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Examining the relationship between exercise induced fatigue and postural stability among geriatric patients with vestibular disorders

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EXAMINING THE RELATIONSHIP BETWEEN EXERCISE INDUCED FATIGUE AND POSTURAL STABILITY AMONG GERIATRIC PATIENTS WITH VESTIBULAR DISORDERS

by

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DEDICATION

This thesis is dedicated to my parents, James and Lori King. Your untiring support and assistance have made my success possible. Thank you for always encouraging me to go on every adventure, especially this one.

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Examining the relationship between exercise induced fatigue and postural stability among geriatric patients with vestibular disorders

Abstract

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Abstract

Purpose: This study examined: (1) the relationship between exercise induced fatigue and postural balance amongst geriatric patients with vestibular disorders. (2) Assessed the duration for postural stability to return to baseline measurements upon induced fatigue.

Methods: A controlled pre-post test experimental design method was used during this study. This study incorporated a quantitative analysis to explore the relationship between exercise induced fatigue and postural balance with a sample of 24 subjects. The subjects were randomly assigned to either an experimental or control group. Baseline postural stability measurements were conducted prior to all subject testing and were accounted for again once testing was completed in order to assess the duration for postural stability to return to baseline measurements. All subject testing was conducted using a treadmill and a CYBEX CSMi balance board.

Results: The results indicated that age can predict baseline balance score, baseline balance percent, maximum heart rate achieved, immediate posttest balance score, terminal posttest balance score, and terminal posttest balance percent. BMI, obesity, gender, were found to be significant among control and experimental groups when holding baseline balance percent and baseline balance scores constant.

Conclusion: It is important for geriatrics who possess a vestibular disorder maintain a healthy and active lifestyle so that they can reduce the risk of falling by lowering their BMI and lowering their chances of obesity. BMI and obesity were found to be positively correlated with an increased risk of falling.

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Chapter 1: Introduction

Movement drives the human race. Each day we wake up; The sudden shift from a sedentary state to a functional movement causes our musculoskeletal system to be challenged. It is then with our first steps we are our most vulnerable (Honaker & Kretschmer, 2014). For example, within the central nervous system (CNS), movement is controlled by neurons which are responsible for cell to cell communication. Moving ones foot requires hundreds and thousands of neurons to relay a message to the brain, which intercepts the signal and in return, provides the foot the capability to move. Externally this movement appears effortless, however, our bodies at this time are more susceptible to falls because our sensory system has yet to adjust to the new stimuli presented and motor control required (McGrath et al., 2014). The fluidity and speed of our actions are dependent on our age, fitness levels, and most importantly our health. Therefore it is important to understand the relationship between exercise and its effects with postural balance in order to prevent falls and injuries.

Activities of daily living are restricted when the impairment of any physiological system. For example, Imagine life without feet, or better yet, life with the impairment or lack of ability to stand. Simple tasks such as walking, running, riding a bicycle, or even driving a car would become impossible. Feet are the mechanism in which humans rely upon as a means for transfer, the foundational support for postural stance, and amongst all, feet with assistance of the brain control our ability to move (Windmaier et al. pp 305-308). An average American adult takes 5,117 steps per day (Bassett et al., 2010). With each step and each movement our bodies rely on our postural balance to maintain an upright position and prevent uncoordinated movements, especially falls. Research has shown that those who are older, unfit, and posses health problems are more susceptible to falling (Ahearn & Umapathy, 2015; Perera et al., 2007). According to the Center for Disease Control and Prevention, each year in the United States 2.5 million geriatric individuals are medically treated for fall injuries (CDC.org, 2015). From these falls, 95% have resulted in a hip fracture which required emergency medical attention (CDC.org, 2015). Within the geriatric population, falls are the leading cause of death (CDC.org, 2015). It is unfortunate that with each incident, an injury could have been prevented and a life saved if the victim had possessed a stronger postural stability.

Falls can be a result of weak muscle groups that support body weight or actions that require one to shift their weight in a sudden direction or fatigue (Tongterm et al., 2015). However, falls commonly occur in geriatric populations due to the sensation of feeling ‘dizzy.’ The dizzy sensation can be an underlying health condition and may bring early diagnosis to a vestibular disorder. The vestibular system is located within the inner ear and has the vital role in monitoring balance, proprioception, and spatial recognition with help from the limbic system (Guidetti, 2013). If the inner ear is damaged, chances of developing a vestibular disorder are high. According to the Vestibular Disorder Association, 69 million Americans suffer from a vestibular disorder ranging from benign paroxysmal positional vertigo (BPPV) to brain tumors, or vestibular neuritis

(Vestibular.org, 2015). Patients with vestibular disorders should be mindful of their physical activity due to their instability. Nevertheless, those will vestibular disorders cease physical activity due to their fear of falling (Honaker & Kretschmer, 2014). From this action, their quality of life is restrained, physical activity diminished, and overall health may begin to degenerate.

The purpose of this study will examine the relationship between exercise induced fatigue and postural balance among geriatric patients with vestibular disorders. Exercise-induced fatigue is characterized by a "loss of maximal voluntary force as well by increased perceived effort to maintain a particular force level" (Enoka & Stuart, 1992 pg 1632). Motor movements essential for life such as breathing or walking require minimal energy at the cellular level. Which in effect produces chain reactions to help facilitate the attainment of a goal (i.e., walking). Nevertheless, if energy is not replenished at the constant rate that it is being used then fatigue will set in and the desired action will cease. The current literature has identified that fatigue may alter balance and postural stability due to decreased motor control weakened by the CNS (Wilkins et al. 2004; Fox et al. 2008; Weist et al. 2011; Pau et al. 2014). Postural stability, or balance, is defined to be "the ability of an an individual to maintain the position of the body, or more specifically, its center of mass, within specific boundaries of space, referred to as stability limits. Stability limits are boundaries in which the body can maintain its position without changing the base of support" (Lord et al. 2007 pg 17). From this theory it can be hypothesized that as exercise-induced fatigue increases, balance decreases. However, the gaps in the literature suggest the need to study how long it will take for a geriatric individual who possesses a vestibular disorder’s postural balance to return to baseline measurements.

The relationship between muscular fatigue and postural stability are important for the reason that it may lead to new methods in the prevention of deaths and injuries for all ages. This research will be studying fatigue in lower extremity muscle groups to further clarify a safe and effective way to improve physical activity and the maintenance of conditioning for geriatric individuals who possess a vestibular disorder. The objective is to provide a better understanding of how geriatric individuals with vestibular disorders can become more physically active without inhibiting their health and postural stability.

Chapter 2: Review of the Literature

In the case of this study, postural balance will be measured to determine if there is a relationship with exercise induced fatigue amongst geriatric patients with vestibular disorders. Throughout this review of the literature, fatigue will be defined and explained on the effects it has on our body, specifically within the CNS. From there, the review of the literature will define fatigue, how fatigue occurs, and address how fatigue has an effect on age, fitness, and balance. Finally, the vestibular system will be further explained regarding its roles within the body as well as the functional effects in which fatigue may alter within the CNS.

2.1 Defining Fatigue

When a person performs a task, their body requires energy. For example, when a person performs a strenuous task, such as chopping wood, their ability to maintain high intensity wood chopping at a consistent rate becomes impossible. This is due to the body's inability maintain the homeostasis of energy inflow and energy output throughout the duration of the activity. When the body requires more energy to complete the task, but cannot supply the demand, fatigue will set in.

Muscle fatigue occurs at a neuromuscular state and is common in our daily lives and activities. With every step and action, our body's postural balance is controlled by the cerebellum, in the brain, as well as sub-systems of the brain and body, such as vestibular, visual, and somatosensory/proprioception (Widmaier et al., 2011). The amount of energy necessary to maintain postural balance depends on the conditions of which the body undergoes and therefore depletion of energy may cause postural balance conditions to diminish due to fatigue. Fatigue is defined as the "inability to maintain a particular force or power output during or following a repeated muscular contraction" (Rozzi et al., 2000 cited in Wright et al., 2013 pg 1303). Although fatigue influences one's ability to perform tasks, it can be manipulated by three factors: fitness, age, and disease (Egerton et al., 2009). Fitness, age, and disease will be discussed further on in the review of literature.

2.2 How Does Fatigue Occur?

The process of fatigue corresponds to the body's internal energy reserve. As energy is depleted the body must work harder due to "an increase in the perceived effort necessary to exert a desired force followed by an eventual inability to produce this force" (Enoka and Stuart 1992 pg 1632). Anaerobic threshold influences fatigue and occurs when "an accumulation of metabolites in the interstitial fluid of the cell wall that then disrupts the functioning of the contractile proteins (Sinoway et al. 1993; cited in Florian et al., 2014 pg 227) and impairs the neuromuscular propagation" (Fuglevand et al. 1993; cited in Florian et al,. 2014 pg 227). When fatigue sets in at the cellular level, metabolites will build up thus causing the CNS to have a "clouded" judgement while it relays signals to the involved muscles to provide muscle adaptations in order to compensate for the fatigued action (Serra-Ano & Lopez-Bueno, 2015). Once the motor movement is altered, the action becomes less systematic to the point where coordination is diminished and balance is deficient. It is important that during the process of fatigue that the CNS is able to withstand and perform functioning motor skills, movements associated with balance and coordination, otherwise degrading responses towards actions will triumph (Gandevia, 2001). Prior to fatigue, the CNS works quickly and efficiently to continually evolve coordination from the input of sensory information to produce motor information output.

2.3 Fatigue Affects the CNS and the Body

The central nervous system (CNS) is the foundation which provides the human body with consistent input and output of vital functions which assist in the maintenance of life. During week three of fetal development, the CNS begins its extensive responsibilities with the formation of neurons, neurotransmitters, as well as integrators that formulate a communication road map that links the brain and spinal cord to all areas and senses within the body (Widmaier et al., 2011). At week nine, the fetus develops fingers and toes which are part of the distinguishing characteristics that make up hands and feet that will be managed by the CNS through motor control (Widmaier et al., 2011). In this important stage of CNS development, the fetus will undergo copious changes to fulfill the necessary requirements prior to birth. After birth, the human body consistently adapts to the new stresses and strains in which the central nervous system will encounter, such as physical activity.

There are over 650 skeletal muscles within the human body. A single muscle is composed of thousands of muscle fibers which are controlled by motor units. A motor unit is a neuron within the CNS which innervates muscle fibers to facilitate in the movement of a muscle (Widmaier et al., 2011). The CNS can dictate a muscles movement through action potentials. An action potential is an “electrical signal propagated by neurons and muscles cells which depolarize cell membranes” (Windmaier et al., 2011 pg 262) However, in order for the electrical signal to reach the level of an action potential it must reach threshold prior to decrement (Widmaier et al., 2011 pg 262). Essentially, there are many processes that occur at the unconscious level in order for a single muscle movement to take place. The science behind the human body is advanced and will always be dependent on the food consumed as an energy source. Our neuromuscular system can be stressed to the point of exhaustion, and the performance of our motor control will undoubtedly be diminished (Enoka & Stuart, 1992).

Adaptability is vital in maintaining a functional motor control. When fatigue overcomes the body metabolites saturate the blood thus causing the muscle to operate in a low functional state. Metabolites inhibit motor actions due to the excess build up. If metabolites are not being recycled or removed at the same rate in which they are being made, energy cycles such as glycolysis build up an excess of lactic acid which inefficiently replenishes energy stores. The process of an action potential reaching threshold becomes harder due to the extent of the energy to help facilitate the movement to be sparse (Gandevia, 2001). Regardless of how fatigued our bodies are, the CNS will respond to any and every action obtained. However, a response does not always qualify as an action, the response from the CNS could also indicate that it is aware of the stimulus of fatigue (Enoka & Stuart, 1992).

2.4 Fitness Influences Fatigue

Indications of fatigue while participating in exercise can be diminished with increased physical fitness of an individual (Egerton et al., 2009). Research has studied and defined anaerobic threshold to hold a direct relationship between fatigue and ones of performance (Pienado et al., 2014). If one is physically fit, their anaerobic threshold is higher than those who are untrained, thus indicating that the onset of fatigue is achieved earlier and at smaller intensities than that of those who are trained. This direct relationship justified by Pienado et al., (2014) explains that once the body reaches anaerobic threshold, the CNS must work harder to respond to efferent activity in order to produce an action through the Peripheral Nervous System (PNS). Throughout this process, the human body has a regulator which is found in the brainstem nuclei and the limbic system that senses when anaerobic threshold is reached which then requires a signaled response to bring the body back to homeostasis before damage and danger occurs. If the body undergoes homeostatic difficulties, the CNS becomes less efficient at processing information processed and communicated throughout the body. Slower processing is inefficient. Slower communication causes a delayed reaction time that leads to a weakened response to motor actions which then cycles back full circle to a slower transit time from the stimulus occurrence to the information processed in the CNS.

During the operation of events, fatigue is the safe-guard which acts as a negative feedback mechanism to alert the body when max effort has been achieved. Externally, researchers can study when fatigue is attained in a subject by using a non-invasive technique that monitors heart rate. Heart rate variability measures how fast the heart is beating based on beats per minute. A recent study conducted by Kaikkonen et al., (2014) found a positive correlation between physical activity and physical fitness to be positively and independently related to heart rate variability in obese adults. Throughout this study the monitored subjects heart rate and associated the rate of perceived exertion during each activity in which they had participated (Kaikkonen et al., 2014). Another study conducted by Purwanto et al., (2014) concluded that "resting heart rate contribute negatively in determining physical endurance" thus indicating that subjects with a rapid heart rate fatigue earlier during an exercise than those who had a lower heart rate (Purwanto et al., 2014 pg 112). From this study, age and heart rate are two factors that influence endurance fitness based on the body's ability to withstand fatigue prior to burnout.

2.5 Aging affects the Brain, Balance, and Fatigue

Physical activity is vital for those of all ages. Movement through exercise influences metabolic pathways to use stored energy obtained from the ingestion of food in order to help facilitate the production of an action. Through this energy depletion, exercise helps maintain a consistent balance of food in take and energy expenditure. Exercise is crucial in the maintenance of our health and prevents the onset of rapid 'aging.' Regardless of health, all things will eventually age. Nevertheless, the extent of ones ability to perform differs from decade to decade. It has been said that age is just a number, yet, age is defined to be "the inherent imperfectness of generations of genome damage by every biological process, at all levels, from small molecules to cells" (Gladyshev, 2013). On the account that the damage genome is abundant at the foundational cellular level, aging has been seen as inevitable (Draelos, 2009). It is crucial, especially for those who are of the geriatric population, to continue daily exercise routines to prevent muscle atrophy. Age related muscle weakness due to atrophy is common in adults after the age of 50. On average adults over the age of 50 will lose 1-2% of muscle mass a year leading to more health related problems and lower rates of physical activity (Muscaritoli et al., 2013).

Elder adults fear of becoming too fatigued since they are at a higher risk of injury due to increased susceptibility of balance loss (Hill et al., 2015). Because falls are more prevalent amongst the geriatric population, fear of falling has become a medical concern due to the avoidance of activities in daily living. Quality of life becomes restricted and therefore provides an increase of mental illness and death (Honaker & Kretschmer, 2014). A cross-sectional study conducted in 2011 by Patel et al, 2014, studied 8,245 adults aged 65 year and older who were enrolled in Medicare. In this study, 40% had stated that they had problems with their balance and coordination and had a medical history resulting from a fall (Patel et al., 2014) 47% of subjects had also stated that pain had limited their activity and that they have developed a fear of falling. Given that the results have indicated that fear of falling restricts activities of daily living and diminishes the quality of life, physical fitness becomes less of a priority due to the risk factors involved. Once physical fitness is no longer a priority, the human body will slowly degenerate, thus following in line with the age related muscles weakness paradox. In conclusion, our bodies age to the extent of what we can control through psychological factors and what we cannot control through physiological factors.

2.6 The Vestibular System

The vestibular system is found within the inner ear and is responsible for sensing spatial orientation, movement, and postural equilibrium. The vestibular system involves both the central and peripheral nervous system. As previously established, the central nervous system involves the brain and brainstem while the peripheral nervous system is responsible for bridging the pathways between the inner ear and the brainstem through the vestibulocochlear cranial nerve eight. (Kim, 2014).

The anatomy of the vestibular system is located within the inner ear which is known as the labyrinth. The labyrinth contains two structures known as the cochlea and vestibular apparatus. The cochlea is responsible for hearing, while the vestibular apparatus maintains balance, stability, and spatial orientation. Within the inner ear there are three semicircular canals which are connected to the cochlea and vestibular apparatus. The semicircular canals are responsible for detecting angular motion and body positioning (Widmaier et al., 2011). The orientation of each canal is 90 degrees from each other, this is vital because each canal can distinctively detect rotation, acceleration, and spatial orientation. Although the orientation of the canals are important, the motion in which the canals sense is influenced by the ampulla which is located inside of each semicircular canal (Kim, 2014). Within the ampulla is a structure called the cupula, which divides the ampulla into two halves. Within the cupula, are hair cells which are made up of one long hair called the kinocilium and multiple short hairs call the steriocilia. During angular movement, the hair cells located within the cupula are pushed or pulled from the flow of endolymph. When the steriocilia moves towards to kinocilium, it causes the cupula to bend, thus it transmits the information and converts into an electrical signal. This electrical signal is sent to the brainstem via the vestibulocochlear nerve and in response produces eye movements (Kim, 2014).

The central nervous system heavily relies on the vestibular peripheral system. With the help of the semicircular canals, the peripheral system can transmit the appropriate information to the brain to produce an action. The semicircular canals are vital within this process, however, the canals rely on the help of two otolithic organs which detect acceleration and deceleration. The otolithic organs involve the utricle and the saccule, the utricle is responsible for detecting linear motion on the horizontal plane, for example this motion can be perceived when one is moving forward or backward. The saccule is responsible for detecting motion in the vertical plane, such as jumping up or down. The perception of movement in which the otolithic organ detects is primarily influenced by the hair cells located within the organ. These hair cells are encapsulated by a viscous material that contains carbonate crystals called otoconia. When the hair cells bend, the stimulus sends a signal through the polysnaptic neural pathway which is interpreted by the thalamus and is then sent to the parietal lobe in the brain (Widmaier et al., 2011). Once this signal is received, the brain interprets the information by sending the appropriate signals to specific designated areas of the body. For example, a stimulus in which the vestibular system receives requires the innervation of the spinal cord, the eyes, as well as the vestibulocochlear cranial nerve to collectively maintain postural reflexes as well as the sensation of movement. The follow section will further discuss how a vestibular disorder may disrupt one's balance.

2.7 Vestibular Disorders Disrupt Balance

A vestibular disorder may effect the vestibular system and the central nervous system by inefficiently responding to a stimulus (Ahearn & Umapathy, 2015). If the vestibular system is damaged or impaired, one begins to feel 'dizzy.' A study conducted in 2010 found that 80% of people who were 65 years and older have experienced dizziness (Ator, 2010). A study in 2008 had found that the most common vestibular disorder diagnosed by health care professionals was benign paroxysmal positional vertigo (BPPV), also known as vertigo, which effected more than 50% of geriatrics who had complained of dizziness (Fife et al., 2008). Dizziness or postural imbalance is due to sensory and motor deficits which in turn impairs the central nervous system. These sensations are primarily due to cranial nerve eight, also known as, vestibulocochlear nerve (Davenport et al., 2012).

Although the vestibulocochlear cranial nerve effects the peripheral nervous system which communicates to the central nervous system, there are three other manifestations which directly correlate to the central nervous system which influences balance. When the vestibular system is challenged, the central nervous system is influenced by perception, ocular motor control, postural control, and autonomic responses (Brandt & Strupp, 2004). The vestibular system is influenced by the vestibulocochlear cranial nerve which communicates cortical spatial orientation to the central nervous system. Vestibular disorders that were found to be most common in 2015 were BPPV, labyrinthitis or vestibular neuritis, Ménière’s disease, secondary endolymphatic hydrops, and perilymph fistula, acoustic neuroma, ototoxicity, enlarged vestibular aqueduct, and mal de débarquement (Vestibular.org). Each disorder listed above challenges the vestibulocochlear cranial nerve, however, there are other disorders that also effect the vestibular system, yet, do not involve the cranial nerve. Nystagmus is a vestibular disorder in which a person has the inability to keep their eyes fixated on an object due to the fact that their eyes are moving involuntary (Brandt & Strupp, 2004). Nystagmus affects ocular motor control by distorting vestibulo-ocular reflexes (VOR) which are activated by the brainstem (VEDA, 2009). The VOR is important with maintaining postural balance because it provides the vestibular, optic, and central nervous system with clear, controlled eye movements. This is critical with activities of daily living. For example, when one moves their head, the eyes are able to compensate for the movement by focusing in on an object which in turn provides postural control.

Finally, postural control is maintained through the activation of monosynaptic and polysynaptic vestibular spinal pathways. A vestibular disorder that not only challenges the monosynaptic and polysynaptic pathways, but also promotes vestibular autonomic dysfunction, is known as cerebellar ataxia (Brandt & Strupp, 2004). The cerebellum communicates directly to the motor cortex and when it is damaged motor learning, postural balance, as well as movement is hard to produce in an efficient and desired manner (Ganos, et al., 2014). Vestibular autonomic responses stimulate the maintenance of postural balance. Nevertheless, in the presence of cerebellar ataxia, vestibular autonomic dysfunction arises which can cause someone to feel nauseous due to motion sickness. (Wu, et al., 2014). Cerebellar ataxia has been suggested to be caused by the degeneration of the cerebellum as a result of old age and the decadency of Purkinje cells (Ganos et al., 2014). The following sections will further discuss the relationship between vestibular disorders and age.

2.8 Aging Vestibular Systems

Aging affects every physiological system within the human body. The vestibular system is no exception. With time, the hair cells located within the inner ear labyrinth begin to degenerate followed by the deterioration of the ganglion receptor cells which connect the vestibular system to the CNS (DeSousa et al., 2011). As the degeneration advances, one may begin to feel 'dizzy.' This dizziness is characterized due to the lack of response between the eyes, ears, and brain. According to a study conducted by Karatas (2008) and Dickerson (2010), the most common causes of dizziness within geriatric patients was due to peripheral vestibular disorders (Karatas, 2008; Dickerson, 2010). From their studies they had indicated that the common diagnosis for subjects who were 65 years and older that had peripheral vestibular disorders was due to vertigo. According to Sogebi et al.,(2014), referenced by Della-Morte (2012), vertigo is defined to be "A subtype of dizziness causing erroneous perception of self or object motion or an unpleasant distortion of static gravitational orientation as a result of a mismatch between vestibular, visual, and somatosensory systems" (Della-Morte, 2012; cited in Sogebi et al., 2014). Vertigo, as well as other vestibular disorders, influences a persons perceptions of fatigue along with an increase of fall related injuries (Sogebi et al., 2014).

Aging of the vestibular system has a threat to people both medically and economically (Zalewski, 2015). It has been estimated that by the year 2050, there will be a population increase of 115% of geriatric individuals within the United States alone (Zalewski, 2015). From this population increase, it has been estimated that the current annual cost for falls within the geriatric community on the national level will only increase. This increase will advance from $20 billion a year and could have the affect that would result in high rates of mortality and financial burdens as a national epidemic (Zalewski, 2015). Nevertheless, this can all be prevented. Aging of the vestibular system is not a new physiological disease. Treatments to help facilitate with the reduction process of vestibular degeneration have been studied and proved to be effective (Cohen, 2011). According to a study conducted by Honaker & Kretschmer (2014), vestibular patients expressed that they were less fearful in participating in activities of daily living after they had took part in physical therapy and vestibular rehabilitation programs. From the involvement of physical therapy, subjects reported that they had grown more confident in maintaining control of their symptoms of ‘dizziness’ and could indicate whether a certain activity would promote symptoms (Honaker & Kretschmer, 2014).

2.9 Gaps in the Literature: How does vestibular system affect the perception of fatigue?

Activities of daily living are vital to those who are of geriatric age. Simple activities, such as walking, sleeping, or standing become a hardship. Perception of fatigue becomes affected because the vestibular system no longer has a high sensitivity of feedback control that is monitored by the brain and the CNS. The gaps in the current research lack the explanation as to why this occurs specifically within this population which is why it is a pressing issue to resolve. If geriatric individuals have a better indicator to how they are able to perceive their fatigue and how it affects their vestibular system, then geriatric individuals will be able to have more of a control on their symptoms and participate in more of their activities of daily living without injuries.

Chapter 3: Methodology

This study used a controlled pre-post test experimental design involving 24 geriatric subjects who possessed a vestibular disorder. All subjects were randomly assigned to either an experimental or a control group. Procedures regarding exercise induced fatigue and balance assessments protocols were elaborated upon in regards to subject involvement. All extraneous variables will be explained further to asses how they were controlled or accounted for during the study.

3.1 Subjects

This study involved the participation of 24 geriatric vestibular patients who attended physical therapy. Prior to participation, all subjects were given a self made questionnaire to determine if their medical history complies with the experiments requirements. Subjects were excluded if they had previous surgeries to the lower extremity, the head, or brain. Subjects were also excluded from the study if they did not possess a present vestibular disorder at the time of the study that was prior diagnosed by their medical doctor. All subjects were chosen through random sampling based on their current diagnosis and enrollment in a physical therapy clinic in San Luis Obispo, California. All subjects were counseled by their physical therapists as to whether or not their participation was recommended for study. After the recruitment process and prior to the reception of the questionnaire, all subjects were provided with an informed consent before they underwent testing. If in the case a subject did not comply with the informed consent, questionnaire, or had chosen to withdraw from the study, the subject was removed from the study and the data collected was void and shredded.

3.2 Procedure

All subjects were randomly selected patients who were currently diagnosed with a vestibular disorder and were enrolled at a physical therapy clinic in San Luis Obispo, California. Subjects were divided and assigned to either an experimental or a control group and stood on the CSMi balance board to obtain baseline measurements of their center of gravity and stability components prior to experimental testing.

Prior to testing, all subjects completed the maximum heart rate formula, which involves subtracting the subjects age from 220 and then multiplying by .85 to determine the value of 85% of their maximum heart rate. Once the value was determined, all subjects were asked to wear a heart rate monitor. The heart rate monitor was strapped under subjects clothing and was securely fastened around their waist. This monitored heart rate every two minutes during testing in order to assess when the subject was nearing 85% of their max heart rate. During testing, subjects were asked to indicate their Rate of Perceived Exertion (Borg RPE scale), which is a self ranked scale from 6-20 that assesses how fatigued the subject feels. The Berg RPE scale indicates 6 to be not fatigued and 20 to indicate very fatigued and will be assessed every two minutes during testing.

All subjects were administered the same procedures prior to data collection. These procedures were as followed: Each subject was provided an informed consent. It was necessary that each subject read, understood, and signed the informed consent prior to their participation with the study. All instructions were read aloud and the subjects had the opportunity to ask questions necessary for clarification prior to the start of the study. Once the informed consent was signed and the instructions were given, all subjects were required to stand on the CSMi balance board with their feet at a narrow based / shoulder width stance with their eyes open for 30 seconds to determine their center of pressure. Once this was complete, subjects were randomly divided into the control or experimental group.

Subjects who were in the control group were asked to complete Stage I of the Bruce Treadmill Protocol only. Stage I involved the subject to walk on the treadmill at a speed of 1.7mph at a 10% grade for 4 minutes. Heart rate was recorded every 2 minutes as well as their rate perceived exertion (Berg RPE scale). After 4 minutes the subjects was removed from the treadmill and was stationed on the balance board to determine if there was a change in their center of gravity and stability. Center of gravity and stability tests were administered every minute until measurements return to their baseline score within a 5% margin of error.

Subjects that were in the experimental group also underwent the Bruce treadmill protocol, however they were asked to complete each stage to the best of their ability or until they reached the defined stages of fatigue. Each subject in this group followed the guidelines listed below:

Modified Bruce Treadmill Protocol (2015)

1. Begin by taking a pre-test heart rate while the subject is in a standing position.

2. Have the subject begin to walk slowly to warm up

3. Every 2 minutes the researcher will:

   - Record HR and RPE

   - Increase intensity/workload of exercise (either % grade or speed)

4. Continue test until subject reaches at least 85-90% of heart rate max.

   - If other max test requirements are met, target HR may be ignored

     *ie: RPE of 20, RER>1.15, etc.

   - Always terminate a test if the subject indicates the need to stop.

5. Upon test termination, decrease the speed of the treadmill to a pace at which the subject can comfortably maintain a walking cool-down.

				MET Requirement*		
Stage	MPH	Grade	Min	Men	Women	Cardiac
	1.7	0%	1	3.2	3.1	3.6
I			2	4.0	3.9	4.3
			3	4.9	4.7	4.9
			4	5.7	5.4	5.6
II	2.5	5%	5	6.6	6.2	6.2
			6	7.4	7.0	7.0
			7	8.3	8.0	7.6
III	3.4	10%	8	9.1	8.6	8.3
			9	10.0	9.4	9.0
			10	10.7	10.1	9.7
IV	4.2	12%	11	11.6	10.9	10.4
			12	12.5	11.7	11.0
			13	13.3	12.5	11.7
V	5.0	14%	14	14.1	13.2	12.3
			15	15.0	14.1	13.0
VI	5.5	16%	16			
			17			
VII	6.0	18%	18			

*Test will continue at stage VII until subject stops.

After the subject reached 85% of their max heart rate, declared an RPE of 18 or greater, or voiced an immediate stop during testing, the speed of the treadmill was reduced to a stop and the subject was removed from the treadmill. Upon removal from the treadmill, the subject was asked to stand on the CSMi balance board to determine if there was a change in their center of gravity and stability. Center of gravity and stability tests were administered every minute until measurements returned to baseline.

3.3 Balance Assessment

The balance assessment test was administered through the CSMi balance board manufactured by CYBEX and Biodex while using HUMAC 2015 balance software. All data was collected using an password protected HP laptop running on Windows 7 software. The CSMi balance board computerized program assessed center of pressure, weight bearing, weight shifting, and limits of stability. For the purpose of this study, the baseline postural balance measures were assessed by calibrating the board before each subject and having the subject stand on the balance board with their feet together and eyes open for 30 seconds to determine their center of gravity. Upon baseline testing, subjects proceeded to the Bruce Treadmill Protocol and after testing requirements were met, the subject returned to the board and stood for 30 seconds. Each subject was given 30 seconds of rest intervals between each measurement test. During the rest interval, subjects kept their feet on the balance board and were allowed to take a seat in a chair which was located directly behind them to ensure validity of the testing position. The procedure of 30 seconds standing, 30 seconds resting continued every minute post-exercise until their center or pressure balance returned to their baseline measurements.

Once the subject reached their baseline measurements, they were dismissed from the experiment and their data was recorded and saved for further analysis.

3.4 Extraneous Variables

The extraneous variables were controlled and accounted for during this study. The extraneous variables included: existing medical conditions involving the eyes, heart, lungs, head, brain, or the lower extremity. Motor cognitive dysfunctions, including but not limited to blindness, history of stroke, and seizures were considered as extraneous variables that were not controlled for based on the subject questionnaire which was administered to each subject prior to their participation in the study. The self report subject questionnaire determined if a subject was eligible for the study based on their answers provided to each question. If a subject had a previous medical condition or had surgery involving the heart, lungs, head, brain, or the lower extremity they were excluded. If a subject did not possess a present vestibular disorder at the time of testing they were excluded. Prior to participation, all subjects were advised to avoid consumption of two or more alcoholic drinks 24 hours prior to testing. Subjects were encouraged to sleep a minimum of six hours, stay hydrated, and eat three hours prior to testing. Due to the fact that the researcher was not able to control for the subjects lifestyles outside of testing, extraneous variables were accounted for by having the subjects complete the self report subject history questionnaire. All subjects were encouraged to answer the questionnaire honestly and to the best of their abilities to prevent invalid results. If subjects did not abide to the requests, they were exempted in participate in the study. Reasons for subject exemption were necessary to facilitate the control of maintaining valid results.

The extraneous variables associated with this study will be furthered explained in regards to their effects with the data. Eye sight is one of the three important factors that effect balance and therefore it is indicated that poor vision is a contraindication to this study due to the higher potential of a fall risk occurring (Willis et al., 2013). Subjects were withdrawn from the study based on their response on the subject history questionnaire if they stated that they have consumed two or more alcoholic beverages within the past 24 hours. Extensive research has shown that alcohol inhibits stimuli that is transmitted to the brain and relayed to the CNS that impairs both motor and cognitive function which negatively effects balance (Flores-Salamanca & Aragon-Vargas, 2014). Sleep deprivation as well as dehydration and malnutrition collectively has been proven to reduce reaction time, slow the CNS response with motor functions, and promote ineffective motor movements and coordination (Ma et al., 2009; Teitelbaum, 2005). Malnutrition specifically inhibits the CNS with deficiencies which cause energy stores to deplete at a faster rate thus causing the onset of fatigue to occur at a faster rate intended (Reid, 2013). If subjects were malnourished their CNS will not be working efficiently which may lead to slower reaction times, poor balance, and limited coordination. Subjects who had disabilities or surgeries involving the lower extremities including hips, knees, legs, ankles, and feet will be excluded from the study because it may have an effect on fatigue and the relationship with balance. A study by Nyland et al,. (2014) concluded that patients had trouble with postural stability five years after their lower extremity surgery. This information has provided grounds to dismiss all subjects with a lower extremity surgery and brain surgery to prevent extraneous variables within the data collection process. Prior to the experiment, subjects were advised to wear close-toed shoes as well as athletic wear. Failure to meet this dress code resulted in the subject dismissal to participate in the study because restricted clothing may inhibit movement during exercise and improper shoes could be a safety liability. Lastly, age of subject may be an extraneous variable in this study. This study was administered to geriatric individuals who possessed a vestibular disorder. To be considered eligible, subjects abided by the standard geriatric age requirement of 65 years or older. Subjects who were not within this age group were excluded from this study in order to prevent age outliers as well as other extraneous variables inessential to address at this present time.

3.5 Validity & Reliability

The extraneous variables and threats to this experiment were minimized by having each subject complete a self report questionnaire prior to their participation in the study. The self report questionnaire assisted in the removal of any subjects that did not match the criteria intended for this study. This study used a single blind random sample to prevent subject bias when selecting subjects for the control group or the experimental group. A script was read to each subject prior to their participation in the study to prevent researcher bias. The script stated the same instructions for all subjects within their testing group. The treadmill, the Bruce Treadmill Protocol, and the CSMi balance board have been validated from previous literature and remained the same throughout the study to prevent researcher error and ensure accuracy in data collecting measurements. The balance board was re-calibrated before each subject prior to testing in order to maintain internal consistency reliability.

An IRB was submitted for this study which included any and all potential risks to subjects who are involved. Potential risks that were probable to occur with those who participate were: minimal loss of confidentiality, minimal physical risks, and minimal psychological risks.

Physical risks were accounted for by providing care to avoid situations where fatigue lead to light headedness or loss of balance. An overseeing trained physical therapist was present onsite who was experienced with working among the specific subject population. During the course of data collection each subject was required to wear a gait belt so if in the case they had a loss of balance the trained physical therapist onsite had the ability to catch their fall or lower them to the ground to prevent injury. The subject was allowed at any time to withdraw from the study at their own consent. In opinion of the researcher or the physical therapist reserved the right to stop the test at any time if there is a concern about subject risk.

Psychological risks were accounted for by monitoring the subject at all times during the experimental study as a prevention method to any unattended problems. Subjects may had experienced anxiety from the knowledge that they are being tested. From this knowledge, the subject may had reacted and performed differently than when they are not under surveillance. Subjects were allowed to read the inform consent and instructions as well as had them read to them aloud prior to the start of the study. This was done so that the subject had full knowledge and power of autonomy to stop and withdraw from the study at anytime to prevent any anxiety or other psychological risks in which the subject may had potentially undergone.

Lastly, confidentiality was maintained by the control of only allowing the researcher to have full access to the informed consent forms and the data collected throughout the study. Confidentiality was maintained during the study by separating the informed consent from the data collected with each subject. Each subject was administered a numerical subject ID to displace their name from all forms collected on data sheets that were also locked and stored away from public viewing. This was intended to prevent breach of confidentiality during the data collection phase of the study. The reporting of the results will not include subjects names in conclusion to the study. At the conclusion of the study, all data will be destroyed by shredding all paper/tangible documents and manually delete all electronic files on the computers used.

3.6 Ethics & Research Design:

This experimental study involved the use of a controlled pre-post test experimental design. This design was chosen based on the fact that it will help ensure the validity and reliability of the content within the study and possess the means to assist future researchers to further expand on this topic.

The ethics regarding this experimental study required all subjects to sign an inform consent indicating what will be expected of them, the potential and preventable risks involved, as well as reasons as to why their participation in the study is important and encouraged. All subjects upheld to the standard that the researcher and study will do no harm, which will be defined under the basis that in as so much as possible potential risks will be reasonably accounted for. The researcher and study ensured justice to all subjects by maintaining random controlled trials in order to ensure all benefits are distributed equally amongst the subjects.

Finally, the researcher and study ensured the confidentiality of all subjects who provided an informed consent of their participation with the study as well as respected the subjects who no longer wished to continue with the research process.

Chapter 4: Results

A total of 25 subjects participated in the study. Complete data was gathered and analyses conducted on 24 of the subjects. One subjects was omitted due to exclusionary criteria or quit. Exclusionary criteria included the subject not having a present vestibular disorder or ineligibility due to surgery or injury to the head or lower extremity in the past five years.

There were two conditions: treatment and control. The treatment group participated in a treadmill exercise protocol that was intended to cause fatigue; the control group underwent a treadmill exercise protocol that was not intended to cause fatigue by maintaining a walking speed of 2 mph for a 4-minute duration at a 0% incline. Prior to testing, the subject stood on the balance board (Computer Sports Medicine Inc., HUMAC Balance with Tilt, Stoughton, MA, USA) and the score (0–100) was a representation of their center of pressure that were dictated within the limits of stability on the balance board. There were four quadrants which were used to score the subjects center of pressure during the 30 seconds of testing. The score was expressed in a number as well as a percentage. The DHI (Dizziness Handicap Index) was a questionnaire in which each subject filled out prior to testing to assess how “dizzy” their symptoms made them feel. Listed on the next page is a table (Table 1) which demonstrates all variables used when analyzing the data.

Table 1: Demographics, balance scores, and outcomes of patients in the total population, control group, and treatment group.

	Total Population	**Treatment**	**Control**	**Significance**
N	24	12	12	
Gender	50% male	58.3% male	41.7% male	p = 0.414
Age (years)	74.7 ± 6.5	74.8 ± 5.8	74.6 ± 6.7	p = 0.923
BMI	28.3 ± 3.2	29.0 ± 2.3	27.7 ± 3.8	p = 0.335
Baseline Balance Score	17.6 ± 10.0	18.9 ± 9.1	16.2 ± 11.1	p = 0.527
Baseline Balance %	90.8 ± 2.7	91.3 ± 2.0	90.4 ± 3.4	p = 0.467
Duration on TM (sec)	395.0 ± 221.6	550.0 ± 224.3	240.0 ± 0.0	p = 0.001
Grade % on TM	5.8 ± 6.6	11.6 ± 4.2	0.0 ± 0.0	p < 0.001
Max HR 85%	123.6 ± 5.0	123.6 ± 4.4	123.7 ± 5.7	p = 0.968
Whether HR was met	33.3% met	66.7% met	0% met	p = 0.001
DHI Score	38.3 ± 18.6	32.7 ± 18.1	44.0 ± 18.0	p = 0.138
Immediate Post-Test Score	20.9 ± 13.4	24.7 ± 10.8	17.1 ± 15.1	p = 0.174
Immediate Post-Test %	91.3 ± 2.4	81.6 ± 8.3	87.6 ± 4.1	p = 0.036
Post-Balance Score	18.5 ± 9.2	21.4 ± 9.8	15.5 ± 7.7	p = 0.115
Post-Balance %	91.3 ± 2.4	91.7 ± 1.6	91.0 ± 3.0	p = 0.507
Duration Until Baseline (sec)	256.3 ± 143.7	375.0 ± 97.8	137.5 ± 53.4	p < 0.001

BMI = Body Mass Index; TM = Treadmill; HR = Heart Rate; DHI = Disability Handicap Index.

From pretest to posttest, the treatment group increased in balance score (5.8 ± 10.0) more than the control group (0.0 ± 5.6), but this difference was not significant (p=0.154). From pretest to posttest, the treatment group decreased balance percent (–9.7 ± 8.0) more than the control group (–2.8 ± 3.7; p=0.013).

There was no difference between men and women in change in balance score. Men increased by 3.0 ± 9.4 while women increased by 3.7 ± 7.4 (p=0.852). Baseline balance percent displayed a larger difference. Men's percentage decreased more (–8.1 ± 7.4) than women's (–4.4 ± 6.4), but this difference was not significant (p=0.208).

From pretest to terminal posttest, the treatment group increased balance score by 2.5 ± 5.8 while the control group decreased (–0.7 ± 4.5). The difference was not significant (p=0.137). Men increased significantly more than women from baseline to posttest (p=0.031). Men's scores increased by 3.2 ± 5.2 (n=12) while women (n=12) experienced a decrease (–1.4 ± 4.6). Owing to the research design, there were no differences in the change in balance percent.

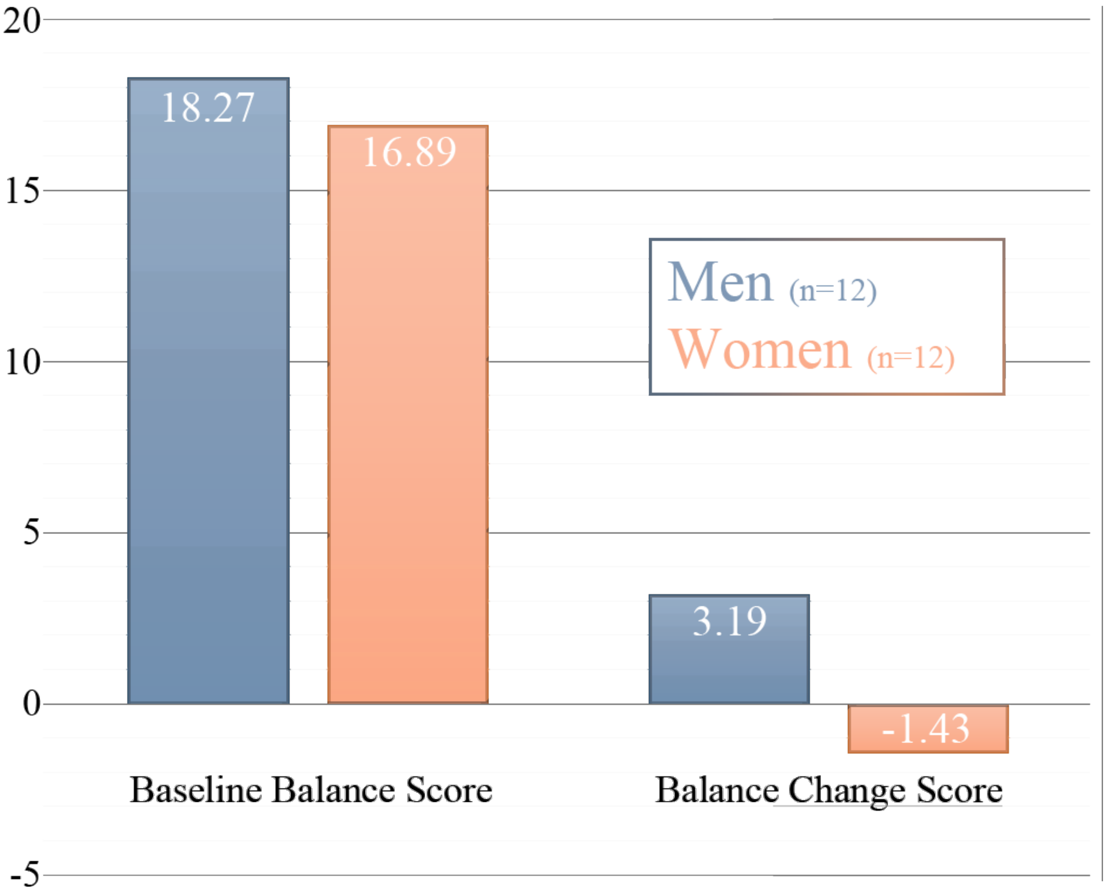

Figure 1: Gender comparison of baseline balance score and balance change score.

Table 2. Multiple linear regression explaining immediate change in baseline balance percent (BMI).

Variable	*Coefficient*	*Standard Error*	*t*	*Significance*	*95% Confidence Interval*
Age	0.535	45.118	2.896	p=0.011	0.143 to 0.927
Gender	4.268	1.786	2.389	p=0.030	0.482 to 8.055
BMI	-0.707	0.283	-2.501	p=0.024	-1.307 to -0.108
Baseline Balance Score	-0.730	0.129	-5.683	p=0.000	-1.003 to -0.458
Baseline Balance Percent	-1.263	0.413	-3.060	p=0.007	-2.138 to -0.388
DHI Score	-0.137	0.054	-0.361	p=0.023	-0.252 to -0.021
Control or Experimental	-3.909	1.788	-2.186	p=0.044	-7.699 to -0.119
Constant	106.436	45.118	2.359	p=0.31	10.790 to 202.082
Model Summary	**Observations**	**F**	**Significance**	**R^2**	**Mean Square**
	24	8.085	$P < 0.001$	0.780	126.350

Dependent variable: Change in immediate balance percent. Predictors: (Constant) DHI score, age, BMI, control or experimental, gender, baseline balance percent, baseline balance score.

Table 2 results determine that a prediction of 78% of the variance of the change in balance with the predictors used ($p<0.001$). For example, a subject in the experimental group has a percentage decreases about 4 points more (3.91 percentage points; $p=0.044$) than a subject that was in the control. From these findings, the fatiguing protocol causes a greater deterioration of balance.

Additionally, with each 1-point increase in BMI, there’s a 0.7% decrease in balance (p=0.024). Thus, if a subject goes from 24 to 27 in his or her BMI, the objective balance measurement, holding all other variables constant, it is predicted that they have an increase chance of falling by 2.1%. This idea can be linked to obese people deteriorate more; which can lead to a greater likelihood of falls after a fatiguing activity.

Table 3. Multiple linear regression explaining immediate change in baseline balance percent (Obesity).

Variable	*Coefficient*	*Standard Error*	*t*	*Significance*	*95% Confidence Interval*
Age	0.560	0.177	3.165	p=0.006	0.185 to 0.934
Gender	4.210	1.705	2.470	p=0.025	0.597 to 7.824
Obesity	-5.018	1.737	-2.889	p=0.011	-8.700 to -1.336
Baseline Balance Score	-0.755	0.124	-6.079	p=0.000	-1.019 to -0.492
Baseline Balance Percent	-1.210	0.393	-3.079	p=0.007	-2.042 to -0.377
DHI Score	-0.131	0.051	-2.567	p=0.021	-0.240 to -0.023
Control or Experimental	-4.745	1.682	-2.821	p=0.012	-8.310 to -1.180
Constant	82.070	41.392	1.983	p=0.065	-5.678 to 169.817
Model Summary	**Observations**	**F**	**Significance**	**R²**	**Mean Square**
	24	9.060	P < 0.001	0.799	129.420

Dependent variable: Change in immediate balance percent. Predictors: (Constant) DHI score, age, obesity, control or experimental, gender, baseline balance percent, baseline balance score.

When holding baseline balance constant, baseline balance score, baseline balance percent, and DHI score are significant. Table 3 explains 79% of the variance in the change in balance percent. The data suggests that if a subject is obese, there is an increase of five percentage points that they are more likely to have a diminished balance score and fall in comparison to a subject that is non-obese (p=0.011).

Table 4. Multiple linear regression explaining immediate change in baseline balance score and age.

Variable	***Coefficient***	***Standard Error***	***t***	***Significance***	***95% Confidence Interval***
Constant	107.360	8.306	12.926	p=0.000	90.034 to 124.686
Age	-0.233	0.085	-2.741	p=0.013	-0.410 to -0.056
BMI	0.038	0.165	0.230	p=0.821	-0.306 to 0.382
Gender	-0.410	1.019	-0.403	p=0.691	-2.536 to 1.716
Model Summary	**Observations**	**F**	**Significance**	**R^2**	**Mean Square**
	24	8.085	P < 0.001	0.780	126.350

Dependent variable: Baseline balance percent. Predictors: (Constant) Age, BMI, gender.

Table 4 explains that when other demographic data is held constant there is a 78% of the variance. This indicates age can predict baseline balance score, baseline balance percent, maximum heart rate achieved, immediate posttest balance score, terminal posttest balance score, and terminal posttest balance percent. While age was controlled based on the inclusionary and exclusionary design of the study, age was found to be a potential confounder. When BMI and gender was held constant, for each additional year of age, the baseline balance percent decreases by 0.23 percentage points (p=0.013; 95% CI -0.410 to -0.056).

Table 5. Multiple linear regression explaining immediate change in baseline balance score and gender.

Variable	*Coefficient*	*Standard Error*	*t*	*Significance*	*95% Confidence Interval*
Constant	6.079	2.119	2.868	p=0.010	1.658 to 10.500
Gender	-4.439	1.699	-2.613	p=0.017	-7.982 to -0.895
Baseline Balance Score	-0.261	0.086	-3.019	p=0.007	-0.441 to -0.081
Control or Experimental	3.224	1.710	1.885	p=0.074	-0.344 to 6.792
Model Summary	**Observations**	**F**	**Significance**	**R^2**	**Mean Square**
	24	6.342	P < 0.003	0.488	106.512

Dependent variable: Change in balance score. Predictors: (Constant) control or experimental, baseline balance score, gender.

Holding all other variables constant, table 5 explains the significance of subject gender. Reflecting on Table 1, female subjects increase balance percentage after fatiguing activity by about 4.3 percentage points (p=0.030). Table 4 explains that immediately after exercise, females are more likely to be closer to their original baseline balance score (p=0.017). However, after a period of recovery, males return to their original baseline balance score at a faster rate than females. From these findings, delayed onset balance decline (DOBD) is more pronounced among women.

Table 6. Multiple linear regression explaining post-test change in baseline balance score and gender.

Variable	***Coefficient***	***Standard Error***	***t***	***Significance***	***95% Confidence Interval***
Constant	6.079	2.119	2.868	p=0.010	1.658 to 10.500
Gender	-4.439	1.699	-2.613	p=0.017	-7.982 to -0.895
Post-Baseline Balance Score	0.739	0.086	8.545	p=0.000	0.559 to 0.919
Control or Experimental	3.224	1.710	1.885	p=0.074	-0.344 to 6.792
Model Summary	**Observations**	**F**	**Significance**	**R^2**	**Mean Square**
	24	31.593	P < 0.001	0.826	530.569

Dependent variable: Post-Balance score. Predictors: (Constant) control or experimental, baseline balance score, gender.

This collection of predictors accounts for 82% of the variance of post-test change in baseline balance score. Holding all other variables constant, women can be expected to have 4.44 points lower balance score than men and subjects in the experimental group have 3.2 points higher post-test balance scores.

Table 7. Multiple linear regression explaining duration until baseline balance score is reached.

Variable	***Coefficient***	***Standard Error***	***t***	***Significance***	***95% Confidence Interval***
Constant	73.094	23.140	3.159	p=0.005	24.826 to 121.363
Control or Experimental	127.622	32.545	3.921	p=0.001	59.734 to 195.510
Duration on TM (sec)	0.169	0.071	2.378	p=0.028	0.021 to 0.317
Change immediate balance percent	-8.409	1.810	-4.647	p=0.000	-12.184 to -4.634
Model Summary	**Observations**	**F**	**Significance**	**R^2**	**Mean Square**
	24	50.301	P < 0.001	0.883	139852.149

Dependent variable: Duration until baseline in seconds. Predictors: (Constant) Change immediate balance percent, duration on TM in seconds, control or experimental.

Table 7 provides the importance of subject performance within the experimental group increases duration time towards recovery. According to Table 1, recovery duration is related to control/treatment group (p<0.001), duration on treadmill (p<0.001), grade percent on treadmill (p<0.001), whether HR was met (p<0.001), immediate posttest percent (p=0.001), and change in immediate balance percent (p<0.001). By comparison, a subject who was grouped in the experimental group, it took them 2 extra minutes (128 seconds) to recover (to get back to baseline values; p=0.001) when compared to a subject in the control group.

Chapter 5: Discussion

The vestibular system provides information to the central nervous system (CNS). Once the CNS receives the somatosensory information the body is able to recognize the body's orientation in space. When the vestibular system experiences progressive degeneration, the actions are compromised. Degeneration usually occurs by aging, poor health, or damage and consists of the removal or reduction of labyrinthine hair cells and vestibular receptor ganglion cells. If this occurs, it is difficult for the CNS to perceive, organize, and execute sensorial information that is being relayed from the eyes and ears.

Overall, our subject population commonly characterized their symptoms to include a spinning sensation prior to their official diagnoses or treatment to their vestibular disorder. Generally, the spinning sensations would lead to the subject to experience inaccurate spatial orientation which would lead to their lack of balance. Although a person may experience a vestibular disorder at any age, it is most commonly diagnosed in individuals over the age of 65 years, thus a positive correlation between old age and diagnosed vestibular disorders is established.

When a person is diagnosed with a vestibular disorder or experiences spinning sensations on a regular occurrence, their activities of daily living may be hindered. For example, climbing up a ladder to hang a picture frame or binding down to grab something may cause a person's spatial orientation and vestibular system to be challenged. When a person is unable to adjust to their spatial orientation based on the stimuli received by the vestibular system, brain, and eyes, their ability to balance and maintain an upright position becomes impossible. Often falls will occur. From this experience, individuals increase their chances of injury which creates the inviting environment of developing the fear of falling.

Whether falling becomes a repeated occurrence or a one time scenario, geriatrics begin to limit their activities of daily living based on their fear of falling. From this limitation, individuals begin to lead a less active lifestyle. When an individual moves less, they fall into the habit of not regularly exposing their body to fatiguing stressors which help promote endurance and other benefits in which exercise provides. Through this process, their bodies learn to adapt to a sedentary lifestyle of restricted movement. Although some physicians may recommend vestibular patients to restrict their physical stress levels, it is important that patients do not exclude exercise entirely.

From this study it was found that subjects who had maintained an active lifestyle had a lower BMI. As a result of subjects that had lower BMI they were more likely to have an increase in their Postural Stability Score (PSS). In comparison, subjects who were less active had a higher BMI which had a positive correlation of having a decrease in their PSS. The results indicated in both Table 2 and Table 3 explained that a decrease in PSS based on BMI and obesity would lead to the subject to experience a higher probability of falling when possessing a vestibular disorder.

Ultimately, the findings suggest that it is important for individuals who possess a vestibular disorder to stay active and maintain a physical activity plan that is controlled and safe for the individual to participate in. Physical activity is important to maintain because it will expose the individual to a consistent physical stress that may help promote exercise endurance and a healthy lifestyle. Physical activity among geriatric populations should be considered as important as to those in younger populations for the same reason of preventing cardiovascular and other underlying health issues associated with sedentary lifestyles.

Limitations

Due to the time constraints and limited resources, there were various issues which may have affected results and outcomes of the study. The lack of a large subject population to complete this study provides a limitation because it does not provide a full representation of all geriatrics who possess a vestibular disorder on a large scale. In short, all subjects were derived from the same clinic and were chosen to participate in the study based on convince random sampling. This provides as a limitation because the subjects included in the study may not be a full representation of all geriatrics with vestibular disorders. This is based on the knowledge that all subjects were located in the same geographic region. Although they could be from different cultures, having the subjects from the same geographic region provides a limited view in comparison to a person that lives in a different cultures, climate, or environment.

Lastly, the study did not collect subject profiles of history of medication that could potentially impair balance nor did it included the analysis of blood pressure.

Future Research

There are many aspects of this study that could have been improved or altered to ensure a more accurate representation of assessing limits of stability, measures to induce fatigue, and improving self report questionnaires. Although this study covered many variables, more data points would have been desired throughout the data collection process in order to properly monitor the effects fatigue has on postural stability. In addition to monitoring the variables recorded in this study, monitoring vestibular rehabilitation programs and exercise would have been a preferred variable to have measured over the course of a 12 week rehabilitation program. By following a full 12 week vestibular rehabilitation program, variables may help determine if exercise at a consistent rate helps improve postural stability. Finally, if the study included and tested more subjects, the results would provide a more accurate representation of postural stability among geriatrics with vestibular disorders.

Practical Application

As obesity roles continue to increase, it is important for a patient's overseeing physician or clinical personnel to consider the effects of the patient's health profile. Patients with a risk of falls (e.g., those with a diagnosed balance disorder) are commonly emphasized to avoid physical activity owing to the elevated risk of fall-related injury. However, the results of this study indicate that minimizing physical activity may exacerbate fall risk in the future, while the engagement in safe, structured exercise may have a protective effect. Thus, obesity should be considered and addressed similarly to blood pressure cholesterol and components of a routine physical among the elderly.

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APPENDIX A

Subject History Questionnaire

1. I am ___________________ years old

2. Gender: Male Female Other:____________________

3. Please list any existing medical conditions that involve the eyes, heart, lungs, head, or brain: (If none skip to #5) ____

4. Have you ever sought medical attention/surgery after a fall? Yes / No

If Yes please explain: ____

5. Please list and date any previous surgeries that involved: (If none skip to #7)

Feet: ____

Knee:____

Legs:____

Hip: ____

Head/Brain: ____

Heart: ____

Lungs:____

Eyes:____

6. Have you been diagnosed with a vestibular disorder? Yes / No

If Yes please state when you were diagnosed: _____________________________

7. Have you consumed water within the past three hours? Yes / No

8. Have you consumed two or more alcoholic drinks in the last 24hrs? Yes / No

9. How many hours of sleep have you had in the last 24 hours? ____________________

10. Have you consumed food within the last three hours? Yes / No

11. Please list prescriptions you are currently taking: ____________________________

APPENDIX B

Dizziness Handicap Inventory

Instructions: The purpose of this scale is to identify difficulties that you may be experiencing because of your dizziness. Please check “always”, <u>or</u> “no” <u>or</u> “sometimes” to each question. Answer each question only as it pertains to your dizziness problem.

	Questions	Always	Sometimes	No
P1	Does looking up increase your problem?			
E2	Because of your problem, do you feel frustrated?			
F3	Because of your problem, do you restrict your travel for business or pleasure?			
P4	Does walking down the aisle of a supermarket increase your problem?			
F5	Because of your problem, do you have difficulty getting into or out of bed?			
F6	Does your problem significantly restrict your participation in social activities, such as going out to dinner, going to movies, dancing or to parties?			
F7	Because of your problem, do you have difficulty reading?			
F8	Does performing more ambitious activities like sports, dancing, and household chores, such as sweeping or putting dishes away; increase your problem?			
E9	Because of your problem, are you afraid to leave your home without having someone accompany you?			
E10	Because of your problem, have you been embarrassed in front of others?			
P11	Do quick movements of your head increase your problem?			
F12	Because of your problem, do you avoid heights?			
P13	Does turning over in bed increase your problem?			
F14	Because of your problem, is it difficult for you to do strenuous housework or yard work?			
E15	Because of your problem, are you afraid people may think that you are intoxicated?			
F16	Because of your problem, is it difficult for you to go for a walk by yourself?			
P17	Does walking down a sidewalk increase your problem?			
E18	Because of your problem, is it difficult for you to concentrate?			
F19	Because of your problem, is it difficult for you to walk around your house in the dark?			
E20	Because of your problem, are you afraid to stay home alone?			
E21	Because of your problem, do you feel handicapped?			
E22	Has your problem placed stress on your relationship with members of your family or friends?			
E23	Because of your problem, are you depressed?			
F24	Does your problem interfere with your job or household responsibilities?			
P25	Does bending over increase your problem?			

Scoring for Dizziness Handicap Inventory

Eval	**Total Functional**	**Total Emotional**	**Total Physical**	**TOTAL SCORE**
Reassess #1				
Reassess #2				
Reassess #3				
Reassess #4				

Always = 4

Sometimes = 2

No = 0

P = physical

E = emotional

F = functional

Subscales

<u>Notes:</u>

1. **Subjective measure of the patient's perception of handicap due to the dizziness**
2. **Top score is 100 (maximum perceived disability)**
3. **Bottom score is 0 (no perceived disability)**
4. **The following 5 items can be useful in predicting BPPV**
    - **Does looking up increase your problem?**
    - **Because of your problem, do you have difficulty getting into or out of bed?**
    - **Do quick movements of your head increase your problem?**
    - **Does bending over increase your problem?**
5. **Can use subscale scores to track change as well**

APPENDIX C

BORG RPE SCALE

Rating	Perceived Exertion
6	No Exertion
7	Extremely Light
8	
9	Very Light
10	
11	Light
12	
13	Somewhat Hard
14	
15	Hard
16	
17	Very Hard
18	
19	Extremely hard
20	Maximal Exertion