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The Effect of High-Intensity Interval Training on Postural Control, Dynamic Balance, and Muscular Strength among Older Adults

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HIGH INTENSITY INTERVAL TRAINING EFFECTS

The Effects of High-Intensity Interval Training on Postural Control, Dynamic Balance, and Muscular Strength among Older Adults

A THESIS

APPROVED FOR THE DEPARTMENT OF KINESIOLOGY AND HEALTH STUDIES

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In Dedication to Mom, Dad, and both of my big brothers

You are the reason I work so hard.

Love you more than words can express!

Abstract

Aging adults are at an increased risk of falling, dependency, and disability due to a decline in physical conditioning. Research has determined muscle weakness and poor balance are associated with these risks. Resistance training may cause muscular strength improvements at any velocity or intensity. High-intensity interval training (HIIT) is an emerging style of fitness, which has shown to be beneficial to muscular strength. **PURPOSE**: To determine the effects of HIIT on postural sway, dynamic balance, and lower body strength among active older adults. **METHODS**: The experimental group (EG) participated in the intervention two times per week for 4-weeks. The control group (CG) continued their current fitness routine. HIIT participants utilized exercises which simulated muscle groups that influence balance. Participants completed interval bouts ranging from 20-30s accompanied by a 30 – 40s recovery phase. Participants were assessed on postural sway in tandem, semi-tandem, and single leg stances performed on the Tekscan™ pressure mat. Each stance was performed with eyes-open (EO) and eyes-closed (EC). Dynamic balance was measured with the Timed-Up-and-Go (TUG), and lower extremity strength was measured with the 30-Second Chair Stand test. The Wilcoxon Sum of Ranks and Mann-Whitney U tests were used to determined differences within and between groups, respectively. **RESULTS**: Postural sway significantly improved during eyes open stances ($p < 0.05$). The experimental group did show a moderate to strong ($d > .30$) reduction in sway in four different EO stances. The EC stances in the EG showed three significant improvements ($p > 0.05$). The EG experienced significant improvements in the TUG ($p = .04$) and approached significant increases in chair stand performance ($p = .07$). **CONCLUSION**: HIIT significantly improved dynamic balance and muscular strength, and meaningfully improved postural sway. Future research should utilize HIIT for a longer duration to examine its effects.

CHAPTER ONE: Introduction

Significance

The older adult population is rapidly growing worldwide. The 65-year-old and older population is expected to increase from 688 million in 2006 to nearly 2 billion by 2050 across the globe (World Health Organization, 2007). Unfortunately, with aging adults the risk of falling is increased. Aging is also directly associated with dependency and risk of disability, due to the decline in physical and psychological health (Latham et al., 2011). Moreover, falls can have a financial effect. Steven, Corso, Finkelstein, and Miller (2006) reported the annual cost of fatal and non-fatal falling accidents approached $19 billion. Rubenstein (2006) reported that 33% of older adults will fall at least once a year. Over 90% of hip injuries are associated with fall accidents. Suffering these types of injuries can be serious for an older adult, the outcome of these injuries can lead to death (Fuller, 2000).

Frequently, sufferers develop a fear of falling which can be associated with immobility and decreased autonomy (Rubenstein, 2006). Decreased autonomy and immobility can restrict older adults from completing their Activities of Daily Living (ADLs), which can lead to muscular atrophy. Shumway-Cook and Woollacott (2012) determined that muscle weakness and poor balance are associated with increased fall risk. Therefore, strengthening lower body musculature could possibly reduce fall rates and improve performance of ADLs. Several safe and effective fitness interventions exist, but more are needed to deliver adequate muscle development to positively influence the rate of falls in older adults.

Studies have provided evidence to support resistance training alone can provide muscular strength improvements through traditional training methods (Beneka et al., 2005; Cantrell, Schilling, Parquette, & Murlasits, 2013; Fatouros et al., 2005). Beneka et al. (2005) and Fatouros et al. (2005) reported that resistance training can provide muscular strength improvements at any velocity or intensity. Although specifically timed intervals have not been heavily researched in this population, several circuit training studies provide evidence of the benefits (muscular strength, and improved cardiovascular functioning) of this style of training (Butcher et al., 2015; Gine-Garriga et al., 2010).

High-intensity interval training (HIIT) is similar to traditional training, but repetitions are timed intervals, and the regimen usually entails short rest periods. HIIT has been shown to improve muscular strength (Meier, Quednow, & Sedlak, 2015; Robinson et al., 1995; Villanueva, Lane, & Schroeder, 2015). Improving one's ability to tolerate longer periods of activity through more efficient muscular strength can improve one's ability to complete ADL's (Cantrell et al., 2013). Bird, Hill, Ball, and William (2009) discovered resistance training may provide a significant improvement in postural sway, lower body strength, and dynamic balance.

Postural sway is another physiological change that can be negatively impacted by aging (Stelmach & Worringham, 1985). The magnitude of postural sway can produce stability or instability (Pavol, 2005). Postural sway is defined as quiet standing which reflects the relationship between forces acting on the body, causing instability or swaying of the body (Shumway-Cook & Woollacott, 2012).Research has shown that the practice of high intensity strength training on postural sway is an effective method to achieve improved postural control (Jakobsen, Sundstrup, Krustrup, & Aagard, 2011). Additionally, significant improvements were observed in dynamic balance, after a resistance training and balance intervention (DiBrezzo, Shadden, Raybon, & Powers, 2005). Age-related declines effect the ability of the vestibular, somatosensory, and visual systems to work effectively, contributing to poor balance in older adults (Shumway-Cook & Woollacott, 2012). Research shows take shorter recovery periods showed muscular improvements. Villanueva et al. (2015) observed shorten rest intervals showed significantly greater strength improvements. By improving specific components, HIIT may improve postural sway, dynamic balance, and lower body strength in older adults.

Background

HIIT is regarded positively for its effectiveness using a short activity duration. The majority of research has been administered to younger adults. Hess and Woollacott (2005) suggest that weak quadricep, hamstring, tibalis anterior, gastrocnemius, and soleus muscle are all contributing factors to poor balance. Research has revealed that muscular strength and endurance can improve from this training modality (Wong, Chaouachi, Chamari, Dellal, & Wisloff, 2010). Due to this increase in muscular function, HIIT may be an effective tool for older adults to improve postural sway and dynamic balance.

Postural sway is referred to as altered postural control. Postural control involves the body's ability to position itself with reference to stability and orientation (Shumway-Cook & Woollacott, 2012). Stability is the body's ability to maintain upright position after movement (Shumway-Cook & Woollacott, 2012). Therefore, if any of these components are altered, it can negatively change one's balance. When postural control changes are expected to cause medio-lateral (ML) sway, lateral stability in the frontal plane, or anterior-posterior (AP) sway, forward to backward stability in the sagittal plane (Shumway-Cook & Woollacott, 2012).

Dynamic balance is one's ability to maintain balance while moving. Due to the reduction of dynamic abilities in preventing falls, it is necessary to develop programs which seek to improve this component. Some studies suggest that strength and balance training can provide a positive effect on muscular strength and balance (Dibrezzo et al., 2005). Muscular strength can be a contributing factor to overall physical performance, which is the premise of this study. The purpose of this study was to evaluate the effects of a 4-week HIIT intervention on ML and AP sway, dynamic balance, and muscular strength in older adults.

Hypotheses

H_1: The researchers hypothesized the treatment group would improve AP parameters during static balance testing, which would positively affect forward and backward sway by reducing the magnitude of sway. It was predicted the control group would not show significant improvements.

$H_{2:}$ The researchers hypothesized the treatment group would improve in ML parameters during static balance testing, which would positively affect lateral sway postural control by reducing the magnitude of sway. It was predicted the control group would not show significant improvements.

$H_{3:}$ The researchers hypothesized the treatment group would show significant improvements in dynamic balance during the Timed-Up-and-Go Test (TUG), the control group would not show improvements.

$H_{4:}$ The researchers hypothesized the treatment group would show significant improvements in muscular strength during the 30 second chair stand, the control group would not show improvements.

Operational Definitions

- **Postural sway:** The phenomenon of constant displacement and correction of the position of the center of gravity within the base of support (Shumway-Cook & Woollacott, 2012).
- **Center of mass (COM):** the point where the entire mass of the body is concentrated (Shumway-Cook & Woollacott, 2012).

- **Base of support (BOS):** the area underneath and between both feet in the upright position (Shumway-Cook & Woollacott, 2012).
- **Center of pressure (COP):** the point where the resultant of all ground reaction forces act (Shumway-Cook & Woollacott, 2012).
- **Postural control**: the act of maintaining, achieving or restoring a state of balance during any posture or activity (Shumway-Cook & Woollacott, 2012).
- **Balance:** Maintain center of mass to stay within the base of support (Shumway-Cook & Woollacott, 2012).
- **Stability**: the ability of an object to maintain equilibrium or resume its original, upright position after displacement (Shumway-Cook & Woollacott, 2012).
- **Dynamic Balance:** the ability of the body to regain balance at the moment of perturbation (Shumway-Cook & Woollacott, 2012)
- **Perturbation:** A deviation of a system or process of moving from its regular or normal state of path, caused by an outside influence (Shumway-Cook & Woollacott, 2012).
- **Muscular Strength:** ability of a muscle to produce maximal contractile force against a resistance (Shumway-Cook & Woollacott, 2012).
- **Muscular endurance:** is the ability of a muscle to apply submaximal strength for an extended period of time (Shumway-Cook & Woollacott, 2012).
- **High-Intensity Interval Training (HIIT):** HIIT is a procedure of exercise applying alternating bouts of high-intensity exercise followed by a bout of low-intensity exercise or rest and can be performed by using an extensive selection of resistance or aerobic training equipment (Meier et al., 2015).

Assumptions:

- Participants performed at their best effort.
- Subjects represented the general population of active older adults.

Limitations:

- The inability to control influence from outside physical activity influences or other health practices.
- Intensity of the exercise was a self-reported measurement.

Delimitations:

- All individuals were over the age of 65 years.
- All individuals were independent living.
- All individuals were high functioning as determined by scores greater than 10 points on the Short Physical Performance Battery (SPPB) test.
- All individuals were willing to work at a relatively high intensities.

Summary

Research entailing high-velocity training of ranging intensities on older adult has been thoroughly studied and provides evidence of muscular improvement (Beneka et al., 2005; Cassilha et al., 2007; Fatouros et al., 2005; Kalapotharakos et al., 2004). Likewise, circuit training has also become more popular and shown success in increasing muscular strength (Butcher et al., 2015; Gine-Garriga et al., 2010). As previously explained, muscular strength is a great indicator of the likelihood of a fall to occur. Research has been conducted to examine the effects of high-velocity training and circuit training, but research about HIIT is not prevalent on older adults. Perhaps this lack of research is due to shorter recovery periods. Robinson et al. (1995) concluded that longer rest intervals resulted in greater muscular strength development, while Villanueva et al. (2015) compared shortened rest intervals to extended rest intervals in older adults and found significantly greater strength improvement in the shortened rest interval group. It is important that HIIT is observed further in order to determine its effects on older adults. If muscular strength improvements do occur, this training modality may cause positive strength, dynamic balance, and postural sway changes, which could positively impact balance and falls risk.

CHAPTER TWO: Literature Review

Introduction

Research has shown that 50% of older adults over 80 years of age fall every year (Hess & Woollacott, 2005). Of these individuals 50% of who suffer from injuries are released to a nursing facilities after being admitted to hospitals (Donald & Bulpitt, 1999). Older adults who are 75-years-old or older and have suffered a fall are four to five times more likely to be discharged to a long-term care facility (Donald & Bulpitt, 1999). Therefore, it is clear that innovative regimens are necessary for older adults to improve balance, help maintain independency, and reduce occurrence of falls. In order for older adults to maintain their independence, and to recover from or avoid the consequences of falling, they must maintain adequate lower body muscular strength, dynamic balance, and postural sway.

This literature review will examine the effects of different training styles on postural sway, dynamic balance, and lower body strength. By translating information about different styles of training for older adults, readers will learn why it is important that scientists must continue to research and implement different variations of fitness programs among this population. Several resistance training studies have shown that postural sway, dynamic balance, and strength can be improved with resistance training (Bird et al., 2009; Egerton, Brauer & Cresswell, 2009; Butcher et al.,2015; Gine-Garriga et al., 2010). While studies exist about the benefits of high intensity interval training (HIIT; Meier et al., 2015; Robinson et al., 1995; Villanueva et al., 2015), research is limited concerning its effects on postural sway, balance, and lower body strength. Several studies have been published that observed the effects of high and low-velocity training and circuit training among older adults’ on muscular strength (Beneka et al. 2005; Cassilha et al. 2007; Fatouros et al. 2005; Kalapotharakos et al. 2004; Gine-Garriga et al., 2010). Understanding that muscular strength can be improved by performing traditional and circuit resistance training creates interest regarding the effects of HIIT on improving muscular strength, dynamic balance, and postural sway.

HIIT is comprised of timed intervals with short rest periods, while high and low-velocity and circuit resistance training involves explosive or slow controlled repetitions with longer rest periods. It is necessary to study the impacts of shorter rest periods on older adults. The purpose of this study was to evaluate the effects of HIIT on postural control, lower body strength, and dynamic balance among older adults.

Risk Factors of Falls

Hauer, Becker, Lindemann, and Beyer (2006) describe a fall as an inadvertent fall on the ground or other lower level. The consequences of falling could cause trauma which could result an injury, loss of consciousness, sudden onset of paralysis, or a seizure (Hauer et al., 2006). Shumway-Cook and Woollacott (2012) explain that a loss of balance is defined by the center of mass (COM) being moved outside of the base of support (BOS). Statistics show that unintentional injuries are among the top five causes of death for older adults, and falls are responsible for two-thirds of these deaths among older adults 65 or older (Rubenstein, 2006). Typically, women fall more often than men. Furthermore, with increased age there is an increased possibility of falling (Shumway-Cook, Ciol, Gruber, & Robinson 2005). Multiple contributing factors are responsible for falls; research has shown that both an extrinsic environment (maneuvering through obstacles such as curbs, ice on the ground, cords, stairs, etc.) and intrinsic factors (such as physiological, musculoskeletal, psychosocial, etc.) influence balance (Shumway-Cook et al. 2005).

Older adults who have been hospitalized due to falls are expected to fall again, with the possibility of sustaining another injury (Mckee et al. 2002). McKee et al. (2002) reported that 17.5% of hip fracture patients had a falling accident within two months of discharge. An additional 19% of discharged patients re-injured their hip or pelvis one year post hospitalization (Colon- Emeric et al., 2000). Furthermore, 53.3% of older adults reported falling one or more times after being released from the hospital for 6 months (Shumway-Cook et al. 2005). Postural control, dynamic balance, and lower body muscular strength are all intrinsic factors that have been recognized as important preventative contribution to falls among older adults (Shumway-Cook & Woollacott, 2012). Therefore, by attempting to improve lower body strength, dynamic balance, and postural sway researchers may be able to reduce rates of falls leading to serious injuries among older adults.

Balance Among Older Adults

Diminished ability to balance can arise from several different factors. Altered balance could occur from deterioration of vestibular sensory, visual sensory, or somatosensory and cognitive functioning (Hess &Woollacott, 2005). Any combination of these factors can be problematic for one's ability to balance. Studies have also concluded that lower extremity strength has significant influences on balance impairment among older adults (Granacher, Gruber, & Gollhofer, 2009). Shumway-Cook and Woollacott (2012) identified the contributing risk factors to falls: as impaired depth perception, slow reaction time, and increased postural sway among older adults. Specifically, decreased lower extremity strength is an important risk factor, due to the association with age and muscle atrophy which can result in reduced mobility (Granacher et al., 2009).

Postural Control

When the body is experiencing anterior-posterior (AP) instability it naturally reacts by using ankle strategy or hip strategy to restore the body's COM (Shumway-Cook & Woollacott, 2012). Ankle strategy is the primary pattern related to the muscular synergy that controls the body's vertical sway. For example, if the body was to sway forward, specific muscles will trigger to move the body backwards. The muscle synergy would initially activate the gastrocnemius, followed by the hamstring, and lastly, the paraspinal muscles (Shumway-Cook & Woollacott, 2012). The gastrocnemius creates a reverse in the body's backwards motion by producing plantar flexion torque, which results in backward sway (Shumway-Cook & Woollacott, 2012). The hamstring and paraspinal muscles are responsible for maintaining the hips and knees in the extended position (Shumway-Cook & Woolacott, 2012). When the body is swaying backwards, balance is reestablished by activating the anterior tibialis, the quadriceps, and the abdominal muscles. Therefore, the sequence of AP perturbation is ankle, knee, and hip activation. Ankle strategy is triggered when the body experiences small perturbation of the equilibrium (Shumway-Cook & Woollacott, 2012).

Hip strategy is activated when large and rapid perturbation occurs or when the ankles are unable to activate necessary muscles to regenerate stability (Shumway-Cook & Woollacott, 2012). Additionally, Horak and Nashner (1986) explain that hip strategy restores equilibrium when the surface is smaller than the feet. Standing up on a balance beam is an illustration; the muscle activation after perturbation activates the abdominal, followed by the quadriceps (Shumway-Cook & Wollacott, 2012). This sequence produces a backwards motion (Shumway-Cook & Woollcott, 2012).

Medio-lateral (ML) stability could be just as important as AP stability (Shumway-Cook & Wollacott, 2012). Due to the alignment different muscle activations at different joints occur, which is a different direction of stability recovery. Strategy for equilibrium recovery is different compared to AP recovery. At the ankle and knee joint, little ML movement is to be expected. Thus, the hip joint and the trunk are the primary joints used to reestablish stability in the ML direction (Shumway-Cook, 2012). Researchers have concluded that ML motion is a lateral movement of the pelvis; this movement requires adduction of one leg and abduction of the other leg. Therefore, in order have to ML control, the gluteus medius and tensor fascia latae must be activated (Winter, Prince, Steriou, & Powell, 1993; Horak & Nashner, 1986).

Although, muscular strength is not expected to provide much improvement to reaction time, it is not the reaction time on which researchers are solely fixated. Reaction is only relevant when an individual is in an unstable position. If the time of instability could be lessened by to strengthening the muscles that provide stability, falls could be reduced due to stronger stabilizing muscles associated with sway. If lower body strength is increased by HIIT, postural sway could be positively affected. The average decline reported in maximal muscular strength ranges from 20% to 40% between 30 and 80 years of age (Merletti, Farina, Gazzini, Schieroni, 2002), therefore it can be expected that decreased postural control will be present among older adults. Era et al. (2006) evaluated static postural control on a pressure mat with individuals 30 years old and older (*n* = 7,979). The young group (30-39) and middle-age group (40-49) showed noticeable declines in their ability to control sway, which effects balance functioning, while the older subjects (> 60 years of age) showed an even greater accelerated decline in balance functioning. Fernie, Gryfe, Holliday, and Llewellyn (1982) found that subjects over 63 years of age that had fallen one or more times in a year showed significantly greater postural sway than those who did not fall. This suggests postural sway is associated with age and trends of falling.

Effects of Training on Postural Sway and Dynamic Balance

Postural sway is an indicator of balance ability and stability (Shumway-Cook & Woollacott,, 2012). Researchers have investigated the effects of balance and resistance training on postural sway. Maciaszek and Osinski (2012) used the 8 Foot-Up-and-Go to measure dynamic balance, and found that 18-weeks of Tai Chi showed a significant improvement of dynamic balance for older adults. Fretler, Weltin, Gollhofer, and Ritzmann (2014) and Sihvonen, Sipila, and Era (2004) discovered similar improvements, after 4-weeks of balance training on older adults. Fretler et al. (2014) investigated postural sway by using partially loaded body weight balance training and Sihvonen et al. (2004) observed the effects of visual feedback training on balance and dynamic balance. Sihvonen et al. (2004) implemented physical activity such as walking, while Fretler et al. (2014) strictly required balance training and dynamic balance training. After the 4-week intervention both studies reported balance functioning improvements. Fretler et al. (2014) reported reduced center of pressure (COP) displacement; ML and AP were both significantly improved, indicating improved postural control. Similarly, Sihvonens' et al. (2004) visual feedback training improved ML sway and dynamic balance, the protocol utilized balance exercises for half the time of the first Fretler et al (2014).

Hutt and Redding (2014) evaluated AP sway, ML sway, and dynamic balance in a group of ballet dancers after a 4-week intervention. Scientist determined that the dancers' ML and AP sway results did not improve. Researchers reported that it was due to "exploratory activity" which was caused by the new movement pattern that dancers performed in order to maintain balance, but the dance did show improvement in dynamic balance. Likewise, Yaggie and

Campbell (2006) conducted a study on balance training using the Both-Sides-Up Balance Trainer (BOSU).

Results were non-significant for ML and AP parameters, but also showed improvements in dynamic balance. Hutt and Redding (2014) stated that with a different style of training focusing on resistance training perhaps AP and ML improvements may have been observed, due to the improved muscle strength. By stimulating the lower body, the muscles could be one of the contributing factors to improved postural control and dynamic balance. These studies suggest balance interventions may provide dynamic balance improvement. Though dynamic balance was improved in most of the interventions, postural control measures were contradictory. The effects reported by Sihvonen et al. (2004) could be attributed to the visual balance training.

Kollmitzer et al. (2000) investigated the effects of regular strength training of the back and balance training, and the influence of the combination of both training types on postural control, force, and muscle efficiency. Subjects were assessed at baseline, 1-month, and 2-months post-testing for balance skill and isometric maximum voluntary back extension testing. Subjects were either strength trained or balance trained. After one month of training, the regimens were switched between groups. Results indicated that subjects in both groups showed postural improvements after 4-weeks of strength training. Research has shown that the practice of high intensity (90% Heart rate max or greater) strength training on postural sway is an effective method to achieve improved postural control (Jakobsen et al.,2011). Jakobsen et at. (2011) completed a 12-week study with a sample of younger subjects and after administering high intensity strength training the sample showed significant improvements in ML and AP parameters. Moreover, HIIT can impact muscular strength, and it is suggested to observe different forms of training on older adults.

Training Modalities

HIIT has been shown to improve muscular strength, muscular power, body composition, and balance (Meier et al., 2015; Robinson et al., 1995; Villanueva et al., 2015); however, there is lack of research relating to HIIT within the older adult population. Studies have been published about high intensity aerobic interval training, high velocity resistance training (HVRT), and circuit training.

Research reports that maximal strength peaks around 30 years of age. Once 30 years of age is exceeded, muscular strength tends to plateau or remain the same, and strength declines starts after 50 years of age. However, there is evidence that muscular strength is improved with endurance training among active older adults. Tarpenning, Hamilton-Wessler, Wiswell, and Hawkins (2004) and Tarpenning, Hawkins, Marcell, and Wiswell (2006) evaluated male master runners, finding no significant difference between age-associated relative strength among different age groups of chronic runners. Furthermore, Rogers and Evans (1993) looked at exercise training on aging muscles. The authors found that older adults who participate in resistance and endurance training may show similar muscle gains, similar to the younger population, if the training is adequate in duration and intensity.

Butcher et al. (2015) conducted a study comparing circuit training and HIIT in the form of Cross Fit. This study observed how it affected the heart rate (HR) and Rate of Perceived Exertion (RPE). The results were nearly parallel; data indicated that both styles (HIIT and circuit training) of fitness effectively stimulated HR during exercise. The circuit training group showed significantly higher overall HR, however the RPE scores were not significantly different between the groups. The HIIT training style may not always achieve greater HR levels than other styles of training, but there are different forms of HIIT that could achieve higher HR. Skelly et al. (2014)

compared HIIT to moderate intensity continuous endurance training. Results showed the HIIT training had a lower oxygen consumption rate during exercise compared the endurance group. However, 24 h after exercise, both groups showed similar levels of oxygen uptake. This study showed that HIIT can have a high oxygen uptake rate after exercise of shorter duration and lower exercise volume. Similarly, Herodek, Simonovic, Pavlovic, and Stankovic (2014) carried out a systemic HITT training protocol that showed HIIT to be effective, safe, and provided better body composition improvements than traditional jogging methods.

Research mentioned earlier shows that HIIT is effective at stimulating HR and RPE, participants have to exhaust muscular components in order to achieve high intensity. This style of training has been shown to provide muscular improvements. Meier et al. (2015) found strength improvements after five weeks of HIIT. The study used kettle bells and battle ropes training, subjects performed 15 s of work and 15 s of rest. Similarly, both Villanueva et al. (2015) and Robinson et al. (1995) report significant improvements with 30 s - 60 s recovery intervals of HIIT. Improvements were shown in lower body muscular performance. Villanueva et al. (2015) compared 60 s to 4 min of exercise intervals within the older adult population, and Robinson et al. (1995) compared 30 s, 60 s, and 1 min 30 s recovery period with the younger populations.

Beneka et al. (2005) observed the effects of low, moderate, and high intensity strength training. Greater increases in muscular strength were noted in the high intensity resistance training group at low velocities. Similarly, Kalapotharakos et al. (2004) proposed that training at high and moderate intensity resistance can lead to muscle strength and muscular mass can be improved. However, high intensity resistance training can lead to superior strength gains and hypertrophy, when compared to moderate resistance training. Additionally, high velocity resistance training (HVRT) also showed improvements in depression, quality of life, and sleep quality (Singh et al., 2005). Seynnes et al. (2004) concluded a free-weight-based HVRT for older adults appeared to be as safe as lower intensity training and is more effective than endurance training. These researchers suggest HVRT is an effective training method for the older adult population.

Furthermore, Fielding et al. (2002) conducted a study based on the effects of HVRT on muscle peak power in older women (> 65 years old). Researchers compared high and low-velocity training for 16-weeks. Significant strength improvements in both the high and low-velocity groups were seen. Additionally, results showed that HVRT elicited greater improvements in power. Cantrell et al. (2013) observed and compared resistance training to sprint training concurrent with resistance training, both resulted in strength improvements; the sprint training group showed greater improvements). Beneka et al. (2005) and Fatouros et al. (2005) studies showed that resistance training can provide muscular strength improvements regardless of the velocity or intensity. Gine-Garriga et al. (2010) conducted a study using older adults, and administered one day of resistance training and one day of balance training. The main focus of this study was to improve functional balance. Balance was assessed by the 2 trials of standing sequences (semi-tandem, tandem, and unipedal) and dynamic balance was assessed with the Modified Timed-Up-and-Go Test. After 12-weeks, the subjects showed improvements in balance and strength. These studies indicated that one or three sessions of resistance training for 4-weeks, might provide improvements in muscular strength regardless of the exercise velocity. Likewise, lower-extremity HVRT for 10-weeks applied to balance-impaired older adults showed strength improvements (Hess & Woollacott, 2005). Due to the aforementioned improvement numbers on HVRT, it is worthwhile to evaluate resistance HIIT programs on older adults.

Due to the increasing numbers of the older adult population accompanied by an increased risk of falls because their functionality, it is important that methods of training are developed in order to attempt to reduce fall rates. Postural sway is an important risk factor for falls that can be decreased by training different sensory systems. Enhancing lower body muscular strength might also positively affect dynamic balance and postural sway. As HIIT training gains popularity among younger adults it is necessary to evaluate its effects on the older population. Studies have suggested 4-weeks may be sufficient to stimulate positive effects on balance and dynamic balance (Fretler et al. 2014; Kollmitzer et al. 2000; Sihvonen et al. 2004). Therefore, this thesis intervention would evaluate the effects of 4-weeks of HIIT and resistance training on lower body strength, postural sway, and dynamic balance.

CHAPTER THREE: Methods

Participants

Participants were men (3) and women (7) over the age of 65 years who are currently physically active and community dwelling. Participants were recruited from the Edmond, Oklahoma area by flyers and word of mouth. All participants (*N* = 10) were pre-screened to prevent high risk participants from enrollment. Participants were ineligible to participate if they were not currently involved in a workout routine at least 2-3 days per week for at least three months, which was determined by a pre-screening questionnaire. Participants had to score greater than 10 points on the Short Physical Performance Battery (SPPB) in order to be eligible to participate (Guralinik et al., 1994). Inclusion criteria can be found Table 1. All participants completed the Exercise and Screening for You (EASY) form to determine if a physician's consent was necessary, if the participant answers "yes" on any of the question a physician approval was obtained (Rolland et al., 2004). All participants were asked to read and sign an informed consent document. The University of Central Oklahoma Institutional Review Board approved the study.

Instrumentation

- **Inclusion Criteria Form (APPENDIX A):** Was designed to ask the participants questions that could exclude them from participating in the study. Table 1 provides the determinants of participation. Those questions were asked, and if the participant answered "yes" on any of the questions provided than they were automatically excluded from participating.
- **Exercise and Screening for You (EASY; APPENDIX B):** was a health screening tool design for older adults. This tool is comprised of six different questions regarding falls, health status, and identifying pains. All questions can either be answered yes or no. The

EASY was administered before exercise, and if participant answers yes on any question, the trainer recommended the participant speak with their physician. If the participant was cleared by the physician, did not circle yes, or understood and was in complete control of the problem, then the participant was clear to exercise. This instrument was validated by Rolland et al. (2004).

- **Short Physical Performance Battery (SPPB; APPENDIX C):** consists of three sub-tests, which are: balance testing, short walk at usual pace, and five consecutive chair stands. For balance participants are asked to remain standing for 10 s in three different positions. These positions are feet close together and semi-tandem position (the ankle of one foot behind the joint of another foot). The short walk is for gait speed, it is a timed 4 meter walk at usual pace. The short walk test is measured twice and the fastest time is used. The chair stand requires the participant to stand and sit five consecutive times as quickly as possible, with their arms crossed over their chest. Low scores on the SPPB have a high predictive value for negative health consequences, which include: disability in ADLs, loss of mobility, disability, hospitalization, duration of stay in hospital, admission to nursing homes, and death. This instrument was validated by Guralinik et al. (1994).
- **Tekscan™ :**is a pressure mat beneath the subject's feet. The mat in which the subject was standing on displayed the amount of sway one's body produce. This measurement is observed through measuring pressure place on the foot due to sway. A Tekscan is capable of accurately measuring stability of the human body. Stability is measured by assessing overall postural alignment and the body's ability to maintain balance. When the body fails to maintain a perpendicular position from the ground it is called medio-lateral

(ML) or anterior-posterior (AP) deviation. Although all humans experience some degree of deviation, it is important that the magnitude of deviation is not large. Large deviation can cause poor balance and possibly increase the risk of falling. Therefore, the Tekscan™ will be evaluate ML and AP deviation. Brenton-Rule et al. (2012) validates this method of measurement.

- **Timed Up and Go (TUG; APPENDIX E):** the subject sat in the chair with his/her back against the chair back. On the command "go", the patient rises from the chair, walks 3 meters at a comfortable and safe pace, turns, walks back to the chair, and sits down. The timing begins at the instruction "go" and stops when the patient is seated. This test measures dynamic balance in older adults. Griswold et al. (2014) provide validity evidence.
- **Borg Rate of Perceived Exertion (RPE; APPENDIX F):** took into account fitness level: participants rate their perceived exertion with numbers from 6 to 20; thus, it is a "relative" scale. The scale starts with "no feeling of exertion," which rates a 6, and ends with "very, very hard," which rates a 20. Moderate activities register 11 to 14 on the Borg scale ("fairly light" to "somewhat hard"), while vigorous activities usually rate a 16 or higher ("hard" to "very, very hard"). Mendelsohn, Connelly, Overend & Petrella (2008) reported validation of this measurement.
- **Mini-Mental State Examination (APPENDIX D):** The mini–mental state examination (MMSE) or Folstein test is a 30-point questionnaire that is used extensively in clinical and research settings to measure cognitive impairment. Crum, Anthony, Bassett, and Folstein (1993) validates the usefulness of this examination.

- **30-second Chair Stand (APPENDIX E):** is designed to assess functional strength and endurance of a lower extremities of older adults. Participants sat in the middle of the chair. With feet shoulder-width apart and knees bent at a 90 degrees angle. One foot was slightly in front of the other. Arms were crossed across the chest. Before the assessment, participants was required to complete two reps, if participants used the chair arms to rise from the chair, the subject overall score was a zero. The participants were encouraged to complete as many full stands as possible within 30 s. The participant will be instructed to fully sit between each stand. Administer will record the number of stands completed. The number recorded is going to range between 0 – 20 or greater. Higher scores indicate that the individuals have a high fitness level. Jones, Rikli, & Beam (1999) validates the assessments.

Procedures

The experimental group participated in the intervention two times per week for 4-weeks. The HIIT session was comprised of 10 exercises (Table 2), which simulated several different muscle groups that have been reported to influence balance. Each session lasted for 36 min, which included the warm up, recovery period between bouts, and the cool-down. Participant completed interval bouts ranging from 20- 30 s, and between each bout there was a 30 – 40 s recovery phase. The interval and recovery times are based on progression of exercise, which progressed at two weeks.

At baseline, participants were assessed on postural sway, by a series of balance stances on the Tekscan^{TM} pressure mat. Participants stood in a quiet area with their feet together (feet were parallel with heels together; FT) and semi tandem (feet parallel dominant foot placed diagonally in front of the other with the heel in line with the other toes; ST). Each stance was performed with eyes-open (EO) and eyes-closed (EC) and was repeated twice. Therefore, the for conditions consisted of: FT/EO, FT/EC, ST/EO, and ST/EC. Participants were instructed to stand on the pressure mat, each stance for 10 s, and the stance was performed barefoot with their eyes at the horizon and their arms were in the neutral position and at their sides. After static balance was assessed, dynamic balance was measured with the TUG, and lower extremity strength was measured with the 30-Second Chair Stand test.

During week 2-3, the experimental group performed HIIT interval training, which was comprised of 20 s of work intervals and 40 s of recovery intervals for 10 different exercises. During week 4-5, the duration of the work intervals was increased and the recovery intervals decreased (30 s of work and 30 s of recovery). After each bout participants were asked their rate of perceived exertion (RPE) during the recovery periods. Participants were required to complete all ten exercises. Each exercise lasted one minute, therefore, one bout lasted a total of 10 min each. The participants were given a 3-min rest period between bouts. Participants were instructed to perform the HIIT at a RPE of 15 or greater (Borg, 1970) without holding their breath to minimize an exercise-induced increase in blood-pressure. If participant's RPE was reported to be below 13, then the level of difficulty was increased by using ankle weights.

The week after the exercise intervention the participants in the both groups were retested for post assessment. The assessments were identical to week one's pre-test assessment.

The control group was instructed to continue their current workout regimen through the 4-weeks of intervention. All participants in the control group was assessed before and after the intervention. The control group's assessment was identical to the experimental group.

Study Design and Statistical Analyses

The study was a randomized 4-week intervention that evaluated the difference within and between a HIIT and control group of active older adults. Postural sway, lower body strength, and dynamic balance were evaluated at pre and post-test. The experimental group participated in the HIIT program and the control group continued their exercise program they were using prior to the study. The mean and standard deviation (SD) of all the variables (postural sway, dynamic balance, and muscular strength) were calculated and documented to check for skewness or kurtosis. The variables showed a high level of skewness and kurtosis. Due to the non-normality of the data, a Wilcoxon Sum of Ranks test was utilized to test for within groups' differences. A Mann-Whitney U determined differences between groups at pre-test and post-test. The alpha was set at .05. Due to the selection of the median for reporting, the outliers were not removed for the analysis of inferential statistics. Outliers were removed for the calculation of effect size. Cohen's d (*d*) was utilized to measure the magnitude of the difference between pre and post means.

CHAPTER FOUR: Results

Postural Sway

$H_0 1$ & $H_0 2$: There will be no difference in postural sway between or within the HIIT group and control group from pre-test to post-test (Table 3 and 4).

Experimental Group (Within Groups). Table 1 and 2 display descriptive and inferential statistics for eyes open and eyes closed conditions, respectively. Three stances from pre- to post-test were significantly different, and several stances experienced large effect sizes. The experimental group in the eye's open segment one significant increase. Semi-tandem (ST) variance (Z=-2.00, p =.05) a strong effect size (d = 1.75), the *Mdn* from pre-test (*Mdn*=.05 ± .02 mm) to post-test (.05 ± .01 mm) indicated that values increased. Non-significant, moderate increases were revealed within the feet together (FT) anterior-posterior (AP; d =.31), ST AP (d = .44), and ST medio-lateral (ML; d = .35). AP (d = .52) experienced a large changes over time. Feet Together (FT) ML results indicated a large decrease (d = .83) in postural sway for pre-test (*Mdn*= 3.43 ± 0.79) to post-test (*Mdn*= 2.58 ± 0.79). Moderate decreases in postural sway were identified in the FT variance (d = .54).

The experimental group eye's closed variables resulted in an increase in FT variance in the experimental group, indicated by the weak magnitude (d = .06). ST variance approached significance (Z = -1.84 = p = .07). There were two variables that displayed significance FT ML (Mdn_{pre} = 3.05 ± 2.95, Mdn_{post} = 4.48 ± 2.08; p = .04) and ST AP (Mdn_{pre} = 4.04 ± 1.38, Mdn_{post} = 2.80mm ± .85; p = .03). All other variables showed weak to moderate change over time.

Control Group (Within Groups). The control group experienced no significant changes. The control group eyes open stances reported three variables that approached significance, FT variance (p = .07; d = .86) increased from pre-test (*Mdn*=.04 ± .01 mm) to post-testing (*Mdn*=.07 ± .02 mm), FT ML (p = .068, d = .76) increased from pre-test (*Mdn*= 2.63 ± .90) to post-testing (*Mdn*= 3.75 ±1.21), and ST variance (p = .068, d = 1.11) increased from pre- (*Mdn*= .05 + .02) to post-testing (*Mdn*=.09 ± .03). No variable within the control group eyes open and eyes closed significantly changed over time and all variables indicated increased sway degree of magnitude over time, respectively (Table 1 and 2).

Between Group. A Mann-Whitney U revealed no significant difference between groups at pre-test. Semi tandem eyes closed anterior posterior (ST EC AP) was significantly different at post-test. The experimental group improved significantly (p = .04) from pre-test (*Mdn* = 4.04 mm ± 1.38 mm) to post-test (*Mdn* = 2.80 mm ± .85 mm) while the CG increased from *Mdn*= 6.16 mm ± 2.49 mm (pre-test) to *Mdn* =5.85mm ± 2.38 mm (post-test).

Timed Up and Go

$H_0$3: There will be no difference between and within groups from pre-test to post-test for dynamic balance (Table 5 and Figure 2).

Experimental (Within Groups). The experimental group experienced a significant difference within groups (Z = -2.02, p < .05) .TUG time decreased from pre-test (*Mdn* = 8.02 + 2.34 sec) post-test (*Mdn* = 5.76 + .94 sec) and displayed a strong effect size (d = .90)

Control Group (Within Groups). The control group experienced a significant difference within groups (Z = -2.02, p = .04). The TUG time decreased from pre-test (*Mdn* = 9.68 + .51 sec) to post-testing (*Mdn* = 7.51 + .71 sec) and also exhibited a very strong magnitude (d = 3.13).

Between Groups. The post Timed Up and Go scores from the experimental group exhibited a significance (Mdn_{pre} = 8.02 sec ± 2.34; Mdn_{post} = 5.76 sec + 0.94; p = .04) difference when compared to the control groups (Mdn_{pre} = 9.68 sec ± .51; Mdn_{post} = 7.51 sec ± .71; p < .05; Table 3 and Figure 2).

Chair Stand

$H_0$4: There will be no difference within or between groups during post testing in lower body strength (Table 5 and Figure 1).

Experimental Group (Within Groups). The experimental group experienced a significant difference (Z = -2.201, p < .05; Mdn_{pre} = 13 + 4.94; Mdn_{post} = 22.50 + 2.30) with a strong magnitude (d = .85).

Control Group (Within Groups). The Control group did not show a significant difference (Z = -1.841, p > .07; Table 3).

Between Groups. The post Chair Stand scores from the experimental group exhibited a significance (Mdn_{pre} = 13 reps $\pm$ 4.94; Mdn_{post} = 22.50 reps $\pm$ 2.30; p = .07) difference when compared to the control groups (Mdn_{pre} = 10 reps $\pm$ .00; Mdn_{post} = 13 reps $\pm$ 3.20; p = .07; Table 3 and Figure 1).

CHAPTER FIVE: Discussion

Following four weeks of HIIT training, significant improvements were reported in the experimental group in Timed Up and Go, Chair Stand, and two measures of postural sway (ST ML and ST AP) with eyes closed. However, the experimental group did not improve in any other postural stances (Table 1 and 2). The non-significant variables in the experimental group did indicate change. Meaningful changes occurred in FT AP and ST ML in the eyes closed stance, while the ST variance displayed a moderate reduction and approached significance. The eyes open postural sway group displayed an increase in sway within the experimental group, which implies a significant amount of change within the group. Moderate to strong changes from pre to post-testing was a result in a couple of variables. These included FT variance and FT ML sway. The single leg measurement were excluded due to the participants in ability to stand on one leg for 10 s. Additionally, the TUG showed a significant decrease in time and the chair stand significantly improved (Table 3).

The control group did not show significant values; nearly all the stances measured displayed an increase of sway of a moderate to strong magnitude, while three stances approached significance due to increased scores, which indicates regression (Table 1). These results imply that the control were not effectively training to decrease postural sway. However, the FT ML eyes closed variable showed decrease of sway. The TUG and chair stand approached significance and displayed very strong (Table 3) effect sizes of performance improvement. Additionally after the intervention the control group subjects were offered to participate the exact same HIIT regimen as the experimental group.

These results also implied that there were differences between the experimental groups versus the control group. Significant dissimilarities occurred between the eyes closed ST AP stance experimental group versus the control group. The TUG indicated the experimental group had a greater improvement than the control group, and the chair stand approached significance.

Practical Implications

Despite the nonsignificant values found, many stances in the postural sway analysis, resulted in positive improvements in the experimental groups. The variables which displayed significance or positive change over time were all in the experimental group. These results are similar to Fretler et al. (2014), Kollmitzer et al. (2000), and Jakobsen et al. (2011). The results in this study suggest that HIIT positively effects postural control, though not significantly, due to the changes over time. Some resistance training and HIIT studies have found significance, but the difference is the duration of the studies, which will be addressed in the future research section.

Although the intervention did not show a significant effect on postural sway, it did impact dynamic balance. The experimental group experienced significant, strong improvements in both the chair stand and TUG. During the intervention, the rest intervals utilized were initially 30 s, then adjusted to 20 s during the last two weeks of the exercise intervention. These results are concurrent with Villanueva et al. (2015) and Robinson et al. (1995). These studies reported significant strength improvements with 30 s - 60 s recovery intervals during HIIT training. Moreover, studies have suggested 4-weeks may be appropriate to positively effects on balance and dynamic balance (Fretler et al. 2014; Kollmitzer et al. 2000; Sihvonen et al. 2004). However, the current study can only acknowledge improvements in dynamic balance. Additionally, the muscular strength component was improved. Participants in the experimental group nearly doubling their pre assessment values (Mdn_{pre} = 13, Mdn_{post} = 22.50). Kollmitzer et al. (2000) saw benefits to balance concurrently with strength improvements in eight weeks. This study included a mid-assessment at week 4, at 4-weeks postural sway improvements and increased lower body strength was a byproduct of the exercise and balance regimen. Furthermore, Villanueva et al. (2015) concluded that muscular strength improvement is possible. Similar to this study, Yaggie and Campbell (2006) reported non-significant results for ML and AP postural sway parameters, but also showed improvements in postural sway following four weeks of balance training on a BOSU ball which implies that balance training has a positive effect on postural sway and lower body strength for older adults. Physical activity programming should extend HIIT in order to improve reactive balance, static balance, and postural sway.

Limitations

The volunteer sample size was a limitation to the study. All of the subjects were already active, therefore the population represented a biased portion of the community and the total size of the sample was low. Subjects were unfamiliar with the timed interval structure and the exercises, which may have kept them from achieving a true high-intensity level (RPE = 16 or greater). A longer familiarization phase for the assessment and the exercise routine would have helped subjects adapt to the intervention. The participants were not able to sustain a consistent high-intensity effort during the exercises. Therefore, this intervention may not have been a true HIIT program, because the subjects were unable to consistently record RPE (16 or greater) values that indicates HIIT. This limitation could be the reason the null hypothesis was accepted for most of the postural sway variables.

Directions for Future Research

Future research should include an exercise familiarization phase, of at least three sessions before starting the intervention. The familiarization will give the participants the opportunity to practice the movement, to become familiar with the exercises. Being familiar the exercise could provide participants the ability to move more confidently and quicker, which could improve work ethic. During the invention researchers documented that subject's showed improved self-confidence and improved body control during the second week of exercise, subjectively.

Future research should consider adding an active recovery of light exercise. Exercise selection is also important, excluding the chair stand and stairs, all of the other exercises used were not able to stimulate RPE effectively (Table 4). As the intervention participants did not seem to be confident in their performance until about a week and a half into the intervention, the addition of a familiarization phase might be important to help subject's confidence. Measuring confidence and self-efficacy before and after could be an important addition to the assessment procedure. Subjective psychological growth could be due to the improved physical coordination, which should be measured. Finding a way to adequately simulate the HR or the RPE scores reported while training targeted muscles should be done in order to more accurately assess the effects of high intensity. Future research should consider adopting this method of time sequence for the exercise structure. The addition of an active recovery which entails balance exercises would be recommended for future research in this area or perhaps devoted one session to HIIT and the other to balance training, could be beneficial.

Conclusions

Hutt and Redding (2014) reported dynamic balance improvements, but no postural control improvements, similar to the current study. The participants were ballet dancer and performed exercise which entailed dynamic balance movements. The current exercise regimen was constructed of similar exercises. These authors also reported that postural improvements did not occur due to the unfamiliar movement, therefore the participants may not have been performing at optimal level. The current study had similar obstacles to adapt to. This is why a familiarization phase is imperative to the participant's performance. This study was not able to create a high intensity workout, as noted by the low - moderate RPE values (Table 6). However, those values still managed to result in significant lower body strength improvements and dynamic balance improvements. Postural sway only showed one variable improvement. Therefore, moderate intensity interval training did not induced sway improvements, but it did stimulate dynamic balance and lower body strength improvements. Therefore, results suggest that moderate intensity interval training can improve dynamic balance and lower body strength, while displaying some positive changes in postural sway.

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Tables

Table 1.

The Determinants of Participation

Exclusion Criteria	Instrument
1. Inactivity 2. Unable to walk without assisted device 3. Under the age of 65 4. Stoke History 5. Myocardial infraction history 6. Terminal illness 7. Unstable cardiovascular disease 8. Lower body fractures with in the last 6 months 9. Uncontrolled hypertension 10. Hip or knee replacement	• Exclusion Criteria Questionnaire (1-10)
11. Inability to pass *EASY* or acquire physician's approval to participate, if EASY is not passed	• Exercise and Screening for You (11)
12. Functional limitation	• Short Physical Performance Battery (12)

Table 2.
Exercise for the HIIT Intervention

Order of the Exercises	Exercise	Muscle Group
1.	Chair Stand	Quadriceps, Hamstrings, Iliacus, and Psoas Major
2.	Seated Alternating Leg Extension	Rectus Femoris, Vastus Lateralis, Vastus Intermedius, Vastus Medialis, transverse abdominis, obliques
3.	Hurdles (Lateral Steps)	Gluteus Medius, Iliacus, Psoas Major, Rectus Femoris, and Rectus Abdominis
4.	Hurdles (Front Steps)	Iliacus, Psoas Major, Rectus Femoris, and Rectus Abdominis
5.	Calf and Toe Raises (Rockers)	Soleus, Gastrocnemius, and Tibilias Anterior
6.	Straight Leg Kickbacks	Gluteus Maximus and Medius
7.	Torso Twist	External Obilique, Rectus Abdominis, Rectus Femoris, Iliacus, and Psoas Major
8.	Hamstring Curls	Biceps femoris, semitendinosus and semimembranosus
9.	Stairs	Gluteus Maximus, Quadriceps, and Hamstrings, Psoas Major, Iliacus, , Gastrocnemius and Tibialis Posterior
10.	High Knees (Marching)	Iliacus, Psoas Major, Rectus Femoris, and Rectus Abdominis

Table 3.

Eye's Open Wilcoxon Descriptive Statistics

Wilcoxon Descriptive										
Variables (cm)	Control Pre & Post					Experiment Pre & Post				
	Mdn (*SD*)	*Mdn* (*SD*)	*p*	*Z*	*d*	*Mdn* (*SD*)	*Mdn* (*SD*)	*p*	*Z*	*d*
<u>Eyes Open</u>										
(FT) Variance	0.04 (.01)	0.07 (0.02)	.07	-1.83	.86	0.06 (0.24)	0.05 (0.14)	.79	-.27	.54
(FT) AP	1.89 (.96)	2.76 (1.60)	.14	-1.46	.54	2.23 (0.77)	2.93 (0.90)	.75	-.31	.31
(FT) ML	2.63(.90)	3.75 (1.21)	.07	-1.87	.76	3.43 (0.79)	2.58 (0.79)	.35	-.94	.83
(ST) Variance	0.05 (.02)	0.09 (.03)	.07	-1.87	1.11	0.05 (0.02)	0.05 (.01)	.05	-2.00	1.747
(ST) AP	2.00 (.39)	2.98 (1.58)	.14	-1.46	1.05	2.03 (0.62)	1.97 (0.70)	.27	-1.10	.44
(ST) ML	3.33 (.94)	3.48 (.65)	.14	-1.46	.44	2.24 (0.63)	2.51 (0.71)	.21	-1.26	.35

Note. *Mdn* = Medium; *SD* = Standard Deviation; Cohan's d = *d*; FT = Feet Together; AP = Anterior-Posterior; ML = Medio-Lateral: ST = Semi-Tandem

Table 4.

Eye's Closed Wilcoxon Descriptive Statistic

Wilcoxon Descriptive Table

Variables (cm)	Control Pre & Post					Experiment Pre & Post				
	Mdn (SD)	*Mdn* (*SD*)	*p*	*Z*	*d*	*M*dn (*SD*)	*Mdn* (*SD*)	*p*	*Z*	*d*
Eyes Closed										
(FT) Variance	0.70 (.04)	0.07 (0.07)	.47	-.73	.26	0.10 (0.33)	0.10 (0.04)	.50	-.674	.057
(FT) AP	2.64 (.39)	2.90 (1.88)	.14	-1.46	.51	3.18 (2.50)	3.22 (1.28)	.92	-.11	.01
(FT) ML	3.46 (.94)	4.02 (0.96)	1.00	.00	.05	3.05 (2.95)	4.48 (2.08)	.04	-2.02	.21
(ST) Variance	0.16 (0.08)	0.22 (0.08)	.47	-.73	.55	0.11 (0.08)	0.13 (0.03)	.07	-1.84	.21
(ST) AP	6.16 (2.49)	5.85 (2.38)	.72	-.37	.13	4.04 (1.38)	2.80 (0.85)	.03	-2.20	.03
(ST) ML	6.78 (3.55)	9.38 (2.72)	.72	-.37	.35	5.46 (1.76)	4.64 (2.37)	.50	-.67	.02

Note. *Mdn* = Medium; *SD* = Standard Deviation; Cohan's d = *d*; FT = Feet Together; AP = Anterior-Posterior; ML = Medio-Lateral: ST = Semi-Tandem; the green highlight indicates any level of improvement

Table 5.
Functional Testing Wilcoxon Descriptive

Wilcoxon Descriptive Table										
Functional Testing Variables	Control Pre & Post					Experiment Pre & Post				
	Mdn (SD)	Mdn (SD)	*p*	*Z*	*d*	Mdn (SD)	Mdn (SD)	*p*	*Z*	*d*
Timed Up and Go	9.68 (0.51)	7.51 (0.71)	.068	-1.83	3.13	8.02 (2.34)	5.76 (0.94)	.04	-2.02	.90
Chair Stand	10.00 (.00)	13.00 (3.20)	.066	-1.84	1.88	13.00 (4.94)	22.50 (2.30)	.04	-2.02	.84

Note. *Mdn* = Medium; *SD* = Standard Deviation; Cohan's d = *d*; the green highlight indicates significant levels of improvement

Table 6.

Rate of Perceived Exertion Statistics

Average Weekly Scores				
Subjects	**Week 1**	**Week 2**	**Week 3**	**Week 4**
1	11.85	12.55	12.9	13.7
2	11.00	12.05	15.40	15.65
3	11.20	11.65	13.15	12.22
4	13.40	13.05	12.22	13.28
5	8.98	12.43	13.25	13.40
6	10.30	8.43	9.50	9.82

Note. Each week entails the average score of two HIIT session Rate of Perceived Exertion score that the subject reported.

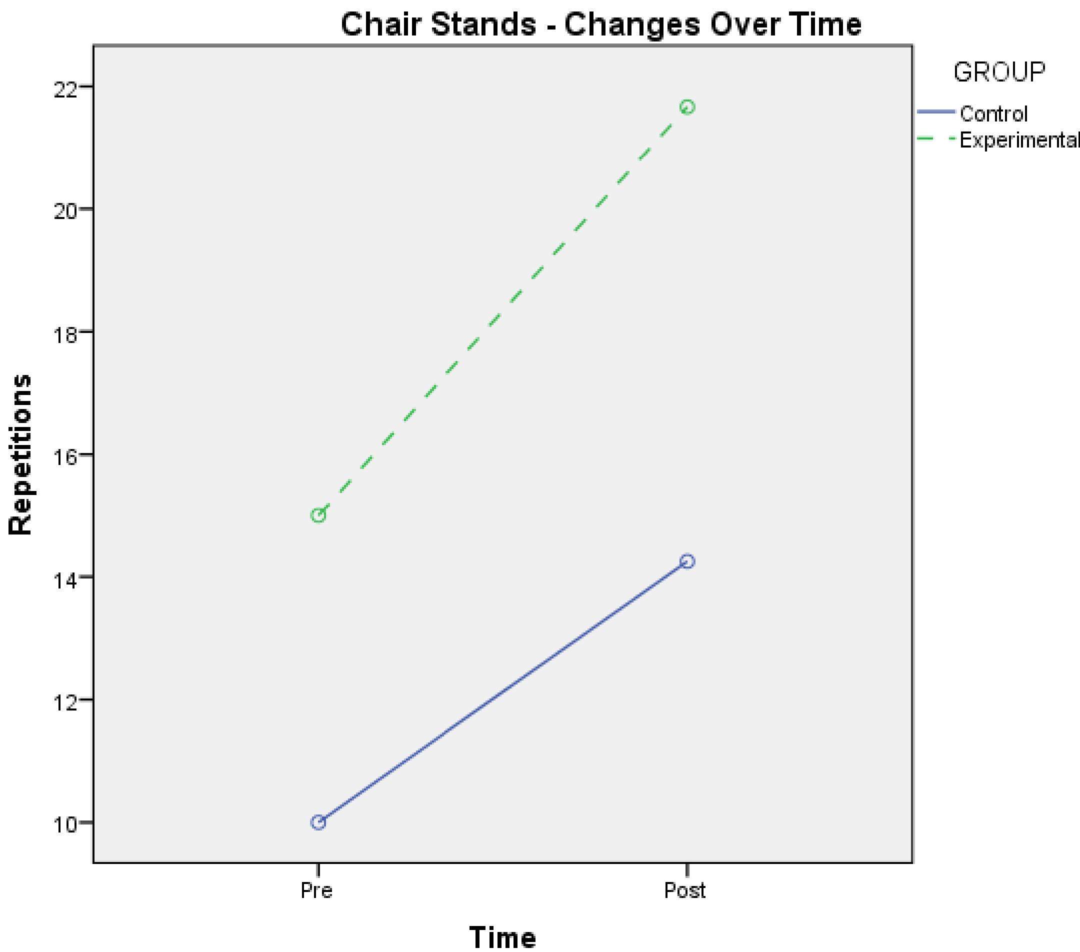


Figure 1. The mean group scores are compared from each group. Both groups improved, the experimental group a displayed significant improvement.

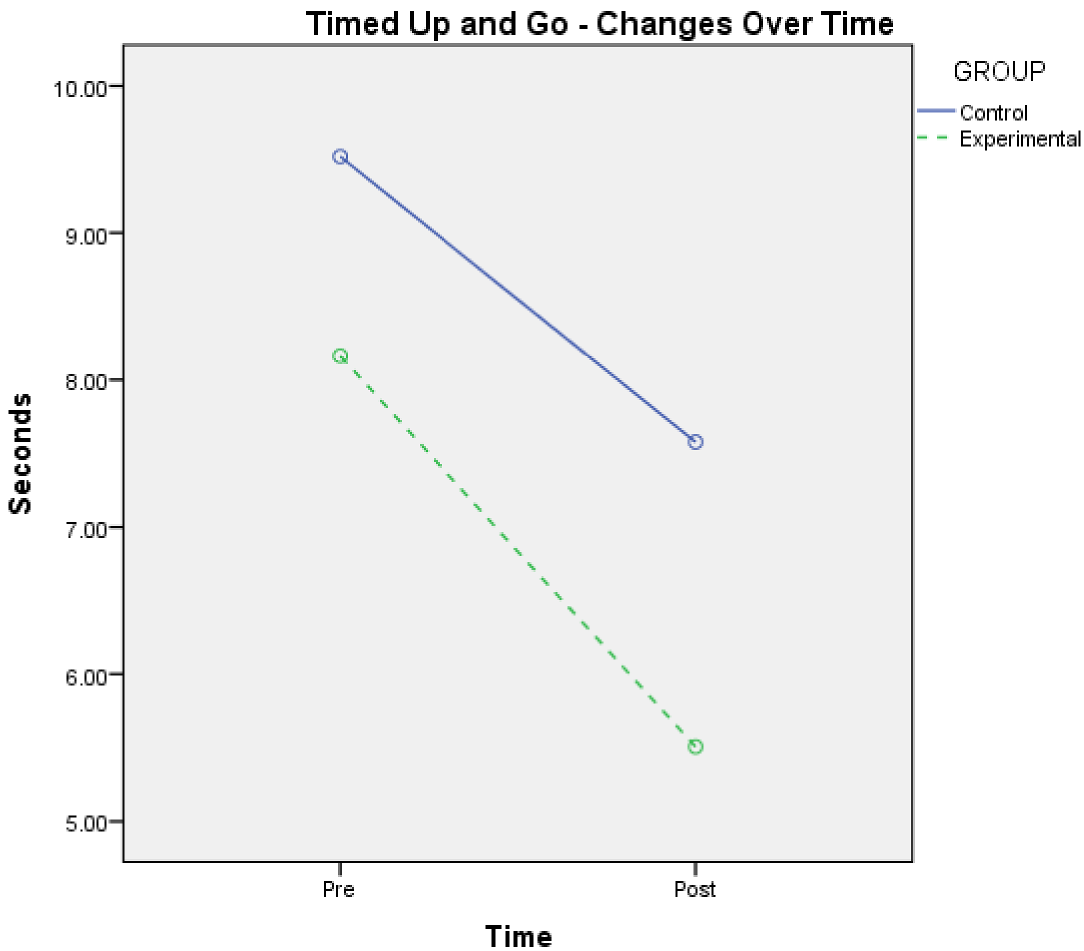


Figure 2. The mean group scores are compared from each group. Both groups improved. The experimental group displayed a significant improvement.

Inclusion Criteria Form

Appendix A

INCLUSION FORM

NAME:

If any question is answered (a circled yes or no indicates the answer) yes, the applicant is automatically disqualified from participating in the intervention.

1.	Do you participate in less than 30 minutes of exercise per day for at least 3-5 days per week?	YES	NO
2.	If yes, have you been active for less than 3 months?	YES	NO
3.	Are you unable to walk without assisted device?	YES	NO
4.	Are you under the age of 65 years old?	YES	NO
5.	Have you ever had a stroke before?	YES	NO
6.	Have you or do you currently have a myocardial infraction?	YES	NO
7.	Do you have a terminal illness?	YES	NO
8.	Do you have an unstable cardiovascular disease?	YES	NO
9.	Do you currently or have you had a lower body fracture(s) within the last 6 months?	YES	NO
10.	Do you have unstable hypertension?	YES	NO
11.	Have you had a hip or knee replacement?	YES	NO

Exercise and Screening for You

(EASY)

Appendix B

Answering the Six Easy Questions:

EASY QUESTIONS (Circle Response):

1) Do you have pains, tightness or pressure in your chest during physical activity (walking, climbing stairs, household chores, similar activities)?	**Yes No**
2) Do you currently experience dizziness or lightheadedness?	**Yes No**
3) Have you ever been told you have high blood pressure?	**Yes No**
4) Do you have pain, stiffness or swelling that limits or prevents you from doing what you want or need to do?	**Yes No**
5) Do you fall, feel unsteady, or use assistive device device while standing or walking?	**Yes No**
6) Is there a health reason not mentioned why you would be concerned about starting an exercise program?	**Yes No**

Short Physical Performance Battery

(SPPB)

Appendix C

Short Physical Performance Battery

1. Repeated Chair Stands

Instructions: Do you think it is safe for you to try and stand up from a chair five times without using your arms? Please stand up straight as quickly as you can five times, without stopping in between. After standing up each time, sit down and then stand up again. Keep your arms folded across your chest. Please watch while I demonstrate. I'll be timing you with a stopwatch. Are you ready? Begin

Grading: Begin stop watch when subject begins to stand up. Count aloud each time subject arises. Stop the stopwatch when subject has straightened up completely for the fifth time. Also stop if the subject uses arms, or after 1 minute, if subject has not completed rises, and if concerned about the subject's safety.. Record the number of seconds and the presence of imbalance.. Then complete ordinal scoring.

Time: _____sec (if five stands are completed)
Number of Stands Completed: 1 2 3 4 5

Chair Stand Ordinal Score: _____

0 = unable

1 = > 16.7 sec

2 = 16.6-13.7 sec

3 = 13.6-11.2 sec

4 = < 11.1 sec

2. Balance Testing

Begin with a semitandem stand (heel of one foot placed by the big toe of the other foot). Individuals unable to hold this position should try the side-by-side position. Those able to stand in the semitandem position should be tested in the full tandem position. Once you have completed time measures, complete ordinal scoring.

a. Semitandem Stand

Instructions: Now I want you to try to stand with the side of the heel of one foot touching the big toe of the other foot for about 10 seconds. You may put either foot in front, whichever is more comfortable for you. Please watch while I demonstrate.

Grading: Stand next to the participant to help him or her into semitandem position. Allow participant to hold onto your arms to get balance. Begin timing when participant has the feet in position and lets go.

Circle one number

2. Held for 10 sec

1. Held for less than 10 sec; number of seconds held _____

0. Not attempted

b. Side-by-Side stand

Instructions: I want you to try to stand with your feet together, side by side, for about 10 sec. Please watch while I demonstrate. You may use your arms, bend your knees, or move your body to maintain your balance, but try not to move your feet. Try to hold this position until I tell you to stop.

Grading: Stand next to the participant to help him or her into the side-by-side position. Allow participant to hold onto your arms to get balance. Begin timing when participant has feet together and lets go.

Grading

2. Held of 10 sec

1. Held for less than 10 sec; number of seconds held_____

0. Not attempted

c. Tandem Stand

Instructions: Now I want you to try to stand with the heel of one foot in front of and touching the toes of the other foot for 10 sec. You may put either foot in front, whichever is more comfortable for you. Please watch while I demonstrate.

Grading: Stand next to the participant to help him or her into the side-by-side position. Allow participant to hold onto your arms to get balance. Begin timing when participant has feet together and lets go.

Grading

2. Held of 10 sec

1. Held for less than 10 sec; number of seconds held_____

0. Not attempted

Balance Ordinal Score: _____

0 = side by side 0-9 sec or unable

1 = side by side 10, <10 sec semitandem

2 = semitandem 10 sec, tandem 0-2 sec

3 = semitandem 10 sec, tandem 3-9 sec

4 = tandem 10 sec

3. 8' Walk (2.44 meters)

Instructions: This is our walking course. If you use a cane or other walking aid when walking outside your home, please use it for this test. I want you to walk at your usual pace to the other end of this course (a distance of 8'). Walk all the way past the other end of the tape before you stop. I will walk with you. Are you ready?

Grading: Press the start button to start the stopwatch as the participant begins walking. Measure the time take to walk 8'. Then complete ordinal scoring.

Time: _____ sec

Gait Ordinal Score: _____

0 = could not do

1 = >5.7 sec (<0.43 m/sec)

2 = 4.1-6.5 sec (0.44-0.60 m/sec)

3 = 3.2-4.0 (0.61-0.77 m/sec)

4 = <3.1 sec (>0.78 m/sec)

Summary Ordinal Score: _____

Range: 0 (worst performance) to 12 (best performance). Shown to have predictive validity showing a gradient of risk for mortality, nursing home admission, and disability.

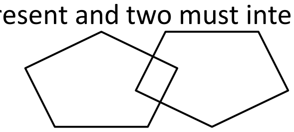
Mini-Mental State Examination

(MMSE)

Appendix D

Mini-Mental State Examination (MMSE)

Patient's Name: ______________________________________ Date: ___________

Maximum Score	Patient's Score	Questions
5		"What is the year? Season? Date? Day of the week? Month?"
5		"Where are we now: State? County? Town/city? Hospital? Floor?"
3		The examiner names three unrelated objects clearly and slowly, then asks the patient to name all three of them. The patient's response is used for scoring. The examiner repeats them until patient learns all of them, if possible. Number of trials: ___________
5		"I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, …) Stop after five answers. Alternative: "Spell WORLD backwards." (D-L-R-O-W)
3		"Earlier I told you the names of three things. Can you tell me what those were?"
2		Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them.
1		"Repeat the phrase: 'No ifs, ands, or buts.'"
3		"Take the paper in your right hand, fold it in half, and put it on the floor." (The examiner gives the patient a piece of blank paper.)
1		"Please read this and do what it says." (Written instruction is "Close your eyes.")
1		"Make up and write a sentence about anything." (This sentence must contain a noun and a verb.)
1		"Please copy this picture." (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.) 
30		TOTAL

0

TUG, Chair Stand, and Borg

(Assessment Sheet)

Appendix E

Check the box if the document has been completed by the participant:

- ☐ **1.** Exclusion Criteria Questionnaire
- ☐ **2.** Exercise and Screening for You (EASY)
- ☐ **3.** Short Physical Performance Battery (SPPB)

Postural Sway Assessment:

Subjects are required to complete each stance twice. Each stance will last 30 seconds, administer is responsible for keeping the time and if the participate does not complete the full 30 seconds, then the time completed should be recorded.

	Check if subject completed the assessment	
1. Feet Together		
a. Eyes open :		
b. Eyes closed:		
2. Semi-Tandem		
a. Eyes open:		
b. Eyes closed:		
3. Unipedal		
a. Right leg eyes open:		
b. Right leg eyes closed:		
c. Left leg eyes open:		
d. Left leg eyes closed:		

Dynamic Balance (timed up and go):

Participants should wear their regular footwear and cannot use a walking aid. Begin by having the participant sit back in a standard arm chair and identify a line 3 meters or 10 feet away on the floor.
Instructions to the patient: When I say "Go," I want you to:
1. Stand up from the chair
2. Walk to the line on the floor at your normal pace
3. Turn
4. Walk back to the chair at your normal pace
5. Sit down again

On the word "Go" begin timing. Stop timing after patient has sat back down and record.

Time: __________ seconds

An older adult who takes ≥12 seconds to complete the TUG is at high risk for falling.

30-Second Chair Stand:

Instructions to the participant:
1. Sit in the middle of the chair.
2. Place your hands on the opposite shoulder crossed at the wrists.
3. Keep your feet flat on the floor.
4. Keep your back straight and keep your arms against your chest.
5. On "Go," rise to a full standing position and then sit back down again.
6. Repeat this for 30 seconds.

On "Go," begin timing. If the participant must use his/her arms to stand, stop the test. Record "0" for the number and score. Count the number of times the patient comes to a full standing position in 30 seconds. If the patient is over halfway to a standing position when 30 seconds have elapsed, count it as a stand. Record the number of times the patient stands in 30 seconds.

Number: Score ___________

Borg Rate of Perceived Exertion

APPENDIX F:

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

IRB Approval Letter

September 8, 2015

IRB Application #: 15085

Proposal Title: The Effects Of High-Intensity Interval Training On Postural Sway, Dynamic Balance, And Muscular Strength Among Older Adults

Type of Review: Amendment-Expedited

Investigator(s):

Mr. Antonio Ross

Dr. Larissa Boyd

Department of Kinesiology and Health Studies

College of Education & Professional Studies

Campus Box 189

University of Central Oklahoma

Edmond, OK 73034

Dear Mr. Ross and Dr. Boyd:

Re: IRB Amendment Application

We have received and reviewed your request for an amendment to your approved IRB application and supporting materials. The UCO IRB approves the following amendments to your application:

Changes to the research team.

Original Approval Date: 6/26/2015

Approval Expiration: 6/25/2016

This project is approved for a one year period from the original approval date and any further modification to the procedures and/or consent form must be approved prior to its incorporation into the study. A written request is needed to initiate the amendment process. You will be notified in writing prior to the expiration of this approval to determine if a continuing review is needed.

We wish you continued success with your project. If our office can be of further assistance, please do not hesitate to contact us.

Sincerely,

Robert D. Mather, Ph.D.
Chair, Institutional Review Board
NUC 341, Campus Box 132
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irb@uco.edu