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Effects of Controlled Whole-Body Vibration Training on Reducing Risk of Falls Among Young Adults with Obesity

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EFFECTS OF CONTROLLED WHOLE-BODY VIBRATION TRAINING ON
REDUCING RISK OF FALLS AMONG YOUNG ADULTS WITH OBESITY

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Abstract

Introduction: Among people with obesity, several factors increase the risk of falls: an abnormal body mass distribution, muscle weakness, and postural instability. Although standard exercise-based training could change these factors, a significant portion of people with obesity may be unable or unwilling to comply with long duration and high intensity training programs.

Therefore, alternative training methods are highly demanded. Growing evidence supports that controlled whole-body vibration (CWBV) training can reduce risk of falls among older adults. No study has yet investigated the potential effect of CWBV training on reducing risk of falls among obese populations. The purpose of this study was to systematically investigate the overall effectiveness and feasibility of CWBV training on young obese populations. Focus was placed on the impact of a 6-week CWBV training on reducing body fat percentage, improving muscle strength, and enhancing dynamic gait stability.

Methods: Eighteen young adults with obesity participated in the experiment and were randomized into two groups: training or control. Participants in the training group received CWBV training 3 days a week for 6-weeks while standing on a side-alternating vibration platform. Training consisted of 5-repetitions of 1-minute vibration followed by 1-minute rest. The vibration frequency was 25 Hz and an amplitude of 10.8 mm. The control group followed the same training procedure except for a 0-mm amplitude. Prior to (pre-training) and following (post-training) the 6-week training, participants were evaluated for their risk of falls in terms of body composition, muscle strength, and dynamic gait stability in response to an unannounced slip during gait.

Results: All measurements were not different between groups at pre-training evaluation. The body composition parameters did not show any significant difference associated with the two

main factors (i.e., group: training vs. control and time: pre-training vs. post-training) and their interaction ($p > 0.05$ for all). For muscle strength, no significant main effect for time or group was detected, however a significant time \times group interaction effect was seen for the knee extensor strength capacity ($p < 0.05$). Dynamic gait stability in response to the slip demonstrated a significant time \times group interaction ($p < 0.05$) without significant main factors effect ($p > 0.05$). The improved stability in the training group was resulted from the improved center of mass position and velocity (marginal time \times group interaction effect for both center of mass position and velocity: $p = 0.060$ for position and $p = 0.062$ for velocity). A similar time \times group interaction effect was also observed for the trunk angle after slip ($p = 0.058$).

Discussion: A 6-week CWBV may not be effective to change the body composition among young individuals with obesity. The CWBV training could improve muscle strength, particularly knee extensor strength. The 6-week training course did increase the dynamic gait stability during the slip in the training group. The findings from this study could provide useful guidance to design effective fall prevention programs for people affected by obesity.

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1. Introduction

Obesity is a condition where excessive fat has accumulated on a person's body (Lai, Leung, Li, & Zhang, 2008). Obesity has been identified as a major risk factor for cardiovascular disease, and shown negative effects on functional movements such as walking and performance (Ko, Stenholm, & Ferrucci, 2010). Obesity's prevalence has increased in many populations including children (Ebbeling, Pawlak & Ludwig, 2002). Obesity can lead to various medical conditions. Over 300 million people worldwide are obese and 115 million of them suffer from hypertension, cancer, heart disease, diabetes, dyslipidemia, cardiovascular disease, and musculoskeletal problems (Lai et al., 2008). It has also been shown that obesity increases the risk of certain cancers and relates to high morbidity rate (Blair & Brodney, 1999). Furthermore, obesity correlates with low physical activity levels and low cardiorespiratory fitness levels (Blair & Brodney, 1999).

1.1 Effects of Obesity on Falls

Falls inevitably occur throughout life and are serious issues due to high amounts of injuries they cause. Falls are associated with many physiological factors such as increased postural sway, reduced dynamic action balance, and decreased knee, hip, and ankle strength (Rogers, Rogers, Takeshima & Islam, 2003). Obesity can elevate the risk of falls. For example, it was reported that abnormal body mass distribution can lead to impaired body balance and increased likelihood of falls (Corbeil, Simoneau, Rancort, Tremblay, & Teasdale, 2001). The effects of obesity can lower the quality of life by making daily functional activities such as walking, standing, or kneeling more difficult to perform (Fjeldstad, Fjeldstad, Acree, Nickel, & Gardner, 2008). These factors place individuals with obesity at a higher risk for falls compared to non-obese individuals. Fjeldstad et al. (2008) reported that nearly 1/3 of individuals with obesity (27%)

have an occurrence of falling compared to 14% of non-obese individuals (Fjeldstad et al., 2008).

1.2 Mechanisms of Obesity Increasing Falls

As mentioned previously, abnormal body mass distribution, lack of muscle strength, and decreased stability are factors through which obesity increases the risk of falls. Walking is a functional movement that is used throughout daily life. Walking patterns, known as gait, are sets of complex movements and cyclical movements that also contain dynamic interactions of both external and internal forces (de Souza, Faintuch, Valezi, Sant Anna, Gama-Rodrigues, Fonseca, Souza, & Senhorini, 2005). Obesity can negatively affect gait patterns by altering step length, cadence, and walking speed (Lai et al., 2008). Additional weight places excess strain leading to joint problems and altered gait commonly seen in obese populations. These gait alterations cause obese populations to have higher risk of falls.

Obesity has also been related to the disabling the performance of daily living activities by affecting muscle strength of the lower body (Lafortuna, Maffiuletti, Agosti, & Sartorio, 2005).

Adequate muscle strength is needed to perform daily functional activities. The reduction of body fat and the increased muscle mass are two current recommendations to fend off obesity (Roelants, Delecluse, Goris, & Verschueren, 2004).

Foot and ankle characteristics are important fall risk identifiers. With the foot as the only source contacting the floor, it was reported that the foot has two main mechanisms for maintaining stability: it provides mechanical support and a structure for the lower limb muscles to contract as needed, and it uses mechanoreceptors to provide sensory information regarding body position (Menz, Morris, & Lord, 2006). Foot sensation decreases with age, causing lack of sensation in the feet to be a risk factor for falls in elderly individuals (Menz et al., 2006). Teasdale et al. (2006) reported that obese individuals have sensory impairment problems. Bernard, Hue,

Amato, Seynnes, & Lantieri (2003) reported obese individuals had increased sway standing on foam surfaces which was in part caused by foot sensation abnormalities.

1.2.1 Body Mass

Alterations in body mass distribution are common in people with obesity. Obesity includes higher amounts of total fat mass and body fat percentage (Karelis, St. Pierre, Conus, Rabas-Lhoret, & Poehlman, 2013). Often times this extra fat distribution is in visceral adipose tissue in the center of the body (Karelis et al., 2013). The greater fat mass leads to alterations in the body's center of mass (COM). These alterations place the COM closer to the edges of the base of support (BOS) which can increase the risk of fall. Abnormal body mass distribution requires individuals with obesity to produce higher amounts of torque to overcome the differences in COM needed to maintain stability and prevent falls (Teasdale et al., 2006).

1.2.2 Muscle Strength

Obesity has effects on muscle strength. Knee extensor muscle strength is of high priority for human balance during locomotion due to its association with the power involved for functional aspects such as gait speed, stair climbing ability, standing from a seated position, and postural stability (Maffiuletti et al., 2007). According to Hulens et al. (2001), individuals with obesity have higher body weight and greater fat free mass compared to lean individuals. Taking this into consideration, it is believed larger muscle mass is associated with overall enhanced muscle strength (Hulens et al., 2001).

Hulens et al. (2001) measured body composition, knee flexion and extension muscle strength and found that weight, body mass index (BMI), fat mass (FM), and fat free mass (FFM) were considerably larger in obese female participants. Lafortuna et al. (2005) measured muscle strength and power using 1-repetition max (RM) leg press tests for strength and a maximum

jump test for muscular power. The findings supported that individuals with obesity produce an overall greater strength and power output but when normalized for body weight, have overall lower strength and power outputs compared to the non-obese individuals (Lafortuna et al., 2005). Lafortuna et al. (2005) reported lower muscular performances in aerobic and anaerobic capacity in obese individuals which they speculated to be caused by muscle fatigue. Maffiuletti et al. (2007) reported that obese individuals contained an overall higher power and torque production for isokinetic knee flexion but when normalized to body weight, the overall power values were significantly lower in the individuals with obesity compared to the non-obese individuals. The previous studies support the importance muscle strength plays in determining gait and physical functional capabilities of obese versus non-obese individuals.

1.2.3 Body Balance

Body balance is a component to prevent the risk of falls. As mentioned earlier, obesity can alter COM and place the individual in a less stable situation. Teasdale et al. (2007) reported abnormal body mass and high amounts of sensory integration problems can also increase the risk of falling. Teasdale et al. (2007) reported that weight loss greatly improved postural stability. It was reported that obese individuals have a longer double stance and foot contact time than non-obese individuals even during faster walking speeds (McGraw, McClenaghan, Williams, Dickerson, & Ward, 2000). McGraw et al. (2000) reported individuals with obesity alter their COM position which had effects in lowering postural stability.

A study by Lai et al. (2008) performed a gait analysis using motion capture software for obese and non-obese participants and found significantly shorter stride length, slower speed, increased stance phase, and double-time walking by the obese populations. De Souza et al. (2005) reported gait alterations seen with obese individuals are indicative of physiological or pathological

compensations. The findings by de Souza et al. (2005) support the findings of Lai et al. (2008), that obese participants had a larger BOS with an enlarged foot angle, slower gait speeds, cadence, and foot stride. Laughton et al. (2003) reported gait characteristics of obese individuals were altered because various muscles groups were trying to overcome sway which led to overcompensation of different movements while trying to maintain posture and stability. Ko et al. (2010) mentioned that the added weight being carried by obese participants places them at greater risk for joint dysfunctions which plays a factor in altering gait. It was reported that individuals with obesity alter ankle and knee flexion times during the landing phase increasing contact time which decreased the amount of force applied to the joints due to the added weight (Ko et al., 2010).

1.2.4 Dynamic Stability

When a person is standing, a loss of balance occurs when the projection of the COM is outside the BOS (Borelli, 1680). Under a dynamic situation like gait, dynamic stability is the ability to maintain the COM's motion state (i.e., the combination of COM velocity and position relative to the BOS) within the Feasible Stability Region (FSR) (Yang, Passariello, & Pai, 2008). Stability was calculated as the shortest distance from the COM motion state to the edge of the limit against backwards balance loss. When calculating stability, a zero value represented COM position directly over the edge of the BOS. The greater the stability value, the more stable against backwards balance loss. Dynamic stability related to risk of falls has not been investigated in people with obesity. As mentioned earlier, obesity individuals have a greater risk of falls. No research has looked at the importance of dynamic stability for young obese individuals.

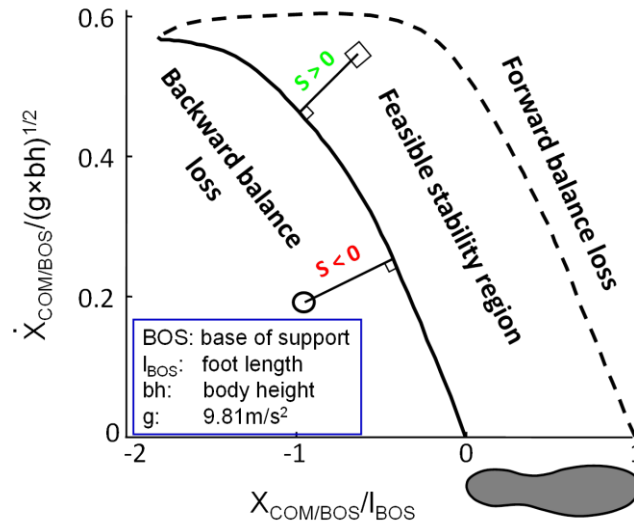


Figure 1. Schematic for dynamic gait stability and the feasibility stability region (FSR). During dynamic gait actions, the feasible stability region depicts the area where COM motion state must remain in order to prevent a backwards balance loss (Yang et al., 2008). The FSR area is relative to BOS (Borelli, 1680).

1.3 Currently Available Training Methods

Given the significant and negative effect of obesity on the risk of falls, it is urgent to develop effective training paradigms to prevent falls from occurring among obese individuals.

1.3.1 Training Methods

Current training methods include aerobic and resistance training programs aimed at changing body composition and increasing muscle strength. Aerobic training can be performed for various durations and intensities each offering up different health results. Resistance training varies based off desired fitness goals. It is suggested that low repetitions (1-5) with high resistance can be used for strength increases, while lower resistances with higher repetitions (> 12) can lead to muscle endurance benefits (Baechle & Earle, 2008). Long duration aerobic training has shown significant improvements in peak oxygen consumption leading to decreased fat content (Geleibter, Maher, Gerace, Gutin, Heymsfield, & Hashim, 1997).

Resistance training has led to increases in FFM due to hypertrophy which can change resting metabolic rate (RMR) and effect body composition (Geleibeter et al., 1997). High intensity resistance training has led to increased muscle mass due to hypertrophy, increased RMR, and produced significant weight loss (Bryner et al., 1999). It was reported that long duration aerobic training altered body composition with decreased body fat and decreased lean muscle mass (Bryner et al., 1999).

A study performed by Irving et al. (2008) looked at the effects of training intensity on abdominal visceral fat and body composition. Irving et al. (2008) reported high intensity training produced significant decreases in total abdominal fat, total body weight, BMI, and fat mass, while the low intensity training produced no effects on fat mass. Resistance training maintained fat free muscle mass more than the aerobic trained individuals (Irving et al., 2008).

Another study (Sarsen, Ardic, Özgen, Topuz, & Sermez, 2006) looked at the effects of aerobic and resistance training on obese women. Participants performed an aerobic training session of brisk walking at 50% heart rate reserve increasing to 85% HRR across the 12-week training period. The resistance training group performed full body strength training exercises and gradually increased training intensity from 40-60% of their 1-repetition max to 75-80% 1-repetition max during the 12-week training program. At the end of the study, Sarsen et al. (2006) reported a significant decrease in body weight of both the resistance and aerobic training groups. Roelants et al. (2004) reported cardiovascular training combined with resistance training to be effective in the past at reducing body fat and increasing muscle mass.

1.3.2 Previous Research

The previous research suggests aerobic and resistance training programs have been beneficial at reducing body weight and altering body composition. Aerobic and resistance training programs

have led to positive results such as lowering visceral abdominal fat and increased muscle mass. Looking at the previous research, it was shown that approximately 20% of all of the participants that participated in these programs are unable to comply or complete the training program requirements due to physical inability. Injuries are another common factor that keep participants from completing their training programs. Another possible explanation could be that the participant themselves were not willing or wanting to further continue the training programs. It would be beneficial to find alternative training methods capable of delivering the same benefits seen with aerobic and resistance training programs, but in a simpler format allowing all individuals to complete the programs they are participating in.

1.4 Controlled Whole-body Vibration Training

Alternative methods of altering body composition and increasing muscle strength can be beneficial. Controlled whole-body vibration training (CWBV) training is a relatively new training paradigm being investigated for its ability to alter body composition and increase muscle strength. CWBV training stimulates sensory receptors such as muscle spindles to cause muscle contractions that possibly alter body composition and increase muscle mass (Roelants et al., 2004). CWBV training is a possible alternative training method to aide in decreasing fat mass and altering body composition while increasing muscle strength. There are several different forms of vibration training being used. Vertical vibration training platforms cause a vertical motion on both sides of the platform. Side alternating vibration platforms cause the vibrations to alternate in a left to right sequence which alleviates the amount of stress placed upon the spine while still providing sufficient amount of stimulus to the lower legs and working muscles (Ritzmann, Gollhofer, & Kramer, 2013).

Few published studies have utilized vibration training for muscle strength gains or body fat

reduction in older overweight or obese populations. However, the use of vibration training as an alternative method for reducing body fat and increasing muscle mass in younger populations is limited. Wilms et al. (2012) reported vibration training is a beneficial alternative method due to the simplicity of the actions and because it does not require high levels of motivation or energy expenditure in order to receive the benefits.

A study performed by Vissers et al. (2010) measured the effects of CWBV training on visceral adipose tissue (VAT) of overweight and obese adults. Following 12 months of CWBV training, a significant decrease in VAT and decreased waist to hip ratio (WHR) was observed (Vissers et al., 2010). The findings reported by Vissers et al. (2010) were different from other studies.

Vissers et al. (2010) reported significant decreases in visceral adipose and body weight, while Bogaerts et al. (2007) reported increases in fat free mass development but no decrease in fat mass. Roelants et al. (2004) reported no changes in body composition. Vissers et al. (2010), Bogaerts et al. (2007), and Roelants et al. (2004), report conflicting results for body composition from CWBV training. Vissers et al. (2010) believed their study showed the potential for decreasing body weight, WHR, and VAT is superior when combining vibration training with diet than when combining aerobic and resistance training with diet. Wilms et al. (2012), conducted a study measuring CWBV training effects on body composition and endurance training in obese adults. Wilms et al. (2012) utilized a 6-week aerobic training or a 6-week aerobic training program combined with CWBV training. They reported the endurance training program led to decreased waist circumference and fat mass but the results were not significantly different from the control group which does not support that CWBV training was in fact the reason behind the results (Wilms et al., 2012). The results were similar to those from Roelants et al. (2004) which reported no significant changes in body composition after a 24-week CWBV training course.

CWBV training is believed to cause physiological and neuromuscular changes in the body by eliciting responses in the muscle bellies and tendons (Cormie et al., 2006). CWBV training has led to muscle hypertrophy of the muscles involved in the training (Bogaerts et al., 2007). With positive results being reported, CWBV training has emerged as a possible alternative training paradigm that could be used in place of aerobic or resistance training programs.

Benefits of CWBV include short training durations. Previous research has used training periods as low as 10 minutes and have reported positive improvements in body composition, strength, and stability. The machine itself is very simple to use and requires no supervision. Except for the platform, there are no outside moving parts that could place the participant in harm's way. The settings are highly controllable. One other aspect that is being looked at for CWBV training is due to its simplicity, it may lead to higher compliance rates for exercise training programs.

According to Roelants et al. (2004) CWBV training produced no changes in fat mass after 24 weeks, but muscle strength of the knee-extensors significantly improved along with increased fat free muscle mass similar to results reported with resistance training. Another study used CWBV training and a combined aerobic and resistance training on muscle strength and muscle mass in older men. The whole-body vibration training produced significant improvements in muscle strength, explosive strength and muscle mass which were all comparable to the improvements seen with the combined aerobic and resistance training results (Bogaerts, Delecluse, Claessens, Coudyzer, Boonen, & Verschueren, 2007). Bogaerts et al. (2007) and Roelants et al. (2004) both reported increases in muscle strength for different populations. Bogaerts et al. (2007), using computed tomography, measured muscle mass of the leg and reported increased muscle mass. CWBV training was reported to lead to muscle strength gains through neurological adaptations and muscle hypertrophy (Bogaerts et al., 2007).

Delecluse, Roelants, Diels, Koninckx, & Verschueren, 2005 investigated the effects of CWBV training on muscle strength and sprint performance in previously sprint-trained athletes. The participants performed tests for muscle strength such as isometric strength and maximal knee extension velocity which using a dynamometer, explosive strength using vertical jump performance, and horizontal force and speed time using load cells (LC) from the starting take-off position from a sprint. After the training program, there were no effects on maximal leg muscle strength, vertical jump, sprint running velocities, or force time characteristics (Delecluse et al., 2005). Maffiuletti et al. (2007) and Lafortuna et al. (2005) reported significant improvements in muscle strength while Delecluse et al. (2005) did not. Possible implications for differences could be that Delecluse et al. (2005) used highly trained athletes that were accustomed to physical training while Maffiuletti et al. (2007) and Lafortuna et al. (2005) used previously untrained participants. Study duration could have played a role as well since Delecluse et al. (2005) used a short duration study period while Maffiuletti et al. (2007) and Lafortuna et al. (2005) used long term training in their respected studies. This opened up possibilities for further approaches to determine if altering training duration and intensity could lead to increased muscle strength and power in highly trained individuals using CWBV training.

Previous research has focused on individuals with obesity and elderly populations (Yang, King, Dillon, & Su, 2015). The previous research has shown that CWBV training can increase muscle strength, improve functional mobility, and alter body composition, leading to improvements in stability and decreased risk of falls in elderly populations. These improvements with elderly populations provide possibilities for CWBV training to be used in other populations. As mentioned earlier, obese populations exhibit characteristics such as lower overall muscle strength and altered COM position which alter gait and leads to an increased risk of falls. Because obese

populations have similar characteristics for fall risk as the elderly, it is reasonable to assume that obese populations may benefit from CWBV training. CWBV training is a fairly new training paradigm with still limited research concerning the training effects of CWBV on reducing falls among people with obesity. With the growing rate of obesity, having a simple alternative training method may be of great benefit.

1.5 Purpose and Hypotheses

The overall purpose of this study was to systematically examine the overall effectiveness and the feasibility of CWBV training for reducing the risk of falls among young individuals with obesity. Three measurements including body composition, muscle strength, and dynamic stability which corresponded with the obesity-induced fall risk factors were of our interest. We hypothesized that among individuals with obesity, a 6-week CWBV training would:

- 1) Alter body composition by decreasing fat mass (kg), fat (%), BMI, and increasing FFM (kg);
- 2) Increase muscle strength of knee extensor and flexor actions;
- 3) Improve the dynamic stability control and reduce the likelihood of falls when exposed to a simulated slip in gait.

2. Methods

2.1 Participants

This study was approved by the University of Texas at El Paso Institutional Review Board. Participants were recruited from the University of Texas at El Paso and the surrounding areas. Presentations were given to various classes throughout the university looking for participants. Sign-up sheets were passed around the classes. Flyers were distributed across local area stores and facilities with contact information attached. To be included in this study, participants must have been young adults aged between 18 and 45 years old. The participants were also required to have no known neurological or muscular degenerative disorders and must be classified as obese based on BMI and fat%.

According to the American College of Sports Medicine (ACSM) guidelines (2014), a BMI of $\geq 30 \text{ kg/m}^2$ is considered to be obese, but there is no set standard for classification of obesity based on fat %. ACSM guidelines (2014) stated that the accepted range for non-essential body fat is 10-22% for men, and 20-32% for women. For this study, obesity was classified as a BMI $\geq 30 \text{ kg/m}^2$ for males and females and a fat % $\geq 30\%$ for females and $\geq 25\%$ for males. All evaluations and training sessions were conducted at the Stanley E. Fulton Biomechanics and Motor Behavior Laboratory at the University of Texas at El Paso. The participants were initially contacted and asked for their body height and weight which were used to calculate their BMI. If BMI was $\geq 30 \text{ kg/m}^2$, an appointment was scheduled to determine if they were qualified for the study and for their first evaluation. Participants were instructed to wear tight fitting comfortable clothing and comfortable walking shoes for the evaluations. Participants were provided a written consent form which explained the extent of the study and all risks or concerns.

Table 1. The physical characteristics for the participants as well as the effects on body composition between the control and training groups at pre- and post-training evaluations.

Measurements	Control Group (n = 9)		Training Group (n = 9)		p value		
	Pre	Post	Pre	Post	Group	Time	Interaction
Height (cm)	171.48 ± 10.67	171.24 ± 10.33	173.76 ± 6.75	173.78 ± 6.60			
Gender	5 males		7 males		0.346		
Age (yrs.)	22.89 ± 2.47		26.56 ± 7.35		0.938		
Body Mass (kg)	101.47 ± 21.54	102.71 ± 22.49	103.52 ± 9.32	104.62 ± 8.49	0.800	0.064	0.817
Fat (%)	36.60 ± 5.61	37.89 ± 6.35	35.16 ± 5.95	34.90 ± 6.20	0.431	0.524	0.294
BMI (kg/m ²)	34.42 ± 6.40	34.96 ± 6.51	34.24 ± 0.86	34.64 ± 1.51	0.910	0.129	0.810
FFM (%)	63.40 ± 5.61	62.11 ± 6.35	64.84 ± 5.95	65.10 ± 6.20	0.433	0.479	0.297

At the beginning of this study, 23 young obese participants were enrolled and randomized into two groups (training vs control). As the study progressed, several participants withdrew for different reasons. One participant was called into active military service so they were not able to complete all of training sessions or the post-training evaluation. Two participants experienced injuries unrelated to the study that prevented them from returning to complete their post-training evaluations. One participant was excluded for having previous experience with the slip perturbation protocol. One participant was excluded as it was discovered they had experienced a stroke before beginning the study. In the end, each group consisted of nine subjects who completed the study (Table 1).

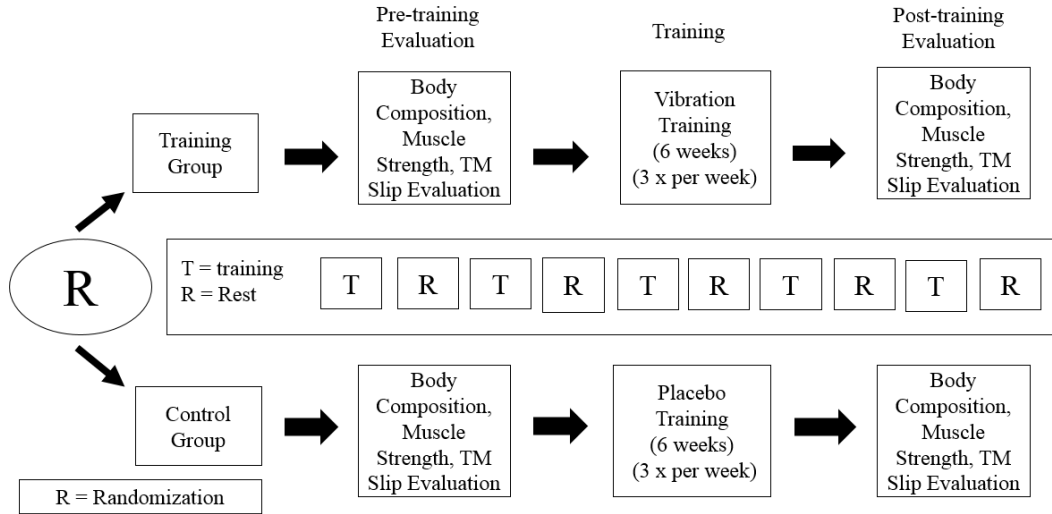


Figure 2. Study design schematic. Shows the order for the evaluations and training sessions for both the control and training groups

2.2 Study Design

Figure 2 shows the study design for the evaluations and trainings for the control and training groups. Both groups performed pre- and post-evaluations for body composition, isometric extensor and flexor strength test, and a treadmill slip perturbation test for dynamic stability. The training group then performed the vibration training protocol and the control group performed the placebo training protocol.

2.3 Fall Risk Evaluations

This study included evaluations for body composition, muscle strength, and dynamic stability. Body composition was evaluated using bioelectrical impedance analysis (BIA). The BIA evaluation measured body mass (kg), fat%, fat free mass percentage (%), and FFM (kg). Muscle strength evaluations consisted of maximal isometric extensor and flexor contractions. Average torque values were recorded by a dynamometer. The average torque values were manually normalized by body mass (Nm/kg). Evaluations for stability were measured on a slip trial

induced during walking on a special treadmill. The control and training group performed the same evaluations at pre- and post-evaluations.

2.3.1 Body Composition

Body composition was measured using (BIA) (TBF-310 01A,). Participants were instructed to follow the proper hydration regulations provided by the BIA manufacturer. Figure 3 shows the foot-placement used during the BIA analysis. Body height, mass, age, and gender were entered into the BIA system. Participants were instructed to remove their shoes, socks, and to stand on the BIA platform. The participants were then instructed to stand as still as possible until the BIA machine completed the measurement.



Figure 3. Shows the foot placement the participants used during the BIA evaluation. The BIA test allowed for all body composition measurements such as fat, fat%, FFM, and FFM%.



Figure 4. Demonstrates how the participants were placed in order to complete the evaluation for isometric extensor and flexor muscle strength.

2.3.2 Muscle Strength

Muscle strength was measured with an isokinetic dynamometer (Biodex system 3, NY).

Maximum knee extensor and flexor strength was measured on the right side of the body using isometric contractions. The participants' maximum knee extensor strength was then normalized for body mass. As shown in Figure 4, the participants sat on the seat of the isokinetic dynamometer with their right knee aligned with the center axis of the dynamometer lever arm. The lever arm was aligned with the participants' lateral malleolus. The length of the lever arm was measured in inches. The participants first performed the lever arm calibration for range of motion. Participants then performed a maximal isometric extensor and flexor muscle strength test with their right leg locked in a 35° position of knee flexion. The maximal extensor muscle contraction test lasted for 7 s, followed by a 15-s rest period. They then performed a maximum flexor contraction for 7 s followed by a 15-s rest period. Each contraction was performed three times. Average isometric torque was recorded and then normalized for body mass (Nm/kg).



Figure 5. Shows how the knee angle was measured. The strap of the harness was full extended while the participants were able to squat at a 45° angle in knee flexion.

2.3.3 Dynamic Stability

Participants walked several times on a 14-m linear walkway at a self-selected speed over ground for familiarization. Participants were placed on the treadmill: Activestep (Simbex, NH).

Participants were safely attached to the treadmill using the safety harness with the strap length individualized for each participant by standing at the rear of the treadmill with knees flexed at 45° and the straps fully extended (Figure 5). Participants began each trial in the center of the treadmill underneath the load-cell device with their left foot slightly ahead of the right foot.

Participants performed three trials at a self-selected walking speed followed by five trials at a normalized walking speed of 1.2 m/s. One slip perturbation trial was performed after the walking trials. The participants had no knowledge of when, where, or how the slip perturbation would occur and were given instructions to recover their balance as quickly as possible and continue to walk if a slip occurs. Dynamic gait stability was calculated for the slip trial using full body kinematics recorded with 8-camera motion capture system (Vicon, Oxford, UK). Twenty-six reflective markers were placed throughout the participants' body to record dynamic gait.

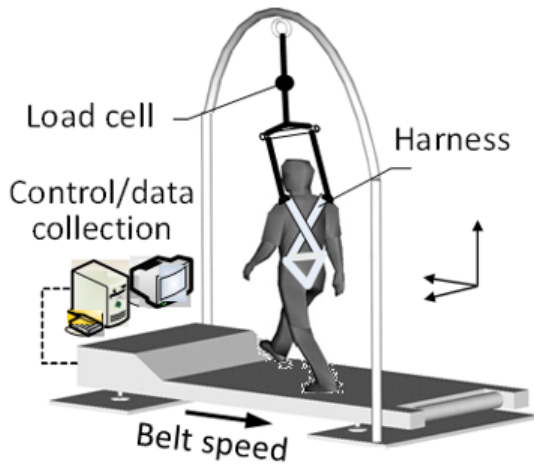


Figure 6 (a)

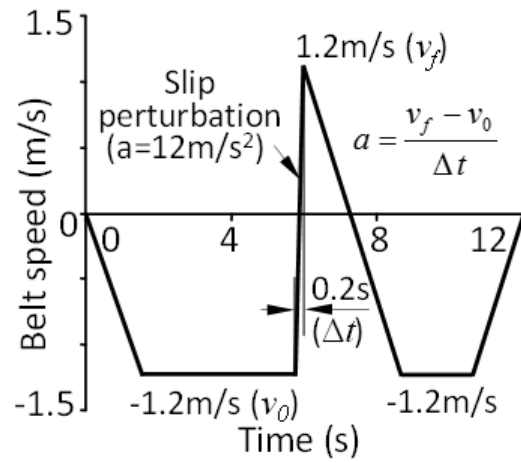


Figure 6 (b)

Figure 6. (a): Depicts a schematic of the treadmill used to induce slip perturbation trials and regular treadmill walking trials (b) Demonstrates the belt speed profile for the treadmill which was used for the slip perturbation trials.

Figure 6 (a) depicts the schematic of the treadmill used for slip perturbation and walking trials.

The participant was strapped into the harness and stood in the center of the treadmill. Figure 6

(b) provides a demonstration for the belt speed profile for the slip perturbation trials. During the

slip perturbation, the treadmill belt changed direction at a rate of 1.2 m/s in a span of 0.2 s

inducing the slip. After the slip, the belt would return to the normal direction and back to its

previous speed.



Figure 7. Displays an example of a participant standing on the vibration platform. It depicts the participant with their feet in position three and a 20° angle of knee flexion and the trunk in an upright position.

2.4 Vibration Training

The vibration training was conducted on a side alternating vibration platform (Orthometrix, NY). The vibration training protocol was performed three times per week for six weeks with 1-minute vibration followed by 1-minute rest for 5 cycles. Participants stood on the vibration platform with knees at a 20° angle and their trunk in an upright vertical position (Figure 7). The vibration frequency was set at 25 Hz. The participants placed their feet at position three which created an amplitude of 10.8 mm. The control group followed the placebo training protocol which was the same procedure as the training group except with a 0-mm vibration amplitude.

2.5 Data Reduction

2.5.1 Body Composition

The body composition variables were expressed by the body mass (kg), fat percentage (%), BMI (kg/m^2), and FFM percent (%). Fat % is the percentage of fat divided by body mass. BMI was calculated as the participants' body mass divided by the square of their body height. FFM % was

measured as a percentage of the amount of fat-free mass divided by body mass. FFM included all other forms of tissues that were not fat.

2.5.2 Muscle Strength

Muscle strength was measured using maximal isometric contractions during extension and flexion. The participants performed three maximal isometric contractions of extension and flexion. The average torque was normalized to the participants' body mass by dividing the average torque by body mass (Nm/kg).

2.5.3 Slip Outcome and Stability

Slip outcome was determined by one of two outcomes: fall vs recovery. Figure 8 depicts an example of the difference between a fall and a recovery. A fall was determined if the load-cell (LC) value was $\geq 30\%$ of the participants body weight (BW). A recovery was determined if the LC force was $< 30\%$ BW. Figures 9 (a) & 9 (b) depict the peak load forces generated during a fall and a recovery (Yang & Pai, 2011). Figure 9 (a) shows a LC force above 30% of the participants body weight (BW) representing a fall, and Figure 9 (b) depicts a LC force below 30% of the participants BW which representing a recovery.

Fall: ($LC \geq 30\% BW$)

Recovery: ($LC < 30\% BW$)



LC = Load Cell

BW = Body Weight

Figure 8. Shows the outcome results for both a fall and a recovery. A slip trial with peak forces placed on the LC that were $\geq 30\% BW$ were classified as a fall. Otherwise it was classified as a recovery.

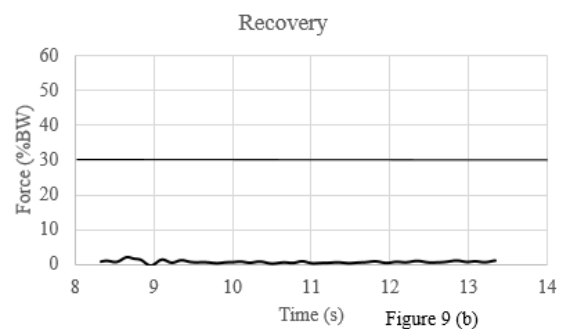
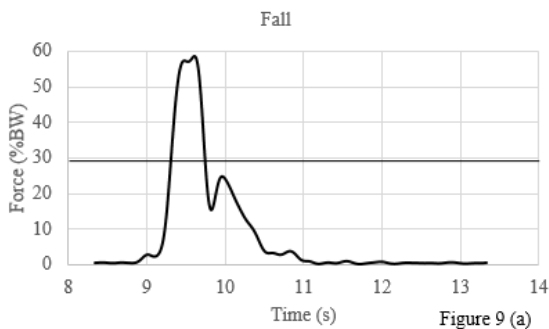


Figure 9. Displays the peak LC forces created during a fall and a recovery trial. Figure 9 (a) shows the forces on the LC were above 30% BW representing a fall. Figure 9 (b) shows the forces on the LC were below 30% BW representing a recovery.

Marker paths were low-pass filtered at marker-specific cut-off frequencies (ranging from 4.5 to 9Hz) using fourth-order, zero-lag Butterworth filters (Winter, 2005). Locations of joint centers, heels, and toes were computed from the filtered marker positions. The recovery foot touchdown (RTD) was determined as the recovery foot made contact with the treadmill belt after the slip and

was determined from foot kinematics: when the vertical velocity of the heel marker was below 0.05 m/s. The two components of the COM motion state, i.e. its position and velocity were calculated relative to the rear of BOS (i.e. the leading heel) and normalized by foot length (l_{BOS}) and $\sqrt{g \times bh}$, respectively, where g is gravitational acceleration and bh is body height. The magnitude of the dynamic stability was computed as the shortest distance from the given COM motions state (i.e. its position and velocity relative to the BOS) to the lower boundary of the FSR. The dynamic gait stability was calculated at RTD. Trunk angle was calculated as the angle created between the trunk segment and the vertical axis. A positive value indicated that the participants' trunk was angled behind the vertical axis. Trunk angle was computed during the RTD.

2.6 Statistical Analysis

Independent t-tests and χ^2 test were applied to examine if there was any significant difference at baseline between groups in the fall risk factors (body composition, muscle strength, trunk angle, and dynamic gait stability at RTD), and fall incidence in response to the slip. To investigate the training effect of CWBV, analysis of variance (ANOVA) with repeated measures was used with the group (training vs control) being the between-subject factor and time (pre vs. post) being the within-subject factor. If an overall F-value was found to be significant, pre-planned t-tests (either paired or independent t-tests) were used to evaluate the difference between pre- and post-training sessions or the differences between groups at either session. General estimating equation (GEE) analysis was used to analyze the fall rate in response to the unexpected slip between groups on both evaluations. SPSS 22.0 (IBM, NY) was used for all data analysis. A p-value of ≤ 0.05 was used to represent whether significance was identified.

3. Results

Throughout the study, none of the participants experienced or reported any adverse effects or injuries with the vibration training or evaluations. A slight itching sensation was experienced by several participants; however, the itching sensation disappeared several minutes after the end of the training session.

3.1 Body Composition

Table 1 shows the results for body composition at both pre- and post-training evaluations for the control and training groups. At the pre-training evaluation, no significant difference in the body composition measurements were found between groups ($p > 0.05$). Neither a significant overall time effect nor a group \times time effect was found for the body composition measurements ($p > 0.05$ for all, Table 1). Fat% dropped in the training group but increased in the control group. However, the changes were not statistically significant. There was a slight increase in FFM% in the training group and a slight decrease in the control group. These slight changes were not significant. FFM% saw a slight increase in the training group and a decrease in the control group but the changes were not significant.

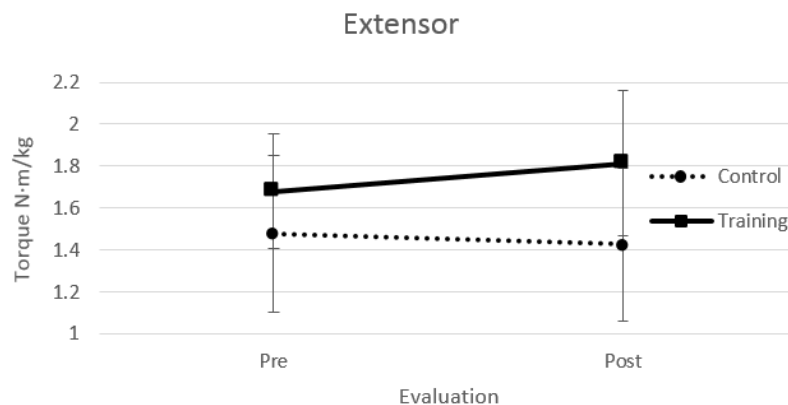


Figure 10. Displays the average torque values during isometric extension muscle contractions for the training and control groups. An interaction can be seen between the pre- and post-training evaluations.

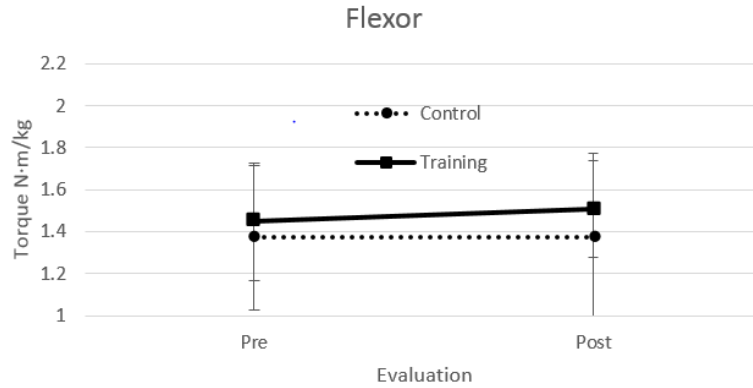


Figure 11. . Shows the average torque values during isometric flexion muscle contractions for the training and control groups. No interaction was seen between pre- and post-training evaluations.

3.2 Muscle Strength

Figure 10 shows the results for knee isometric extensor strength capacity. At pre-training test, the knee extensor peak torque did not differ between groups ($p > 0.05$). No significant difference associated with the main factors of groups or time was found ($p > 0.05$ for both main factors). However, a significant group \times time interaction effect was observed ($p < 0.05$). Independent t-test result revealed that the knee extensor strength capacity among the training group was significantly greater than the control group at the post-training evaluation (Figure 10, 1.81 ± 0.35 vs. 1.42 ± 0.36 Nm/kg, $p < 0.05$). There was no significant difference seen in knee flexor strength between-groups at pre- and post-training evaluations. Further, no training-related difference was observed for the flexor strength (Figure 11) ($p > 0.05$ for all).

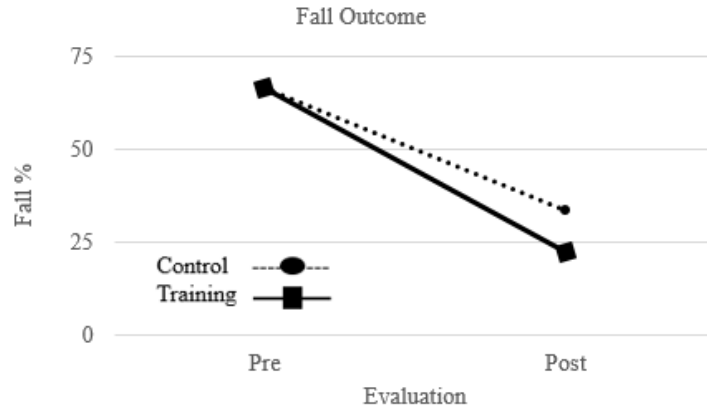


Figure 12. Shows the fall percentage outcome between pre-training and post-training for the control and training groups.

3.3 Falls and Dynamic Stability

Fall outcome at pre- and post-training for training and control groups can be seen in Figure 12.

At the pre-training evaluation, 6 of 9 (66.7%) participants fell during the slip perturbation in each group. At the post-training evaluation, three participants (33.3%) from the control group fell while two (22.2%) participants from the training group fell. The results showed no significant difference between the control and training groups ($p > 0.05$). GEE analysis demonstrated a significant reduction in the fall rate from pre-training test to the post-training test for both groups ($p < 0.01$). No significant group \times time interaction was detected.

No significant main effects for group or time were observed associated with the COM position, COM velocity, and dynamic gait stability at RTD (Figure 13). However, borderline or significant p values were found with the group \times time effect for the COM position ($p = 0.060$), COM velocity ($p = 0.062$), and dynamic stability ($p < 0.05$). Planned independent t -tests further indicated that the training group placed their COM position more anterior during post-training (Figure 13a, -0.184 ± 0.22 vs. -0.38 ± 0.33 , $p < 0.05$) with a less backward COM velocity (Figure 13b, -0.224 ± 0.156 vs. -0.301 ± 0.04 , $p < 0.01$) in comparison with the control group at the post-

training evaluation indicating the training group was more stable than the control group at post-training evaluation (Figure 13c, -0.294 ± 0.23 vs. -0.458 ± 0.19 , $p < 0.05$).

As seen in Figure 14, no main effect associated with the group or time was detected for the trunk angle at RTD. A marginal p value was found for the interaction effect of the group \times time ($p = 0.055$). Planned independent t -test indicated that the control group had a larger trunk angle in comparison with the training group at RTD during the post-training slip (Figure 14, $4.07^\circ \pm 0.09^\circ$ vs. $0.127^\circ \pm 0.04^\circ$).

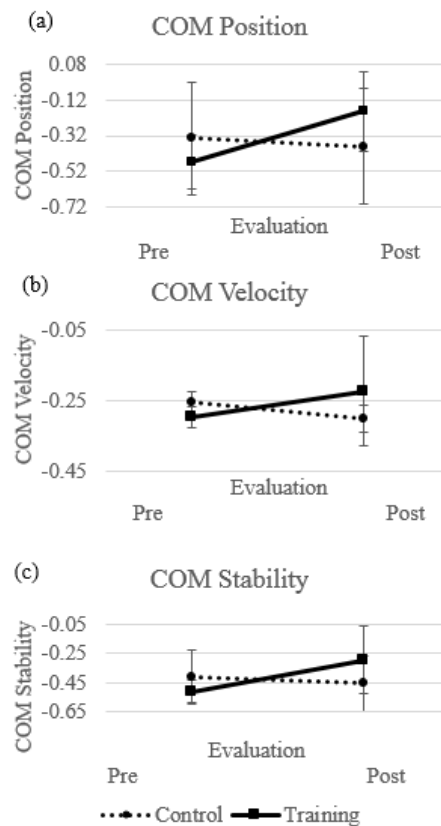


Figure 13. Figure 13 (a), 13 (b), and 13 (c) show the schematic for the COM position, COM velocity, and COM stability. Figure 13 (a) shows the change in the COM position between groups at pre-training and post-training. Figure 13 (b) displays the changes in COM velocity between groups at pre-training and post-training. Figure 13 (c) depicts the difference in COM stability between groups at pre-training and post-training.

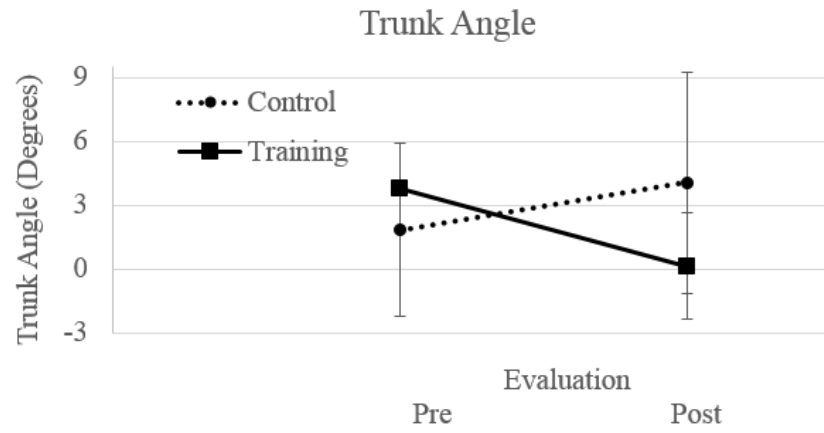


Figure 14. The trunk angles created between groups at pre-training and post-training.

4. Discussion

To our knowledge, this was the first study to investigate the effects of CWBV training on muscle strength, dynamic stability, and body composition of young obese participants. After 6-weeks of CWBV training, there was no significant differences for body composition. Significant increases in isometric muscle extensor strength and improvement in dynamic gait stability in response to the slip perturbation following training were reported. The feasibility of CWBV training improving fall risk factors has been reported in various studies. Changes in body composition and increased muscle strength and dynamic stability has been observed in various populations which gives reason to believe CWBV training could be used to decrease fall risk factors.

4.1 Body Composition

The results for body composition did not support our hypothesis. We hypothesized that CWBV training would alter body composition specifically by decreasing fat mass, fat %, BMI, and increasing FFM. No significant difference on body composition was seen from CWBV training. Various studies have shown different results in body composition from the whole body vibration training. Bogaerts et al. (2007) used CWBV training with older men and saw increased muscle strength, but mention that the increase was from muscle hypertrophy and not just neurological adaptations. CT scans showed an increase in muscle mass of the legs with CWBV training which showed that hypertrophy occurred with the vibration stimulus (Bogaerts et al., 2007).

Milanese, Piscitelli, Zenti, Moghetti, & Sandri, & Zancanaro (2013) performed CWBV training for obese women and found decreased BMI and body fat. They reported decreased fat mass occurred mostly in the trunk, which they speculated refers to a higher effect on visceral fat tissue (Milanese 2013). Oddly, Milanese et al. (2013) did reported no changes in FFM and speculated the training duration (2 x per week, for 10 weeks) being too short to cause gains in hypertrophy.

A study performed by Vissers et al. (2010) produced a significant effect on reducing body fat when combining CWBV training with caloric restriction. A study performed by Roelants et al. (2004) reported similar results and found no significant effect on fat loss, but reported increased FFM. Osawa, Oguma, & Onishi (2011) reported no effects on body composition with the CWBV training and speculated the reason was because the duration of the training (5-8 minutes per session for 12-weeks) was too short to illicit effects for FFM or fat mass (Osawa et al., 2011). In this study, there was no significant effect on body composition, specifically fat %, FFM %, or BMI. Vissers et al. (2010) reported that their greater effects on body composition occurred after 6-month and 12-month training periods. Since the duration of this study was only 6 weeks, it is possible that a longer duration would allow for significant changes to be seen for body composition.

For this study, the vibration training protocol was 5 minutes of training per day, and it may not have been sufficient to affect fat percentage. BMI was not different between the control and training groups at pre-training and post-training evaluations. The measurement accuracy level of the BIA machine is $\pm 5\%$ which could account for some of the changes in the results reported. There was no significant change seen in FFM %. However, changes occurred in the desired directions implying that CWBV training could affect body composition. Roelants et al. (2004) saw increased FFM and decreased fat mass with 24-weeks of training but did not see any significant changes on body composition. Roelants et al. (2004) related the short duration of 20 minutes training was not long enough duration to lead to decreases in body composition seen with aerobic exercises.

For this study, vibration experience was for a total of 5 minutes. The duration of the training may be too short to illicit aerobic training benefits such as a decrease in body fat %. It may be

possible to illicit increases in FFM due to muscle hypertrophy if the CWBV training is above the participants' normal physical activity. In a study by Bogaerts, Delecluse, Claessens, Troosters, Boonen, & Verschueren (2009), combining an exercise and vibration training protocol for 40 minutes 3-times per week reported significant improvements in VO_2 and changes in body composition such as decreased fat %. Bogaerts et al. (2009) relate the changes to the longer duration of the CWBV training protocol used. This supports the need for longer duration protocols in order to produce changes in body composition, mainly reductions in fat mass.

4.2 Muscle Strength

The results for muscle strength partially supported the hypothesis. We hypothesized that muscle strength would increase with CWBV training. The results showed Isometric extension strength significantly increased from 1.68 Nm/kg to 1.81 Nm/kg for the training group, while the control group did not have a significant increase in extensor strength. These results were similar to the results seen in a study performed by Bogaerts, Delecluse, Claessens, Coudyzer, Boonen, & Verschueren, (2007) which reported a significant increased isometric knee extensor strength. Bogaerts et al. (2007) reported significant increases in knee extension strength in elderly participants while this study reported significant increases in extensor strength in young individuals. This may show that age may not be a factor in the effectiveness of CWBV training. Claerbout, Gebara, Ilsbroukx, Verschueren, Van Asch, & Feys (2012) reported increased muscle strength for knee extension with a CWBV training study involving multiple sclerosis participants. Claerbout et al. (2012) believed that the vibration training was able to illicit greater muscle activity which led to the increased muscle strength. Regular exercises were performed with and without the vibration stimulus added and it was reported the vibration stimulus group had greater amounts of muscle activity and increased muscle strength (Claerbout et al., 2012).

In this study, it is possible that the CWBV training caused higher muscle activation in the young obese participants which led to the increased knee extensor strength. For isometric flexor strength, there was no significant difference after the 6-weeks of CWBV training. An interaction between flexion strength and the vibration training was seen but it was not significant. Our findings for flexor strength are similar to those of Delecluse, Roelants, Diels, Koninckx, & Verschueren (2005) who reported isometric flexion strength was not affected by CWBV training. Delecluse et al. (2005) included sprint-trained athletes while this study included young obese participants. Roelants et al. (2004) reported a significant increase for isometric knee extensor strength but not for isometric flexor strength. Roelants et al. (2004) reported that CWBV training activated an increase in the stretch reflex sensitivity and advanced the neurological activations leading to the increased muscle strength. However, they reported that since the vibration training protocol involved holding a static position, the specificity of the exercise could be a factor for the greater improvements for knee extensor strength compared to knee flexor strength (Roelants et al., 2004). This study used a static 20° position during the vibration training which produced greater increases in knee extensor strength compared with knee flexor strength. These findings support the findings by Roelants et al. (2004).

Delecluse, Roelants, & Verschueren (2003) conducted a CWBV training study that included performing dynamic knee extension exercises while standing on a vibration platform. Delecluse et al. (2003) compared the effects for strength from CWBV training with the strength effects from resistance exercises such as leg press and squats. They reported isometric knee extensor strength was significantly increased and was comparable to the knee extensor strength increases seen with resistance training exercises. Delecluse et al. (2003) believe CWBV produced a similar neurological response as with standard resistance training effects. However, their study

also increased intensity by altering the frequency and duration throughout the 12-week program. Delecluse et al. (2003) believe that longer training sessions were able to cause muscle fatigue which led to muscle adaptations and not just neurological adaptations.

A study conducted by de Ruiter, van Raak, Schilperoort, Hollander, & de Haan (2003) involved a CWBV training program for young physically active adults over 11 weeks. After the training, Ruiter et al. (2003) reported no significant difference in muscle strength activation. de Ruiter et al. (2003) reported the reason that they did not see a significant change was the training intensity was not sufficient to stimulate muscle strength improvements in the young active participants.

A study performed by Smidt (1973) reported that the maximal force exertion for knee flexion occurs at approximately 45- 60°. Baechle, & Earle, (2008) report that training sessions that closely mimic the performance situation would allow for the best results in performance. This study utilized a 20° static flexion for the vibration training and a 35° testing angle. It is possible that the 20° flexion used for training was not flexed enough to fully allow flexor strength adaptations to occur. The testing angle of 35° also may not have been specific enough to the training angle, inhibiting the participants' performance.

Although this study did not report a significant improvement in knee flexor strength, changes in flexor strength may infer that knee flexion strength could be significantly increased with CWBV training. This is important because this suggests that the static position used allowed for benefits to be seen inferring that the muscles were stimulated more than what they were accustomed to. Increasing duration, intensity, or performing movement specific actions could lead to greater increases in the knee flexion and knee extension strength gains involved with CWBV training.

4.3 Falls and Dynamic Stability

We hypothesized that CWBV training would increase stability and lead to a decrease in risk of

falls. The results from this study supported the hypothesis. The increased knee extensor muscle strength could have allowed participants to improve gait patterns leading to improved COM position and improvements in stability. There was no significant effect on COM velocity or COM position. The control group had improvements in stability but they were not significant.

There was no significant effect on the rate of falls in response to a slip. Both groups reported 6 of 9 falling at pre-evaluation. At post-evaluation 3 of 9 fell in the control group, and 2 of 9 fell in the training group. Visual observation is often used to identify falls during slip perturbation (Lockhart, Woldstad, & Smith, 2003). Peak LC forces are often used to identify falls. A study performed by Yang & Pai (2011) used visual criteria for fall identification such as heel velocity, heel height, and harness involvement to create a standard LC force output that would accurately identify a fall. It was reported that a peak LC force of 30% of the participants BW could accurately represent a fall outcome (Yang & Pai, 2011).

According to Heiden, Sanderson, Inglis, & Siegmund (2006), it's possible to alter gait and COM by having previous slip experience. The control group performed the same protocol at the pre-evaluation and the post-evaluation. The previous experience could allow a more cautious gait pattern which lowered the fall outcome. Heiden et al. (2006) reported that the participants were more likely to fall when walking without knowledge of a slip occurring compared to walking on a slippery surface or after having experienced the first slip. Shorter step length and frequency create a cautious gait pattern which could lower the number of falls (Heiden et al., 2006).

Muscle activity and gait alterations are also altered with prior knowledge of a task (Marigold & Patla, 2002). Marigold & Patla (2002) performed electromyography and kinematic readings during slip induced walking trials. They reported that when the participants were aware of upcoming slip trials, muscle activity was altered and participants used a more cautious gait

(Marigold & Patla, 2002). These findings supported Heiden et al. (2006) explaining why improvements for stability were reported for both the control and training groups. Having performed the first evaluation provided the control group the prior knowledge which leads to altered gait and possibly increase stability. However, the training groups had larger effects showing that the CWBV training is still able to increase the effects and improve stability.

Another aspect reported was a change in the participants' trunk angle. The control group had an increase in trunk angle while the training group had a smaller trunk angle after the training. A smaller trunk angle signifies greater control of the trunk and more stability. The trunk creates a large portion of the human body. In order to control the trunk, more muscle strength is needed. A study performed by Karatas, Cetin, Bayramoglu, & Dilek (2004) reported increased stability when muscle strength was sufficient to control the trunk. A lack of muscle strength does not allow the participant to maintain COM and balance and can place a person at a higher risk of falls (Karatas et al., 2004). Due to the significant mass of the trunk, if muscle strength is not sufficient, a person's stability could be in jeopardy. Adequate muscle strength is needed to fully control the trunk (Kibler, Press, & Sciascia, 2006). The trunk and core create a large portion of the body, and if muscle strength is not able to support it, COM is altered and the body compensates for the lack of strength by placing the body in altered positions which lower balance and stability (Kibler et al., 2006). In this study, the training group had a reduced trunk angle. Following training, muscle strength is greatly important for controlling the trunk and maintaining balance. The increase in muscle strength may lead to the improvements seen in trunk angle, and increase in stability and a lower risk of falls.

4.4 Limitations and Future Direction

This study had several limitations. First, the sample size (9 per group) was small. This could be

a reason why the differences between groups did not exhibit statistical significance. After conducting a power analysis based on the existing data from this study, a sample size of 58 participants per group would have been required in order to reach a significance level of 0.05 with a power of 0.95.

Second, training duration could be another factor limiting the results for body composition. The CWBV training lasted 6 weeks which was enough time for neurological modifications to occur, but may not have been sufficient to change FFM, FFM%, and Fat% (Osawa et al., 2011). Conflicting results from CWBV training make it difficult when determining whether the effects being seen are from vibration training, or if they are induced by another stimulus.

Third, the protocol design of this study could be a limitation. Both the training and control groups performed the same evaluation at the beginning and at the end of the study. For the second evaluation, both groups had prior experience and knowledge of what to expect during the slip perturbation. Having had this prior experience could have caused alterations in their gait pattern which could adversely affect the results leading to a decrease in falls at the second evaluation. Including a control group could have possibly improved the study design. It may have been beneficial to have participants perform the 6-weeks CWBV training program and after complete the slip perturbation evaluation. It is possible that the results could have shown participants that underwent the training had a lower fall rate during their first experience with the slip perturbation evaluation than those who did not have training before the first slip evaluation.

Fourth, there was a lack of control for the shoe type, or particularly the sole type. The participants were told to wear comfortable walking shoes for the evaluation, but the shoes were not controlled for traction or friction on the soles of the shoe. Shoes with increased traction could allow participants to maintain stability during a slip perturbation while shoes with less

traction could possibly lead to a higher chance of a fall.

Lastly, the occurrence of the slip perturbation during a gait cycle could not be precisely controlled due to technical difficulty. The slip perturbation occurs within 80-120 ms after touchdown of the leading foot. Although the time duration is very small, the initiation of the slip could possibly occur at different times causing the participant to be in different phases of the gait cycle. The different phases of the gait cycle have different levels of stability associated with them. If the slip is occurring at different phases, it may lead to different fall outcomes. These findings indicate that CWBV training may reduce the risk of falls among individuals affected by obesity. Future studies are still needed in order distinguish if CWBV training can effect body composition, lead to muscle strength increases in flexor strength, further its effects on extensor strength, and report significant improvements on body stability.

4.5 Conclusions

Risk of fall factors associated with obesity include altered COM location due to changes in body composition, muscle weakness, and a lower body stability increasing risk of falls. CWBV training is an alternative training paradigm being investigated for its feasibility of altering the three fall risk factors. In the present study a 6-week CWBV training did not produce any significant effects on body composition. Knee extensor strength was significantly increased with CWBV training. Stability in response to an unexpected slip was also improved as the result of the improved control of the COM position and velocity due to the CWBV training.

References

- ACSM's Guidelines for Exercise Testing and Prescription. 7th edition. Baltimore: Lippincott Williams & Wilkins; 2014.
- Baechle, T., & Earle, R. (2008). *Essentials of strength training and conditioning* (3rd ed.). Champaign, IL: Human Kinetics.
- Bernard, P. L., Geraci, M., Hue, O., Amato, M., Seynnes, O., & Lantieri, D. (2003, May). [Influence of obesity on postural capacities of teenagers. Preliminary study]. In *Annales de Readaptation et de Medecine Physique: revue Scientifique de la Societe Francaise de Reeducation Fonctionnelle de Readaptation et de Medecine Physique*, 46(4), 184-190.
- Blair, S. N., & Brodney, S. (1999). Effects of physical inactivity and obesity on morbidity and mortality: current evidence and research issues. *Medicine and Science in Sports and Exercise*, 31(11), 646-662.
- Bogaerts, A., Delecluse, C., Claessens, A. L., Coudyzer, W., Boonen, S., & Verschueren, S. M. (2007). Impact of whole-body vibration training versus fitness training on muscle strength and muscle mass in older men: a 1-year randomized controlled trial. *Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 62(6), 630-635.
- Bogaerts, A. C., Delecluse, C., Claessens, A. L., Troosters, T., Boonen, S., & Verschueren, S. M. (2009). Effects of whole body vibration training on cardiorespiratory fitness and muscle strength in older individuals (a 1-year randomised controlled trial). *Age and Ageing*, 38(4), 448-454.
- Borelli, G.A. (1989). *De motu animalium* (1680). *Translated as on the movement of animals, translated by Maquet, P., Springer-Verlag, Berlin.*
- Bryner, R. W., Ullrich, I. H., Sauers, J., Donley, D., Hornsby, G., Kolar, M., & Yeater, R.

- (1999). Effects of resistance vs. aerobic training combined with an 800 calorie liquid diet on lean body mass and resting metabolic rate. *Journal of the American College of Nutrition*, 18(2), 115-121.
- Claerbout, M., Gebara, B., Ilsbroukx, S., Verschueren, S., Peers, K., Van Asch, P., & Feys, P. (2012). Effects of 3 weeks whole body vibration training on muscle strength and functional mobility in hospitalized persons with multiple sclerosis. *Multiple Sclerosis Journal*, 18(4), 498-505.
- Corbeil, P., Simoneau, M., Rancourt, D., Tremblay, A., & Teasdale, N. (2001). Increased risk for falling associated with obesity: mathematical modeling of postural control. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 9(2), 126-136.
- Cormie, P., Deane, R. S., Triplett, N. T., & McBride, J. M. (2006). Acute effects of whole-body vibration on muscle activity, strength, and power. *Journal of Strength & Conditioning Research*, 20(2), 257-261.
- Delecluse, C., Roelants, M., & Verschueren, S. (2003). Strength increase after whole-body vibration compared with resistance training. *Medicine and Science in Sports and Exercise*, 35(6), 1033-1041.
- Delecluse, C., Roelants, M., Diels, R., Koninckx, E., & Verschueren, S. (2005). Effects of whole body vibration training on muscle strength and sprint performance in sprint-trained athletes. *International Journal of Sports Medicine*, 26(8), 662-668.
- de Ruiter, C. J., Van Raak, S. M., Schilperoort, J. V., Hollander, A. P., & De Haan, A. (2003). The effects of 11 weeks whole body vibration training on jump height, contractile properties and activation of human knee extensors. *European Journal of Applied Physiology*, 90(5-6), 595-600.

- de Souza, S. A. F., Faintuch, J., Valezi, A. C., Sant'Anna, A. F., Gama-Rodrigues, J. J., de Batista Fonseca, I. C., Souza, R.B., & Senhorini, R. C. (2005). Gait cinematic analysis in morbidly obese patients. *Obesity Surgery*, 15(9), 1238-1242.
- Ebbeling, C. B., Pawlak, D. B., & Ludwig, D. S. (2002). Childhood obesity: public-health crisis, common sense cure. *Lancet*, 360(9331), 473-482.
- Fjeldstad, C., Fjeldstad, A. S., Acree, L. S., Nickel, K. J., & Gardner, A. W. (2008). The influence of obesity on falls and quality of life. *Dynamic Medicine*, 7(1), 4-4.
- Geliebter, A., Maher, M. M., Gerace, L., Gutin, B., Heymsfield, S. B., & Hashim, S. A. (1997). Effects of strength or aerobic training on body composition, resting metabolic rate, and peak oxygen consumption in obese dieting subjects. *American Journal of Clinical Nutrition*, 66(3), 557-563.
- Heiden, T. L., Sanderson, D. J., Inglis, J. T., & Siegmund, G. P. (2006). Adaptations to normal human gait on potentially slippery surfaces: the effects of awareness and prior slip experience. *Gait & Posture*, 24(2), 237-246.
- Hulens, M., Vansant, G., Lysens, R., Claessens, A. L., Muls, E., & Brumagne, S. (2001). Study of differences in peripheral muscle strength of lean versus obese women: an allometric approach. *International Journal of Obesity and Related Metabolic Disorders*, 25(5), 676-681.
- Hurley, B. F., Seals, D. R., Ehsani, A. A., Cartier, L. J., Dalsky, G. P., Hagberg, J. M., & Holloszy, J. O. (1984). Effects of high-intensity strength training on cardiovascular function. *Medicine and Science in Sports and Exercise*, 16(5), 483-488.
- Irving, B. A., Davis, C. K., Brock, D. W., Weltman, J. Y., Swift, D., Barrett, E. J., Gaesser, G.A., & Weltman, A. (2008). Effect of exercise training intensity on abdominal visceral fat and

- body composition. *Medicine and Science in Sports and Exercise*, 40(11), 1863-1872.
- Karelis, A. D., St-Pierre, D. H., Conus, F., Rabasa-Lhoret, R., & Poehlman, E. T. (2004). Metabolic and body composition factors in subgroups of obesity: what do we know? *Journal of Clinical Endocrinology & Metabolism*, 89(6), 2569-2575.
- Karatas, M., Çetin, N., Bayramoglu, M., & Dilek, A. (2004). Trunk muscle strength in relation to balance and functional disability in unihemispheric stroke patients. *American Journal of Physical Medicine & Rehabilitation*, 83(2), 81-87.
- Kibler, W. B., Press, J., & Sciascia, A. (2006). The role of core stability in athletic function. *Sports Medicine*, 36(3), 189-198.
- Ko, S. U., Stenholm, S., & Ferrucci, L. (2010). Characteristic gait patterns in older adults with obesity—Results from the Baltimore Longitudinal Study of Aging. *Journal of Biomechanics*, 43(6), 1104-1110.
- Lafortuna, C. L., Maffiuletti, N. A., Agosti, F., & Sartorio, A. (2005). Gender variations of body composition, muscle strength and power output in morbid obesity. *International Journal of Obesity*, 29(7), 833-841.
- Laughton, C. A., Slavin, M., Katdare, K., Nolan, L., Bean, J. F., Kerrigan, D. C., Phillips, E., Lipsitz, L.A., & Collins, J. J. (2003). Aging, muscle activity, and balance control: physiologic changes associated with balance impairment. *Gait & Posture*, 18(2), 101-108.
- Lai, P. P., Leung, A. K., Li, A. N., & Zhang, M. (2008). Three-dimensional gait analysis of obese adults. *Clinical Biomechanics*, 23, S2-S6.
- Luo, J., McNamara, B., & Moran, K. (2005). The use of vibration training to enhance muscle strength and power. *Sports Medicine*, 35(1), 23-41.

- Maffiuletti, N. A., Jubeau, M., Munzinger, U., Bizzini, M., Agosti, F., De Col, A., Lafortuna, C.L., & Sartorio, A. (2007). Differences in quadriceps muscle strength and fatigue between lean and obese subjects. *European Journal of Applied Physiology*, 101(1), 51-59.
- Marigold, D. S., & Patla, A. E. (2002). Strategies for dynamic stability during locomotion on a slippery surface: effects of prior experience and knowledge. *Journal of Neurophysiology*, 88(1), 339-353.
- McGraw, B., McClenaghan, B. A., Williams, H. G., Dickerson, J., & Ward, D. S. (2000). Gait and postural stability in obese and non-obese prepubertal boys. *Archives of Physical Medicine and Rehabilitation*, 81(4), 484-489.
- Menz, H. B., Morris, M. E., & Lord, S. R. (2006). Foot and ankle risk factors for falls in older people: a prospective study. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 61(8), 866-870.
- Milanese, C., Piscitelli, F., Zenti, M. G., Moghetti, P., Sandri, M., & Zancanaro, C. (2013). Ten-week whole-body vibration training improves body composition and muscle strength in obese women. *International Journal of Medical Sciences*, 10(3), 307-311.
- Osawa, Y., Oguma, Y., & Onishi, S. (2011). Effects of whole-body vibration training on bone-free lean body mass and muscle strength in young adults. *Journal of Sports Science & Medicine*, 10(1), 97-104.
- Pai, Y.C., & Patton, J. (1997). Center of mass velocity-position predictions for balance control. *Journal of Biomechanics*, 30(4), 347-354.
- Ritzmann, R., Gollhofer, A., & Kramer, A. (2013). The influence of vibration type, frequency, body position and additional load on the neuromuscular activity during whole body

- vibration. *European Journal of Applied Physiology*, 113(1), 1-11.
- Roelants, M., Delecluse, C., Goris, M., & Verschueren, S. (2004). Effects of 24 weeks of whole body vibration training on body composition and muscle strength in untrained females. *International Journal of Sports Medicine*, 25(1), 1-5.
- Rogers, M. E., Rogers, N. L., Takeshima, N., & Islam, M. M. (2003). Methods to assess and improve the physical parameters associated with fall risk in older adults. *Preventive Medicine*, 36(3), 255-264.
- Smidt, G. L. (1973). Biomechanical analysis of knee flexion and extension. *Journal of Biomechanics*, 6(1), 79-92.
- Teasdale, N., Hue, O., Marcotte, J., Berrigan, F., Simoneau, M., Dore, J., Marceau, P., Marceau, S., & Tremblay, A. (2007). Reducing weight increases postural stability in obese and morbid obese men. *International Journal of Obesity*, 31(1), 153-160.
- Vissers, D., Verrijken, A., Mertens, I., Van Gils, C., Van de Sompel, A., Truijen, S., & Van Gaal, L. (2010). Effect of long-term whole body vibration training on visceral adipose tissue: a preliminary report. *Obesity Facts*, 3(2), 93-100.
- Whitney, S. L., Hudak, M. T., & Marchetti, G. F. (1999). The dynamic gait index relates to self-reported fall history in individuals with vestibular dysfunction. *Journal of Vestibular Research: Equilibrium & Orientation*, 10(2), 99-105.
- Wilms, B., Frick, J., Ernst, B., Mueller, R., Wirth, B., & Schultes, B. (2012). Whole body vibration added to endurance training in obese women—a pilot study. *International Journal of Sports Medicine*, 33(9), 740-743.
- Winter, D.A. (2005). Kinesiological electromyography. *Biomechanics and Motor Control of Human Movement, Fourth Edition*, 250-280

- Yang, F., & Pai, Y.C. (2011). Automatic recognition of falls in gait-slip training: Harness load cell based criteria. *Journal of Biomechanics*, 44(12), 2243-2249.
- Yang, F., Bhatt, T., & Pai, Y.C. (2009). Role of stability and limb support in recovery against a fall following a novel slip induced in different daily activities. *Journal of Biomechanics*, 42(12), 1903-1908.
- Yang, F., Passariello, F., & Pai, Y.C. (2008). Determination of instantaneous stability against backward balance loss: Two computational approaches. *Journal of Biomechanics*, 41(8), 1818-1822.
- Yang, F., King, G. A., Dillon, L., & Su, X. (2015). Controlled whole-body vibration training reduces risk of falls among community-dwelling older adults. *Journal of biomechanics*, 48(12), 3206-3212.

Curriculum Vita

Jose Munoz, the only son of Maria Munoz, was born in El Paso, Texas. After he graduated from Canutillo High School, El Paso, Texas, Jose Munoz entered The University of Texas at El Paso in the fall of 2008. While pursuing a bachelor's degree in Kinesiology, he worked at Cesar Scott Inc., a manufacturing company in El Paso, Texas, and Juarez, Mexico until earning his bachelor's degree in fall 2012. In the fall of 2013, he entered the Master Program in the Department of Kinesiology at The University of Texas at El Paso. He was a presenter at various conferences such as the South Central American Society of Biomechanics & Texas American College of Sports Medicine in 2015.

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