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The effects of whole-body vibration exercise on muscular strength in seniors

Chantelle C. Lachance

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THE EFFECTS OF WHOLE-BODY VIBRATION EXERCISE ON MUSCULAR
STRENGTH IN SENIORS

by

Chantelle C. Lachance

A Thesis
Submitted to the Faculty of Graduate Studies
through the Faculty of Human Kinetics
in Partial Fulfillment of the Requirements for
the Degree of Master of Human Kinetics at the
University of Windsor

Windsor, Ontario, Canada

2012

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The Effects of Whole-Body Vibration Exercise on Muscular Strength

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Declaration of Originality

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Abstract

Sarcopenia, the associated decline in muscle strength that occurs during the normal aging process, contributes to seniors' impairment of activities of daily living (ADLs) and overall independence. Previous research suggests resistance (RES) training, and more recently whole-body vibration (WBV) exercise, can help combat sarcopenia. While WBV exercise is now more prevalent in the literature, there is little known about its potential impact on seniors' upper body strength. This study aims to further evaluate the effectiveness of WBV exercise on seniors' lower body strength and explore the potential effects WBV training has on upper body strength. 55 community dwelling participants (33 males and 22 females; age range: 55-90 years; mean age: 73.3 ± 7.9 years) were divided into either a WBV or RES exercise group. Both exercise groups trained twice a week. Participants were assessed at baseline, after 8 sessions, and after 16 sessions. Outcome measures included the chair rise, 8-foot timed up-and-go (TUG), arm curl, tricep extension, and grip strength tests. There was a significant main effect of time found in 4 of the 5 dependent measures: chair rise, TUG, arm curl, and tricep extension tests. Consistent with previous WBV literature, improvements from baseline in both groups suggests WBV exercise is as effective as conventional RES training.

Dedication

I dedicate my thesis to my grandmother, Mary Fox.

Acknowledgements

I would like to express the deepest appreciation to my primary advisor, Dr. Sean Horton, who has provided me with continual guidance and support throughout my academic journey. Thank you for encouraging me to pursue a career in academia; it is truly one of the best decisions I have made. Thank you to Dr. Kenji Kenno, my co-advisor, for always being available to assist me with my thesis project and for your mentorship over the last five years. I would like to thank my thesis committee members, Dr. Patti Weir and Dr. Karen Williamson. I appreciate your contributions to my thesis, and the time and effort you have sacrificed for me.

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This thesis would not have been possible without my grandmother, Mary Fox, informing me about the whole-body vibration machine. She encouraged me to research about it to see if it would help with her own strength and bone density. Without her initially inquiring about vibration exercise, I may have never researched it, which is why this thesis is dedicated to her.

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List of Abbreviations

%ile = percentile

ADLs = activities of daily living

ANOVA = analysis of variance

BL = baseline

BMD = bone mineral density

EMG = electromyography

Hz = hertz

mm = millimeters

MVIC = maximum voluntary isometric contraction

OLPS = one-legged postural steadiness

RCT = randomized controlled trial

RES = resistance

secs = seconds

SPSS = Statistical Package for Social Sciences

TUG = timed up-and-go test

WBV = whole-body vibration

Introduction

A Shift in Distribution

As global life expectancy continues to rise, the age distribution of populations has shifted towards older age groups (Anderson & Hussey, 2000; Lloyd-Sherlock, 2000). A large aging population increases the likelihood of individuals having chronic diseases and disabilities that affect activities of daily living (ADLs) (Gojanovic, Feihl, Liaudet, Gremion, & Waeber, 2002; Schroll, Bjørnsbo-Schroll, Ferry, & Livingstone, 1996). Individuals with impaired abilities and/or functioning require much more time, attention, and resources from health-care providers and the health-care system (Guralnik, Fried, & Salive, 1996). Therefore, it is more important than ever to encourage older individuals to maintain good health through physical activity in order to remain independent (DiPietro, 2001).

Functional abilities during the normal aging process are often reduced due to sarcopenia, the natural aging decline in muscular strength, which affects the functional independence of the aging adult (Johnston, De Lisio, & Parise, 2008; Uher, Pullmannova-Svedova, Brtkova, & Junger, 2010). Seniors with decreased strength may have difficulty rising from a chair or doing basic household chores (Uher et al., 2010). Resistance (RES) exercise is currently the most effective known strategy to increase strength (Johnston et al., 2008); however, other forms of training are now being investigated in order to determine their suitability for older adults. (e.g., Rogan, Hilfiker, Herren, Radlinger, & de Bruin, 2011; Turbanski, Haas, Schmidtbleicher, Friedrich, & Duisberg, 2005).

Whole-Body Vibration Exercise

An alternative form of strength training is whole-body vibration (WBV) exercise (Lorenzen, Maschette, Koh, & Wilson, 2009), which uses a vertically oscillating platform (frequency [hz] x amplitude [mm]) to elicit reflexive muscle contractions, increasing skeletal muscle activity, and improving strength (Bissonnette, Weir, Leigh, & Kenno, 2010; Cardinale & Wakeling, 2005; Roelants, Delecluse, & Verschueren, 2004). Signorile (2006) suggests WBV training provides both a musculoskeletal and neural overload that stimulates adaptation within these respective systems. Studies using the vibration platform have reported increases in leg strength, power, postural control, balance, and electromyographical (EMG) activity in the muscles being trained (Bird, Hill, Ball, & Williams, 2009; Hazell, Jakobi, & Kenno, 2007; Hazell, Kenno, & Jakobi, 2010; Machado, Garcia-Lopez, Gonzalez-Gallego, & Garatachea, 2010; Signorile, 2006). This research has been consistent with not only young and athletic participants, but with older adults as well (e.g., Bissonnette et al., 2010; Rees, Murphy, & Watsford, 2007).

The practical appeal of WBV training is that research reports that WBV is as effective as conventional RES training, but it takes less time (Bissonnette et al., 2010, Signorile, 2006). For example, using a randomized sample of 43 seniors (66-85 years), Rees and colleagues (2007) investigated the extent to which WBV training enhanced standard RES training outcomes and muscle performance. After training 3 times a week for 2 months, they reported significant improvements in the sit-to-stand (12.4%, 10.2%), the knee-extension strength (8.1%, 7.2%), and the 5-meter walk (3.0%, 2.7%) tests in both WBV and RES groups, respectively. However, no significant differences were found when comparing WBV and RES training (Rees et al., 2007).

In a recent review, we concluded that WBV improved seniors' lower body strength, but found only one study that examined WBV and upper body strength in seniors (Lachance, Weir, Kenno, & Horton, 2012). Bissonnette et al. (2010) tested seniors (60-85 years) who trained 3 times per week for 8 weeks using WBV lower body (squats, heel raises, lunges) and specific static arm exercises (bicep curls, tricep extensions). Improvements were measured using the standardized chair rise, timed up-and-go (TUG), and arm curl tests to evaluate muscular strength. WBV training improved upper (49%) and lower (62%) body performance measures compared to their baseline numbers (Bissonnette et al., 2010). These improvements were dramatic and illustrate the potential benefits of upper extremity WBV training for seniors as many ADLs (e.g., carrying groceries, vacuuming, gardening, putting away dishes, and picking up grandchildren) would be positively enhanced with strength gains.

Research Purpose and Hypotheses

The current study is, based on our review of the literature, the first to compare the effects of WBV exercise to similar RES training exercises for improving seniors' lower and upper body strength. Consistent with previous WBV literature, we hypothesized both groups would show increases in muscular strength after the intervention and WBV training would be as effective as conventional resistance training when aiming to increase upper and lower body strength (Delecluse, Roelants, & Verschueren 2003; Rees et al., 2007; Roelants et al., 2004).

Methods

Participants

Upon receiving ethics approval, 65 volunteer community-dwelling seniors aged 55 to 90 years were recruited from a local exercise program in Southwestern Ontario. This specific group was targeted because the majority of participants were seniors spanning a wide spectrum in terms of age, ethnicity, social economic status, and physical ability, and they had already received medical clearance from their doctor to exercise.

All participants were informed verbally and in a handout about the training, design, measurement protocols, and the possible risks and benefits of the study. Interested individuals completed the consent form (see Appendix A) and participant profile to determine their eligibility. In order to qualify, individuals had to be 55 years of age or older and active members of the local seniors' exercise program. Eligible participants were assigned to one of two groups (WBV exercise or RES exercise) based upon exercise program location.

A typical day of exercise training, for both groups, involved a 15-minute warm-up, which included walking around an indoor track and following an instructor-guided routine of basic movements and stretches. After the warm-up, participants engaged in either WBV training (WBV group) or carried out the normal regimen of the exercise program (RES group). To help control for the extraneous variables, each participant trained at the same time of day, under the same exercise conditions, and was instructed by the same trained investigator. Subsequent training sessions were separated by a minimum of 24 hours.

Whole-body Vibration Exercise Group

The WBV training program involved the participants performing all exercises statically. Squats, lunges, and heel raises were performed to train lower body strength. Bicep curls and tricep extensions were executed to improve upper body strength. Participants were asked to wear the same pair of running shoes to each session to control for any dampening of vibration.

To ensure proper technique, the investigator explained and demonstrated every exercise. Before the performance of any exercise, the investigator calibrated the vibration platform to the participant's weight. The participant was then asked to mimic the specific positions while the investigator provided guidance, when necessary. When the participant was in the proper position for the exercise to be performed, the platform was set to the selected duration, frequency, and amplitude and then turned on.

Static lower body exercises were initially performed at low amplitude (2 mm) at a frequency of 35 hertz (hz):

Squat. The squat was performed with feet shoulder-width apart, knees bent at approximately 60°, back straight, and head facing forward (Gusi, Raimundo, & Leal, 2006). Participants held onto the handle of the machine so that balance was maintained (Please see Figure 1 in Appendix C).

Heel Raise. Participants were asked to complete a heel raise by standing on their toes, back straight, and knees slightly bent in order to prevent the vibration from resonating throughout their body (Bissonnette et al., 2010) (Please see Figure 2 in Appendix C).

Lunges. Lunges were performed by keeping the back straight, feet shoulder-width apart and staggered, with one foot approximately 50 cm in front of the other.

Knees were bent to lower the body towards the floor so that the front knee was at 60°, always ensuring the knees were behind the toes. This position was held for the prescribed amount of time and then repeated with the other leg. Executing the lunge position with each leg was considered one repetition (Please see Figure 3 in Appendix C).

Upper body exercises were performed with the participant standing beside the platform, holding a pair of nylon straps that were directly connected to the surface of the platform. Consistent with Bissonnette et al. (2010), frequency and amplitude were initially set to 40 hz at high amplitude (4 mm) for the upper body exercises to compensate for any dampening of vibration through the straps.

Bicep Curl. The bicep curl was executed by grasping the two straps by the handles. Arms were in flexion with the elbows close to their sides and bent at 90° (Please see Figure 4 in Appendix C).

Tricep Extension. Tricep extensions were performed by having both arms straight and down at the side of the body; straps were held with palms facing the body. Participants extended both arms posteriorly until there was a 30° angle between their torso and upper arm (Please see Figure 5 in Appendix C).

For the first 4 sessions, all exercises were performed twice for 30 seconds (secs) at a time. After 4 exercise sessions were completed, components of the exercise program (repetitions and/or duration) were progressively increased to enhance training effects.

Please refer to Table 4 in Appendix B for a full description of the WBV exercise program.

Resistance Exercise Group

The RES group was part of the normal on-going regimen with the local exercise program. These participants performed conventional exercises in a group setting that were similar to the WBV group's exercises, including bicep curls, tricep extensions, lunges, squats, and heel raises. Exercises were progressive in nature by safely increasing the number of repetitions completed and/or weight of the dumbbells. All exercise sessions were monitored by at least two trained Exercise Rehabilitation Specialists.

Equipment

The WBV exercises utilized the WAVE Pro® (Figure 6 in Appendix C), a vertically oscillating vibration platform that self calibrates to the participant's weight to ensure consistent vibration effects (WAVE Manufacturing, 2010; WAVE Pro [apparatus], 2006). The WAVE machine has an adjustable frequency ranging from 20 to 50 hz and an amplitude selection of 2 mm (low) or 4 mm (high). Increasing amplitude and/or frequency result in an increase in EMG muscle activity (Hazell et al., 2007).

Measurement Outcome Protocols

Individual muscular strength performance scores of the upper and lower body were assessed and recorded at baseline, after 8, and after 16 sessions using the following protocols:

Chair Rise Test. Assessed lower body strength and endurance (Rikli & Jones, 2001). Participants were guided to sit in the middle of the chair with their back straight, feet flat on the floor, and arms crossed at the wrists and held against the chest. They were then instructed to stand (without using their arms for support) and return to a seated position (Please see Figures 7 and 8 in Appendix C). The objective was to complete as many stands as possible in 30 secs; the total number of stands completed was recorded (Rikli et al., 2001).

8-foot Timed Up-and-Go Test. Assessed functional mobility (Rikli et al., 2001). The participants were asked to rise from an armless chair of a standardized height (17 inches or 42.18 cm), walk around a pylon located 8 feet away, turn, walk back to the chair, and sit down again. One practice trial was allotted followed by two test trials. For evaluation purposes, the faster time of the two test trials (to the nearest tenth of a second) was recorded (Podsiadlo & Richardson, 1991; Rikli et al., 2001). Please refer to Figure 9 for the protocol layout and Figure 10 for the starting position, which are both found in Appendix C.

Arm Curl Test. Assessed upper body strength and endurance (Rikli et al., 2001). The Senior Fitness Test Protocol (Rikli et al., 2001) was followed, which consisted of performing as many complete bicep curls as possible in 30 secs. Participants were seated upright in a chair, holding a dumbbell in their dominant hand using a suitcase grip (palm facing towards the body). From the down position, the arm was brought up with the palm facing towards the ceiling during flexion (Please see Figures 11 and 12 in Appendix C). Women used a 5 lb dumbbell, whereas the men used an 8 lb dumbbell. The score

reflected the total number of curls executed in 30 secs (Bissonnette et al., 2010; Rikli et al., 2001).

Tricep Extension Test (adapted from the arm curl test). Assessed upper body strength and endurance. The participants performed as many complete tricep kickbacks (extensions) as possible in 30 secs. Participants stood in front of a chair for support while they held a dumbbell in their dominant hand using a suitcase grip. Participants had their arm at 90° and then extended their hand posteriorly to straighten their arm (Please see Figures 13 and 14 in Appendix C). Women used a 5 lb dumbbell, whereas the men used an 8 lb dumbbell. The score reflected the total number of extensions executed in 30 secs (Rikli et al., 2001).

Grip Strength Test. The LaFayette Grip Strength Dynamometer was used to assess wrist and forearm strength (LaFayette Instrument Company Incorporated, 2004). Participants were instructed to sit in the chair with their feet on the floor with their arms hanging down at their sides. The calibrated dynamometer was adjusted to comfortably fit in the hand and the handle setting was recorded on the participant's scorecard to ensure the same settings were used for subsequent testing. To test grip strength, participants were asked to squeeze the dynamometer in their dominant hand with the elbow slightly bent (approximately 20°) with maximum isometric effort for approximately 5 secs (Please see Figures 15 and 16 in Appendix C). One practice trial was allotted, followed by three recorded trials (30 secs of rest between attempts). Readings were taken to the nearest whole kilogram; the three recorded trials were then averaged (LaFayette Instrument Company Incorporated, 2004).

Interviews

After training, semi-structured interviews were administered to gain insight on the performed exercise intervention. The one-on-one interviews took place on-site and lasted approximately 5 minutes. The specific questions asked of each participant were: *What did you notice happening to your body over the last 16 sessions?* and *What did you notice happening to your strength over the last 16 sessions?* The WBV group was asked additional questions specific to the WBV platform: *Was there anything you liked/disliked about WBV exercise?; Did you have any adverse effects with WBV training?* and *Would you seek this type of intervention in the future?* All responses were recorded for each participant.

Statistical Analyses

To determine the effects of the training protocol, all raw data were analyzed using the Statistical Package for Social Sciences (SPSS) for Windows, version 20 (Chicago, IL). To investigate the potential influence of age and gender a series of 2 (Age: 55 – 73 years vs. 74 – 90 years) x 2 (Gender: male vs. female) x 2 (Condition: RES vs. WBV) x 3 (Time: baseline vs. 8 sessions vs. 16 sessions) ANOVAs with repeated measures on the last factor were conducted for each of the dependent variables. There was no main effect or interaction of age or gender, with the exception of grip strength (main effect of gender, $p = .000$). Therefore, data were collapsed across age and gender and reanalysed with repeated-measures ANOVAs for the chair stand, TUG, arm curl, and tricep extension tests. For grip strength, a 2 (Condition) x 2 (Gender) x 3 (Time) ANOVA with repeated measures on the last factor was performed. Greenhouse-Geisser corrections were employed for four dependent measures (TUG, arm curl, tricep extension, and grip

strength tests) where sphericity was violated. Post hoc testing was completed using the Bonferroni correction to verify the time period at which differences existed.

Results

Participant Characteristics and Intervention Adherence

Sixty-five individuals were initially recruited. Fifty-five participants, (33 males and 22 females, mean age of 73.3 ± 7.9 years), completed the exercise program and were included in the analysis. Ten participants either dropped out or were excluded from the study. A full participant flow diagram is provided in Figure 17 in Appendix C. Consistent with previous WBV research, large effect sizes were predicted and, therefore, power was calculated based on an effect size of 0.8 (Cohen, 1992). With a p -value of $\leq .05$, power analysis revealed that a sample of 26 participants was required for each group (Cohen, 1992). After dropout, there were 26 and 29 participants in the WBV and RES groups, respectively.

Table 1 provides a summary of the participants' baseline characteristics and performance scores. There were three instances where differences between baseline groups existed: age, prevalence of diabetes between groups, and baseline chair stand performance. An independent samples t test on age indicated that the groups were significantly different. Due to the fact that age showed no main effects or interactions in our preliminary analysis, this variable was collapsed across groups and not considered further.

Table 1

Participant Characteristics at Baseline

Characteristic / Measure	Total (<i>n</i> = 55)	WBV (<i>n</i> = 26)	RES (<i>n</i> = 29)	<i>P</i> -value
Male / Female (<i>n</i>)	33 / 22	15 / 11	18 / 11	0.138 ^a
Age (mean/SD)	73.3 (7.9)	70.4 (7.7)	75.9 (7.2)	0.009^b
Prevalent Comorbidities (<i>n</i>)				
High Blood Pressure (controlled)	28	14	14	0.893 ^a
Heart Disease	23	10	13	0.225 ^a
Arthritis	23	12	11	0.225 ^a
Diabetes (controlled)	18	11	7	0.010^a
Dependent Measures (mean/SD)				
Chair Stand Test (# of stands)	13.1 (5.6)	11.2 (4.7)	14.9 (5.8)	0.012^b
TUG Test (in secs)	6.4 (1.9)	6.9 (2.2)	6.0 (1.3)	0.067 ^b
Arm Curl Test (# of curls)	15.7 (4.3)	15.4 (4.9)	15.9 (3.6)	0.639 ^b
Tricep Extension Test (# of extensions)	17.3 (5.7)	17.0 (5.8)	17.5 (5.6)	0.721 ^b
Grip Strength Test (in kg)	25.8 (7.2)	26.4 (7.5)	25.3 (7.1)	0.600 ^b

Note. ^a χ^2 test; ^b independent samples *t* test.

Boldface values represent statistically significant differences between groups, $p < 0.05$.

Participant Outcome Measures at Baseline and After Exercise Programs

The outcome measures of WBV and RES exercise programs at baseline and after 8 and 16 sessions are shown in Table 2.

Chair Stand Test. After 16 sessions of exercise training both conditions showed a significant increase in the number of chair stands performed, $F(2,106) = 12.706, p = .000$, showing a main effect of time (Please see Table 3). Overall, the WBV group improved 20.5%, from baseline through session 16, and the RES group improved by 11.4%. The RES group performed more chair stands at baseline (14.9 ± 5.8) than the WBV group (11.2 ± 4.7), which was significant ($p = .012$). There was no interaction between time and condition, $F(2,106) = 2.662, p = .074$, or significant differences between conditions ($p = .056$), although these values did approach significance. Post-hoc testing revealed that the significant increases occurred between baseline (13.1 ± 5.6) and 8 sessions (14.7 ± 6.2) and baseline and 16 sessions (15.1 ± 6.0).

8-ft Timed Up-and-Go Test. TUG times (in secs) showed a main effect of time, $F(1.267,67.138) = 8.232, p = .003$. There was a significant interaction between time and condition, $F(1.267, 67.138) = 6.022, p = .011$, likely due to the differences between conditions at baseline, which approached significance ($p = .067$). TUG times were faster for the RES group compared to the WBV group at baseline. Overall, both groups improved on their TUG time performance (15.0% and 5.3% improvement in WBV and RES groups, respectively). However, these differences were not statistically significant ($p = .418$). Post-hoc tests revealed that both forms of exercise elicited significant improvements from baseline (6.4 ± 1.9 secs) to 16 sessions (5.9 ± 1.9 secs) and 8 sessions (6.1 ± 2.1 secs) to 16 sessions. Changes from baseline to 8 sessions were not significant.

Arm Curl Test. No significant differences were found between conditions ($p = .993$). There was a statistically significant main effect of time, $F(1.645, 87.173) = 58.024$, $p = .000$, but no interaction between time and condition, $F(1.645, 87.173) = 0.729$, $p = .460$. Post-hoc analysis revealed significant increases in the number of arm curls completed across all time points: baseline (15.7 ± 4.3) to 8 sessions (18.6 ± 5.0), baseline to 16 sessions (19.9 ± 5.5), and 8 sessions to 16 sessions. Overall, the WBV group improved their performance by 29.9% and the RES group improved by 24.5%.

Tricep Extension Test. Both conditions yielded significant increases in the number of tricep extensions performed as a function of training sessions, $F(1.441, 76.359) = 32.428$, $p = .000$. Post hoc analysis confirmed the improvements were seen across all time points: baseline (17.3 ± 5.7), 8 sessions (20.4 ± 6.0), and 16 sessions (21.5 ± 6.2). There was no significant interaction between time and condition, $F(1.441, 76.359) = 0.679$, $p = .464$), nor a significant main effect of condition ($p = .738$). Taken together, these results suggest both training conditions yielded comparable improvements to triceps strength, with the WBV group improving 22.9% and the RES group improving 25.7%.

Grip Strength Test. Not surprisingly, there was a main effect of gender, $F(1,51) = 39.497$, $p = .000$, with males producing greater grip strength recordings (30.3 ± 6.9 kg) compared to females (20.0 ± 4.7 kg). However, analysis failed to reveal significant main effects of condition, $F(1, 51) = 1.580$, $p = .214$, or time $F(1.598, 81.479) = 1.399$, $p = .251$, nor any significant interactions. Although non-significant, the WBV improved by 4.2% and the RES group improved by 1.6% overall.

Table 2

Measurement outcomes for baseline and following 8 and 16 sessions of whole-body vibration (WBV) or resistance exercise (RES)

Outcome Measure	Baseline		8 sessions		16 sessions	
	WBV (<i>n</i> = 26)	RES (<i>n</i> = 29)	WBV (<i>n</i> = 26)	RES (<i>n</i> = 29)	WBV (<i>n</i> = 26)	RES (<i>n</i> = 29)
Chair Stand Test (# of stands)	11.2 (4.7)	14.9 (5.8)	13.7 (6.0)	15.5 (6.4)	13.5 (4.6)	16.6 (6.8)
TUG Test (secs)	6.9 (2.2)	6.0 (1.3)	6.1 (1.9)	6.1 (2.2)	6.0 (2.0)	5.7 (1.8)
Arm Curl Test (# of curls)	15.4 (4.9)	15.9 (3.6)	18.8 (5.5)	18.4 (4.7)	20.0 (6.3)	19.8 (4.7)
Tricep Extension Test (# of extensions)	17.0 (5.8)	17.5 (5.6)	20.5 (7.0)	20.3 (5.0)	20.9 (7.0)	22.0 (5.5)
Grip Strength Test (kg)	26.4 (7.5)	25.3 (7.1)	26.8 (8.8)	25.5 (7.7)	27.5 (9.1)	25.7 (7.7)

Note. Values are mean (standard deviation)

Table 3

Results for strength assessments, collapsing across condition

Outcome Measure	<i>F</i> statistic	<i>p</i> -Value	Partial Eta Squared	Post-hoc (Bonferroni)		
				BL to 8 sessions	8 - 16 sessions	BL - 16 sessions
Chair Stand Test	(2, 106) = 12.706	0.000	0.193	0.004	1.000	0.000
TUG Test	(1.267, 67.138) = 8.232	0.003	0.134	0.263	0.007	0.001
Arm Curl Test	(1.645, 87.173) = 58.024	0.000	0.523	0.000	0.001	0.000
Tricep Extension Test	(1.441, 76.359) = 32.428	0.000	0.380	0.000	0.018	0.000
Grip Strength Test	(1.598, 81.479) = 1.399	0.251	0.027	N/A	N/A	N/A

Note. Boldface values represent statistically significant, $p < 0.05$. Baseline represents baseline.

Effects of the Exercise Program from a Qualitative and Subjective Perspective

All 55 participants completed the interview. Prior to receiving feedback on their performance scores, participants were asked if they believed their strength improved; 41% ($n = 12$) of the RES group participants believed their strength had increased, 55% ($n = 16$) did not notice any changes, and 4% ($n = 1$) thought their strength decreased. Consistent with this perception, this one participant decreased on three measures, scored the same on one, and improved on one measure. The participants who reported improvements in overall ADLs mentioned that they could walk more easily, had better balance, and more energy.

Similar to the RES group, 42% ($n = 12$) of WBV participants believed their strength had improved, 54% ($n = 14$) did not notice any changes, and 4% ($n = 1$) thought their strength may have decreased. In sharp contrast to these perceptions, this participant improved on all five dependent measures. Those in the WBV group who believed they had improved their strength mentioned that it was easier to climb stairs, lift up their grandchildren, and do things at home. In addition to strength changes, three participants noted decreased arthritis pain which, to our knowledge, has not been investigated in previous WBV literature.

In general, all WBV participants thought the exercise intervention was a positive experience. Some of the positive comments included: “I really enjoyed it, it helped with my arthritis”, “I preferred whole-body vibration over resistance training because it seemed like a better workout in less time”, and “it is now easier to perform activities of daily living”. The majority of the participants stated there was nothing they disliked about WBV exercise ($n = 19$). However, some respondents reported reasons for disliking

aspects of WBV training, which included: a few positions aggravated a pre-existing knee or sciatica problem ($n = 4$), the exercises were sometimes hard ($n = 2$), or monotonous ($n = 1$). When asked if WBV training had any adverse effects, 81% said no. The five complaints were: muscle stiffness ($n = 3$), knee stiffness ($n = 1$), and shoulder pain that was due to a previous injury ($n = 1$). When WBV participants were asked if they would seek this type of training again, 54% said yes. Cost was the most significant barrier ($n = 11$) affecting the use of a WBV platform again.

Discussion

Overall, these results indicated that 16 sessions of either WBV or RES training elicited significant improvements in the chair stand, TUG, bicep curl, and tricep extension tests. Our data supported both hypotheses: WBV exercise training increased seniors' upper and lower body muscular strength and WBV exercise was as effective as RES exercise when training for whole-body strength gains. These findings suggest that seniors can attain significant improvements in overall strength by training twice a week for 16 sessions through either RES or WBV exercise.

The original purpose of the WBV platform was to help cosmonauts minimize the loss of bone and muscle mass in space (Gojanovic et al., 2011). More recently, WBV exercise has been used to train individuals of different abilities, needs, and ages (Lachance et al., 2012). Within the last decade, numerous studies have examined the effect of WBV training on the aging population, with a primary focus on lower body strength (Lachance et al., 2012). Comparable to the current study, Rees et al. (2007) used the TUG and sit-to-stand (similar to the chair rise test) tests to assess improvements in lower body strength. Forty-three older adults were randomly assigned to one of three groups, a WBV, RES, or a control group. All participants were involved in a low-intensity walking program. In addition, the WBV and RES groups specifically trained the lower body 3 times per week for 8 weeks. For the first 4 weeks of training, the WBV group stood with their knees bent on the platform; the last 4 weeks involved dynamic lower limb exercises, including squats and heel raises. Rees et al. (2007) concluded that WBV training improved seniors' lower body strength and both exercise groups (WBV and RES) improved on the measurement protocols compared to the control group. These

results were consistent with the general consensus of WBV research with older adults: WBV training is a comparable alternative to RES training for improving lower body strength via increased muscle recruitment, cross-sectional area, and protein synthesis (Bogaerts, Verschueren, Delecluse, Clasesens, & Boonen, 2007; Lachance et al., 2012; Machado et al., 2010; Roelants et al., 2004; Verschueren et al., 2004).

Although vibration studies specific to seniors' lower body strength are increasingly prevalent in the academic literature, there is still a distinct lack of WBV research on upper body strength training. With the exception of the current study, only Bissonnette and colleagues (2010) have examined WBV training on seniors' upper body strength. Bissonnette et al. (2010) had participants train on a WBV machine 3 times per week for 8 weeks, which resulted in a 49% increase in the number of times the weight could be lifted in the arm curl test. In an attempt to build on their findings, we incorporated two upper body outcome measures in addition to the arm curl test: the grip strength and the tricep extension test. This allowed us to quantify bicep, tricep, and grip strength changes.

In the current study, both groups displayed significant improvements in four of the five measurement protocols: the arm curl, tricep extension, chair rise, and TUG tests. Grip strength did not significantly improve after 16 sessions of training, potentially due to the fact that participants did not perform any exercises that specifically targeted the muscles involved in grip strength. Consistent with previous WBV literature, all outcome measures revealed no significant differences between WBV and RES exercise groups (Bogaerts et al., 2007; Roelants et al., 2004; Verschueren et al., 2004).

The present study complements and expands Bissonnette et al.'s (2010) findings in that we can now suggest that WBV exercise is as effective as RES exercise when seniors are training for upper body strength gains. Upper body strength is important to perform ADLs such as carrying and putting away groceries, vacuuming, opening jars, or picking up grandchildren. If seniors lack the strength to perform such tasks, they are at an increased risk of losing their independence. Maintaining or improving upper (and lower) body strength will facilitate overall quality of life and maintenance of functional independence, which in turn allows seniors to live in their own homes for longer periods of time (Bissonnette et al., 2010).

Conversely, if an individual is already beyond the stage of living independently, WBV may be a viable option to help regain (or maintain) their current level of functional ability. Previous research has used WBV training to increase lower body strength in nursing home residents (Bautmans, Van Hees, Lemper, & Mets, 2005; Bruyere et al., 2005). Since all of the WBV exercises in the current study were performed statically, participants with limited mobility can partake, as long as they are able to weight-bear. Therefore, individuals who may not be able or willing to perform conventional RES training may benefit from the effects of WBV exercise to improve whole-body strength.

Bissonnette et al. (2010) reported that the exercises on the WBV platform were easy to perform, time efficient, and resulted in positive results in a short time frame. The participants in the present study reiterated these benefits in the one-on-one interviews. Overall, WBV training was a positive experience for the majority of the participants. Eight participants reported that it was now easier to perform their ADLs, and three participants reported decreased arthritis pain. Twenty percent of WBV participants

mentioned cost would influence their decision to train on a vibration machine again. As vibration platforms become more affordable and commercially available, this deterrent may be reduced.

In summary, this study provides additional evidence to the growing literature on the effectiveness of WBV exercise on increasing lower body strength in seniors. In addition, we can now suggest WBV as an alternative method of training upper body strength in seniors.

Limitations and Future Research

Due to the multi-site nature of the study, randomization of participants was problematic. The study was initially intended to be a randomized controlled trial. However, in order to obtain our desired sample size, we needed to recruit from satellite locations. Randomization was not possible as participants exercised at the location nearest their home and we only had access to one vibration platform. Consequently, participants at the satellite locations were automatically assigned to the RES group. This also impacted our potential to blind the investigator, since it was known that satellite locations did not have any participants from the WBV group.

As this is the first study to compare WBV to RES training for upper body strength gains in seniors, more research in this area is warranted. To extend the literature, future studies could increase the duration of the exercise trial, include dynamic upper body exercises (such as dynamic bicep curls, dynamic tricep extensions, and dynamic forearm extensions) and make the exercise regimen more progressive in nature by increasing the relative time and/or frequency of the WBV exercises performed. Since there were no

significant increases in grip strength over time, specific exercises to target the forearms would be beneficial to see if WBV can increase overall grip strength.

Currently, there is no gold standard for either measurement protocols or WBV exercise programs. Therefore, previous WBV researchers have used various tests to measure strength, including the chair stand test, timed up-and-go test, isometric and isokinetic knee extension strength test, and the leg press maximal involuntary contraction test (Bautmans et al., 2005; Bissonnette et al., 2010; Brogardh et al., 2010; Machado et al., 2010). Similarly, there have been several WBV exercise programs used with seniors; studies ranged from 1 session to 1 year, participants exercised between 2 and 5 times per week and the WBV platform's frequency ranged from 6 to 40 Hz (Lachance et al., 2012). Determining optimal frequency and amplitude settings to maximize results is an important area of future research, as well as establishing standardized measurement protocols to measure these changes in strength.

Future WBV research could also employ the current study's WBV exercise regimen in an institutionalized setting to determine whether this type of training is effective in the non-community dwelling senior population. Previous lower body research concluded that WBV is feasible for nursing home residents and can improve seniors' balance, mobility, elements of fall risk, and self-reported quality of life (Bautmans et al., 2005; Bruyere et al., 2005). Our findings indicate that similar improvements may be possible in this population when aiming to increase upper body strength.

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Literature Review

Introduction

Over the last century, life expectancy has increased dramatically to the point that individuals in developed nations can expect to live beyond 80 years of age (Delecluse, Roelants, & Verschueren, 2003; DiBrezza, Shadden, Raybon, & Powers, 2005; Johnston, De Lisio, & Parise, 2008). With continuing advancement in medical technology and baby boomers approaching mid-to-late adulthood, the aging population is steadily increasing. Seniors aged 65 and older will soon comprise a massive proportion of the global population, growing to an estimated 690 million in developed countries by 2030 from 249 million in 2000 (US Census, 2010). Governments and private funding agencies have recognized that seniors will be a large portion of the general population and have increased age-related funding initiatives (Janssen, Heymsfield, Wang, & Ross, 2000). The goal of these initiatives is to further understand the mechanisms of aging so effective strategies can be developed for treating age-related ailments, maintaining seniors' independence, reducing risk factors, and improving ADLs (Janssen et al., 2000).

Slips and falls

Slips and falls are a common occurrence in the aging population (Liu-Ambrose, Khan, Eng, Lord, & McKay, 2004). Approximately 30% of the community-dwelling population over 65 years of age falls at least once a year (Liu-Ambrose et al., 2004; Veterans Affairs Canada, 2009). Of those who fall, 50% will never regain functional walking (Payne & Isaacs, 2008). This high prevalence of seniors falling puts a substantial financial burden on national governments. For example, the Canadian government spends

2.4 billion dollars per year (one billion in direct costs) because of the injuries and rehabilitation that are associated with seniors' falls (Veterans Affairs Canada, 2009).

Musculoskeletal integrity is a major reason why seniors are more susceptible to falling (Bissonnette, Weir, Leigh & Kenno, 2010; Delbono, 2003). Recently, researchers have examined skeletal muscle to better understand how it deteriorates with age in order to determine methods of reversing its adverse effects and reducing seniors' risk of falling (Delecluse et al., 2003; DiBrezzo, et al., 2005; Janssen et al., 2000; McCroy, Salacinski, Hunt, & Greenspan, 2009). Sarcopenia has been identified as the normal age-related loss of muscle mass and strength (Johnston et al., 2008). Typical sarcopenic characteristics include reduced muscle mass, a shift in fiber-type distribution, a loss of force-generating capacity, and reduced ability to effectively perform ADLs (Johnston et al., 2008). Cross-sectional research has demonstrated that skeletal muscle mass noticeably decreases by 45 years of age, and declines by 0.5–1% per year thereafter (Janssen et al., 2000). Evans and Lexell (1995) found that limb muscles of older men and women are 25–35% smaller than younger individuals. When biopsies were compared between the young and old participants, type II (fast twitch) fibers and to a lesser extent type I (slow twitch) fibers were smaller in the older participants, reducing the ability to produce strong muscular contractions (Evans et al., 1995). Evans et al. (1995) concluded that with advancing age, there is a gradual decrease in muscle fiber size and volume, which is accompanied by a replacement with fat and connective tissue. Most of these changes are a primary consequence of aging, which can be delayed in the elderly with increases in physical activity.

Resistance training

A loss in muscle mass and strength influences the prevalence of falls, thereby reducing the quality of life and perhaps decreasing longevity in seniors (Johnston et al., 2008). Leigh (1995) emphasized the need for nonpharmacological intervention to help reduce fall risk factors. Since aging does not alter the skeletal muscle response to strength training, RES training (e.g., free weights, exercise machines, rubber bands) is currently the most effective known strategy to combat sarcopenia and increase strength (Johnston et al., 2008). However, RES exercise programs may not be feasible with seniors who have mobility and/or neurological impairments (Turbanski, Haas, Schmidtbleicher, Friedrich, & Duisberg, 2005).

Whole-body vibration

WBV has shown potential as an alternative form of strength training. WBV has benefits over conventional RES exercise as it generally requires less time and effort (Signorile, 2006), yet evidence suggests it is as effective as RES training (Roelants, Delecluse, & Verschueren, 2004). WBV training normally consists of performing static and/or dynamic exercises on a vibrating platform (Lorenzen, Maschette, Koh, & Wilson, 2009). There are two common forms of vibration platforms: synchronous vibration or side altering vibration (Rauch et al., 2010). Synchronous platforms have a vertical or up and down vibration stimulus (Cardinale & Wakeling, 2005; Lorenzen et al., 2009; Rauch et al., 2010) and side altering vibration platforms deliver an asynchronous vibration (teeter totter) stimulus as the platform balances around a central fulcrum (Lorenzen et al., 2009; Rauch et al., 2010; Rittweger, 2010). WBV apparatuses vary in terms of frequency (in hertz) they can produce and the magnitude of vibration. While researchers have used

both “amplitude” and “peak-to-peak displacement” to describe the magnitude of vibration, the latter (peak to peak) is the recommended term, which is the total vibration excursion of a point (in millimeters) between its positive and negative extremes (Lorenzen et al., 2009; Rauch et al., 2010).

Typically the vibrations are transmitted through the legs to the body, stimulating the neuromuscular system (Roelants et al., 2004). With each vibration the platform shifts slightly downward (vertical displacement ~1–10 mm), lengthening the tendon resulting in an involuntary contraction (Bissonnette et al., 2010; Cardinale, 2005). The platform then shifts back to its initial position and repeats (normal frequency range is 15–60 Hz) (Cardinale, 2005). By the WBV platform providing both physical and neural overloads, it causes the body’s skeletal and neural tissues to adapt (Signorile, 2006). Pairing WBV with a common task, such as a squat, has been reported to increase electromyographical activity, strength, power, balance and postural control in the muscles being trained (Signorile, 2006). Although there are several proposed theories that attempt to explain how WBV enhances muscle function (e.g., neural potentiation of the stretch reflex (Ritzmann, Kramer, Gruber, Gollhofer, & Taube, 2010) and muscle tuning hypothesis (Cardinale, 2005), the biological mechanisms elicited due to WBV remain equivocal and require further investigation.

Whole-body vibration studies among the aging population: *targeting specific needs*

Initially, WBV training studies examined primarily young and athletic participants. More recently WBV research has been applied to a wide variety of populations, including the young and old, fit and unfit, and healthy and pathological participants (e.g., Bogaerts, Verschueren, Delecluse, Claessens, & Boonen, 2007; Janssen

et al., 2000; Marin, Herrero, Sainz, Rhea, & Garcia-Lopez, 2010; Turbanski et al., 2005). A search was conducted using electronic databases PubMed and Sport Discus using the following combination of search words: (whole-body vibration OR vibration training OR vibration exercise) AND (elder* OR ag* OR senior). There was no time restriction on the literature search, performed in April 2011, which resulted in a total of 139 journal articles. Articles were checked for relevant content and were included if they were published in English and used participants aged 55 and older. Review articles, duplicates, and studies that used locally applied vibration and/or used animals as test participants were excluded. An extensive hand search supplemented the database results to find other journal articles specific to seniors and WBV. Potential articles were retrieved and read to attain three additional WBV aging studies. While other review articles have included WBV and aging as part of a larger context, this paper focuses solely and exclusively on WBV as it applies to the older population. Thus, the search uncovered 27 journal articles, which are compiled and summarized in Table 5. This table draws upon and builds on Rehn, Lidstrom, Skoglund, and Lindstrom (2007) and Totosy de Zepetnek, Giangregorio, and Craven (2009), but is specific to WBV within an older population. Table 5 identifies each study's specific objectives, design (i.e., randomized controlled study), and whether the participants were institutionalized or non-institutionalized. In addition, Table 5 (see Appendix B) identifies the WBV plate and parameters¹ exercises performed, along with measurements and results specific to each study. All 27 studies have been published in the last 8 years, reflecting the recent and growing interest in this area. This is an

¹ The reader should be cautioned that there has been inconsistent use of the words amplitude and peak-to-peak displacement in the literature (Lorenzen et al., 2009). Although peak-to-peak displacement is the recommended term, both are still used in research articles. Therefore, the values in the chart may be either of the two terms: peak-to-peak displacement or amplitude. Caution is warranted here, particularly as researchers themselves occasionally confused the two terms (Lorenzen et al., 2009).

opportune time to provide an overview of the research and provide direction for future areas of investigation.

Balance and fall prevention

Thirteen published articles discussed the effects of WBV on seniors' postural control and balance. Twelve of the articles showed significant benefits of using WBV to improve balance and/or postural control, while one showed no significant improvement (Carlucci, Mazza, & Cappozzo, 2010). A potential limitation of the Carlucci et al. (2010) study was that their intervention consisted of one session of WBV. The articles that show significant results suggest WBV can improve elements of fall risk and improve postural control (Bautmans, Van Hees, Lemper, & Mets, 2005; Bruyere et al., 2005; Cheung et al., 2007; Kawanabe et al., 2007; Rees, Murphy, & Watsford, 2009).

In an attempt to decrease fall risk and improve health-related quality of life in nursing home residents, Bruyere and colleagues (2005) investigated the effects of WBV on 42 seniors who resided in a nursing home. Participants were randomized to receive physical therapy alone or physical therapy plus a WBV intervention. Physical therapy consisted of a standard exercise program with components of balance and gait training along with strengthening exercises. The experimental group participated in 3 sessions of WBV training per week for 6 weeks. A typical session involved the participant standing on the vibration platform for 1 min of vibration stimulus 4 times, with 90 secs of rest between sets.

The Tinetti Test consists of 16 test variables used to assess balance and gait, as it grades gait speed, stride, symmetry, and balance. Each component of the test was graded from 0 to 1 or 0 to 2 (the lower score indicates poorer physical ability), with the highest

possible overall score on the test being 28. The test was performed on each participant at baseline and after 6 weeks of training. The overall score of the Tinetti Test increased by 5.6 ± 3.7 points in the WBV experimental group vs. the physical therapy only group, which actually decreased 0.1 ± 1.3 points after 6 weeks. This suggests that combining WBV exercise with physical therapy is more effective at improving gait and balance as measured by the Tinetti Test than physical therapy alone and, therefore, may reduce nursing home residents' risk of falling (Bruyere et al., 2005).

In a separate study, Kawanabe and colleagues (2007) found that after 2 months of training, WBV in addition to routine exercise (walking, balance training, and muscle strengthening) significantly improved maximum standing time on one leg. The group that only performed routine exercises did not show any significant improvement with maximum standing time, suggesting adding WBV exercise to an exercise regimen can improve selected balance tasks (Kawanabe et al., 2007).

Rees et al. (2009) conducted a 2-month trial in an attempt to delineate the direct effects of WBV by randomly assigning 43 participants (66–85 years) into three groups: a WBV group, an exercise without WBV group, and a control group. The study was designed to determine the effectiveness of WBV exercise on postural steadiness by evaluating 8 weeks of standard WBV exercise with respect to the same program performed without vibration (Rees et al., 2009) Both exercise groups performed static squats for the first 4 weeks and dynamic squats and dynamic calf raises for the last 4 weeks of training, the key difference being that the WBV group performed all of the exercises on a vibration platform.

To determine the effectiveness of WBV on postural steadiness, all participants

were assessed by analyzing patterns of ground reaction force variability via a one-legged postural steadiness (OLPS) test. The OLPS starting position had the participant stand with feet shoulder width apart, with their eyes looking forward. The investigator then instructed the participant to stand freely on one leg for a maximum of 15 secs. Three consecutive trials of OLPS were performed on both legs of all participants; however, only the results for the right leg were reported. Results indicated WBV improved OLPS between 24.9% and 27.5%, on average following 8 weeks of WBV exercise. There were no significant differences found pre- to posttest for the exercise without WBV group or the control group. Of interest was the fact that individuals with the largest improvements were those with the worst baseline scores; thus, the authors postulated that those with very poor balance are the ones most likely to derive the largest benefits from a WBV intervention (Rees et al., 2009).

Lower extremity power and strength

Fourteen studies examined muscular power and/or strength while using WBV. A pilot study examining polio patients was the only study that did not show increased strength benefits with WBV training (Brogardh, Flansbjer, & Lexell, 2010). For the remaining 13 articles specific to lower body strength, two main themes exist; WBV improves muscular strength in seniors (e.g., [Bird, Hill, Ball, & Williams, 2009; Machado, Garcia-Lopez, Gonzalez-Gallego, & Garatachea, 2010; Verschueren et al., 2004]), and WBV is as effective as RES training (e.g., [Rees, Murphy, & Watford, 2007, Roelants et al., 2004]).

To determine if WBV improved seniors' muscular power, Russo and colleagues (2003) recruited 29 postmenopausal women who were randomly assigned to a WBV group or a control group. The WBV group stood on the WBV platform with their knees slightly bent for three 2-min sessions twice a week, for 6 months. The control group did not receive any training. Muscular power was quantified by measuring participants' ground reaction forces from jumps on a force plate. After 6 months, muscle power improved 5% in women who received WBV training, whereas the control group declined slightly. This suggests that WBV may be useful for improving muscular power in postmenopausal women (Russo et al., 2003).

Verschuere et al. (2004) investigated postmenopausal women to determine if WBV training would improve muscular strength. Seventy women (58–74 years) were randomly divided into three groups: WBV training group (WBV), exercise without vibration group, and a control group. Baseline measures were taken for all participants to determine initial isometric and dynamic strength. The WBV and exercise group trained 3 times per week for 24 weeks; the WBV group performed various static and dynamic lower body exercises on the vibration platform, while the exercise group trained their lower body by leg extension exercises and dynamic leg presses. After training, isometric strength of the knee extensors increased in both WBV and exercise groups, by 15% and 16%, respectively. Dynamic strength increased by 16.5% in the WBV group and 10.6% in the exercise group. The controls showed no significant change in isometric and dynamic strength from pre- to posttest (Verschuere et al., 2004). These results are consistent with Roelants et al. (2004), who had parallel results with 89 postmenopausal women. Both studies suggest WBV can significantly improve dynamic and isometric

strength in postmenopausal women. Roelants and colleagues (2004) also proposed WBV was as effective as conventional RES training when testing knee extension strength, speed of movement of knee extension (the highest possible speed the participant could extend their knee from 90° to 160°), and countermovement jump performance (flight time of a concentric muscle contraction following an eccentric muscle contraction) in older women (2004).

To determine if WBV training has a significant effect on both muscular strength and power, Machado et al. (2010) randomly assigned 26 senior women (65–90 years) to either a WBV training group or a control group. The WBV group trained for 10 weeks on the WBV platform performing calf raises and various squatting exercises, after which participants were compared to their baseline measurements. The WBV group had increases in maximum voluntary isometric contraction (MVIC—38.8%) as well as increases in the cross-sectional area of both the vastus femoris (8.7%) and biceps femoris muscles (15.5%). No changes were detected in the control group. Muscle power with an external RES of 20%, 40%, and 60% MVIC decreased from pre- to posttest only in the control group; the authors concluded that WBV training prevented the decrease in muscular power in the WBV group. These results further suggest that WBV can improve muscular strength in older women, which Machado et al. (2010) attributed to thigh muscle hypertrophy.

Flexibility

Bautmans and colleagues (2005) were the first researchers to test an element of flexibility training with WBV in seniors. Twenty-four nursing home residents (9 male and 15 female) were randomly selected to either a WBV group or a control group.

Participants from both groups were examined on flexibility pre- and posttest utilizing the chair sit-and-reach test (lower body flexibility) and the back scratch test (upper body flexibility). The WBV group performed lunges along with various types of squats and calf raises on a vibration platform, which target all the lower limb muscles. After 6 weeks, lower body flexibility improved significantly in the WBV group, indicating that general exercises may benefit flexibility. No significant differences were found in upper body flexibility pre- to posttest in either group, which may be attributed to participants not performing any exercises that targeted the upper body specifically (Bautmans et al., 2005).

Similarly, Bissonnette et al. (2010) examined upper and lower extremity flexibility using the same protocol. Nineteen participants (60–85 years) performed the chair sit-and-reach test and back scratch test pre- and post-WBV training. After completing the initial assessment, participants performed squats, calf raises, tricep extensions, and bicep curls on the WBV platform 3 times per week for 8 weeks. At week 4, lunges were added to the participants' exercise regimen. Both upper and lower body flexibility increased significantly from 0 to 8 weeks. Although the two aforementioned articles studied flexibility somewhat indirectly, results suggest WBV can be a very promising intervention to maintain or regain flexibility. This is noteworthy considering that flexibility can decline by up to 50% in certain joints by age 70 (Chapman, deVries, & Swezey, 1972). Based upon the search of the literature, these are the only two studies that tested a component of flexibility, indicating a vast potential to examine the effects of targeted flexibility exercises using WBV.

Upper body studies

Along with flexibility, upper body studies are one of the least established areas of WBV research with older adults. Bissonnette and colleagues (2010) are the sole investigators of the 27 articles to examine upper body strength. Nineteen participants (60–85 years) were tested on upper body strength at baseline and after 4 and 8 weeks of training by performing a standardized arm curl test. Following their initial assessment, participants performed static WBV tricep extensions and bicep curls 3 times per week for 8 weeks. Following training participants could lift 49% more weight compared to baseline performance, on average. This implies meaningful improvement in upper body strength can be attained from WBV exercises targeting those specific muscles (2010).

Randomized controlled trials

Of the 27 WBV studies examining older adults, 19 were randomized controlled trials (RCTs). Components most frequently examined were muscular strength (nine studies) and balance (seven studies). Other variables measured included muscular power (five studies), mobility (four studies), and bone mineral density (BMD—three studies). To a lesser extent, RCTs have examined functional capacity, cardiorespiratory fitness, anabolic hormones, electromyographic activity, torque, motor control, and muscle mass.

The nine studies that examined strength all found statistically significant improvements in muscular strength (Bautmans et al., 2005; Bogaerts et al., 2009; Machado et al., 2010; Raimundo, Gusi, & Tomus-Carus, 2009; Rees et al., 2007; Rees, Murphy, & Watsford, 2008; Roelants et al., 2004; Verschueren et al., 2004; von Stengel, Kemmler, Engelke, & Kalender, 2010), and three studies suggested WBV is as effective as conventional RES training (Bogaerts et al., 2009; Roelants et al., 2004; Verschueren et

al., 2004). Of the seven studies that examined balance, each one found statistically significant improvements in the components measured. WBV exercise increased balance/postural control (Bogaerts et al., 2011; Brogardh et al., 2010; Cheung et al., 2007; Rees et al., 2009), WBV exercise was more effective than walking to improve balance (Gusi, Raimundo, & Leal, 2006), and WBV exercise was as effective (Ebersbach, Edler, Kaufhold, & Wissel, 2008) or possibly superior (Rees et al., 2009; van Nees et al., 2006) to their comparative traditional exercise programs.

Two studies examining BMD revealed increases in the hip (Verschueren et al., 2004) and femoral neck (Gusi et al., 2006). In addition, Russo et al. (2003) found the decline of cortical BMD tended to be less in the WBV group than the control group. Of the three studies that examined BMD, there were no reported adverse effects due to treatment, with the exception of one participant who complained of knee pain (Russo et al., 2003). Therefore, WBV may be a viable alternative for individuals who have low BMD, although Totosy de Zepetnek and colleagues (2009) have advised caution for individuals suffering from severe osteoporosis. With just three studies specific to adults over 55, this work is clearly in its early stages, and more research is needed prior to providing definitive recommendations for those in this age category who have low BMD or osteoporosis. In the absence of a substantive body of research, caution is warranted.

It is important to note that there were considerable differences in methodologies among the RCTs. Studies ranged from one session to 1 year, participants exercised between two and 5 times per week and the WBV platform's frequency ranged from 6 to 40 Hz. In addition, there was an underrepresentation of men in the 19 RCT studies. Of the 1315 individuals who participated in the RCTs, 316 (24.0%) were men. Therefore,

the literature would benefit from replication and/or greater consistency in the methodologies employed, particularly with respect to study duration, the number of weekly exercise sessions, and the hertz utilized.

Limitations and future research

Although WBV research specific to an older population is relatively new, the evidence suggests that WBV training is a viable option for increasing muscular strength, improving flexibility, improving balance, and reducing the risk of seniors falling. Many of the published studies show that WBV is as effective as RES training. Readers should be cautioned that this may be due, at least in part, to publication bias; studies with significant findings are more likely find their way into the academic literature.

Additionally, the majority of the studies that we reviewed did not mention whether or not the experimenters were blinded when taking measurements. The potential for investigator bias should be controlled for in future studies.

While there are potential limitations, the scientific literature indicates that there is substantial evidence supporting WBV as an effective intervention for older adults, which is important information for seniors who are unable to perform conventional exercise. Additionally, WBV may be appropriate for those with time constraints, as a typical WBV training session takes approximately 15 min, considerably less time than a traditional 45–60 min RES training regimen (Signorile, 2006). In the studies reviewed, 6 minutes per body part was the maximum time allotted for WBV training.

Specific vibration platform settings varied significantly from study to study. This can be partially attributed to the different types of WBV platforms used. In addition, researchers have increased the frequency and peak-to-peak displacement of the WBV

platform after a few weeks of training to counteract any potential plateau effect (Bissonnette et al., 2010; Bogaerts et al., 2007; Liu-Ambrose et al., 2004). Determining optimal frequency and peak-to-peak displacement settings to maximize results is an important area of future research.

From a practical standpoint, WBV training can be an expensive intervention for the senior population. A vibration platform for home use can cost up to 2000 Euros (WAVE Manufacturing, 2010). Seniors may find it more cost-effective to go to a facility that has an industrial size vibration platform and pay a monthly membership fee. Although, as WBV training for the general public is relatively new, fitness clubs are only beginning to incorporate these devices.

Of the 27 studies that are specific to WBV and the senior population, the primary focus has been on strength or balance components of the lower body. While the results suggest that WBV is effective for lower body muscular strength and postural control, more conclusive evidence is needed to determine if WBV can improve overall flexibility and upper body strength with the aging population, as this area of research is still in its infancy. Ideally, future flexibility and upper body strength WBV research would incorporate a randomized controlled study utilizing a WBV group, an exercise without vibration group, and a control group.

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Appendix A



CONSENT TO PARTICIPATE IN RESEARCH

Title of Study: **The Effects of Whole-Body Vibration Exercise on Muscular Strength in Seniors**

You are being asked to participate in a research study conducted by **Ms. Chantelle Lachance, Dr. Sean Horton, Dr. Patricia Weir, Dr. Kenji Kenno, and Ms. Kelly Carr** from the **Department of Kinesiology** at the University of Windsor, **the results of which will contribute to Ms. Chantelle Lachance's Master's thesis.**

If you have any questions or concerns about the research, please feel to contact **Ms. Chantelle Lachance: Primary Investigator. (519) 984-8801**

PURPOSE OF THE STUDY

This study will determine if there is an effect of whole-body vibration (WBV) on improving muscular strength with seniors.

PROCEDURES

If you volunteer to participate in this study, we would ask you to do the following things:

- 1) Fill out a brief profile regarding personal information and health history
- 2) Complete assessment protocols: arm curl test, tricep extension test, grip strength, chair rise test, and timed "up & go" test. These protocols will be completed at baseline, after 8 sessions and at the end of the study (16 sessions).
 - a.) Arm Curl Test: You will be asked to perform as many complete bicep curls as you can in 30 seconds. Women will hold a 5lb dumbbell, whereas men will hold an 8lb dumbbell.
 - b.) Tricep Extension Test: You will be asked to complete as many tricep extensions as you can in 30 seconds. Women will hold a 5lb dumbbell, whereas men will hold an 8lb dumbbell.
 - c.) Grip Strength Test: You will be asked, while seated, to grasp the dynamometer as hard as you can for 4-5 seconds. You will perform 3 trials in total including rest breaks in between.
 - d.) Chair Rise Test: You will be asked to rise from a chair as many times as possible in 30 seconds without using your arms for support
 - e.) Timed "Up & Go" test: You will be asked to rise from a chair, walk to a marker located 8 feet away, turn, walk back to the chair and sit down again. Your score will be timed in seconds.

Participants will be assigned to either the WBV group or resistance exercise group. The WBV group will perform their exercises on a whole-body vibration platform twice a week for 8 weeks (16 sessions). Each exercise session will take approximately 15 minutes.

The resistance exercise group will perform exercises that may involve resistance bands and light weights, but not the vibration platform. This is part of the normal on-going regimen with the Chronic Disease Management Program. They too will perform the exercises twice a week for eight weeks (16 sessions). Each exercise session will take approximately 25 minutes. The duration and number of repetitions performed will gradually increase throughout the weeks to prevent plateau (little to no change in progress).

POTENTIAL RISKS AND DISCOMFORTS

With any exercise, there is the possibility for abnormal responses to occur. These include unexpected changes in blood pressure, irregular heart rate, fainting, shortness of breath, muscle cramps, muscle soreness, muscular strain or joint injury, and in rare cases, a cardiac event. Risks will be minimized by having trained personnel leading you through all the exercises in each session. In addition, a registered nurse will be on site at all times.

As a participant, you should understand that exercise training may cause muscle soreness for 1-3 days following a training session. Soreness may be greatest after the first 1-2 sessions, but is normally reduced afterwards. Exercise targeted to increase muscular strength involves a risk of injury due to strained muscles, ligaments, or tendons, as does any form of exercise. As a safety precaution, we will have you warm-up and research assistants will be stationed near the equipment at all times to ensure proper form and technique during each exercise.

POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

As a participant, you may benefit from this research by increasing your muscular strength and improving your overall quality of life by learning the benefits and importance of exercising regularly and by working with trained, knowledgeable exercise practitioners.

COMPENSATION FOR PARTICIPATION

Participants will receive a kinesiology t-shirt and a reusable shopping bag.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential. As we are interested in the results of the group as a whole, individual data will not be reported in any public forum. Publications or conference presentations will focus exclusively on group results. All data will be stored in the Lifespan Development Lab in the Department of Kinesiology. Only the Primary and Co-investigators will be able to access the data.

PARTICIPATION AND WITHDRAWAL

You can choose whether or not to participate in this study. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE PARTICIPANTS

Given the confidentiality of the study, participants will have their results mailed to them individually, approximately three months after the study is complete. Results of the study in its entirety will be available online.

Web address: <http://web4.uwindsor.ca/units/researchEthicsBoard/studyresultforms.nsf>

Date when results are available: December 2012

SUBSEQUENT USE OF DATA

This data may be used in subsequent studies.

RIGHTS OF RESEARCH PARTICIPANTS

You may withdraw your consent at any time and discontinue participation without penalty. If you have questions regarding your rights as a research participant, contact: Research Ethics Coordinator, University of Windsor, Windsor, Ontario, N9B 3P4; Telephone: 519-253-3000, ext. 3948; e-mail: ethics@uwindsor.ca

SIGNATURE OF RESEARCH PARTICIPANT/LEGAL REPRESENTATIVE

I understand the information provided for the study The Effects of Whole-Body Vibration Exercise on Muscular Strength in Seniors as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

Name of Participant

Signature of Participant

Date

SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

Signature of Investigator

Date

Appendix B

Table 4

Characteristics of the whole-body vibration (WBV) training program

Sessions	Volume	Sets per exercise	Duration of each exercise (secs)	Intensity			Intensity		
				Static lower body exercises			Static upper body exercises		
	Training frequency (sessions/week)	(#)	(secs)	Amplitude (mm)	Frequency (hz)	Rest (secs)	Amplitude (mm)	Frequency (hz)	Rest (secs)
1-4	2	2	30	2	35	180	4	40	180
5-8	2	3	30	2	35	180	4	40	180
9-12	2	2	45	2	35	180	4	40	180
13-16	2	3	45	2	35	180	4	40	180

Note. Exercises performed included: static squats, heel raises, lunges, bicep curls, and tricep extensions.

Table 5- Please see appended documents and insert table “5a”

Table 5- Please see appended documents and insert table “5b”

Table 5- Please see appended documents and insert table “5c”

Table 5- Please see appended documents and insert table “5d”

Table 5- Please see appended documents and insert table “5e”

Table 5- Please see appended documents and insert table “5f”

Appendix C

Figure 1 - Static Squat



Appendix C

Figure 2 - Static Heel Raise



Appendix C

Figure 3- Static Lunge



Appendix C

Figure 4- Static Bicep Curl



Appendix C

Figure 5- Static Tricep Extension



Appendix C

Figure 6- WAVE Pro vibration platform



Appendix C

Figure 7- Chair Stand Test (start position)



Appendix C

Figure 8- Chair Stand Test (finish position)



Appendix C

Figure 9- 8-foot Up-and-Go Test (test set-up)



Appendix C

Figure 10- 8-foot Timed Up-and-Go Test (start position)



Appendix C

Figure 11- Arm Curl Test (start position)



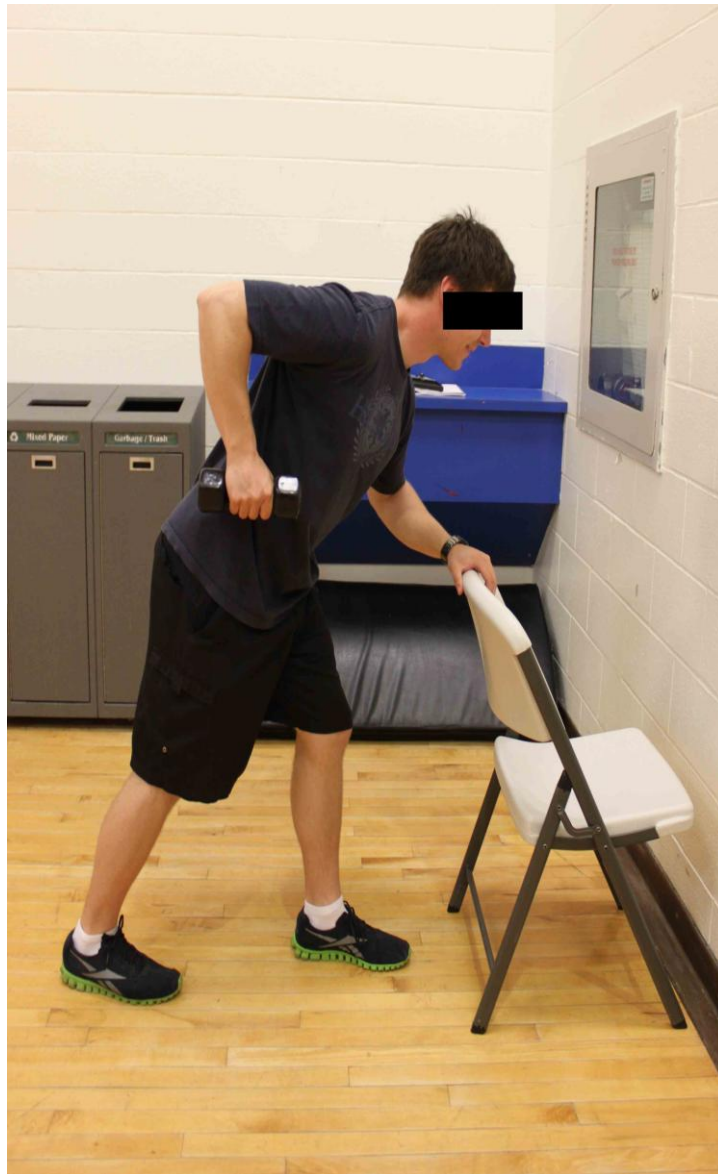
Appendix C

Figure 12- Arm Curl Test (finish position)



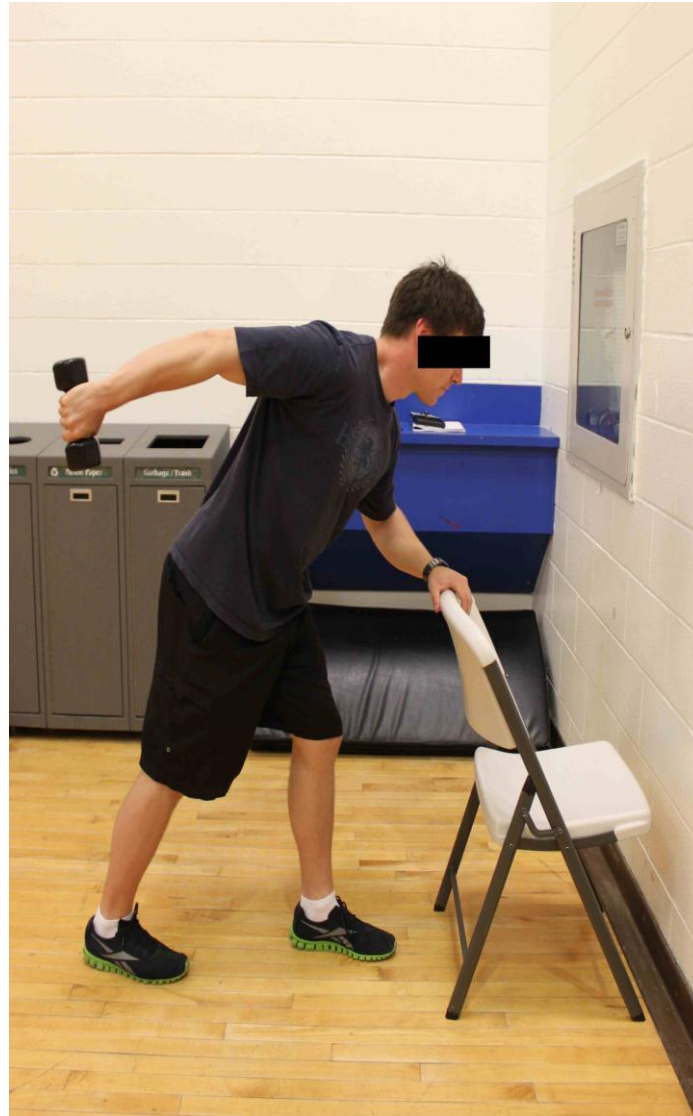
Appendix C

Figure 13- Tricep Extension Test (start position)



Appendix C

Figure 14- Tricep Extension Test (finish position)



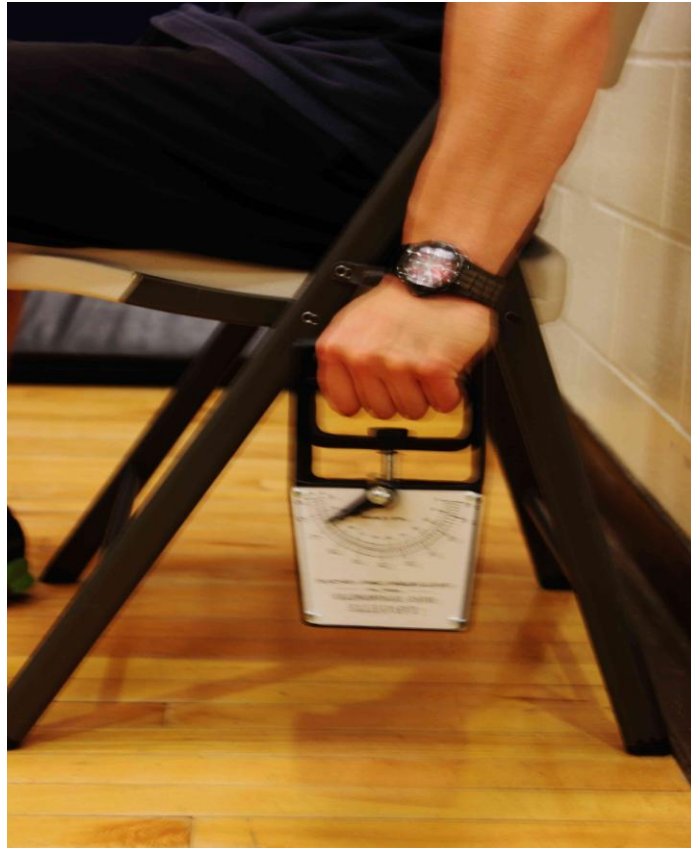
Appendix C

Figure 15- Grip Strength Test (start position)



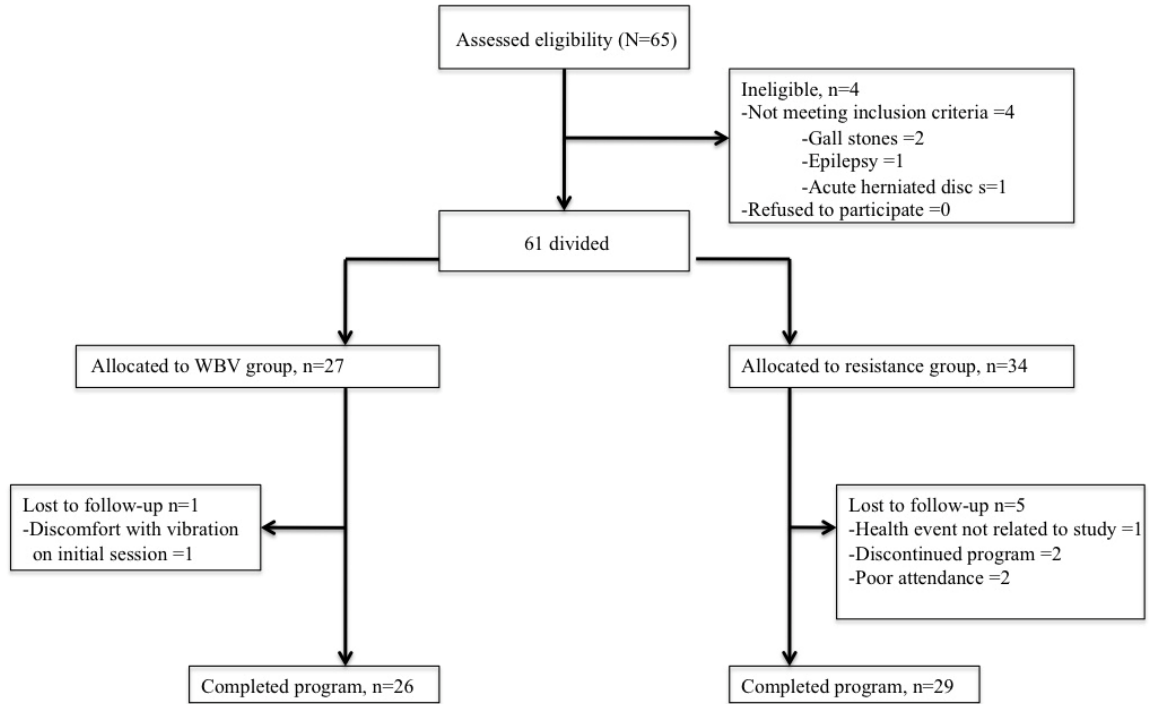
Appendix C

Figure 16- Grip Strength Test (finish position)



Appendix C

Figure 17- Flow chart of the participant assignment to condition



Note. After exclusion and drop-out, there were a total of 55 participants in the study (26 in the whole-body vibration group and 29 in the resistance group).

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