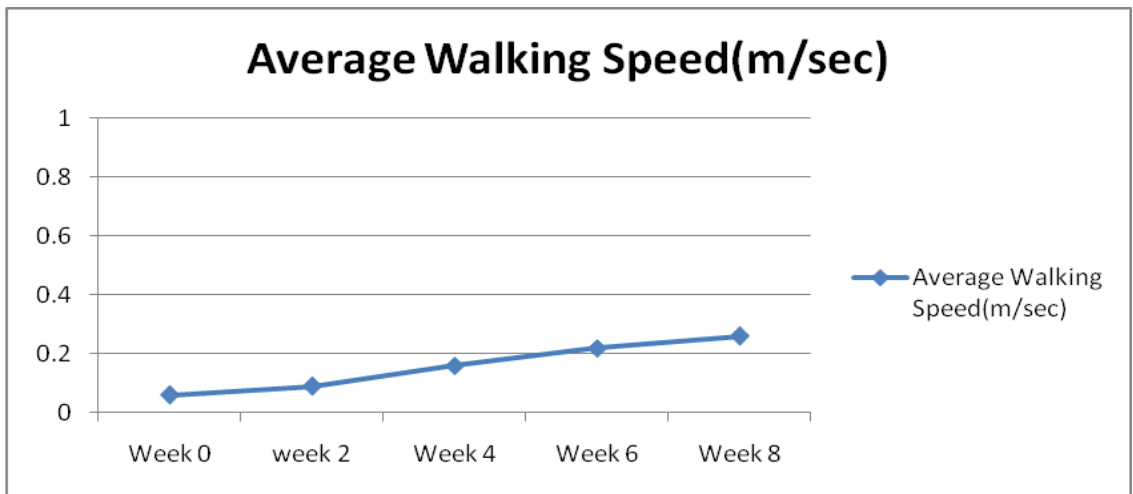
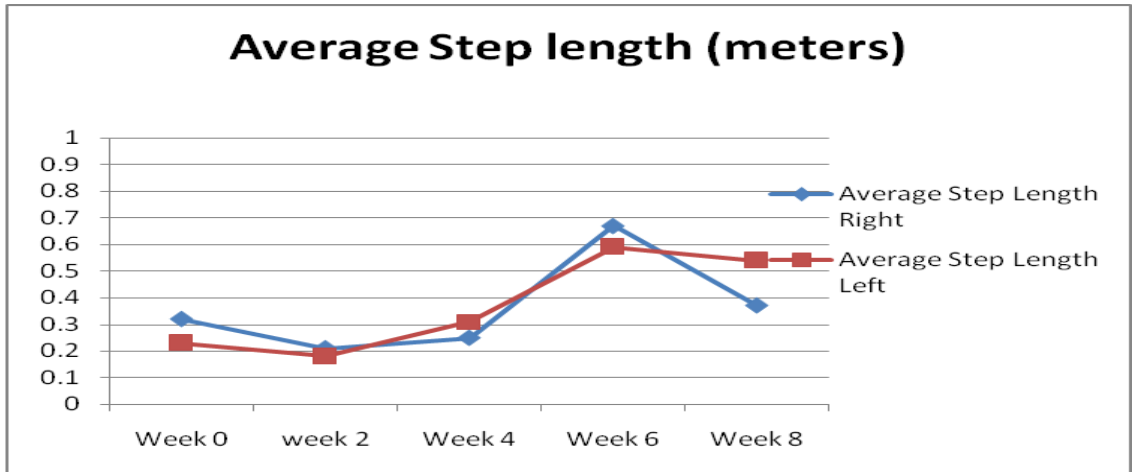
*(Land-based exercise participant 1)*

The time series graphs of the participant who took part in an 8-week land-based training program showed significant improvement in coefficient of variation, step length, walking speed, and cadence. However, they did not show improvement in ambulation index or the time they spent on each foot. (Figure 5a, 5b, 5c, 5d, 5e, 5f).

## Gait

(Land-based exercise participant)





*Figure 5a, 5b, 5c, 5d, 5e, 5f*



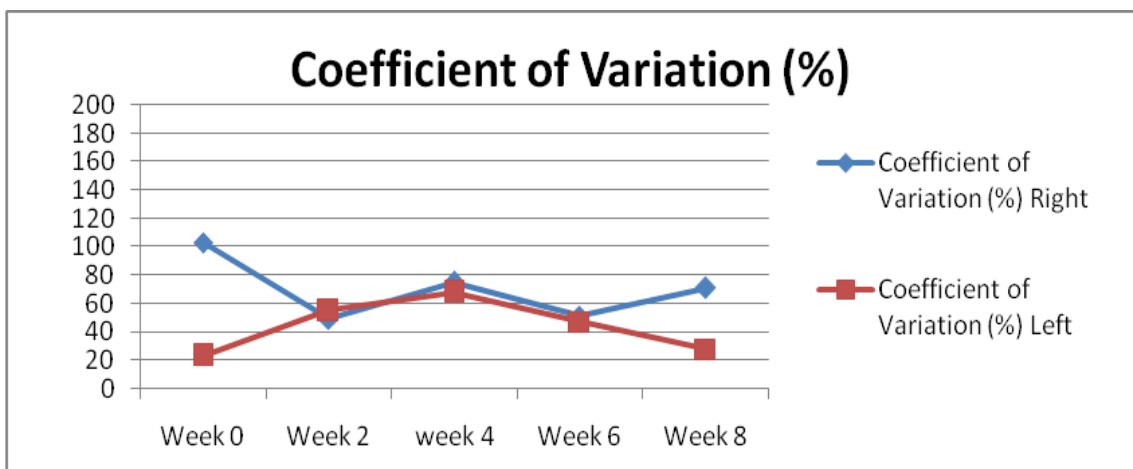
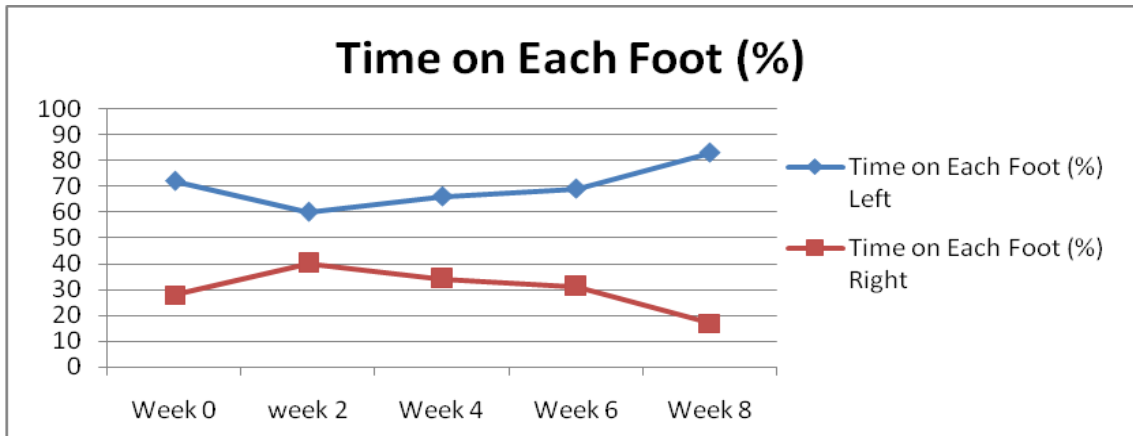
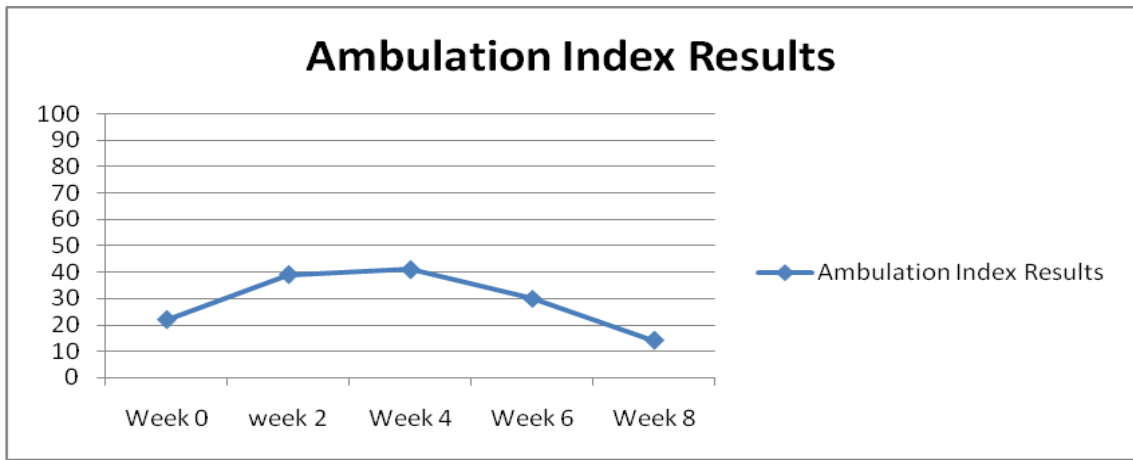
## **Gait Outcomes**

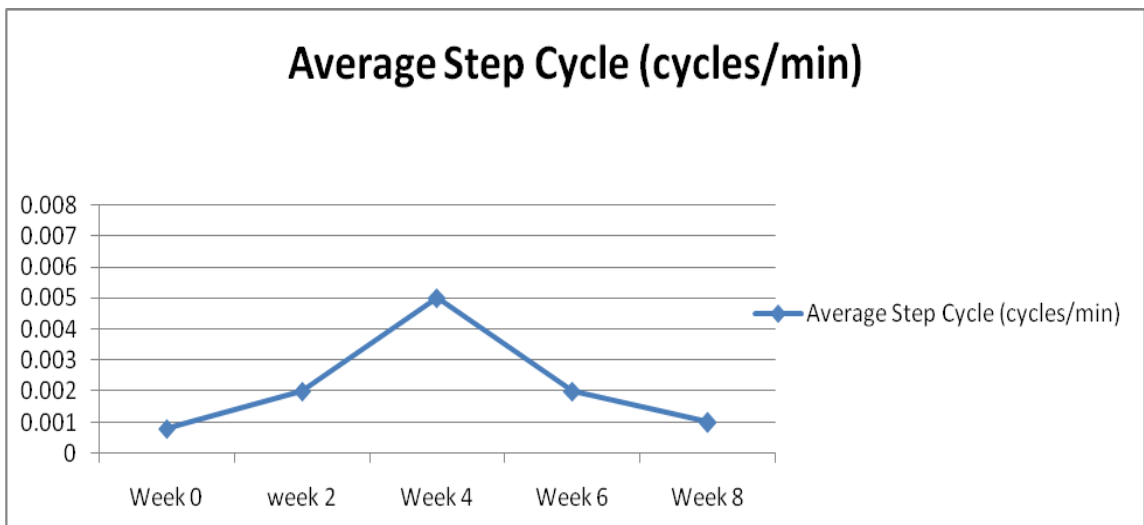
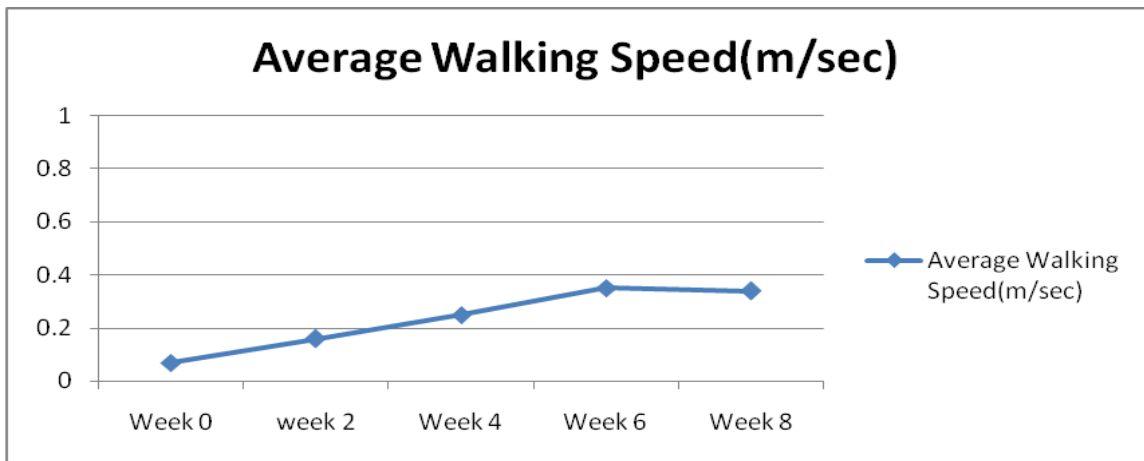
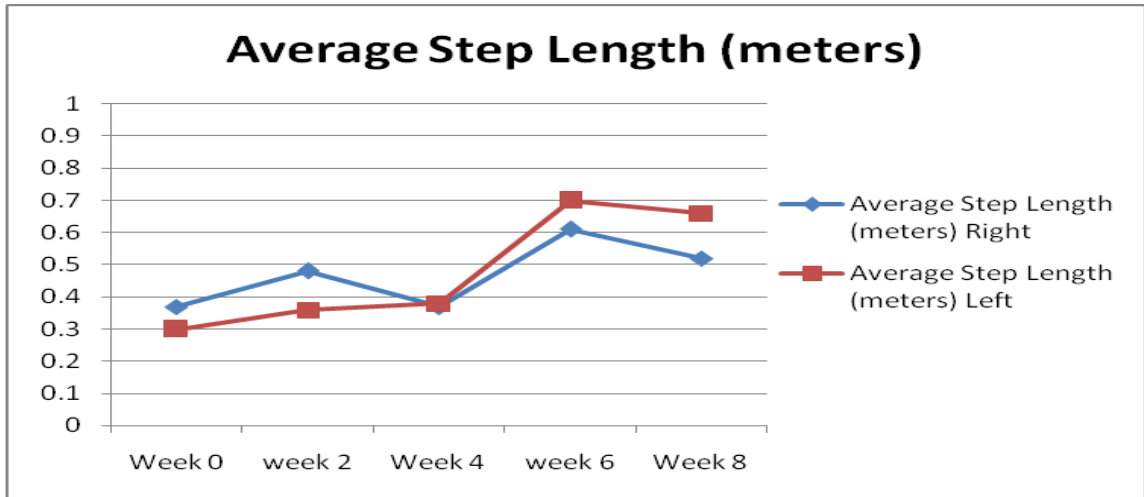
*(Aquatic exercise participant 1)*

The time series graphs of the participant 1 who took part in an 8-week aquatic exercise program showed improvement in coefficient of variation, step length, and walking speed. However, they did not show improvement in ambulation index, time spent in each foot or cadence. (Figure 6a, 6b, 6c, 6d, 6e, 6f).

## Gait

(Aquatic exercise participant 1)





*Figure 6a, 6b, 6c, 6d, 6e, 6f*

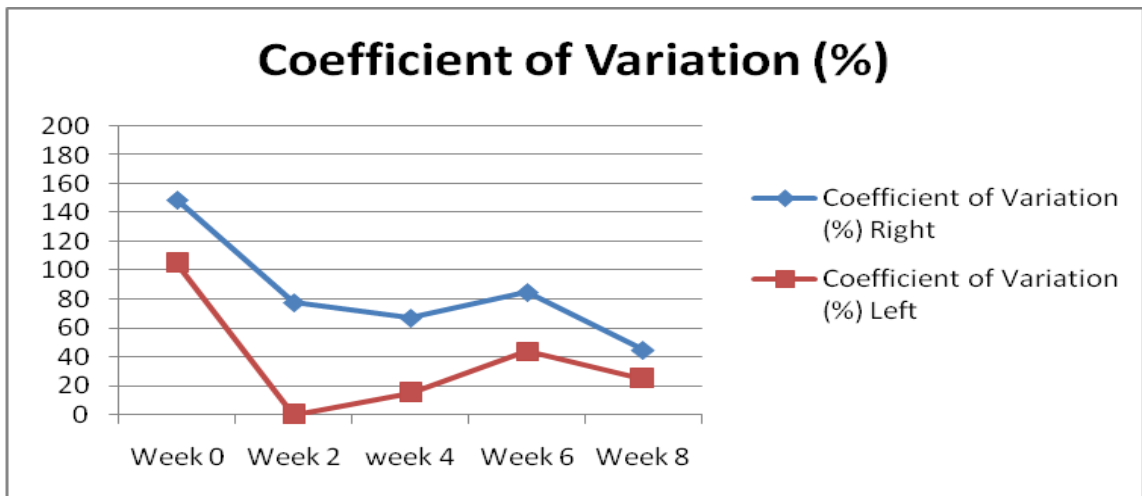
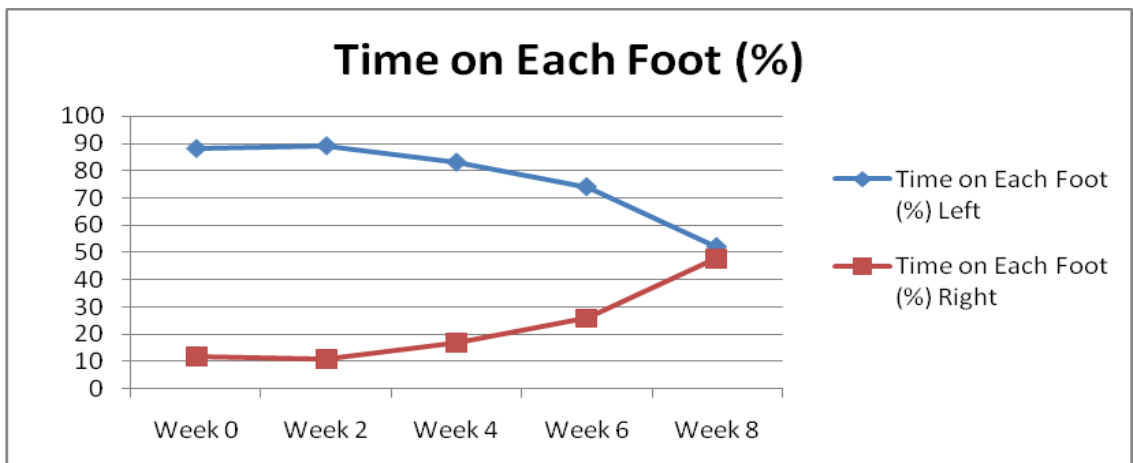
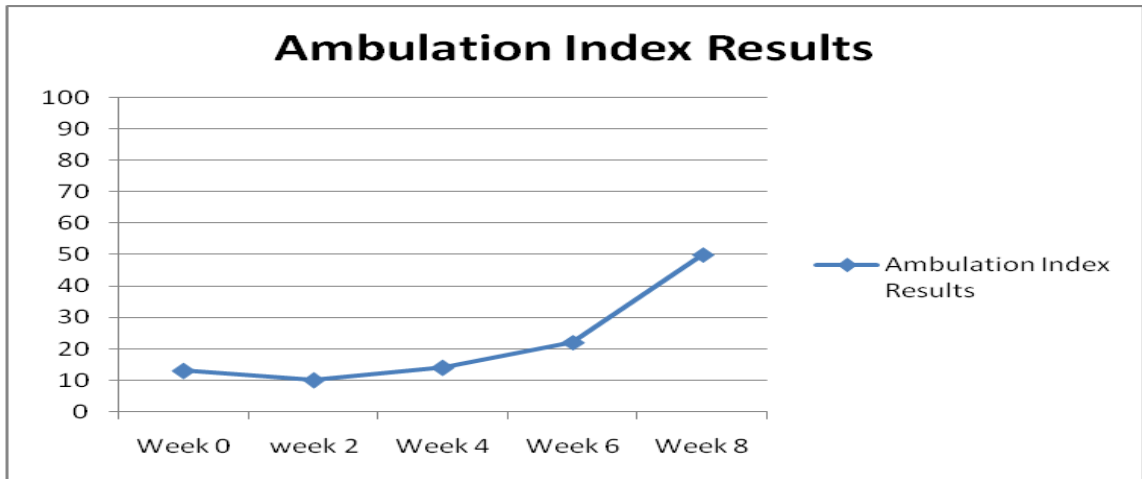
## **Gait Outcomes**

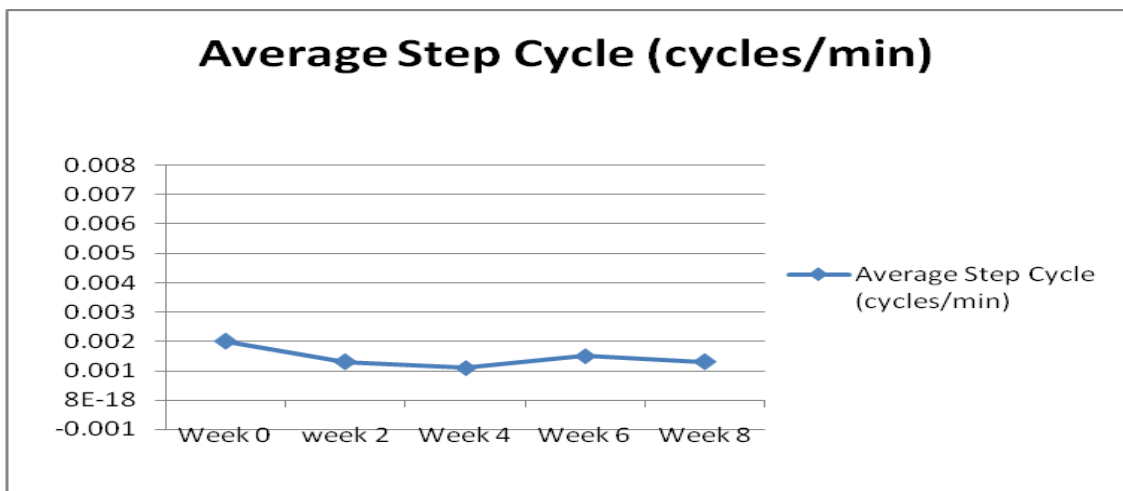
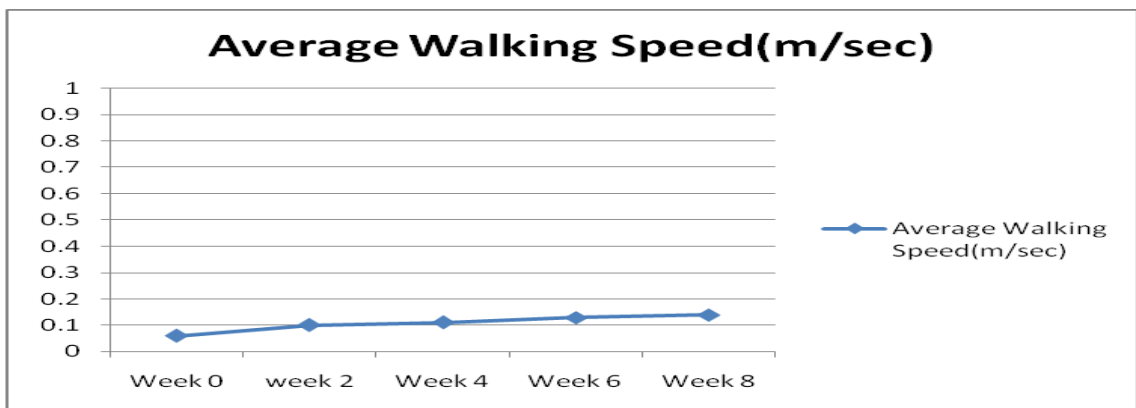
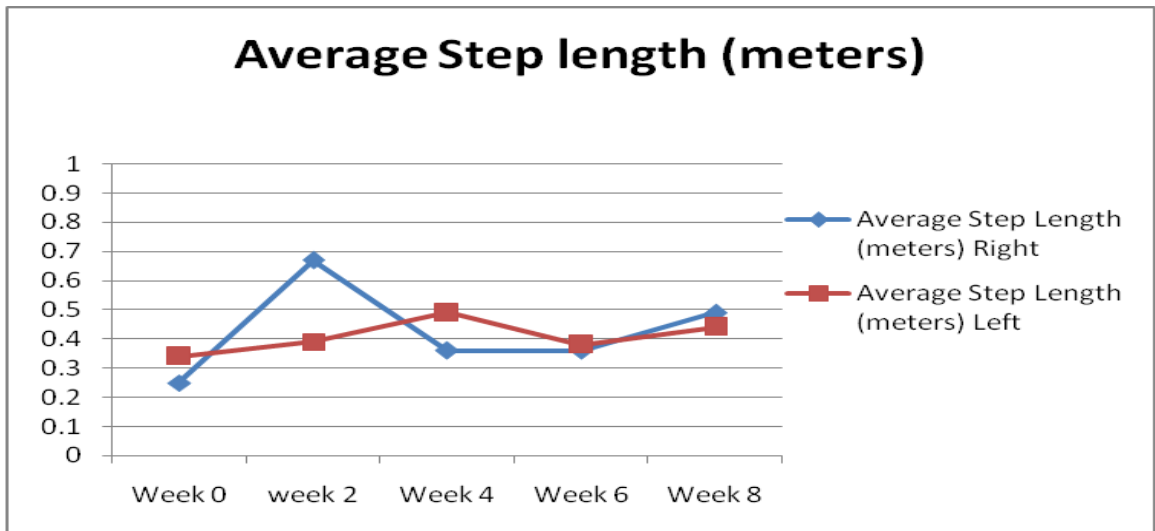
*(Aquatic exercise participant 2)*

The time series graphs of the participant 2 who took part in an 8-week aquatic exercise program showed improvement in ambulation index, the time they spent on each foot, coefficient of variation, step length, and walking speed. However, they did not show improvement in step length or cadence (Figure 7a, 7b, 7c, 7d, 7e, 7f).

## Gait

(Aquatic exercise participant 2)





*Figure 7a, 7b, 7c, 7d, 7e, 7f*

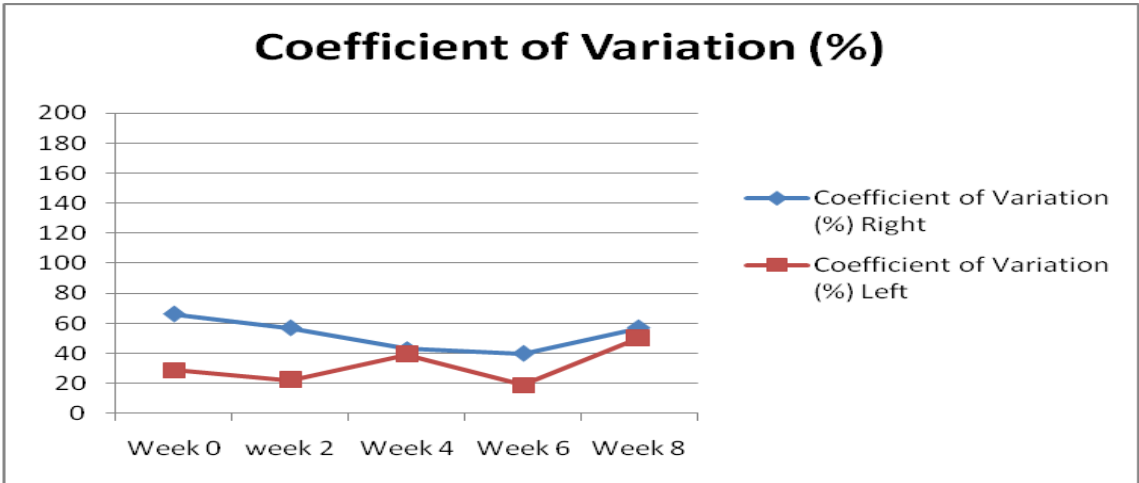
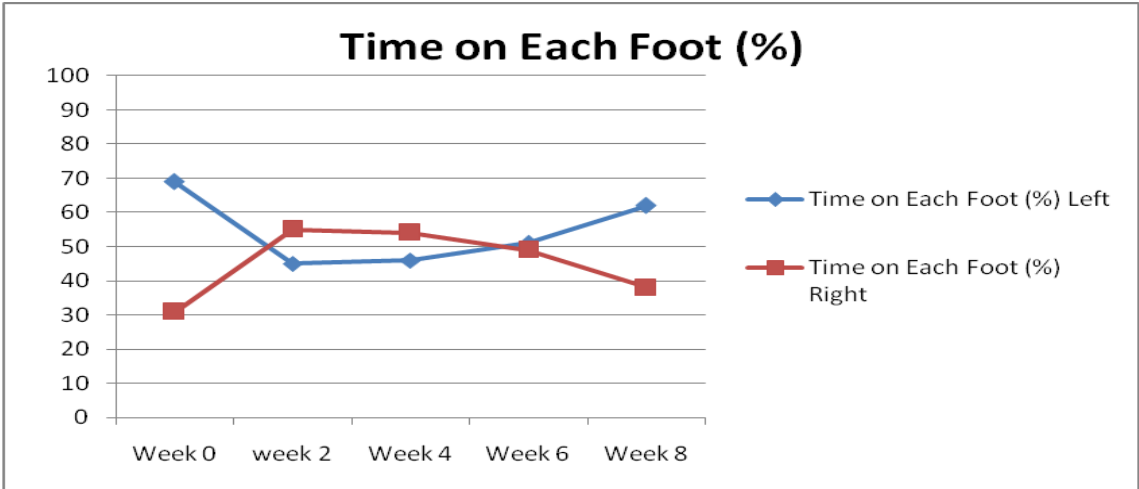
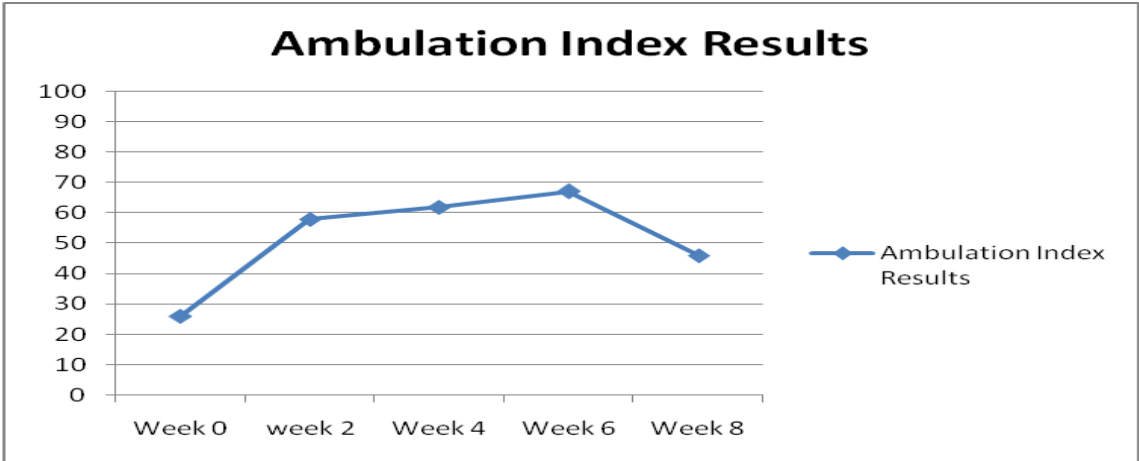
## **Gait Outcomes**

*(Home-based exercise participant)*

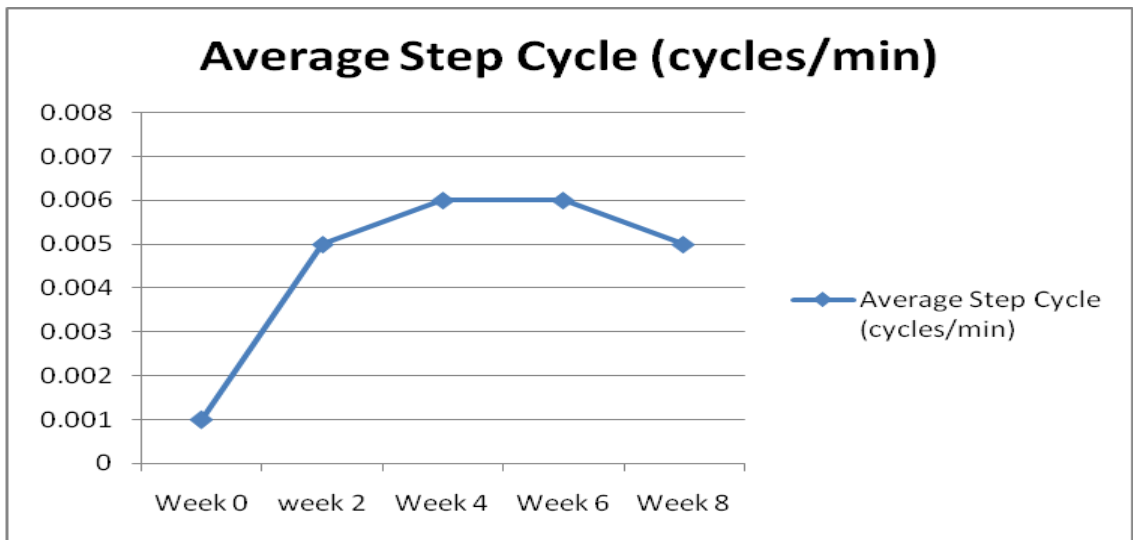
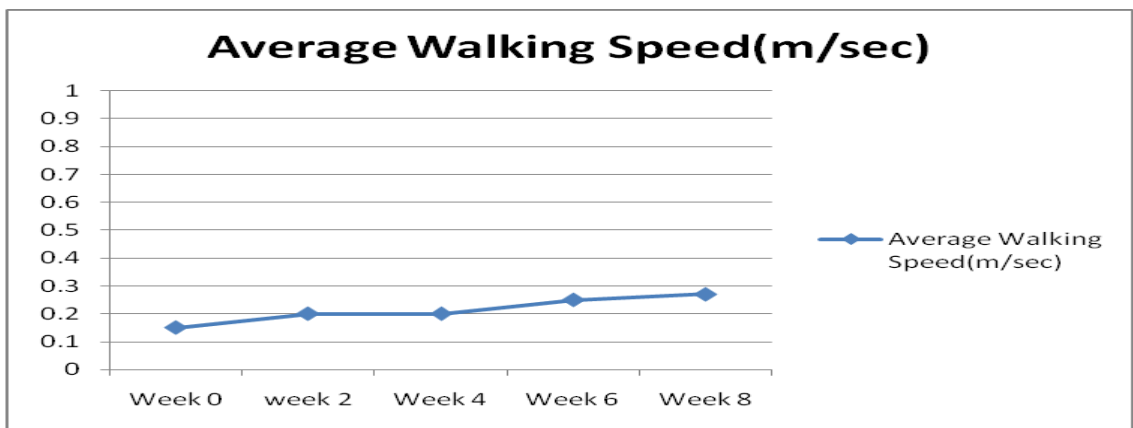
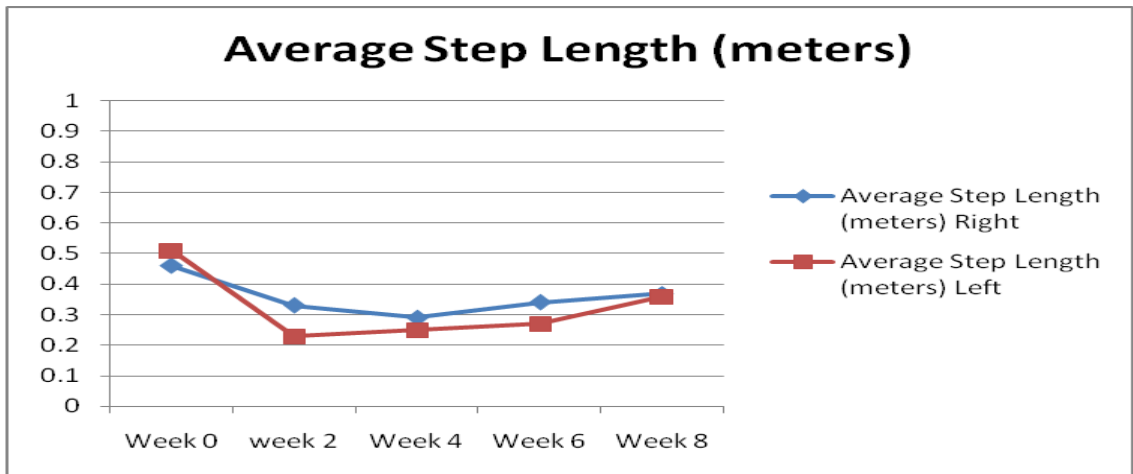
The time series graphs of the participant who took part in an 8-week home-based exercise program showed improvement in ambulation index, time they spent on each foot, walking speed, and cadence. However, they did not show improvement in step length or coefficient of variation (Figure 8a, 8b, 8c, 8d, 8e, 8f).

**Gait**

*(Home-based exercise participant)*







*Figure 8a, 8b, 8c, 8d, 8e, 8f*

## DISCUSSION

This case study was a detailed observation of the effects of balance and gait outcomes in aquatic, land-based and home-based exercise programs in people post-stroke. The training programs on land and in the aquatic environment were designed for three times a week for 50 minutes/session over 8 weeks. The land-based training program included 10 minutes of balance exercises, 10 minutes of treadmill walking followed by 10 minutes of parallel bar walking. The aquatic training included 10 minutes of balance exercises, 10 minutes of underwater treadmill walking followed by 10 minutes of pool floor walking. Some of the training sessions were suspended due to the seizure onset in one participant. Make-up sessions were held at the end of the training program. One out of the five participants was unable to complete the study. The participants were assessed bi-weekly to monitor their line of progress. The participants demonstrated progress in their balance, walking speed, ambulation index, gait symmetry ratio, coefficient of variation, step length, and step cycle. Throughout the program there were no adverse cardiovascular responses or unfavorable events reported.

The balance time series graph of the participant who took part in the 8-week land-based exercise program revealed a decrease in overall scores, medial-lateral index, and anterior-posterior index. The overall balance scores decreased from 4.9 to 2.4. The medial-lateral scores decreased from 3.8 to 1.6 and the anterior-posterior balance decreased from 2.3 to 1.6

The balance time series graph of the participant (1) who took part in the 8-week aquatic exercise program revealed a decrease in overall scores and anterior-posterior index. However, an increase in the medial lateral balance was observed. The overall

balance scores decreased from 3.0 to 2.3 and the anterior-posterior balance decreased from 2.5 to 1.6. The medial-lateral scores increased from 1.2 to 1.6.

The balance time series graph of participant (2) who took part in the 8-week aquatic training programs revealed a decrease in overall scores, anterior-posterior index, and medial-lateral index. The overall balance scores improved from 8.7 – 3.6. The anterior-posterior balance improved from 7.6 – 3.0 and the medial-lateral scores improved from 3.2 – 1.9.

The balance time series graph of the participant who participated in the 8-week home-based exercise program showed a slight improvement in overall scores, anterior-posterior index, and medial-lateral index; however, these improvements were not significant. The overall balance scores improved from 1 – 0.8. The anterior-posterior balance improved from 0.6 – 0.4, and the medial-lateral scores improved from 0.7 – 0.6.

These findings were similar to Douris, et al. (2003) as it was concluded that significant improvements in balance were found in land-based exercise and aquatic group in older adults. Additionally, Chu, et al. (2004) found that aquatic training effectively improved cardiovascular endurance, maximal workload, gait speed, and paretic lower-extremity muscle strength in people post-stroke.

The results of this study demonstrated improvements in balance in both the land-based exercise participant and aquatic exercise participants 1 and 2. However, this study was unable to determine the superiority of land-based training or aquatic training in improving balance in people post-stroke due to the small sample size and a noticeable difference in their baseline balance data.

The gait time series graph of the participant who took part in the 8-week land-based training program showed significant improvements in coefficient of variation, step length, walking speed, and cadence. The participant with the more involved left side started the training at an average step length of 0.23 meters (left) and 0.32 meters (right) and showed an increase to 0.54 meters (left) and 0.37 meters (right) by the post evaluation at week 8. The coefficient of variation (%) in the left and right lower extremity, while walking, showed a significant trend of improvement by week 4 bi-weekly evaluation (64% in left and 75% in right) followed by a decrease in the trend by week 6 post-evaluation (34% in left and 26% in right). However, a significant improvement in the coefficient of variation was again seen by the post evaluation at week 8 (65% in left and 32% in right). The walking speed significantly improved from 0.06 m/sec to 0.26 m/sec by the post evaluation at week 8. The trend increase in the average step cycle was seen from 2.88 cycles/minute to 14.4 cycles/minute by week 4 bi-weekly evaluation. However, the average step cycle decreased to 3.6 cycles/minute by week (omit) by week 6 bi-weekly evaluation and then improved suddenly to 10.8cycles/minute by the post evaluation at week 8. The participant did not show improvement in ambulation index and the time spent on each foot. The ambulation index decreased from 27 before week 1 pre-evaluation to 25 by the post evaluation at week 8. The gait symmetry ratio showed significant improvement from 0.49 to 1 by week 4 bi-weekly evaluation. However, gait symmetry was found decreased to 0.3 by the week 8 post-evaluation.

The gait time series graph of the participant 1 who took part in the 8-week aquatic exercise program showed significant improvement in coefficient of variation, step

length, and walking speed. The participant with the more involved right side started the training at the average step length of 0.30 meters (left) and 0.37 meters (right) and showed a trend of increase to 0.66 meters (left) and 0.52 meters (right) by the post evaluation at week 8. The coefficient of variation (%), while walking showed a trend of improvement by week 2 bi-weekly evaluation (55% in left and 49% in right). By week 4 and week 6 bi-weekly evaluation, the coefficient of variation improved further from week 4: 64% in left and 75% in right to week 6: 47% in left and 51% in right. However, a trend of decrease in the improvement was found by week 8 post evaluation (28% in left and 71% in right). The walking speed was significantly improved from 0.07m/sec to 0.35m/sec by week 6 post-evaluation. However, walking speed decreased to 0.34m/sec by week 8 post-evaluation. The participant 1 did not show improvement in ambulation index, cadence or the time they spent on each foot. The gait symmetry ratio was improved from 2.57 to 1.5 by week 2 post-evaluation. However, gait symmetry was decreased to 4.88 by the post evaluation at week 8 post-evaluation. The trend of increase in the average step cycle was seen from 2.88cycles/minute – 18.0cycles/minute by week 4 post-evaluation. However, a decrease in the trend of improvement (7.2 cycles/minute) was found by week 6 post-evaluation followed by a further decrease (3.6cycles/minute) by the post evaluation at week 8. The ambulation index decreased from 22 before week 1 pre-evaluation to 14 by week 8 post-evaluation.

The gait time series graph of the participant 2 who took part in the 8-week aquatic exercise program showed significant improvement in ambulation index, the time spent on each foot, coefficient of variation, step length, and walking speed. The participant 2 with the more involved right side started the training at an average step length of 0.34

meters (left) and 0.25 meters (right) and showed a trend of increase to 0.66 meters (left) and 0.52 meters (right) by the post evaluation at week 8. However, no notable change was found in the stride length symmetry. The coefficient of variation (%), while walking, showed a significant improvement by week 8 post-evaluation (25% in left and 45% in right). However, a lesser trend was found in the steps. The gait symmetry ratio showed significant improvement from 0.13 to 0.92 by the post evaluation at week 8. The walking speed was significantly improved from 0.06 m/sec to 0.14 m/sec by the post evaluation at week 8. The ambulation index increased from 13 before week 1 pre-evaluation to 50 by the post evaluation at week 8. The participant did not show improvement in step length or cadence. A decreased trend in the average step cycle was seen from 7.2 cycles/minute – 3.96 cycles/minute by week 4 biweekly evaluation. However, an increased trend of improvement (5.4 cycles/minute) was found by week 6 biweekly-evaluation followed by a further decrease in the trend (4.68 cycles/minute).

The gait time series graph of the participant who took part in the 8-week home-based exercise program showed significant improvement in ambulation index, time they spent on each foot, cadence, and walking speed. The participant with the more involved left side started the exercise program at the average walking speed of 0.15 m/sec and improved significantly to 0.27 m/sec by the post evaluation at week 8. A trend increase in the average step cycle was seen from 3.6 cycles/minute to 21.6 cycles/minute by week 4 bi-weekly evaluation and then plateaued at week 6 bi-weekly evaluation. The participant did not show any improvement in step length or coefficient of variation. The average step cycle was decreased to 18.6 cycles/minute by the post evaluation at week 8. The ambulation index improved significantly from 26 before week 1 pre-evaluation to

46 by week 8 post-evaluation. The average step length of 0.51meters (left) and 0.46meters (right) showed a decreased trend to 0.37meters (left) and 0.36meters (right) by the post evaluation at week 8. The coefficient of variation (%) in the left and right lower extremity, while walking, did not show a significant trend of improvement by the post evaluation at week 8 (50% in left and 57% in right). The gait symmetry ratio did not show a trend of symmetric improvement from 2.22 to 1.63 by the post evaluation at week 8.

Chu, et al. (2004) concluded that aquatic training was effective in improving cardiovascular endurance, maximal workload, gait speed, and paretic lower-extremity muscle strength in people post-stroke. Waters, et al. (2007) found aquatic exercises to be potentially beneficial for improving gait and balance in older people. Moreover, the participants in the experimental group also reported a greater range of perceived psychological and physical benefits after exercising in water when compared to home-based exercise group (Waters & Hale, 2007).

The results of this study also demonstrated improvement in gait parameters in both land-based exercise participant and aquatic exercise participant 1 and 2. However, this study was unable to determine which of the two medium would be more beneficial in improving gait parameters in people post-stroke due to the small sample size and a noticeable difference in their baseline balance data.

The participants in this study had severe balance and gait impairments. Their gait and balance was (were) considered poor compared to the gait and balance in people post-stroke in other studies. The participants in the study demonstrated differences in their baseline gait and balance data and had low exercise capacity. However, they were able to

demonstrate considerable exercise tolerance and adherence to the programs. One participant from land-based exercise group dropped out due to medical reasons. This study was able to show improvements in gait and balance outcomes in both the land-based and aquatic exercise groups in a relatively short period of time in people post-stroke. The clinical importance of this study showed detailed patterns of improvement in gait and balance outcomes in people post-stroke who participated in both land and aquatic exercise programs. However, modest improvements were documented in aquatic exercise participants when compared to land-based exercise participant because of the difference in their baseline gait and balance data.

### **Future Research**

The results of this research have created a baseline for future research in this area. First, this study focused on a small sample size of people post-stroke. Secondly, the 8-week aquatic and land-based exercise program to determine the effects on balance and gait outcomes was considerably shorter. It would be interesting to see the balance and gait outcomes in aquatic, land-based and home-based setting in people post-stroke with a larger sample size and longer period of intervention with multiple data collection points. Moreover, the research method in this study would serve as a good example to apply to individuals with similar neurological disabilities.



## REFERENCES

- Bayat, R., Barbeau, H., & Lamontagne, A. (2005). Speed and temporal-distance adaptations during treadmill and over-ground walking following stroke. *Neurorehabil Neural Repair, 19*(2), 115-124.
- Beaman, C., Peterson, C., Neptune, R., Kautz, S. (2010) *Differences in self-selected and fastest- comfortable walking in post-stroke hemiparetic persons. Gait & Posture 31, 311–316.*
- Benelli, P., Massimiliano, D., Vito, G. (2009), *Physiological responses to fitness activities: A comparison between land-based and water aerobics exercise. American College of Sports Medicine.*
- Bintzler, S. (2006). Water Works Wonders. *Parks & Recreation, 41*(11), 26.
- Butler, C. (2002). Walking in Water. *Inside MS, 20*(3), 66.
- Carr & Shepherd (2003). *Stroke Rehabilitation: Guidelines for exercise and training to optimize motor Skill ( 1<sup>st</sup> ed.)*. Leith Walk, Edinburgh: Elsevier.
- Chu, K. S., Eng, J. J., Dawson, A. S., Harris, J. E., Ozkaplan, A., & Gylfadottir, S. (2004). Water-based exercise for cardiovascular fitness in people with chronic stroke: a randomized controlled trial. *Archives of Physical Medicine and Rehabilitation, 85*(6), 870-874.
- Douris, P., PT, EdD, Southard, V., PT, MS, GCS, Varga, C., PT, MS, Schauss, W., PT, MS, Gennaro, C., PT, MS, Reiss, A., PT, MS. (2003) *The Effect of Land and Aquatic Exercise on Balance Scores in Older Adults. Journal of Geriatric Physical Therapy Vol. 26*(1)

- Eva Saltskår Jentoft, K. A., Marit Mengshoel. (2001). Effects of pool-based and land-based aerobic exercise on women with fibromyalgia/chronic widespread muscle pain. *Arthritis Care & Research*, 45(1), 42-47.
- Feigin, V. L. (2005). Stroke epidemiology in the developing world. *Lancet*, 365(9478), 2160-2161.
- Greene, N.P., Lambert, B. S., Greene, E. S., Carbuhn, A. F., Green, J. S., Crouse, S. F. (Sept. 2009). *Comparative Efficacy of Water and Land Treadmill Training for Overweight or Obese Adults. Med Sci Sports Exerc.* 41(9):1808-15.
- Gresham , G. (1995). Post stroke rehabilitation: Clinical Practice Guideline (1<sup>st</sup> ed.). Rockville, Maryland: Aspen.
- Jonsdottir, J., Recalcati, M., Rabuffetti, M., Casiraghi, A., Boccardi, S., Ferrarin, M. (2009). *Functional resources to increase gait speed in people with stroke: Strategies adopted compared to healthy controls. Gait & Posture* 29, 355–359
- Jonkers, I., Delp, S., Patten, C. (2009). *Capacity to increase walking speed is limited by impaired hip and ankle power generation in lower functioning persons post-stroke. Gait & Posture*, 29 (129–137.)
- Kenji Masumoto, Kazutaka Fujishima, Yukihide Iwamoto. (2004). Muscle activity and heart rate response during backward walking in water and on dry land. *European Journal of applied Physiology*, 94, 54-61.
- Kritley, C. (2006). *Clinical Gait Analysis, Theory and Practice*. Elsevier Ltd.
- Laufer, Y., Dickstein, R., Chefez, Y., & Marcovitz, E. (2001). The effect of treadmill training on the ambulation of stroke survivors in the early stages of rehabilitation:

A randomized study. *Journal of Rehabilitation Research & Development*, 38(1), 69-78.

Macko, R., MD, Smith, G., PhD, PT, Dobrovolny, C., MA, Sorkin, J., MD, PhD, Andrew, P., Goldberg, MD, Silver, K., MD. (July 2001). *Treadmill Training Improves Fitness Reserve in Chronic Stroke Patients. Arch Phys Med Rehabil Vol* 82.

Marie-Helene Milot, Phd; Denis Gravel, Phd; Luis F. Requiao, MSc. (2006). Bilateral Level of effort of planter flexors, hip flexors, and extensors during gait in hemiparetic and healthy individuals. *Stroke* 37.

Marie-Helene Milot, S. N., Denis Gravel. (2006). Muscular utilization of planterflexors, hip flexors and extensors in persons with hemiparesis walking at self-selected and maximal speeds. *Journal of Electromyography and Kinesiology*, 17, 184-193.

Nadeau, S., Gravel, D., Arsenault, A. B., & Bourbonnais, D. (1999). Plantarflexor weakness as a limiting factor of gait speed in stroke subjects and the compensating role of hip flexors. *Clinical Biomechanics*, 14(2), 125-135.

Parvataneni, K., Olney, S. J., & Brouwer, B. (2007). Changes in muscle group work associated with changes in gait speed of persons with stroke. *Clinical Biomechanics*, 22(7), 813-820.

Perry, J.(1992). *Gait Analysis, Normal and Pathological Gait*. Illustrated by Bill Schoneberger, PT. SLACK Incorporated.

Peurala, S., PhD, PT, Airaksinen, O., MD, PhD, Huuskonen, P, PT, Jäkälä, P., MD, PhD, Juhakoski, M., MD, Sandell, K., MD, PhD, Tarkka, I., PhD, Sivenius, J.,MD, PhD. (2009). *Effects of intensive therapy using gait trainer*

*or floor walking exercises early after stroke. J Rehabil Med, 41, 166–173*

- Petrofsky, J. S., Petrofsky, A. K., & Bweir, S. (2004). Stroke: Present therapy and treatment part 2. *Palaestra, 20(3), 35(39)*.
- Piero Benelli, M. D., Giuseppe De Vito. (2004). Physiological Responses To Fitness Activities: A Comparasion Between Land-based and Water Aerobics Exercise *Journal of Strength and Conditioning Research, 18(4), 719-722*.
- Ross Bogey, T. G. H. (2007). Gait training strategies utilized in poststroke rehabilitation: Are we really making a difference? *Stroke Rehabilitation, 14(6), 1-8*.
- Silva, L. E., Valim, V., Pessanha, A. P. C., Oliveira, L. M., Myamoto, S., Jones, A., et al. (2008). Hydrotherapy versus conventional land-based exercise for the management of patients with osteoarthritis of the knee: A randomized clinical trial. *Physical Therapy, 88(1), 12-21*.
- Sullivan, S., Schmitz, T. (2007). Physical Rehabilitation. 5<sup>th</sup> edition. FA Davis Company.
- Tokuno, C. D., & Eng, J. J. (2006). Gait initiation is dependent on the function of the paretic trailing limb in individuals with stroke. *Gait & Posture, 24(4), 424-428*.
- Warlow, C., Sudlow, C., Dennis, M., Wardlaw, J., & Sandercock, P. (2003). Stroke. *Lancet, 362(9391), 1211-1224*.
- Waters, D., & Hale, L. (2007). Do aqua-aerobics improve gait and balance in older people? A pilot study. *International Journal of Therapy & Rehabilitation, 14(12), 538-543*.
- Yen, C.-L., Wang, R.-Y., Liao, K.-K., Huang, C.-C., & Yang, Y.-R. (2008). Gait Training--Induced Change in Corticomotor Excitability in Patients With Chronic Stroke. *Neurorehabilitation and Neural Repair, 22(1), 22(29)*.

## APPENDIX A

*California State University, Northridge*  
**The Effects of Aquatic and Land-based Exercise on Balance and Gait in People Post-Stroke**

### INFORMED CONSENT FORM

#### **Introduction**

You are invited to participate in a study titled “The effects of aquatic and land based exercise on Balance and Gait outcomes in people post-stroke”, conducted by Meera Motta, a graduate student in the department of Kinesiology. The study will be held at the Center Of Achievement / Brown Center, California State University, Northridge, under the supervision of Dr. Taeyou Jung.

Improvement of gait function is one of the major goals in the rehabilitation program for people post-stroke. Many studies have shown the benefits of aquatic and land-based exercise in people with disabilities, and have found water to be more suitable and effective environment for exercise. However, no study has examined the influence of aquatic and land-based exercise on balance and gait outcomes in people post-stroke. The purpose of this study is to see the effects of balance and gait outcomes between aquatic exercise and land-based exercise in people post-stroke.

You are invited to participate in this study if you meet the inclusion criteria a.) Age 45-85,

b.) minimum 1 year post-stroke, c.) ability to ambulate, d.) ability to communicate, d.)no other neurological and/or orthopedic conditions , e.) no cardiac conditions, f.) bladder and bowel control, g.) no surgery within last six months , h.) no fear of water, and i.) medical clearance for adapted exercise, and j.) no current participation in any aquatic or land intervention.

#### **Description of Research**

In this study, you will participate in a 8-week exercise program which will emphyze on gait training. You will be assigned to one of three exercise programs: aquatic, land and home-based program. Each program will have a 10-minute warm up including stretching followed by a 15-minute lower body strengthening exercise. After strengthening exercises you will be asked to do a 10-20 minute walking, which will be followed by 5-minute cool down. You will be asked to participate in the exercise program, 3 times a week for 50 minutes.

You will receive a total of 5 evaluations: week-0 (pre-evaluation), week-2 evaluation, week-4 evaluation, week-6 evaluation, and week-8 (post-evaluation).

When you come to the evaluation session, you will follow the testing procedures as below.

### **Data collection procedures**

- 1) You will be asked to sign the informed consent form.
- 2) The testing procedures will be explained to you.
- 3) The participant will then be escorted to the assessment room.
- 4) You will be given 2 practice trials for familiarization and to determine their level of instability on Biodex Balance Equipment.
- 5) You will then be given a 2-minute resting period, followed by 3 data collection trials.
- 6) After the Balance data collection, you will be given a 2-minute resting period followed by the gait data collection.
- 7) For gait data collection, you will be given one practice trial (2-minute walk) on the Biodex Gait Trainer to determine your comfortable speed and for the familiarization of the equipment.
- 8) You will then be given a 2-minute resting period followed by a 2-minute walk test on the Biodex Gait Trainer.

The entire data collection will take approximately 1 hour.

### **Risks**

The study may have potential for risks including cardiovascular complications, dehydration, drowning, falling, physical fatigue, muscle cramps, skin irritation and other water safety issues. Physician clearance must be obtained to ensure that you do not have contraindications for our exercise protocols. You will be asked to drink plenty of water in order to keep yourself hydrated during the intervention. To minimize the risk of falling during treadmill walking, active spotting by a research assistant will be provided to ensure your safety. There will be scheduled rest periods provided between each trial to minimize physical fatigue. A certified lifeguard will ensure your safety in the water. In case of emergency, emergency services (911) will be contacted and you will be referred to your primary care physician.

### **Confidentiality**

Any information and video clips collected in this study will remain confidential and will be disclosed only with your written permission or if required by law. The cumulative results of this study will be published, but your name will be replaced by numeric code for confidentiality. All documentation/ data/video tape will be secured in a locked file cabinet located in the Center of Achievement's main office up to three years and will be destroyed after three years. Only Meera Motta, the primary researcher, and Dr. Teayou Jung, research advisor will be allowed to access the data and the video clips.

**Benefit of participation**

You may not receive any benefit from taking part in this study. However, your participation in this study may help us in better understanding of the effects of aquatic and land-based exercise on gait outcomes in people post-stroke. If you are in home-based program, you will receive a complimentary 12-week exercise program in Center of Achievement following this study.

**Concerns**

If you wish to express any concern about the research, you may direct your question(s) to Research and Sponsored Projects, 18111 Nordhoff Street, California State University, Northridge, CA 91330-8232, or phone no. 818-677-2901. With specific questions and concerns about this study, you may contact Dr. Taeyou Jung, research advisor, at the Center of Achievement, 18111 Nordhoff Street, Northridge, CA 91330-8287, or call (818) 677-2182. You will get the copy of the consent

**Voluntary Participation & Rights**

You should understand that participation in this study is completely voluntary and you may withdraw from the study at anytime without jeopardy.

I have read (or someone has read to me) the above and understand the conditions outlined for participation in the described study. I give the informed consent of myself to participate in the study.

Name \_\_\_\_\_  
 Last \_\_\_\_\_ First \_\_\_\_\_ MI \_\_\_\_\_  
 Date of Birth \_\_\_\_\_ Sex M F  
 (circle one)  
 Address \_\_\_\_\_  
 \_\_\_\_\_  
 City \_\_\_\_\_ State \_\_\_\_\_ Zip \_\_\_\_\_  
 Signature \_\_\_\_\_ Date \_\_\_\_\_  
 Witness/ P.I. Signature \_\_\_\_\_  
 Date \_\_\_\_\_

## Cover Letter

To

The Primary Care Physician

I hope this letter finds in best of your health. I am a Kinesiology Graduate Student, Meera Motta, at California State University, Northridge. I am doing a study to compare the effects of Aquatic and Land-Based Exercise Programs for improving the gait patterns in people post-stroke. The study will be held in Center of Achievement, also called as Brown Center, at California State University, Northridge.

**Purpose:** The purpose of this letter is to obtain their Medical Release so that they can participate in my study.

In the study, the participant will participate in a 8-week exercise program which will emphyze on gait training. They will be assigned to one of three exercise programs: aquatic, land and home-based program. Each program will have a 10-minute warm up including stretching followd by a 15-minute lower body strengthening exercise. After strengthening exercises the participant will be will be asked to do a 10-20 minute walking, which will be followed by 5-minute cool down. The participant will be asked to participate in the exercise program, 3 times a week for 50 minutes. They will receive a total of 5 evaluations: 0 week (pre-evaluation), every alternate week eveluation and 8<sup>th</sup> (post-evaluation). The study may have potential for risks including cardiovascular complications, dehydration, drowning, falling, physical fatigue, muscle cramps, skin irritation and other water safety issues. The participant will be asked to drink plenty of water in order to keep themselves hydrated during the intervention. To minimize the risk of falling during treadmill walking, active spotting by a research assistant will be provided to ensure your safety. There will be scheduled rest periods provided between each trial to minimize physical fatigue. A certified lifeguard will ensure your safety in the water. In case of emergency, emergency services (911) will be contacted and the participant will be referred to their primary care physician.

Your signature is required on the completed form, attached with this letter for us to have them as one of our participants for the study. If you have any questions or concerns, please feel free to contact me at your convenience.

Thanks for your cooperation.

Regards  
Meera Motta  
Graduate Student  
Department Of Kinesiology  
California State University, Northridge



***CALIFORNIA STATE UNIVERSITY, NORTHRIDGE***  
**EXPERIMENTAL SUBJECTS**  
**BILL OF RIGHTS**

The rights below are the rights of every person who is asked to research the study.

As an experimental subject I have the following rights:

To be told what the study is trying to find out,

To be told what will happen to me and whether any of the procedures, drugs, or devices is different from what would be used in standard practice,

To be told about the frequent and/or important risks, side effects or the discomforts of the things that will happen to me for the research purposes,

To be told if I can expect any benefit from participating, and, if so, what the benefits might be,

To be told the other choices I have and how they may be better or worse than being in the study,

To be allowed to ask any questions concerning the study both before agreeing to be involved and during the course of the study,

To be told what sort of medical treatment (if needed) is available if any complications arise,

To refuse to participate at all or to change my mind about the participation after the study is started. This decision will not effect my right to receive the care I receive if I were not in the study,

To receive a copy of the signed and dated consent form,

To be free of pressure when considering whether I wish to agree to be in the study.

If I have other questions I should ask the researcher or the research assistant, or contact Research and sponsored Projects, California State University, Northridge, CA 91330-8232, or phone (818)677-2941.

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Signature of Subject

Date

