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EFFECTS OF WHOLE BODY VIBRATION TRAINING ON DYNAMIC BALANCE AND RISK OF FALLS IN ELDERLY WOMEN

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ABSTRACT

The purpose of this study was to determine the effectiveness of Whole Body Vibration Training (WBVT) in improving dynamic balance and reducing the risk of falls in elderly women. Recent studies presented WBVT as a plausible intervention for improving the physical fitness of the elderly population. Research in the past years looking into the association of muscle weakness and balance have shown the benefits of strengthening exercise, specifically in the lower extremities, as an effective intervention to augment balance in the elderly and consequently reduce the risk of falls. Seven elderly women (mean age 67 +5.9 yrs.) participated in a 7-week, twice-per-week WBVT program for a total of 14 sessions. Pre-, mid-, and post-tests were measured for dynamic balance, through the Modified Star Excursion Balance Test (MSEBT), and risk of falls, through Timed Up and Go Test (TUG). Repeated measures ANOVA followed by Tukey's HSD indicated improvements ($p<0.05$) in dynamic balance in the anterior, posteriolateral and posteriomedial reach directions of the MSEBT. The TUG scores indicated a significant reduction ($p<0.05$) in risk of falls in as early as the first three weeks continuing all throughout the seven-week duration of the intervention with a 3.2-sec improvement in TUG time overall. The authors conclude that WBVT improves dynamic balance and reduces risk of falls in elderly women.

***Keywords:** Whole body vibration training, elderly, balance, risk of falls.*

1. INTRODUCTION

For the elderly population, maintaining optimal balance and reducing risk for falls is an important component in functioning and mobility, and is therefore a vital

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determinant for their independence and lifestyle (Howe, Rochester, Jackson, Banks, & Blair, 2007; Jogi, 2010; Zeug, 2005). However as one increases in age, a variety of changes and adaptations on an individual's biological, physical, psychological, and social aspect (Zeug, 2005). Among the numerous changes an elderly individual undergoes is a deterioration in maintaining balance brought about by a significant change in the musculoskeletal system called sarcopenia, the degenerative loss of muscle tissue associated with aging (Albasini, Krause, & Rembitzki, 2010; Hess, 2004; Kang, 2000). In addition, there is a degradation of the neural adaptation and force production of the muscles (Hess, 2004; Kang, 2000). This deterioration of the neuro-muscular system contributes to increased risk of falls and balance impairment, which are considered as part of the world's most prevalent complications and major health problems found in the elderly (Albasini *et al*., 2010; Laroia, Hamdani, & Noohu, 2013; Shubert, 2011; Weerdesteyn, Rijken, Geurts, Smits-Engelsman, Mulder, & Duysens, 2006).

Numerous studies suggest that an involvement in physical activity and evidence-based programs is the first step to improve one's balance (Contant, 2006). Involvement in exercise, specifically strength and resistance training, contribute to the modification and improvement of balance impairment due to abridged muscle strength and sarcopenia, and/or can delay further muscle weakness and deterioration (McClain, 2014). According to Hess (2004), resistance training enhances neural adaptation, force production of the muscle, and increases muscle mass, which in turn improves the elderly's balance. In certain situations, some elderly (especially the frail ones) tend to overburden the musculoskeletal system due to overtraining combined with a diminished ability of the muscles to adapt to high levels of loading when performing resistance training (McClain, 2014). Situations such as these call upon further research and studying in order to find new, innovative, more effective yet safer interventions that would cater to the elderly population.

A recent technological and machine based intervention called Whole Body Vibration Training (WBVT) and its effectiveness to increase muscle mass and develop muscular strength caught attention being a new alternative or supplement to resistance training (Eckhardt, Wollny, Müller, Bärtsch, & Friedmann-Bette, 2011). WBVT is a neuromuscular training modality which enhances strength and motor-neuron recruitment using vibrating machines (Kurt & Pekünlü, 2014; Eckhardt *et al.*, 2011). An oscillatory motion brought about by the machine was found to be effective in enhancing muscle fiber recruitment and motor-neuron recruitment (Kurt & Pekünlü, 2014; Eckhardt *et al.*, 2011). The resilient sensory stimulus brought about by the vibration helps activate the muscle spindles faster and easier (Bogaers, Vershueren, Delecluse, Claessens, & Boonen, 2007). This vibratory load of the WBVT-initiated muscular activation depends on the variation of the machine's frequency (hertz), amplitude (millimeters), and duration (seconds-minutes) (Kurt & Pekünlü, 2014).

According to Bogaers *et al.* (2007), incorporating a variety of resistance exercises done on vibration plates may result in a higher increase of the lower extremity muscles (mainly the quadriceps, gluteus, and hamstrings). The researchers opted to incorporate the squat as it targets and strengthens the lower extremity muscle groups needed to maintain balance and stability (Albasini *et al.*, 2010; Rivera, 2005). Furthermore, McClain (2014) mentioned that squatting on the vibration platform reduces the vibration transmissibility to the spine and head, therefore reducing transient effects of vibration exposure.

The purpose of this study is to evaluate the role and effectiveness of WBVT on the dynamic balance and risk of falls of Filipino elderly women. This study employed and determined the effectiveness of a 7-week WBVT squat program on the lower extremity strength and balance of the elderly women with pre-, mid- and post-test comparisons.

It is vital that older adults to be informed and educated regarding the importance of exercise specifically exercising to improve balance (Zeug, 2005) hence implementing exercise programs may help the elderly deeply understand and realize the benefits of optimal balance in their quality of life and daily activities. This research hopes to reiterate the importance of exercise, specifically resistance training, to people who are in their youth to pre-elderly years.

2. METHODS AND MATERIALS

2.1 Subjects

Seven Filipino elderly women (mean age 67 +5.9 yrs.) participated in the study. The participants were selected via convenience sampling. They were all able to ambulate and move about independently and did not have any pre-existing conditions that may limit their capacity to perform the prescribed exercises and/or follow instructions.

The inclusion criteria are as follows: the participant must be a Filipino female 60 years of age and above, must be able to ambulate and move about without the need for walking aid or assistance from another person, must be able to perform a partial squat reaching to a minimum flex of the knees at 60º (Simão *et al.*, 2012), must be able to follow verbal instructions. Individuals with pre-existing conditions that may limit their capacity to perform the prescribed exercises and/or follow instructions were excluded.

2.2 Instruments

2.2.1 Modified Star Excursion Balance Test: The modified Star Excursion Balance Test (MSEBT) is a screening and assessment tool, commonly used by physical therapists to identify dynamic balance discrepancies and to assess dynamic balance improvement in individuals (van Lieshout, Reijneveld, van den Berg, Haerkens, Koenders, de Leeuw, van Oorsouw, Paap, Scheffer, Weterings, Stukstette, 2016). The MSEBT measures dynamic balance through a person's goal of sustaining their balance on a single leg and simultaneously reaching out with the other leg on three directions - the anterior, posteriomedial, and posteriolateral (Coughlan *et al.*, 2012; van Lieshout *et al.*, 2016).

Three (3) tape measures on the floor were affixed, one (1) oriented anterior to the apex and two (2) aligned at 135º to the posteriomedial and posteriolateral directions forming a Y (Coughlan, Delahunt, & Caulfield, 2012; van Lieshout *et al.*, 2016). Lines were constructed with standard tape measures and white tape on the floor for marking (van Lieshout *et al.*, 2016). Participants were asked to be barefooted and to have their hands on their hips during the duration of the testing (van Lieshout et al., 2016). Similar to the Y Balance Test, the anterior edges of the participants' feet were positioned at the junction of the reach direction lines of the modified-SEBT at the second toe (Coughlan *et al.*, 2012; van Lieshout *et al.*, 2016). The score was record as the farthest distance reached in centimetres.

2.2.2 Timed Up and Go Test: The Timed Up and Go Test (TUG) was established to evaluate risk of falls in older adults (Alexandre *et al.*, 2012; Barry *et al.*, 2014). The TUG starts with a patient sitting on the chair with their back against the chair (Bohannon, 2006; Podsialdo & Richardson, 1991; Shumway-Cook *et al.*, 2000). The TUG uses the amount of time it takes for elderly individuals to move from a seated position, walk 3 meters at a normal and safe pace, turn around, and walk back to sit down on the chair (Boulgarides *et al.*, 2003; Rivera, 2005). On the command "go", the participant ascends from the chair, walks for a comfortable and safe-paced distance of 3 meters, turns, then walk backs to the chair and sits down (Bohannon, 2006; Podsialdo & Richardson, 1991; Shumway-Cook *et al.*, 2000). Older adults are said to have a higher risk of falls if they perform the TUG at or greater than 12 seconds. The participants were given one practice trial. Equipment required for this test is a standard armchair that is approximately 46 centimeters high, and a stopwatch.

2.3 Procedure

Participants were given a consent form, answered the Physical Activity Readiness Questionnaire, and performed a 1-repetition partial squat test. They were assigned to a WBVT squat training program with fourteen (14) twice per week sessions for seven weeks. Training sessions were done on a Compex Winplate Vibration platform (Fig. 1).

Only a maximum of two (2) absences were allowed per elderly participant; if a participant exceeded two (2) absences from training, she was excluded from the training program. Those with a missed session were allowed to have a makeup session to fulfil the 14 sessions needed for this study. In addition, the participants were instructed to carry on with their normal and usual day-to-day activities for the duration of the study.

Figure 1: Compex winplate vibration platform

In the squat training program, the participants were instructed to squat down in a continuous motion until the knee is flexed at 60º forming a partial squat (Rivera, 2005; Simão, Avelar, Tossige-Gomes, Neves, Mendonça, Miranda, Teixeira, Teixeria, Andrade, Coimbra, & Lacerda, 2012). Once the desired angle has been reached, the participants shall ascend back in a continuous motion using only their body as resistance (Rivera, 2005). Participants were asked to maintain this standard squatting technique and a flat-to-slight lordosis. The participants must also descend for two seconds and ascend for two seconds (Bogaerts *et al.*, 2007; Eckhardt *et al.*, 2011).

Handlebars, located on vibration platform, were used for holding in order to ensure safety especially in the bottom part of the movement (Fig. 2). All training sessions were preceded by a warm up which included knee flexion, hip flexion, hip abduction, hip extension while standing, standing on tip-toes, and knee extension for 10 repetitions per leg or both legs (Clark *et al.*, 2012; Rivera, 2005; Wonjong, Changsik, & Hyungkyu, 2013). The training sessions were ended with a static stretching routine for the different muscles of the legs such as the hip flexors and extensors, knee flexors and extensors, and plantar and dorsi flexors (Rivera, 2005). Every training session was done in the presence of licensed physicians and medical professionals. The participants were also informed that they can withdraw their participation at any point during the intervention's duration.

Figure 2: Bottom position of the squat on the Compex Winplate vibration platform

The goal in every training session was to perform 10 partial squats per set. This study implemented a baseline of three sets of 10 repetitions. The progression scheme implemented entails an increase in volume and/or intensity as the weeks progressed and is presented in detail in Table 1.

Table 1: WBVT squat progression scheme

Week #: Session #	Intensity (Hz)	Amplitude (mm)	Vibration Stimulus (Hz x mm)	Duration (sec)	Reps	Sets	Training (Stimulus x Reps x Sets)	Volume
Wk1: 1	30	Low (2mm)	60	40	10	3	60 x 30	1800
Wk1: 2	35	Low (2mm)	70	40	10	3	70 x 30	2100
Wk2: 3	40	Low (2mm)	80	40	10	3	80 x 30	2400
Wk2: 4	30	High (4mm)	120	40	10	3	120 x 30	3600
Wk3: 5	35	High (4mm)	140	40	10	3	140 x 30	4200
Wk3: 6	40	High (4mm)	160	40	10	3	160 x 30	4800
Wk4: 7	40	High (4mm)	160	40	10	4	160 x 40	6400
Wk4: 8	40	High (4mm)	160	40	10	5	160 x 50	8000
Wk5: 9	40	High (4mm)	160	40	10	6	160 x 60	9600
Wk5: 10	40	High (4mm)	160	40	10	7	160 x 70	11200
Wk6: 11	40	High (4mm)	160	40	10	8	160 x 80	12800
Wk6: 12	40	High (4mm)	160	40	10	9	160 x 90	14400
Wk7: 13	40	High (4mm)	160	40	10	10	160 x 100	16000
Wk7: 14	40	High (4mm)	160	40	10	11	160 x 110	17600

2.3 Statistical Analysis

Descriptive statistics (means and standard deviations) were used for the demographic information. To determine the effect of the WBVT program on the MSEBT and TUG scores of the participants, a repeated measures ANOVA was utilized to determine the differences between pre-, mid-, and post-test scores with Tukey's HSD as the post-hoc test. Level of significance was set at $p<0.05$.

3. RESULTS

MSEBT Anterior Reach: There was a statistically significant improvement between pre-, mid-, and post-tests of the MSEBT Anterior reach after three weeks and after seven weeks of WBVT. The highest difference observed was between the pre-test and post-test. From pre-test to mid-test, the elderly women increased their reach by a mean of 5.3 and from mid-test to post-test the mean increase was 7.5. This demonstrates that the elderly women improved their dynamic balance as measured by the MSEBT Anterior reach.
MSEBT Posteriolateral Reach: There was a statistically significant improvement between in the Posteriolateral reach after three weeks. There was also a statistically significant improvement from pre- and post-test. The highest difference was observed between pre-test and post-test with a mean difference of 60.7. From pre-test to mid-test, they increased their reach by a mean of 54.9, and from mid-test to post-test the mean increased by 5.7. This demonstrates that the elderly women improved their dynamic balance in the Posteriolateral reach of the MSEBT.
MSEBT Posteriomedial Reach: There was a statistically significant improvement between pre- and mid-test in the MSEBT posteriomedial reach. There was also a statistically significant improvement from pre- and post-test. The highest difference was observed between pre-test and post-test with a mean difference of 28.9. From pre-test to mid-test, they increased their reach by a mean of 27.2 and from mid-test to post-test the mean increased by 1.8.
Timed Up and Go Test (TUG): As with the MSEBT, there were also statistically significant difference in the TUG scores. Data gathered revealed that the mean score for the TUG pre-test was 9.97 (±1.76). Three weeks into the WBVT squat program, a TUG mid-test was administered showing a mean of 7.76 (±0.80) and at the conclusion of the study, a mean score of 6.73 (±0.92) was observed as the TUG post-test. The highest difference was observed between pre-test and post-test with a mean improvement of 3.24 seconds. From pre-test to mid-test, they improved their time by a mean of 2.21 seconds, and from mid-test to post-test the mean further improved by 1.03 seconds. This demonstrates that the elderly women improved their balance as measured by the Timed Up and Go Test. As such, a perceived decrease in risk of falls is observed.

4. DISCUSSION

Improvements on the MSEBT are deemed reliable despite a supposed learning effect. A study by McClain (2014) suggests that a learning effect may have occurred due to the four practice trials and the three recorded trials, resulting in an increase in final testing measurements and a consistency of the distances. In this study, practice trial scores were inconsistent despite the practice trials. Also it was seen that on the mid- and post-test of the MSEBT that participants were able to maintain their balance more on the stance leg. This was also seen in a study by McClain (2014) stating that the participants in the researcher's study were also more stable and can maintain their balance on the stance leg while reaching out with the other leg.

Referring to the TUG findings, data presented reinforce the necessity to increase muscular strength in the lower extremity to improve balance and is corroborative to preceding studies that present decline of muscular strength brought about by aging. It was identified in a review of aging on the neuromuscular system that from age 60 and above, a steady deterioration of muscular strength of roughly 1.0-1.5% per year exists (Rivera, 2005). As the elderly continue to age, it was theorized that there is a decrease or absence of propulsive power in the plantar flexor muscles of the elderly hence walking patterns are altered, excessive muscle fatigue is present, and more requirement on the other leg muscles are needed, thereby slowing them significantly. This demand in turn makes the task difficult and could lead to the loss of balance, postural adjustments and the need to contain the body's center of gravity (Rivera, 2005). Hence, the present study presented that improvements gained from WBVT may have helped in increasing muscular strength, and thus led to the enhancement of balance skills.

The study showed that a manipulation of frequency and amplitude, it being crucial components of WBVT, was a beneficial outcome for muscular strength as seen in the significant improvements in balance scores. This is similar to a study by Furnes and Maschette (2009) where manipulation of amplitude and frequency elicited beneficial neuromuscular adaptations in a population of community-dwelling elderly. Consequently, improvements in balance scores may be attributed to neural adaptation which was also seen in other studies (Furness & Maschette, 2009). Results showed that there were significant improvements in the elderly's balance in as little as three weeks of WBVT as was also observed by Peterson (2009). Another possible explanation for the balance scores with regards to neuromuscular improvements is increased synchronous motor unit recruitment, hence causing excitability and greater motor unit recruitment brought about by the vibrations (Furness & Maschette, 2009).

5. CONCLUSION

A twice-a-week WBVT program for seven weeks using a variety of progression parameters resulted in significant improvements in the balance and reduction of risk of falls in elderly women based on the MSEBT and TUG scores. Further studies may be done to investigate the effect of modifying other progression protocols such as training frequency, intensity and cadence. A study on its effect in the elderly with pre-existing or limiting conditions may also be investigated but with great caution.

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