2014

COMPARISON OF SHOD VS NONSHOD ON BALANCE AND POSTURAL SWAY IN OLDER ADULTS

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COMPARISON OF SHOD VS NONSHOD ON BALANCE AND POSTURAL SWAY
IN OLDER ADULTS

A Thesis

Presented To

Eastern Washington University

Cheney, Washington

In Partial Fulfillment of the Requirements

for the Degree

Master of Science

By

Annika Vyakhk

Spring 2014

THESIS OF ANNIKA VYAKHK APPROVED BY

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MASTER’S THESIS

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ABSTRACT

Among older adults, falls are the leading cause of death due to injury and hospitalization. With age, cutaneous sensation in the foot sole diminishes, contributing to balance impairment. Discovering an effective method for retraining the mechanoreceptors of the feet will possibly increase balance control. Training the different physiological systems involved in balance maintenance is important for decreasing fall risks. The purpose of this study was to investigate whether a balance training intervention involving barefoot training (BT) yields better static and dynamic balance, and postural sway values than a group wearing shoes (WS). Twelve older adults (65-92 years) were randomly assigned into a BT or WS group. Both groups participated in 50 minute exercise sessions, three days a week, for six weeks. The sessions included strength, balance, and stretching exercises based on the Stay Active and Independent for Life (SAIL) program. All participants completed a functional reach test (FRT), single-leg stance (SLS), timed up and go (TUG), 30 second chair stand (CS), and postural sway analysis with eyes open (SEO) and eyes closed (SEC). A repeated measures 2x6 ANOVA found no significant difference between the mean difference of the two groups. Pearson correlations were run to identify relationships between leg strength and all variables, pre to pre scores, and post to post scores. A two-tailed paired samples *t* test was used to compare mean differences from pre (Pre) to post (Post) scores. PreTUG and PreFRT (r = -.65, p = .022) had a significant negative relationship, as well as, PreTUG and PreCS (r = -.71, p = .009). A significant positive relationship was noted between the PreSEC and PreSEO. PostCS and PostTUG (r =-.85, p = .000) and PostCS to PostSEC (r = -.58, p = .05) remained significant. A significant association was found between the PostSLS and PostFRT ($r = .63$, $p = .027$). PreFRT to PostFRT means had a significant difference ($p = .000$), as did PreCS to PostCS ($p = .000$). No difference was found between the two groups in static and dynamic balance or postural sway. The results suggest that leg strength is an important factor in dynamic balance and postural sway without visual input. Also, static balance and leg strength can be significantly improved in older adults participating in a six week balance and strength training intervention.

ACKNOWLEDGEMENTS

Foremost, I would like to express my appreciation and gratefulness for Dr. Wendy Repovich. Her support, advice, and continual strive for success provided inspiration and dedication. Moreover, the knowledge and experience gained through her advisement has equipped me with the tools necessary for success in the future.

Additionally, I would like to thank Dr. Emily Messina for further comments and suggestions on the betterment and completion of this document. Her constant input helped prepare me for my thesis proposal and defense. Without Brenda Jurich and the volunteers at Rockwood Retirement South Hill this project couldn't have been accomplished, so a special thanks to them.

Lastly, my sincere appreciation goes out to my family, friends, and fellow grad students who offered endless support, confidence, and optimism during moments of hopelessness. Particularly, I would like to express my gratitude for my husband who continues to believe in me and pushes me to grow in my educational and professional career.

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Chapter 1

Introduction

According to the Department of Health and Human Services (DHHS), there were 39.6 million persons aged 65 or older in 2009 (DHHS, 2011). This value is anticipated to nearly double by 2030, reaching 72.1 million. The main contributor to this rapid growth is the aging Baby Boomers. This specific population is comprised of individuals that were born between 1946 and 1964, who began turning 65 in 2011 and are expected to represent 20% of the United States population by the year 2030 (Federal Interagency Forum on Aging-Related Statistics, 2012). This growing older population creates a need to provide exercise facilities and programs that address their specific concerns such as maintaining independence, activities of daily living (ADLs), quality of life (QOL), and preventing falls, which is one of the most debilitating things that can happen to older adults.

About one-third of adults aged 65 and older are expected to fall annually (Shaffer & Harrison, 2007; Sherrington et al., 2008). The frequency of falls continues to rise with increasing age; 40% of the community-dwelling individuals over the age of 80 will experience a fall (Hauer et al., 2001). The alarming prevalence of falls within the older population creates a major healthcare cost issue. An estimated $32 billion will be spent on fall-related costs by the year 2020 (Shaffer & Harrison, 2007). Among older adults, falls are the leading cause of death due to injury and hospitalization (Stevens, 2005). Training the different physiological systems involved in balance maintenance is important for decreasing fall risks.

Physical activity benefits the aging population in many ways, including slowing the physiological transformations that occur with age (American College of Sports Medicine [ACSM], 2010). If deterioration is slowed, especially in the physiological systems involved in balance maintenance, falls can be decreased. Despite gains made, the older population remains the least active out of all age groups (ACSM, 2010). The combination of physiological changes associated with aging and a decrease in physical fitness results in the increased vulnerability to falling among older adults.

Risk of Falling

Several of the risk factors involved in falling include a decrease in muscular strength, as well as a decline in balance and gait (Faber, Bosscher, Chin A Paw, & van Wieringen, 2006; Hauer et al., 2001; Sherrington et al., 2008). Older adults with impaired balance systems have a difficult time maintaining stability or recovering from a perturbation which leads to an increased risk of falling (Shephard, 1997). In the older population, for those who are osteoporotic, the injuries most commonly sustained from falls include fractures of the hip, wrist, vertebrae, or forearm (Stevens, 2005). The physical injuries that arise from a fall decrease independence among the older population. In turn, the ability to perform ADLs becomes difficult, resulting in a sedentary lifestyle. Only about 21% of the older population participates in regular physical activity (ACSM, 2010). An inactive lifestyle leads to a decline in physical fitness and an increase of fall risk factors. This reduced physical fitness also aids in the decrease of the physiological systems that maintain balance, leading to issues with stability.

Women tend to experience a higher fall injury rate than men. This value is as high as 72% more in females than males (Stevens, 2005). Females also display greater postural sway than males do, regardless of the age group (Shephard, 1997). The increased sway is associated with the reduced muscle mass noted in females compared to males (Shephard, 1997). This fall risk factor decreases the ability to maintain stability, as well as recover from a disturbance in balance.

Physiology of Balance

Multiple sensorimotor control systems including the vestibular, vision, proprioception, and musculoskeletal systems, are involved in maintaining balance (Konrad, Girardi, & Helfert, 1999; Rodgers & Mille, 2003). When the balance systems are compromised, the body's efficiency of monitoring stability decreases, resulting in a fall. An inverse relationship has been noted between age and balance (Bohannon, Larkin, & Cook, 1984). Each system has a specific function and the aging process affects them differently.

The vestibular apparatus, which includes the utricle, saccule, and semicircular canals, provides feedback on the orientation and movement of the head (Guyton, 1971; Marieb & Hoehn, 2010). This group of organs comprises the greatest percent of involvement in balance. Static balance in older adults has been researched and reported that the vestibular comprises 22% of balance control (Lord, Clark, & Webster, 1991). In an aging individual, this sensory organ begins to lose the sensory cells that detect movement, negatively affecting the ability to maintain equilibrium (Guyton, 1971; Marieb & Hoehn, 2010).

The intricate visual system involves the translation of light rays into an image (Anthony & Thibodeau, 1983; Guyton, 1971). When older adults were assessed for static balance without visual input, postural sway increased almost one and a half times (Lord et al., 1991). With age, a decline has been noted in this system; the elastic property of the lens decreases, reducing the visual input sent to the visual cortex (Anthony & Thibodeau, 1983). Cataracts, which are the clouding of the lens, are a common disorder among older adults (Saxon & Etten, 1994; Taylor & Johnson, 2008). By the age of 80, over half of older Americans have a cataract or have had cataract surgery (National Eye Institute, 2009). The consequence of an untreated cataract is reduced awareness of the surrounding environment. Without visual input, adults over the age of 70 were unable to balance on one leg longer than 13 seconds compared to 75% of younger adults aged 20-39 years who could balance for a minimum of 30 seconds (Bohannon et al., 1984).

During a perturbation, feedback from the sensory systems travels to the brain where the motor cortex initiates the activation of skeletal muscles for recovery (Guyton, 1971). With age, there is a decrease in the regeneration of muscles, sarcopenia, due to reduced hormonal levels (Wilmore, Costill, & Kenney, 2008). Fibrosis, the translation of muscle fibers to connective tissue, also occurs in certain muscles making them inflexible (Anthony & Thibodeau, 1983). These reductions and weaknesses in muscles, especially of the lower limbs, affects balance maintenance by decreasing the ability to utilize the appropriate muscles required for stability and recovery (Lord et al., 1991).

Sensory organs located in the joints, muscles, tendons, neck, and feet all relay information on the orientation of the body to the cortex (Guyton, 1971; Marieb & Hoehn, 2010; Shaffer & Harrison, 2007; Shephard, 1997). The older population displays losses in the stimulation of these proprioceptors, including cutaneous sensation in the feet, when compared to a younger population (Bohannon et al., 1984; Shephard, 1997). With these diminished inputs, maintaining balance and the ability to respond to a disturbance of equilibrium are both negatively affected.

Foot Mechanoreceptors

In addition to the mechanoreceptors in the muscles and joints, there are balance mechanoreceptors located in the feet. These mechanoreceptors in the plantar soles of the feet provide proprioceptive feedback on the orientation of the body when it moves off balance (Guyton, 1971; Marieb & Hoehn, 2010; Shaffer & Harrison, 2007). They cause a reflex reaction to the leg in the direction moved or opposing muscle to fire to return the body back upright. When sight is lost these mechanoreceptors become dominant but the reaction is much slower so the sway is greater. The process of aging decreases the sensory perception that the cutaneous sensation of the foot sole contributes to balance maintenance (Maki, Perry, Norrie, & McIlroy, 1999; Manor et al., 2010; Morioka, Hiyamizu, Fukumoto, Kataoka, & Yagi, 2009; Spirduso, 1995). A reduction in tactile sensitivity also displays impairments in static and dynamic balance (Lord et al., 1991). The strong correlation that exists between postural sway and plantar sole tactile sensitivity supports the importance of the sensory feedback received from mechanoreceptors for maintaining stability (Menz, Morris, & Lord, 2005). Improvements in plantar tactile sensation benefit individuals by allowing greater mobility and decreasing fall risks (Menz et al., 2005).

Tactile Sensitivity Training

Research on fall prevention has suggested several things. Little can be done in the vestibular system (Spirudo, 1995), cataract surgery increases the visual input (Saxon & Etten, 1994; Taylor & Johnson, 2008), maintaining strength improves balance (Hue, Seynees, Ledrole, Colson, & Bernard, 2004; Lord et al., 1991; Shaffer & Harrison, 2007), and finally, focusing on tactile training helps improve postural sway and balance (Lord et al., 1991; Maki et al., 1999). There are multiple exercise programs available to improve balance in older adults and decrease fall risks (Hauer et al., 2001; Sherrington et al., 2008).

The research available on tactile sensitivity training is limited to programs that utilize foam hardness discrimination, mechanical facilitation, and plantar-surface boundary facilitation (Maki et al., 1999; Morioka et al., 2009). In these studies the participants are barefoot and the mechanoreceptors are stimulated with additional materials including foam rubber and flexible tubing. To date, no studies have investigated the simple exposure of the mechanoreceptors through a barefoot technique without additional tools to stimulate the sensory organs. Interventions involving the facilitation of the mechanoreceptors have demonstrated improvements in the afferent nerve activation in the feet and decreased postural sway (Lord et al., 1991; Maki et al., 1999).

When participants aged 65 and older, underwent a retraining of the mechanoreceptors, researchers found that an improvement in cutaneous sensation increased the ability to react to a disturbance in balance (Lord et al., 1991; Maki et al., 1999). After older subjects were tested with their eyes open on a foam surface, which decreased peripheral feedback, postural sway increased 2.58 times (Lord et al., 1991). This increase in sway indicated that peripheral sensation was a major contributor in the maintenance of static stability. Individuals with diminished cutaneous sensation also displayed a greater sway in posture than those with visual impairments (Lord et al., 1991; Maki et al., 1999; Manor et al., 2010).

Another factor that may affect cutaneous sensation is footwear. The varying soles of footwear can have a negative effect on the mechanoreceptors by limiting the amount of pressure stimulating them (Hijmans, Geertzen, Dijkstra, & Postema, 2007; Menz & Lord, 1990; Robbins, Gouw, & McClaran, 1992). Depending on the differing design of available footwear, the ability to balance is affected. Midsole thickness and density, heel height, and slip resistance are all factors that may interfere with stability control. Regardless of the type of shoe that the participants are utilizing, balance is affected similarly by potentially decreasing sensation to the mechanoreceptors due to the interference between the sensory organs and the ground.

Inadequate balance and increased postural sway also limit the ability to perform movements efficiently, affecting the recovery from a perturbation (Shephard, 1997). Providing the older population with some type of an intervention for training the physiological systems involved with monitoring stability, improves balance and thus may decrease the prevalence of falls, as well as increase functionality (Carter et al., 2002). While the diminished peripheral sensation noticed with age is usually irreversible, current research on the positive effects of training the sensory organs in the feet is still emerging (Menz et al., 2005). Due to the limited research on tactile sensitivity training and the positive gains in balance with this type of training, the purpose for this study was to expand the research on improving sensory feedback and thus balance in older adults through the investigation of an intervention using a barefoot approach.

Purpose Statement

The purpose of this study was to investigate whether a balance training intervention involving barefoot training (BT) yielded better static balance, dynamic balance, and postural sway values than a group wearing shoes (WS).

Null Hypotheses

The first null hypothesis was that there would be no significant difference in static balance between the barefoot balance training group and the shoe balance training group. The second null hypothesis was that there would be no significant difference in dynamic balance between the barefoot balance training group and shoe balance training group. The third null hypothesis was that there would be no significant difference in postural sway between the barefoot balance training group and shoe balance training group. The alpha level was set at $p \leq .05$ for all three hypotheses.

Delimitations, Limitations, and Assumptions

The participants of the study were delimited to a convenient sample of 12 older adults from a retirement center in Spokane, WA. The balance and strength training exercises were delimited to the Stay Independent and Active for Life (SAIL) program (Morrison, Shumway-Cook, & Silver, 2008) with additional balance exercises (Madureira et al., 2007). Inter-participant variability of footwear was a limitation because there was no control of the shoes, which created a variety of designs in athletic footwear and possibly influenced the balance gains among the participants. It was assumed that all of the participants would maintain their normal daily activities. It was also assumed that all participants were honest in disclosing medical history information that may have excluded them from the study.

Summary

This chapter has discussed the growing older population, risks of falling, and physiological systems involved in balance maintenance. In further detail the introduction covered foot mechanoreceptors and the type of tactile sensitivity training that is available. The purpose, null hypotheses, delimitations, limitations, and assumptions were also included in this chapter.

Chapter 2

Review of Literature

Introduction

The purpose of this study was to investigate whether a balance training intervention involving BT yields better static balance, dynamic balance, and postural sway values than the group WS. The review of literature on improving balance in older adults will be discussed in this chapter, as well as the physiological systems involved in balance maintenance and the specific training principles associated with balance training.

Physiological Systems in Balance Maintenance

The ability to balance involves maintaining the body's center of mass within its base of support (Maki et al., 1999). Balance is a multidimensional concept that requires varying inputs from the body. It is maintained by multiple sensorimotor control systems; including feedback from the vestibular, vision, proprioception, and musculoskeletal systems (Konrad et al., 1999; Rodgers & Mille, 2003).

Vestibular system. The vestibular apparatus is composed of the utricle, saccule, and three semicircular canals located in the inner ear (Guyton, 1971). This sensory organ identifies any sensations involved with equilibrium, mainly the orientation and movements of the head or position of the head in line with the body (Guyton, 1971; Marieb & Hoehn, 2010). The utricle and semicircular canals are important contributors for the maintenance of equilibrium (Best & Taylor, 1963; Guyton, 1971). When an individual experiences a disruption of equilibrium the macula which contains otoconia, tiny calcified crystals, in the utricle are stimulated; relaying information to the spinal cord and brain (Guyton, 1971). The integration of this sensory input results in a correctional response by muscles to maintain stability (Anthony & Thibodeau, 1983).

As opposed to the detection of linear acceleration by the utricle, the semicircular canals recognize rotational movement of the head in all planes of motion (Best & Taylor, 1963; Guyton, 1971). Crista, tiny hair cells, located in the canals are stimulated by fluid movement when the head rotates; sending signals to the flocculonodular lobes of the cerebellum (Guyton, 1971). The cerebellum maintains equilibrium by controlling postural reflexes as well as the synergists of the agonist muscles (Anthony & Thibodeau, 1983). The basal ganglia transmits the impulse to the cerebral cortex, which processes memory and thinking. From here the cerebellum adjusts for impulses to the motor cortex and then to the appropriate muscles to correct for mal-equilibrium (Guyton, 1971). When an individual is suffering from Parkinson's disease, the neurons in the substantia nigra decrease, which results in difficulty performing voluntary movements (Guyton, 1971; Marieb & Hoehn, 2010). By the age of 70 a person may lose 40% of the sensory cells located in the vestibular apparatus (Spirudo, 1995). This loss creates inefficiency in controlling stability, increasing postural sway and contributing to a greater chance of falling.

Visual system. Another important factor contributing to the homeostasis of balance is vision (Woollacott & Shumway-Cook, 1990). Vision provides images of the environment around the body. The retina contains two types of photopigment containing receptors: the cones which identify specific colors of red, green, and blue; and the rods, which are very light sensitive, but not color sensitive (Anthony & Thibodeau, 1983). The majority of cone concentration is located in the fovea centralis of the retinal macula

(Guyton, 1971; Marieb & Hoehn, 2010). This is why when attempting to focus on an object, turning the head to look straight at it enables the fovea centralis to be in line with the object and maximizes the amount of visibility. Light rays travel through a transparent lens, stimulating the rods and cones, which send a signal to the retina and the optic nerve fibers. From the optic nerve the signal travels to the visual cortex of the occipital lobe (Anthony & Thibodeau, 1983; Guyton, 1971). This visual input is integrated by the visual cortex and provides information on our body's orientation in regards to the objects around it.

As an individual advances in age, the lenses decrease in elasticity, negatively impacting vision by reducing the ability of accommodation for near vision (Anthony & Thibodeau, 1983). Far-sightedness is a result of this degenerating effect, creating the necessity for corrective lenses. Even with a combined loss of vestibular and proprioceptive feedback, an individual is capable of maintaining balance as long as vision is not impaired and bodily movements are performed slowly (Guyton, 1971). In support of this, older adults appeared to be similar to younger adults in that visual input is the strongest control for balance (Woollacott & Shumway-Cook, 1990). When the visual input was absent the older adults over the age of 70 years did not exceed 13 seconds on a single-leg stance (Bohannon et al., 1984). In younger group (20-39 year olds) 75% could balance for at least 30 seconds in the same condition. This suggests that vision loss or decrements that occur with aging result in a decrease of task completion, which depends on visual input, leading to reduced performance. The most common eye disorder among the older population is cataracts, which is a clouding of the lens (Saxon & Etten, 1994; Taylor & Johnson, 2008). Cataracts limit the ability to see surroundings clearly, reducing the visual input involved in equilibrium maintenance. Older adults, that have experienced a fall, were reported to have poorer visual acuity, when compared to non-fallers (Lord, Ward, Williams, & Anstey, 1994). When the visual input is limited, due to health or aging issues, performance of ADLs are reduced.

Proprioception system. The body contains different types of sensory receptors that function in producing sensations; such as touch, pressure, vibration, temperature, and pain (Anthony & Thibodeau, 1983). These receptors include the deep receptors or proprioceptors, which provide sensory input on the body's movements and position (Anthony & Thibodeau, 1983; Guyton, 1971). Localization of the kinesthetic receptors is within muscles, tendons, and joints (Anthony & Thibodeau, 1983; Guyton, 1971). Muscle spindles are located within the muscle fibers (Marieb & Hoehn, 2010). When the muscle is stretched, the muscle spindles reflexively contract to prevent overstretching and fiber damage. Sensation of muscle length provides feedback on the sensation of position and movement of the body. Proprioceptors in the joint capsules include the Ruffini endings and joint kinesthetic receptors; these offer kinesthetic sense (Marieb & Hoehn, 2010; Shaffer & Harrison, 2007).

Sensory impulses from the somatosensory systems, including touch, vibration, kinesthetic, and pressure senses, are transmitted to the spinal cord through the posterior roots and continue through the dorsal columns allowing a quick travel to the cerebral cortex for integration (Guyton, 1971). The dorsal column pathway allows for the transmission of signals at high-velocities permitting the central nervous system to control further movements when an individual is moving rapidly (Guyton, 1971). This control of subsequent movements during motion maintains equilibrium. With increasing age, the proprioceptors located in the joints diminish in identifying the positions of the limbs in motion (Shephard, 1997). The lack of an efficient sensory input from the proprioceptors on limb displacements leads to an impaired control of balance because the brain is incapable of registering the change in position quickly enough to respond adequately.

Neck proprioceptors. Proprioceptors in the neck muscles also play a major role in maintaining equilibrium by providing the central nervous system with information on the orientation of the head (Guyton, 1971). Sensory input from the proprioceptors in the neck is transmitted to the brain stem where it is processed and sorted (Guyton, 1971). The resultant of this process is a transmission of the signal to the cerebral cortex for the initiation of the correction for equilibrium by postural muscles (Guyton, 1971).These proprioceptors are especially important because they allow for regular movements of the head when the body is stationary, without causing the vestibular apparatus to respond for a disturbance in equilibrium when one does not exist (Guyton, 1971). However, in the achievement of a new position, the vestibular apparatus informs the individual of a distress in equilibrium. These proprioceptors located in the neck muscles slowly decrease in function with age, leading to diminished perception of the position of the neck and head with respect to the body (Wyke, 1979). This results in the inability of the proprioceptors to provide the brain with information on the position of these body segments, decreasing equilibrium control.

Plantar sole proprioceptors. Meissner’s corpuscles and Pacinian corpuscles are both mechanoreceptors that are located in the soles of the feet and relay information involving proprioception (Guyton, 1971; Marieb & Hoehn, 2010; Shaffer & Harrison, 2007). With age, cutaneous sensation in the foot sole diminishes, contributing to balance impairment (Maki et. al., 1999; Manor et al., 2010; Morioka et al., 2009; Spirduso, 1995). A declination of the tactile sensation affects both static and dynamic balance (Lord et al., 1991). When visual and auditory input are excluded, the tactile sensory information from the feet provide sufficient feedback for the maintenance of stability (Morioka et al., 2009) A strong correlation is found between tactile sensitivity of the bottom of the foot and postural sway (Menz et al., 2005). When tested for static and dynamic balance, older adults displayed greater scores in two of the three tests when in a barefoot condition (Lord & Bashford, 1996). Thus, it is evident that tactile sensory input from the feet plays a major role in providing the brain with feedback on the status of balance. A discovery of an effective method for retraining the mechanoreceptors in individuals that have impairments could possibly increase balance control.

Musculoskeletal system. Another essential component involved in balance maintenance is the musculoskeletal system (Shaffer & Harrison, 2007). When the body experiences a disturbance in equilibrium, impulses from the sensory systems are transmitted to the brain. Once the signal reaches the motor cortex an initiation of skeletal muscle contractions occur (Guyton, 1971). The availability and productivity of these muscles is a contributor to postural control. A vital element in maintaining stability is the efficiency of the muscular activity of the eye muscles (Best & Taylor, 1963). These muscles allow appropriate eye movements required to observe the objects around the body and avoid colliding with them. With aging, a process of fibrosis occurs within certain muscles resulting in the replacement of muscle fibers with connective tissue (Anthony & Thibodeau, 1983). This exchange of tissue causes a decline in muscular strength and its properties within the older population. The rate at which muscles are created also slows down in older adults, but the breakdown rate is unchanged; this imbalance causes a loss of muscles (Wilmore et al., 2008). This decline in protein synthesis is likely the result of decreased hormone production in the aging adults (Wilmore et al., 2008).

A reduction in the fast twitch muscles is shown with age, but the aging factor itself being the main reason behind it still remains unclear (Shephard, 1997; Wilmore et al., 2008). A decrease in this fiber type may be due to the decreased mobility within the older population which leads to muscular atrophy. The absence of weight-bearing exercises may also be a factor. Specific Type 2 muscles could be the main contributors in maintaining balance, as was found in the research by Rogers & Mille (2003) where atrophy of certain fast twitch muscle fibers in the gluteus medius prevented recovery from a disturbance. Weakness in the ankle dorsiflexor muscles may also be associated with poor static balance (Lord et al., 1991).

Muscular power is another component that is reduced with age, but has been shown to be retrainable in older adults, even among individuals over 90 (Cadore et al., 2013). The response time for recuperation from a balance disturbance also declines with age, leading to an inability to signal muscles for a quick recovery from a postural perturbation (Shephard, 1997). Certain factors, such as diminished joint movement and muscle activity with age, are part of the reason for slower reactions (Shephard, 1997). According to Spirduso (1995), a possible main contributor to the decreased response time with age is the diminished ability of the brain to process and integrate the information that it receives, resulting in an interrupted transmission of stimuli to the muscles.

Principles of Training

When creating an exercise program the basic training principles should be considered to ensure that the desired fitness goals for the individual are met. These general principles include specificity, individuality, progressive overload, periodization, and recovery (Wilmore et al., 2008). The same principles should be applied in a program for older adults because the diminishment in the ability to control balance leads to a decrease in functionality (Shephard, 1997). An increase in the maintenance of stability is produced in the creation of a balance training program, which implements these principles.

Specificity. Among the older population, exercise is administered with the aims of maintaining functional performance (Chandler & Hadley, 1996). Regardless of age, exercise benefits are attainable and similar improvements are noted across both the younger and older populations (ACSM, 2010). Exercises should mimic the movements that are required throughout the day for the increase of functionality. According to a meta-analysis on multifactorial and exercise-alone interventions, the exercise-alone interventions were approximately five times more effective in reducing the incidence of falls (Petridou, Manit, & Ntinapogias, 2009). These exercise-alone programs focused on balance and strength training and movement coordination, as opposed to the widened practices of the multicomponent programs, which included occupational therapy, home modification, and group activities. The reasoning behind this significance might have been that the exercise-alone programs included less information and a similar pattern during each visit, which is attractive to the older adult.

An evaluation of the different physiological systems involved in maintaining balance within the older adults prior to the initiation of a program is necessary (“An Introduction to Stay Active and Independent for Life: An Evidence-Based Intervention for Preventing Falls in Older Adults”, 2011). This will create an outline of the specific areas that require attention and allow for the tracking of progression. For the assessment of muscular strength, the 30 second chair stand (Jones, Rikli, & Beam, 1999) and bicep curl are simple tests that could be administered to gather upper and lower body strength values in older adults (“An Introduction to Stay Active and Independent for Life: An Evidence-Based Intervention for Preventing Falls in Older Adults”, 2011; York, Shumway-Cook, Silver, & Morrison, 2007). When measuring static balance the single-leg stance and functional reach tests are both reliable and valid (Duncan, Weiner, Chandler, & Studenski, 1990; Vellas et al., 1997). These tests are easy to set up and perform.

In measuring balance, no gold standard exists (Hertel, Gay & Denegar, D. R., 2002; Hijman et al., 2007) and a measurement of static balance alone would lack additional important information n stability (Jue et al., 2004). Therefore, dynamic balance also needs to be assessed; the timed up and go test is most commonly used for this (Podsiadlo & Richardson, 1991; Ries, Echfernach, Nof, & Blodgett, 2009). Posturography is the quantitative assessment of the body’s center of pressure displacement using a force platform (De Kegel et al., 2010; Topp, Mikesky, & Thompson, 1998). An analysis of postural sway has been correlated to predict certain functional tasks among older adults and provides information on the somatosensory feedback during balance control (Topp et al., 1998). This method measures postural sway medial to lateral as well as anterior to posterior. The test is brief and provides information on sway with visual input and without. All of these assessments of stability can provide a baseline value in which the administrator can see the weaknesses and strengths of the participant.

Specificity is utilized when there is a deficit in one of the systems compared to the others. With age, among other things, the cutaneous sensation in the feet decreases, limiting the amount of proprioceptive feedback provided. Focusing on this aspect of balance control can improve the feedback received in regards to the body's position. While there is minimal research available on tactile sensitivity training in older adults, the current methods, including the facilitation of the mechanoreceptors in the feet without any barriers, have shown balance gains in older adults (Maki et al., 1999; Morioka et al., 2009). The individuals with impaired tactile sensitivity should focus on retraining this system first and then supplementing other training approaches (Maki et al., 1999). To focus on the mechanoreceptors in the feet, the program must be modified towards training these sensory organs. A review of different interventions for older adults found that the combination of balance, musculature, and proprioceptive training displayed better results when compared to separate programs (Chandler & Hadley, 1996). This variation in programs ensures adequate training of the different physiological systems involved in stability control, so although one system may be the focus of the training the others should also be included in an exercise program for older adults.

A consideration of the specific type of balance training needs to also be included in the creation of a program. Static and dynamic balance training differ in their outcomes. While static includes the ability to balance while stationary, dynamic involves a higher functionality component (Maki et al., 1999). Beginners should start at a static or a low-intensity dynamic level training to establish the necessary balancing skills required for ADLs. The active older adults, who are seeking to improve balance for complex tasks can start at a higher level. Without the inclusion of a balance component in an exercise program there may be non-significant gains in balance (Buchner et al., 1997; Shumway-Cook et al., 2007). While exercise was found to reduce fall rates in older adults, balance training was one of the most important components for this (Sherrington et al., 2008).

Individuality. Certain genetic and physical characteristic variables distinguish participants from one another in fitness levels and gains. Gender is one of the factors that create variability between individuals. Older males have decreased postural sway when compared to older females (Shephard, 1997). Possible reasons for these differences include muscle mass, health conditions, and the time required to display physiological changes (Faber et al., 2006; Latham et al., 2003; Shepard, 1997). The primary factor is the greater ratio of muscle mass in males. When planning a balance program for a variety of participants, this must be considered. A lack of improvement in males could occur if the program intensity or frequency of sessions is not adequate to stimulate muscle growth. Lower intensity of the exercises could be large enough to stimulate muscular growth in older female participants, but not for older males. Likewise, a program including only two sessions per week may not provide a stimuli large enough to cause changes in fitness (Faber et al., 2006), as opposed to a program involving five sessions a week (Gatts & Woollacott, 2006). For example, if a participant missed one of the two training sessions during the week, the appropriate effect of exercise may not occur (Means et al., 2005).

Combine exercise modalities has also shown promise. A program using balance training followed with a Tai Chi maintenance program suggests that there is an ability to retrain balance in healthy older adults of 75 to 90 years of age (Wolfson et al., 1996). The flowing method of Tai Chi has also shown to be successful in maintaining fitness in older adults (Wolfson et al., 1996; Woo, Hong, Lau, & Lynn, 2007). While the gentle method of Tai Chi was able to produce significant improvements in balance for females, it was not seen in males (Woo et al., 2007). Again, this discrepancy in results may be due to intensity being high enough to stimulate growth in the female participants, who have less muscle mass, but not in the males.

It is important to consider the physical activity levels and health conditions of potential participants when beginning an intervention program. When combining older adults in a program, a problem is created. Frail participants may need to progress slower than healthy individuals to prevent injury. Older individuals participating in a progressive resistance training program, showed no improvements, possibly due to their existing frail condition or due to the length of the study (Latham et al., 2003). There is a decreased ability for the body to gain improvements during the time at which the vital systems are impaired. Unlike the frail individuals, healthy older adults require larger stimuli to notice the positive effects of a program (Hiyamizu, Morioka, Shomoto, & Shimada, 2011). If a program is geared towards the frail population, progression may be too slow to cause improvements in healthy older adults. The intensity of the exercises should be at an appropriate level for each individual so optimal improvements can be achieved.

Motivational levels are also important to consider because they differ vastly between individual. Although gains in balance have been noted in home based exercise programs, this type of program is most appropriate for individuals who can exercise on their own without additional instruction from a trainer and extrinsic motivation (Madureira et al., 2007). Many older adults require social interaction during group exercise sessions to help motivate them to complete their exercises. A group exercise setting allows socialization, which can increase both intrinsic and extrinsic motivation for exercising. When a participant can compare their fitness level to others around them, their self-esteem can be positively affected, which will promote them to continue exercising. Careful consideration is required when creating a competition between the group because the participants may also be negatively affected when comparing themselves to others, which will decrease their motivation.

Progressive overload. With training, physiological changes occur to meet the demands placed on the body (Taylor & Johnson, 2008). Without the proper increases in training intensity, the effects of a program can be limited to non significant differences between baseline and post intervention values (Hiyamizu et al., 2011). This absence of increased progression and thus fitness gains was noticed in a low-intensity program including exercises such as wall sits, chair raises/sits, and wall push-ups utilizing only body weight (Hiyamizu et al., 2011). Once strength adaptations occurred from the body weight strength training, a lack of further increases in the intensity (via additional resistance), resulted in no additional strength gains. For progression to occur overload must be applied; this can be achieved by increasing the volume, intensity, or frequency (ACSM, 2010).

The current guideline for decreasing falls in older adults is neuromuscular training two to three days a week (ACSM, 2010). Regarding balance, there are a variety of different methods to increase the intensity. The increase of duration or a decrease of the base of support demands a participant to work at a greater intensity (York et al., 2007). Progression may also involve a transition of static to dynamic training. For instance the implementation of different challenging movements, such as walking on toes/heels and tandem walking after static training, cause the body to progress in adapting; acquiring the necessary skills for performing the movements (Campbell, Robertson, Gardner, Norton, & Tilyard, 1997; Madueira et al., 2007). With the initiation of a balance intervention, the sedentary older population experiences positive results (Morrison, Colberg, Mariano, Parson, & Vinik, 2010). These gains are noted due to the introduction of an unfamiliar stimulus, which is placed upon the body, causing adaptation.

Methods for measuring progression. Continual monitoring of the individual and their level of fitness within the program is required to ensure that the prescribed exercises are creating a large enough stimulus to produce progressive overload on the body. The one repetition maximum (1-RM) assessment is a good assessment tool to use for gathering values on muscular fitness at a baseline and using a percentage of that value to train the muscles (Judge, Lindsey, Underwood, & Winsemius, 1993; Wolfson et al., 1996). With the older population, especially the inactive individuals, using a 6-RM or 10-RM is recommended to prevent injury (Taylor & Johnson, 2008). Another method for assessing progression in older adults involves the completion of 12 repetitions at the end of every two weeks. If the repetitions are done with ease then the participant increases the initial weight to once again establish moderate intensity (Center for Disease Control and Prevention [CDC], 2011).

A method for monitoring intensity is required to ensure that all of the participants are working at a similar intensity during the exercises. The talk test has been validated in determining moderate intensity and is an easy tool to use in a group exercise setting (Foster et al., 2008; Persinger, Foster, Gibson, Fater, & Porcari, 2004). The test could be administered during different types of exercises, including balance and aerobic exercises. At moderate intensity the participants should be able to comfortably recite, not sing, a short speech or count the number of repetitions they are performing. If the participant is unable to complete the talk test, due to shortness of breath, then the intensity is too vigorous and should be reduced. Monitoring intensity allows for appropriate changes to the training load, which is important for progression.

Periodization and Reversibility. This principle involves the variations within the training in an exercise program. At certain time intervals an individual will cycle through the specificity, volume, and intensity of training to ensure optimal gains are reached (Wilmore et al., 2008; Wolfson et al., 1996). Throughout a balance intervention the transition from training one physiological system to the next will ensure that all of the systems are working efficiently in maintaining equilibrium. While the input from one system is beneficial, all of the systems work in harmony to achieve a control of balance (Guyton, 1971). Focusing on only a portion of the problem results in an improvement in just that area; lacking overall gains in the balance components if the others are also impaired. The transition between static and dynamic training provides gains and maintenance in both of these components of balance (Wolfson et al., 1996).

Once the training stimulus that is placed upon the body disappears, the improvements acquired from physical fitness will be lost (Wilmore et al., 2008). While adequate rest is required for recovery, prolonged times of no physical activity results in the loss of the physiological adaptations. The same principle applies to balance; if not utilized, the body will decrease the adaptation that was necessary to achieve equilibrium. Sedentary older adults with these physiological declines, also have a decrease in functionality, making the ability to perform certain tasks challenging (Konrad et al., 1999). A method for preventing reversibility involves the participation in a maintenance program. After a balance and strength training program, older adults who continued with a Tai Chi maintenance program were able to maintain the gains without specific strength training (Wolfson et al., 1996). The regular attendance of a multicomponent program for at least two times a week allows for the maintenance of fitness, preventing deconditioning (Means et al., 2005; Nelson et al., 2007).

Summary

With the increase of the number of older adults in the United States and the compounding effects of aging on balance, interventions for improving stability are of great need (Konrad et al., 1999). Exercise, including balance training, increases functionality and duration of independence in older adults (Hue et al., 2004; Shumway-Cook, 2007). The participation in an exercise intervention among the older population is recommended for increasing the quality and longevity of life. Interventions which include tactile sensory training have been shown to decrease postural sway, therefore increasing stability (Maki et al., 1999; Menz et al., 2005).

Chapter 3

Methodology

Introduction

The purpose of this study was to investigate whether a balance training intervention involving BT yielded better static balance, dynamic balance, and postural sway values than the WS group. In this chapter the methodology of this study is discussed including the participants, equipment, physical assessments and procedures, selection testing and program, and statistical analyses.

Study Participants

The study population consisted of 12 subjects (six females and six males) who were living independently and over the age of 65 years. Participants were recruited from a retirement center in Spokane, WA via flyers.

Equipment

This study was conducted in a group exercise classroom located at Rockwood Retirement. The necessary equipment for the exercise sessions included 13 chairs, 13 ankle weights ranging from one to two pounds, and 13 sets of hand weights ranging from two to ten pounds for the 12 participants and instructor. For the timed up and go (TUG) and single-leg stance (SLS) tests that were administered, a digital stopwatch was required. Additionally, for the TUG test, a small cone, measuring tape, and a chair were used. A yardstick was used for the functional reach test (FRT). An arm-free chair was used for the 30 second chair stand (CS) test. The Modified Clinical Test of Sensory Interaction on Balance (mCTSIB) machine (Neurocom Incorporation, Portland, OR) was used for gathering postural sway data.

Physical Assessments and Procedures

Prior to the initiation of the intervention, approval was requested and granted from the Institutional Review Board (IRB) at Eastern Washington University. Before height, weight, and age were recorded a Physical Activity Readiness Questionnaire (PAR-Q; see Appendix A) was administered and any participants with cardiovascular, skeletal, or neuromuscular health issues were excluded from this study. The participants were provided with an informed consent form (See Appendix B) displaying the objective and procedures of the study, as well as the risks and benefits that were involved. The participants had 24 to 48 hours to complete the consent form. The required inclusion criterion for the study involved having the ability to perform three arm-assisted chair stands and balance in a single-leg stance for at least three seconds.

Once the participants arrived for baseline measurements weight, age, and height were recorded. Weight was recorded using a kilogram physician's scale (Continental Scale Corporation, Chicago, IL). Height (cm) was measured using a stadiometer (Quick Medical, Issaquah, WA).On the initial measurement day, after age, height, and weight were recorded, the participants began with a practice trial starting with the FRT, SLS, and postural sway analysis. The practice testing was completed with the CS and TUG tests. After the practice trials, the participants performed all of the tests once; the TUG test was completed twice. In measuring balance, no gold standard exists (Hertel, Gay, & Denegar, D. R., 2002; Hijmans et al., 2007). Therefore the commonly used SLS, TUG, FRT, and postural sway analysis were included in this study to assess the different aspects of balance.

Participants were required to complete the FRT and SLS assessments barefoot to assess static balance. Both tests have been validated and are used to identify impaired balance in older adults (Duncan et al., 1990; Vellas et al., 1997). During the SLS the participant was instructed to stand on a preferred leg for as long as possible; the test was terminated when the other foot made contact with the floor. A stopwatch was used to time the test; values were recorded in minutes and seconds. In the FRT, a yardstick was placed horizontally on the wall at shoulder height; the participant stood close to the wall with their dominant arm parallel to the yardstick. The participant was instructed to make a fist and extend the dominant arm, reaching forward towards the end of the yardstick. The test was finished when the participant completed a maximal reach or took a step. The third metatarsal of the closed fist was marked on the yardstick and the length of reach was recorded in inches.

A common measurement of displaying poor balance is body sway (Lord, et al., 1994). Posturography via the mCTSIB machine was the technique utilized to assess postural sway. During the test, the participant stood barefoot on a force plate, with eyes open for 10 seconds; three trials were recorded. Another three trials were completed with eyes closed. Postural analysis measured the amount of sway velocity in degrees per seconds for anterior-posterior and medial-lateral movements of the body’s center of gravity (De Kegel, 2010).

The TUG test was found to be test-retest reliable and valid for measuring functional mobility in older adults and was used in this study to assess dynamic balance (Podsiadlo & Richardson, 1991; Ries et al., 2009). During the test the participant was required to get off a chair without assistance, walk as quickly as possible three meters forward, turn at a cone, walk back, and sit down (Podsiadlo & Richardson, 1991). A digital stop watch was used to start the time as soon as the participant's bottom left the chair and stopped when it touched the chair.

After two trials, the average time was recorded in minutes. The CS test has been found to have good test-retest reliability and is a valid measure of lower leg strength among older adults (Jones et al., 1999). This test was administered to examine whether leg musculature correlated with balance gains. During the CS test, the participant was asked to sit in the middle of the chair with their feet flat on the floor. Once the signal was given to begin the participant completed as many unassisted chair stands as possible in 30 seconds (Hiyamizu et al., 2011). The number of completed chair stands was recorded. If the participant was unable to complete any chair stands a "0" was recorded. For both the CS and TUG tests, the participants were required to wear shoes.

Selection Testing and Program

Once all of the testing was completed, the participants' names were placed in a hat and a blocked random assignment by gender was used to assign the participants into either a barefoot training group (BT) or a group wearing shoe (WS). The BT and WS groups both had six participants. All participants followed the same training program (SAIL), which was administered in the same classroom three days a week for six weeks. The ACSM and the American Heart Association (AHA) recommend at least two days a week of balance training for older adults (Nelson et al., 2007); in this study three days a week was chosen to account for any exercise sessions missed by the participants. Previous research has shown that six weeks or less of training was found to be an adequate amount of time for physiological changes to occur and for balance improvements to be noticed (Gatts & Woollacott, 2006; Means et al., 2005; Morioka et al., 2009; Morrison et al., 2010). A meta-analysis on multifactorial and exercise-alone interventions, found shorter duration programs, six weeks to nine months, were best at reducing recurrent falls (Petridou & Manti, 2009). A current intern at Rockwood Retirement, certified as a SAIL program instructor lead the class sessions. Each session lasted 50 minutes, including a five-minute warm up, 40 minutes of balance and strength exercises, and a five- minute cool down. The first day of the program was used to familiarize the participants with the exercises and assess fitness levels. Fitness level was self-assessed by the participants during the performance of sitting and standing exercises. On this day participants were also taught the 1-10 Borg scale on ratings of perceived exertion (Borg, 1998) to understand moderate intensity. Attendance was taken every day, if a participant missed more than two days during the study (Means et al., 2005; Wolfson et al., 1996) the data was excluded from the analyses.

The warm up included low intensity exercises; there was no restriction on the exercises the class leader could use. The SAIL balance exercises were performed by all of the participants and resistance training followed for every session (Morrison et al., 2008). These exercises included a variety of static and dynamic balance training (See Appendix A). Individuals at a lower fitness level began at a low intensity training, which required exercises one through five to be performed holding onto a chair for support and exercises six through ten to be performed in a chair. Those at a higher fitness level began the program at a higher intensity, which required them to stand. Throughout the program, as progression occurred, all participants transitioned to an absence of support or a longer duration for exercises one through five. Depending on the fitness level of the participant, for exercises six through ten, the standing version or an increased duration was implemented for progression. Supplemental exercises for balance training also involved those performed in a study that was successful in improving balance (Madureira et al., 2007; see Appendix A). These additional exercises were included to expand the variety of static and dynamic exercises.

After the balance exercises, strength training was performed (See Appendix A). The participants self-selected dumbbells and ankle weights to use throughout the exercises to remain at a moderate level of intensity. Each exercise included two sets of 10 repetitions. As the program progressed, the subjects adjusted the free weights for further progression. At the end of every two weeks, if the participant could perform at least 12 repetitions with ease then the initial resistance for upper and lower body was increased to a higher weight; sets and repetitions of the exercises remained the same (CDC, 2011). A talk test was administered during the balance and strength exercises to ensure that all of the participants were working at an appropriate intensity (Foster et al., 2008; Persinger et al., 2004). The last five minutes of each session was completed with a cool down in the chairs. During the cool down, SAIL stretching exercises were incorporated (See Appendix C).

After the six week training, post-testing was conducted including all of the same tests that were included in the pre-testing of the participants.

Statistical Analyses

All data analyses were conducted in the IBM Statistical Package for the Social Sciences (SPSS, v 21.0). A two-tailed independent samples *t* test was used to compare baseline characteristics between the WS and BT groups. A 2x6 repeated measures

ANOVA was conducted to compare the mean difference between the BT and WS groups. A Pearson correlation was used to investigate any relationships between the CS performance (leg strength) and the balance test scores. Separate Pearson correlations were run to assess any relationships between the pre to pre variables and the post to post variables. A two-tailed paired samples *t* test was used to compare means from pre to post for all variables. Significance was set at an alpha level of 0.05.

Summary

The variety of clinical and functional tests that were used in this study to assess balance provided information on different aspects of balance. The addition of the mCTSIB machine allowed for the additional analysis of postural sway under a condition lacking visual input. This information permitted the observation of the sensory feedback from the feet during a static stance. Prior to every training session the wellness exercise classroom was cleaned to ensure that all participants were comfortable and safe throughout the intervention. All sessions were monitored by an individual with 30 years of experience teaching group exercise and who is a certified SAIL program course trainer.

Chapter 4

Results

Introduction

The purpose of this study was to identify any differences in static and dynamic balance, as well as postural sway and leg strength between a group wearing shoes and a group without shoes. This chapter discusses the demographics, differences between the barefoot (BT) and shod (WS) groups, pre to pre associations, post to post associations, pre to post mean comparisons, and leg strength correlations. An independent samples *t*-test was run to compare the two groups at baseline. A 2x6 repeated measures ANOVA was used to compare mean differences for the FRT, SLS, SEO, SEC, CS, and TUG variables between the two groups. Pearson correlations were run to investigate any relationships between leg strength and the variables, pre to pre variables, and post to post variables. Lastly, a two-tailed paired samples *t* test was used to compare any differences between the mean from pre to post of all variables.

Demographics

This study included 12 older adult participants residing at a retirement center in Spokane, WA. The sample size consisted of six females and six males with no major health issues. Demographics for the subjects that participated in the study are listed in Table 1. An independent samples *t*-test was calculated comparing the demographics of the BT ($n = 6$) and WS ($n = 6$) groups. The two groups were similar at baseline; no significant differences were found for any of the variables.

Table 1

Subject Demographics of the BT and WS Groups

Variables	BT Group (*n* = 6)	WS Group (*n* = 6)
Age (years)	82.8 ± 8.7	80.8 ± 8.6
Height (cm)	167.7 ± 7.1	162.4 ± 10.2
Weight (kg)	71.5 ± 10.4	68.2 ± 22.2

BT and WS Group Mean Difference

The 2x6 repeated measures ANOVA of the mean difference did not find significance. The BT group had a smaller mean difference (M = 1.102, SE = .819) than the WS group (M = 1.182, SE = .819). Regardless of the group, the program did not have an effect on the variables (F(1,10) =.921, p > .05). The results show that there was no significant effect on which group a participant was in for the variables recorded (F(1,10) = .005, p > .05). There was also no significant interaction effect for the group by variable (F(1,10) = .228), p >.05). The groups did not differ on their change, regardless of the variable measured. Pairwise comparisons suggested similar relationships as the correlation tests.

Correlation of Leg Strength to all Variables

Pearson correlations were calculated to examine the relationships between leg strength (CS) and all of the variables recorded (FRT, SLS, TUG, SEO, and SEC; see Table 2). A moderate non-significant positive correlation was found between the FRT and leg strength (r(10) = .35, p > .05. Leg strength was not related to the FRT. A strong positive non-significant correlation was found between the SLS and leg strength (r(10) = .53, p > .05). Leg strength was not related to the SLS test. When calculating a Pearson correlation for the relationship between leg strength and the TUG test, a strong negative correlation was found ($r(10) = -.85$, $p = .00$), indicating a significant linear relationship between the two variables. As leg strength decreases, the time required to complete the TUG test increases. In regards to the sway analysis, a moderate negative relationship was found between leg strength and SEO values ($r(10) = -.42$, $p > .05$). This lack of significance indicates that leg strength was not related to the SEO values. When examining the relationship between leg strength and SEC values, a strong negative relationship was noted ($r(10) = -.58$, $p = .05$). With a decrease in leg strength, an increase was seen in the SEC values.

Table 2
Leg Strength Correlations

Variable		PostCS
PostFRT	*r*	.35
	Sig.	.261
PostSLS	*r*	.53
	Sig.	.077
PostTUG	*r*	-.85**
	Sig.	.000
PostSEO	*r*	-.42
	Sig.	.172
PostSEC	*r*	-.58*
	Sig.	.050

*** $p > 0.05$. ** $p > 0.01$.**

Correlation of Pre to Pre Variables

An additional Pearson correlation was run to investigate any relationships between the variables measured at the beginning of the study (Pre; see Table 3). PreTUG and PreFRT were found to have a significant strong negative relationship ($r = -.65$, $p = .022$). As the score for the TUG test increased, the FRT score decreased. PreTUG and PreCS had a strong negative relationship that was significant ($r = -.71$, $p = .009$). The TUG value increased when the CS value decreased. A strong positive relationship, which was significant, was noted between the PreSEC and PreSEO (r = .72, p = .008). If the participant's SEO value increased, so would the SEC value, due to the increased challenge of stability control without a visual input.

Table 3
Correlation of Initial Measurements for all Variables

Variable	PreFRT	PreSLS	PreTUG	PreCS	PreSEO	PreSEC
PreFRT						
PreSLS	r = .20 p = .528					
PreTUG	r = -.65* p = .022	r = -.33 p = .291				
PreCS	r = .55 p = .066	r = .46 p = .135	r =-.71** p = .009			
PreSEO	r = -.51 p = .085	r = -.41 p = .184	r = .33 p = .296	r = -.48 p = .114		
PreSEC	r = -.39 p = .206	r = -.43 p = .162	r = .18 p = .575	r = -.52 p = .085	r = .72** p = .008	

* p > 0.05. ** p > 0.01.

Correlation of Post to Post Variables

A further Pearson correlation was analyzed to see if the relationships that existed initially remained similarly associated among the post study measurements for all of the variables tested (Post; see Table 4). A significant strong positive relationship was found between the PostSLS and PostFRT(r = .63, p = .027). PostCS and PostTUG remained significant, but the relationship was stronger compared to the initial measurement (Pre r = -.71, Post r = -.848). As the participants' leg strength increased throughout the intervention, TUG values decreased to a greater degree. A significant strong negative correlation was found between the PostSEC and PostCS (r = -.58, p = .050); this relationship did not initially exist. With an increase in the leg strength, the value for the SEC decreased, indicating that leg strength gained throughout the program aided in maintaining greater postural sway. The PostSEC and PostSEO were found to have a significant relationship (*r* = .78, *p* = .003), as they did initially, but the relationship was stronger (Pre *r* = .72, Post *r* = .78).

Table 4
Correlation of Post Study Measurements for all Variables

Variable	PostFRT	PostSLS	PostTUG	PostCS	PostSEO	PostSEC
PostFRT						
PostSLS	*r* = .63* *p* = .027					
PostTUG	*r* = -.27 *p* = .406	*r* = -.5.15 *p* = .087				
PostCS	*r* = .35 *p* = .261	*r* = .53 *p* = .077	*r* =-.85** *p* = .000			
PostSEO	*r* = -.08 *p* = .809	*r* = -.31 *p* = .335	*r* = .24 *p* = .449	*r* = -.42 *p* = .172		
PostSEC	*r* = -.42 *p* = .176	*r* = -.43 *p* = .163	*r* = .51 *p* = .090	*r* = -.58* *p* = .050	*r* = .78** *p* = .003	

* *p* > 0.05. ** *p* > 0.01.

Comparison of Pre to Post Variables

A two-tailed paired-samples *t* test was calculated to compare the mean pre scores to the mean post scores for all variables. A significant increase was found from PreFRT (*M* = 11.60, *SD* = 2.95) to PostFRT (*M* = 14.46, *SD* = 2.97; *t*(11) = -4.879, *p* = .000). A significant increase was also found from PreCS (*M* = 9.08, *SD* = 5.95) to PostCS (*M* = 11.75, *SD* = 5.71; *t*(11) = -15.533, *p* = .000). No significant differences were found from the PreSLS (*M* = 9.90, *SD* = 11.90) to Post SLS (*M* = 10.68, *SD* = 8.41; *t*(11) = -.251, p > .05), PreTUG (*M* = 9.42, *SD* = 4.42) to PostTUG (*M* = 8.79, *SD* = 3.82; *t*(11) = 1.256, *p* > .05), PreSEO (*M* = 0.32, *SD* = 0.15) to PostSEO (*M* = 0.34, *SD* = 0.19; *t*(11) = -.290, *p* > .05), and PreSEC (*M* = 0.55, *SD* = 0.39) to Post SEC (*M* = 0.60, *SD* = 0.34; *t*(11) = -.711, *p* > .05).

Summary

Both the BT and WS groups were comparable at baseline. The pre and post measurements for all of the variables were non-significant between the two groups. Post intervention leg strength was significantly correlated to the PostTUG (negative relationship) and PostSEC (positive relationship). Further Pearson correlations found significant relationships between multiple pre to pre and post to post scores. The paired-samples *t* test found a significant increase from PreFRT to PostFRT, as well as, PreCS to PostCS.

Chapter 5

Discussion

Introduction

The purpose of this study was to investigate the effects of a balance training intervention involving a BT and WS group. Static balance, dynamic balance, postural sway, and leg strength were examined between the two groups. This chapter discusses the summary of the procedures, discussion, conclusions, and recommendations for further research.

Summary

Participants were chosen on a volunteer basis. The twelve subjects (six female, six male) were all independently living at a retirement center in Spokane, WA. All subjects were required to fill out a PAR-Q and informed consent to determine eligibility. Certain criteria limited participation in the study; participants needed to be at least 65 years of age, have no major physical or health limitations including diabetic neuropathies, ability to stand on a single leg for at least three seconds, ability to perform three unassisted chair stands, and obtain a doctor's clearance if any of the PAR-Q answers were "yes."

During the initial measurement day, after demographics (height, weight, and age) were recorded, the participants went through a practice trial of all of the tests: FRT, SLS, SEC, SEO, CS, and TUG. The same tests were administered at the end of the study. After the measurements, subjects were randomly assigned by gender to either the BT or WS group. Prior to the initiation of the six week intervention a familiarization day was conducted to acquaint the participants with the exercises and the RPE scale. The subjects met three days a week for 50 minutes at the same location and time. The program included a warm-up, balance, strength, and stretching exercises, in which the balance, strength, and stretching exercises were derived from the SAIL program; additional balance exercises were used from a study that investigated balance gains in older adults with osteoporosis (Madureira et al., 2007). The resistance training included both upper and lower body exercises using dumbbells and ankle weights. All exercises consisted of two sets of 12 repetitions and if the participant could complete all 12 repetitions with ease then at the end of every two weeks the initial weight was increased. The duration of the static balance exercises was also increased as the program progressed, to ensure that exercise continued to pose a challenge for the subjects.

Discussion

Current research has found significant improvements in balance after six weeks of training (Means et al., 2005; Morioka et al., 2009; Morrison et al., 2010). While there were increases in pre and post values for a majority of the participants, significance between the BT and WS groups was not found. This could have been due to the participants' subjective evaluation of moderate intensity, intrinsic motivation, and/or the small sample size. The level of stimulating the mechanoreceptors could also have been at too low of an intensity to gain results within the six weeks. Presenting the challenge of discriminating between foam hardness is more intense than simple barefoot exposure on a hardwood surface (Morioka et al., 2009). While there was an absence of significance, it indicates that participants can achieve improvements in balance, training with either a shod or nonshod method.

This study provided evidence that with a decrease in leg strength, an increase was seen in the SEC values. This finding was similar to other research (Hue et al., 2004, Menz et al., 2005). Without a visual input, the body relies on other means for stability of postural control (Morioka et al., 2009). The absence of support from strong leg muscles, negatively affects equilibrium among older individuals. This intervention also showed that as leg strength increased, the time it took to complete the TUG test decreased. Lower body strength has a major impact on dynamic balance (Lord et al., 1991; Lord et al., 1994; Rodgers & Mille, 2003). The findings from this study suggested that implementing resistance training for the leg muscles can aid in improving balance in older adults.

When the initial scores for all of the variables tested were compared, significance was displayed between the TUG and FRT tests. As the score for the TUG test increased, the FRT score decreased. This finding indicated that if the participant's static balance was good, it didn't translate into the dynamic balance (Lord et al., 1994), as was seen with the increased time to finish the TUG test. The ability to acquire dynamic control is more challenging than maintaining static control. PreTUG and PreCS had a very strong negative relationship, which was significant; the TUG value increased when the CS value decreased. This was anticipated, as previous research found a similar relationship (Lord et al., 1991; Rodgers & Mille, 2003). Leg strength allows for better dynamic stability. Independently mobile older adults display better TUG test scores when compared to less mobile individuals (Podsiadlo & Richardso, 1991).

All post variables recorded were analyzed to investigate if the same associations, which were evident at the beginning of the study, remained significant. The PostTUG and PostCS values remained significant, but the relationship grew stronger. As leg strength continued to increase in the participants, their scores for the TUG tests improved. A significant strong positive relationship was found between the PostSLS and PostFRT.

This relationship was not significant at the beginning of the study, but expected because both tests measure static balance (Duncan et al., 1990; Vellas et al., 1997).

A significant increase was noted from PreFRT to PostFRT in mean differences. An explanation of this increase could have been that, during the program, multiple stretching exercises were utilized, that simulated this test. The participants were able to improve on this movement due to the repeated exposure of displacing the body’s center of gravity while maintaining a stable base of support (Gatts & Woollacott, 2006). A similar increase was also found from PreCS to PostCS. Resistance training allowed for the participants to increase lower extremity strength throughout the intervention (Morrison et al., 2010; Shumway-Cook et al., 2007; York et al., 2011).

Although all of the participants attended the same training program, lifestyles outside of the group exercise sessions were not controlled. While they were all healthy older adults, there were different levels of physical fitness. This was evident when the initial measurements were recorded. The participants were instructed to maintain their normal daily routines without increasing physical activity; some were more active than others. Throughout the program, the participants were instructed to challenge themselves during the balance training and although progression was noted across individuals, intrinsic motivation might have reduced optimal balance gains among some participants. This might have been the factor for the individuals at a higher fitness level; the static and dynamic balance exercises may not have been of a great enough intensity and therefore, due to comfort, the limits were not pushed. As has been seen in younger adults, when balance was disturbed, older adults were found to have a decreased willingness to attempt to recover from the disturbance (Bohannon et al., 1984). Due to fear of falling and desire to stay in a comfort zone, it appears an older participant is less likely to push their limits of equilibrium.

Shoes may alter the interaction between the sole of the foot and the ground, but with proper footwear a decrement in this interface can be decreased (Menz & Lord, 1999). Multiple factors, including the midsole thickness, heel, and slip resistance, influence the stability that a shoe can provide. While shoe variability was not controlled for in this study, other research has shown that shoe design did not interfere with significant balance gains in older adults (Campbell et al., 1997; Hauer et al., 2001 Morrison et al., 2010). A benefit of this is that participants could train in a variety of footwear, as long as it is appropriate for the activities, and still exhibit improvements in balance.

Conclusions

It was hypothesized that there would be no significant difference in static and dynamic balance and postural sway between the BT and WS group. All three null hypotheses were accepted, no significant differences were found for any of the variables tested. However, a Pearson correlation did find a significant negative relationship between leg strength and the TUG and SEC values. Prior to the initiation of the intervention significant negative relationships existed between PreTUG and PreFRT, as well as, PreTUG and PreCS. The relationship between PostTUG and PostCS remained significant at the end of the study. A positive relationship was found between PreSEC and PreSEO; this association remained significant during the post intervention measurements. New relationships were noted between PostSLS and PostFRT, as well as, PostSEC and PostCS. When comparing the means of the pre to post variables, increases in the differences were displayed from PreFRT to PostFRT and PreCS to PostCS, indicating that the participants significantly improved their static balance and leg strength.

The subjects were older adult volunteers that participated in a six week intervention. The participants met three days a week for a 50 min group exercise. The program included balance, strengthening, and stretching exercises. The FRT, SLS, SEO, SEC, CS, and TUG tests, after a practice trial, were administered at the beginning and end of the study. Although the BT and WS groups did not have any differences between the variables tested, leg strength was correlated to the TUG and SEC variables. Leg strength plays an important role in dynamic balance and static balance when visual input is removed. A program including balance and strength training can improve static balance and dynamic balance, as well as, increase leg strength.

Recommendations

Originally, the length of this study was to be eight weeks but due to the availability of the instructor and participant involvement, the intervention was terminated early. Further research should consider increasing the length of the intervention, to ensure that physiological adaptations occur. Also providing the older population with multiple class times will help increase their adherence or participation in the program, thereby reducing the risk of having a small sample size. Many facilities offer different classes combining populations, which can increase the sample size and allow for participant drop out or intermittent participation due to travel or illness, both common experiences in older adult living. The design of the footwear within the WS group was not controlled for. While improvements are noted, controlling this factor would eliminate inter-participant variability of footwear and possibly result in difference findings.

To ensure that all participants understand the RPE scale and what moderate intensity should feel like, a more in depth discussion should be provided. The participant should understand that even as progression occurs during the program, the RPE for moderate intensity should remain the same. The participant is just able to work against a greater resistance than they had initially started with at the same intensity level. A full understanding of the RPE scale could result in greater gains in balance and strength throughout the intervention. Finding a method of increasing intrinsic motivation of the participants, may also yield greater improvements. Creating individual challenges or small competitions with the group can increase the participants' self-esteem, making them feel better about their fitness and stimulating motivation for continuing training. Participants are likely to return to a training session if they had a good experience.

Summary

This chapter reviewed the summary of the procedures, discussion of the results, conclusions from the results, and recommendations for further research.

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Appendix A – Physical Activity Readiness Questionnaire Form

Physical Activity Readiness Questionnaire (PAR-Q) and You

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly:

YES	NO		
☐	☐	1.	Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
☐	☐	2.	Do you feel pain in your chest when you do physical activity?
☐	☐	3.	In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4.	Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5.	Do you have a bone or joint problem that could be made worse by a change in your physical activity?
☐	☐	6.	Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	7.	Do you know of <u>any other reason</u> why you should not do physical activity?

If you answered:

YES to one or more questions

Talk to your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want – as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to <u>all</u> PAR-Q questions, you can be reasonably sure that you can:

- Start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- Take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively.

Delay becoming much more active:

- If you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- If you are or may be pregnant – talk to your doctor before you start becoming more active.

Please note: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed use of the PAR-Q: Reprinted from ACSM's Health/Fitness Facility Standards and Guidelines, 1997 by American College of Sports Medicine

Appendix B: Informed Consent Form

Informed Consent Form

"Comparison of Shod vs Nonshod on Balance and Postural Sway in Older Adults"
In partial fulfillment of the Master's Thesis for Annika Vyakhk

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Purpose and Benefits

The objective of this study is to compare a barefoot training group (BT) and a group with shoes (WS) on balance gains after a 6 week balance training intervention. If you are selected into either the BT or WS groups you will benefit by meeting the recommended weekly exercise guidelines for adults.

Procedures

As a subject in this study, you will be tested before and after the intervention in the Wellness Exercise Room, including a single-leg stance test, functional reach test, timed up and go test, and postural sway analysis. Following the pretest you will be randomly assigned to the WS or BT group. The intervention groups will train for 6 weeks 3-times per week using an identical exercise program. All exercise sessions last 50 minutes.

Static and Dynamic Balance:

The functional reach and single-leg stance tests will assess static balance. During the functional reach you will be required to reach forward as far as you can, until you take a step; the length of reach will be measured. The single-leg stance test will be terminated when the other foot touches the ground. Time of single-leg stance will be recorded. Dynamic balance values will be gathered from a timed up and go test in which you will start sitting in a chair, on go you will stand up, walk 3 meters, turn at a cone, and return to the starting position. You will be required to do your best to perform all three of these tests.

Postural Sway:

The Modified Clinical Test of Sensory Interaction on Balance machine will analyze postural sway. You will be required to stand on a force plate with your eyes open for 10 seconds and then with your eyes closed for 10 seconds. The amount of displacement in sway will be recorded.

Leg Strength:

The 30 second chair stand test will assess leg strength. You will be required to complete as many chair stands within 30 seconds as possible. The repetitions will be recorded.

Intervention:

BT Group

For each training session you will begin with a 5 minute warm up, spend 40 minutes performing balance and strength exercises, and finish with a 5 minute cool down. In this group you will be barefoot.

WS Group

For each training session you will begin with a 5 minute warm up, spend 40 minutes performing balance and strength exercises, and finish with a 5 minute cool down. In this group you will be wearing exercise shoes.

Risk, Stress or Discomfort

All participants must take part in the single-leg stance, functional reach, timed up and go, and postural sway analysis. Due to the nature of the tests there will be a potential risk for stress or discomfort. Adverse effects during or after the exercise sessions are muscle soreness and possible muscular injury. Very rarely, abnormal physiological changes could occur during the test or intervention. These include abnormal blood pressure, fainting irregular, fast, or slow heart rhythm, and in rare instances heart attack, stroke, or death.

Inquiries

Any questions about the procedures used in this study are encouraged. If you have any concerns, questions, or would like more information please contact Wendy Repovich or Annika Vyakhk prior to signing the informed consent form. We can be reached at (509)-359-7960; wrepovich@ewu.edu, and (509)-989-2224; annikavahk@yahoo.com.

Other Information

In this study you will not be anonymous, the principal investigator will be supervising the testing. Brenda Jurich will be present for majority of the exercise sessions. Britney Wolfe, and intern from WSU will be instructing the exercise sessions. All data will be reported in aggregate so your data will not be able to be identified. All participation in this study is voluntary and the participants will not be penalized or punished if the training protocol is not completed. To participate in this study you will have to confirm that you are able to complete 3 chair stands and hold a single-leg stance for 5 seconds. You are also being asked to not change your diet or activity level outside of the study protocols while you are taking part in the study. If you have any concerns about your rights as a participant in this research or any complaints you wish to make, you may contact Ruth Galm, Human Protection Administrator, (509) 359-6567 or rgalm@ewu.edu.

Signature of Principal Investigator　　　　　　　　　　Date

Subject Statement

My participation in this study is completely voluntary. I am free to refuse participation and to stop at any point in this study. I understand the study procedures that I will perform, and the possible risks that go along with the testing and training. Knowing all of the risks and discomforts, and being allowed to ask questions that have been answered to my satisfaction, I consent to take part in this study. I am not waiving my legal rights by signing this form. I understand I will receive a signed copy of this consent form.

____ _______________

Signature of Subject Date

Appendix C: Program Exercises

Balance Exercises – Moving (SAIL, 2008)

1. Walking with head turns
2. Stepping over objects
3. Heel-to-toe walk (Tandem walk)
4. Turing a circle
5. Sit to stand

Balance Exercises – Standing still or sitting (SAIL, 2008)

6. Shifting your weight
7. Twisting side to side
8. Heel-to-toe stand (without support)
9. Reaching forward and out to side
10. Standing on one leg

Supplemental Balance Exercises (Madureira et al., 2007)

1. Static hold in tandem position
2. Walking on toes
3. Waling on heels
4. Walking sideways
5. Walking high knees with opposite arm raise

Strength Exercises – Upper Body (SAIL, 2008)

1. Arm bending (biceps)
2. Arm straightening (triceps)
3. Arm raises: side (deltoids)
4. Arm raises: front (deltoids)
5. Overhead press (upper back and deltoids)
6. Seated crunches (abdominals)

Strength Exercises – Lower Body (SAIL, 2008)

7. Knee bending (hamstrings)
8. Knee straightening (quadriceps)
9. Leg lifts: forward (quadriceps)
10. Leg lifts: backwards (gluteal muscles and hamstrings)
11. Leg lifts: side (gluteal muscles)
12. Toe stands (gastrocnemius)

Stretching Exercises – Upper Body (SAIL, 2008)

1. Neck stretch
2. Arm circles
3. Scratch between shoulder blades
4. Clasp hands in front
5. Clasp hands behind head
6. Hand stretch

Stretching Exercises – Lower Body (SAIL, 2008)

7. Quadriceps stretch
8. Hamstring stretch
9. Inner thigh stretch
10.
11. Calf stretch

CIRRICULUM VITAE
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Education:

M.S., Eastern Washington University, Exercise Science, 2014
B.S., Eastern Washington University, Exercise Science, 2012

Employment History:

09/2012 - Present: Graduate Assistant, Physical Education, Health and Recreation (PHER), Eastern Washington University

Teaching Experiences:

03/2014-06/2014 - Eastern Washington University
PHED 125 - Tennis (2), Basketball (2), Archery (2) – Created syllabi, taught skills and rules of the sports. Facilitated classes to be safe and educational.

03/2014-06/2014 - Eastern Washington University
PHED 455 - Research and Analysis - Graded assignments and exams.

01/2014-03/2014 - Eastern Washington University
PHED 125 - Tennis (2), Volleyball, Basketball, Racquetball (2) – Created syllabi, taught skills and rules of the sports. Facilitated a safe and educational environment.

01/2014-03/2014 - Health and Wellness Center, Fairchild Air Force Base
Running Clinic - Participated in teaching course material and aided in video analysis for biomechanics.

09/2013-12/2013 - Eastern Washington University
PHED 125 - Tennis (3), Archery, Volleyball - Created syllabi, taught skills and rules of the sports. Facilitated a safe and competitive environment.

09/2013-12/2013 - Eastern Washington University
PHED 460 - Physiology of Exercise - Taught lectures; graded assignments and exams.

03/2013-06/2013 - Eastern Washington University
PHED 125 - Tennis (2), Archery (2), Racquetball - Created syllabi, taught skills and rules of the sports. Facilitated a safe and educational environment.

03/2013-06/2013 - Eastern Washington University
PHED 350 - Physiology Kinesiology - Aided in running labs and graded research abstracts.

01/2013-03/2013 - Eastern Washington University
PHED 125 - Tennis, Racquetball (2), Swim Conditioning - Created syllabi, taught skills and rules of the sports. Facilitated a safe and competitive environment.

01/2013-03/2013 - Eastern Washington University
PHED 350 - Physiology Kinesiology - Aided in running labs and graded research abstracts.

09/2013-12/2013 - Eastern Washington University

PHED 125 - Archery, Volleyball, Racquetball, Tennis - Created syllabi, taught skills and rules of the sports. Facilitated a safe and educational environment.

09/2013-12/2013 - Eastern Washington University

PHED 350 - Physiology Kinesiology - Aided in running labs and graded research abstracts.

12/2011-06/2012 - Rockwood Retirement South Hill

Health and Wellness Assistant – Taught group exercise classes including yoga, water aerobics, step aerobics and gentle moves for older adults. Created programs for physical fitness and aided in administrative tasks.

Academic/Research Interests:

Geriatric health and wellness

Prevention and treatment of obesity in children

Professional Activities:

Organization Membership

American College of Sports Medicine Northwest Chapter (ACSM NW)

American College of Sports Medicine (ACSM)

Eastern Washington University - Exercise Science Club

Eastern Washington University - PEHR Graduate Club

Research Presentation

Original Research:

2012 - Eastern Washington University - Creative Works

Symposium

2012 - Western Society for Kinesiology and Wellness Conference

2013 - ACSM NW Conference

2013 - Western Society for Kinesiology and Wellness Conference

2014 - ACSM NW Conference

2014 - Eastern Washington University – Creative Works

Symposium

Service

Vice President of the PEHR Graduate Club - 2013-2014

Similes Fair - Gonzaga University - 2012

Awards/Honors:

Rob Carlson Literature Review Award - 2014

Summa Cum Laude Honor - 2012