EFFECTS OF WHOLE BODY VIBRATION ON NEUROMUSCULAR PERFORMANCE OF COMMUNITY DWELLING OLDER ADULTS

Submitted by

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STATEMENT OF SOURCES

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ABSTRACT

Whole body vibration (WBV) is a mode of exercise by which an individual stands on a vibration platform that may be oscillating and therefore creating vertical displacement which affects gravitational forces acting upon the whole body. Manipulations of platform amplitude or frequency can affect the rate of change of the WBV (i.e. acceleration) acting upon an individual. The specific influences of frequency or amplitude, however, are unknown. The aim of the study, therefore, was two fold; (1) to identify chronic WBV effects of neuromuscular performance within a community dwelling older adult sample, and; (2) to identify WBV methods that would elicit chronic neuromuscular performance changes within such a sample. The study incorporated a randomised controlled experimental design to examine the aim. Seventy-three community dwelling older adults freely consented to the requirements of the study (mean age = 72.0 years). Neuromuscular performance was quantified with the 5-Chair Stands test, the Timed Up and Go (TUG) test and the Tinetti test. Health Related Quality of Life (HRQOL) was qualified with the SF-36 Health Survey. A six week WBV intervention significantly changed the quantifiers of neuromuscular performance in a community dwelling older adult sample. The WBV intervention significantly reduced time taken to complete the 5-Chair Stands test ($p < .05$) and the TUG test ($p < .05$). The six week WBV intervention significantly improved Tinetti test scores ($p < .05$). The six week WBV intervention significantly improved all components of HRQOL. For the 5-Chair Stands test, a three WBV sessions per week intervention elicited significantly larger ($p < .05$) neuromuscular performance gains than a two WBV sessions per week intervention in the target sample. For the TUG test, a three WBV sessions per week intervention elicited significantly larger ($p < .05$) neuromuscular performance gains than a zero and one WBV session per week intervention in the target sample. A significant difference ($p < .05$) was found between pre-test and post-test Tinetti test scores for all WBV intervention groups. There was an insignificant difference ($p > .05$) found within the control group of community dwelling older adults for the Tinetti test. Detraining effects were observed three weeks after the cessation of the six week WBV intervention for the three WBV sessions per week group. Neuromuscular performance reduced after the detraining period. Vibration platform dynamics (manipulated frequency and controlled amplitude) showed that gravitational forces created by the WBV were safe since no injuries were associated with the intervention and since participant compliance was 100% during the six week WBV intervention. The methods of this study showed a chronic WBV intervention to be a safe and easily administered exercise to improve neuromuscular performance and HRQOL of a community dwelling older adult sample. Specifically, WBV could be used as a safe and effective tool to improve aspects of normal daily function such as body balance and gait speed.

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Dedicated to the memory of Dr Rob Sands.

CHAPTER 1. INTRODUCTION

Whole Body Vibration (WBV) is a mode of exercise by which an individual stands on a vibration platform that may be oscillating and therefore creating vertical displacement. Vibrations are transmitted to the body through the contact point on the surface of the platform. WBV, as a relatively recent area of Exercise Science research, requires further investigation since knowledge of effects and methods to elicit effects in various samples are relatively unknown (Cardinale & Wakeling, 2005). To date, most investigations have reported acute WBV effects in young adult samples, but chronic WBV effects in that sample are relatively unknown.

The reported effects of WBV on community dwelling older adults, however, are limited and therefore, a dearth of research literature was identified. Furthermore, chronic effects of WBV and subsequent detraining effects within such a sample of community dwelling older adults are relatively unknown. The aim of the study, therefore, was two fold. Firstly, to identify chronic effects of WBV on such a sample, and secondly, to identify methods that would elicit chronic effects in such a sample.

1.1 WBV Effects

Reported literature suggested that combined with resistance training, WBV can improve neuromuscular performance (Rittweger, Beller & Felsenberg, 2000; Torvinen, Kannus, Sievänen, Järvinen, Pasanen, Kontulainen, Järvinen, Järvinen, Oja, & Vuori, 2002a; Delecluse, Roelants & Verschueren, 2003; Rittweger, Mutschelknauss & Felsenberg, 2003). Studies have shown various functional improvements in lower limb muscular strength and muscular power. WBV is thought of as a facilitator when used in conjunction with resistance training (Torvinen et al., 2002a; Delecluse, Roelants & Verschueren, 2003; Lou, McNamara, & Moran, 2005).

Other WBV interventions elicited significant improvement in leg press average velocity, average power and average force for young adult participants (Bosco, Colli, Introini, Cardinale, Tsarpela, Mandella Tihanyi & Viru, 1999; Bosco, Iacovelli, Tsarpela, Cardinale, Bonifazi, Tihanyi, Viru, De Lorenzo & Viru, 2000). Those improvements were attributed to neurogenic adaptation and an improvement in neuromuscular efficiency. Functionally, the neural pathways of muscular contraction were affected by the WBV allowing significant performance improvement

In support, EMG data led to a suggestion that central nervous system recruitment of predominantly larger motor units occurred during WBV (Rittweger, Mutschelkanuss & Felsenberg, 2003). In that study, comparable levels of neuromuscular fatigue (blood lactate and rate of perceived exertion) were observed between an exercise group with WBV and an exercise group without WBV. Since muscular exhaustion occurred more rapidly to the group with WBV than to the group without WBV it was supposed that WBV led to alterations in neuromuscular recruitment patterns. The aforementioned investigations support a theory of neural adaptation elicited by WBV.

Most studies have examined young adults (e.g. Delecluse, Roelants & Verschueren, 2003; de Ruiter, van der Linden, van der Zijden, Hollander, & de Haan, 2003). One can only speculate the effects on an older adult sample. This study, therefore, was significant since it assessed such a sample. This was considered important since locally and globally, an ageing population increases the burden on social systems such as Public Health Care and other health related services. Sarcopenia, for example, is a condition affecting all older adults that reduces the quality of life of such individuals, reduces neuromuscular performance and can lead to dependence on health related services (Nigg, Fisher & Ronsky, 1994; Gross, Stevenson, Charette, Pyka & Marcus, 1998; Häkkinen, Pakarinen, Kraemer, Häkkinen, Valkeinen & Alen, 2001).

Inactivity effects sarcopenia in a negative way (Bean, Vora & Frontera, 2004). Inactivity is avoidable for most individuals. Sarcopenia, therefore, a condition that reduces functional abilities and quality of life, can be mitigated, or at least addressed through exercise (Luo, McNamara & Moran, 2005). The role of WBV as a form of exercise for older adults, therefore, must be initially established as effective and secondly implemented to measure effects of such interventions on the older adult population.

Questions of significance were raised by considering pervious WBV interventions and particularly what platform dynamics (amplitude and frequency) were adopted. The questions of significance were; can a chronic WBV intervention elicit neuromuscular improvement in a community dwelling older adult sample to potentially delay or reduce the effect of debilitating conditions such as sarcopenia? Can a chronic WBV intervention elicit functional improvement as it had in young adult populations? Furthermore, does a chronic WBV intervention affect health related quality of life? Those questions could only be answered by a systematic scientific investigation of the factors involved in WBV.

1.2 WBV Methods

Methods to elicit both acute and chronic WBV effects are mostly unique since a common standard has not been established. The independent variables, vibration platform frequency (Hz) and amplitude (mm) have been manipulated to affect dependent variables. The ideal frequency and/or amplitude to elicit maximum benefit from acute and/or chronic WBV interventions have, therefore, not been conclusively reported. Furthermore, the ideal frequency and amplitude for beneficial neuromuscular performance and health related quality of life (HRQOL) affects have not been addressed, in any from, with a sample of community dwelling older adults.

This study controlled the variables of: group (zero, one, two and three WBV sessions per week), test occasion (pre-test, post-test and retention-test), vibration platform amplitude, WBV bout duration and rest duration. Vibration platform frequency, however, was manipulated to affect the dependent variables (i.e. neuromuscular performance measures). By controlling amplitude, a more conclusive effect of frequency was observed. Moreover, effects of detraining (i.e. retention-test data) had not previously been reported for chronic WBV training in the target sample.

Vibration platform frequency between 12 Hz and 30 Hz have been safe, whilst amplitude as high as 3.0 mm has caused injury in healthy participants (Mester, Spitenpfeil, Schwarzer & Seifriz, 1999; Cronin, Oliver & McNair, 2004). Such injuries included chronic tendonitis and muscular soreness. Practically, WBV must be safe so that practitioners can advise clients. For this study, therefore, frequency was between 15 Hz and 25 Hz and amplitude was controlled at 0.5 mm.

For this study a mixed research design was used to examine effects of WBV on neuromuscular performance of community dwelling older adults. The design allowed a high degree of confidence in the validity of outcomes and enabled the investigator to draw meaningful conclusions about the expected differences observed between and within sample groups (Portney & Watkins, 2000).

Such a design allowed the investigator to address the following questions of significance.

1. Can vibration platform frequency and magnitude elicit neuromuscular performance improvement in the target population?
2. Can vibration platform amplitude remain fixed and frequency be manipulated in conjunction to achieve a change in the target population?
3. How many sessions per week are required to elicit neuromuscular performance improvement?
4. What are effects of WBV in the target sample after a six week intervention?

For this study three standardised tests were used to quantify changes that occurred in a community dwelling older adult sample.

1. 5-Chair Stands test, which was used to quantify neuromuscular performance.
2. Timed Up and Go test (TUG) test, which was used to show body balance, gait speed, and functional ability of older adults.
3. Tinetti test, which was used to show body balance and gait.

1.3 General Objectives

The aforementioned questions formed the basis of significance, uniqueness and subsequent objectives of the study. The objectives of the study were:

1. To measure the neuromuscular performance and HRQOL of community dwelling older adults.
2. To measure pre-test, post-test and retention-test qualitative and quantitative data of the target sample.
3. To identify methods that elicit neuromuscular performance improvement in the target sample.
4. To establish a WBV intervention method for the target sample.

1.3.1 Specific Objectives

1. To examine effects of a WBV intervention on neuromuscular performance and HRQOL of a community dwelling older adult sample.
2. To compare qualitative and quantitative data between and within intervention sample groups that completed a six week WBV intervention.
3. To determine the number of days per week a community dwelling older adult must receive WBV in order to elicit neuromuscular performance benefit.
4. To establish the appropriate frequency (Hz) to elicit neuromuscular and HRQOL improvement in the target sample.

1.3.2 Research Hypotheses

The following hypotheses were proposed to measure effects of WBV on neuromuscular performance of community dwelling older adults.

> H_1: A six week WBV intervention, by which a community dwelling older adult sample group stood on a vibration platform with fixed amplitude and manipulated frequency for one, two or three WBV sessions per week will improve neuromuscular performance as quantified by the 5-Chair Stands test.

> H_1: A six week WBV intervention, by which a community dwelling older adult sample group stood on a vibration platform with fixed amplitude and manipulated frequency for one, two or three WBV sessions per week will improve neuromuscular performance as quantified by the TUG test.

> H_1: A six week, three WBV sessions per week intervention, by which a community dwelling older adult sample group stood on a vibration platform with fixed amplitude and manipulated frequency will elicit significantly larger neuromuscular performance improvement as quantified by the 5-Chair Stands test and the TUG test compared to six week, one WBV session per week and two WBV sessions per week interventions in participants of the same sample.

H_1: Post-test neuromuscular performance data, as quantified by the 5-Chair Stands test and the TUG test, for a three WBV sessions per week intervention sample group of community dwelling older adults who stood on a vibration platform with fixed amplitude and manipulated frequency for three weeks will show lager performance gains when compared to retention-test (three week detraining period) data of the same three WBV sessions per week sample group.

H_1: A six week WBV intervention, by which a community dwelling older adult sample group stood on a vibration platform with fixed amplitude and manipulated frequency for one, two or three WBV sessions per week will improve neuromuscular performance as quantified by the Tinetti test.

H_1: A six week WBV intervention, by which a community dwelling older adult sample stood on a vibration platform with fixed amplitude and manipulated frequency will significantly improve HRQOL as qualified by the SF-36 Health Survey.

H_1: A community dwelling older adult sample group that did not attend a WBV intervention will not significantly improve quantifiers of neuromuscular performance (5-Chair Stands test data, TUG test data, Tinetti test data) or qualifiers of HRQOL (SF-36 Health Survey data).

1.4 Summary

Whole body vibration is considered a mode of exercise that is beneficial for both athletic and non athletic populations (Bosco et al., 2000; Torvinen, Kannus, Sievänen, Järvinen, Pasanen, Kontulainen, Järvinen, Järvinen, Oja & Vuori, 2002; Roelants, Delecluse & Verschueren, 2004). Beneficial effects of WBV interventions have been reported, though, the ideal vibration parameters of such exercise programmes (vibration platform dynamics, intervention duration and intensity) also remain largely unknown. That is, the influence of the vibration platform frequency and amplitude and subsequent effects of WBV to an individual are unclear. Other components of a WBV exercise programme remain unclear or unestablished. The number of WBV sessions per week to elicit neuromuscular performance improvement, for example, remains unknown. WBV exercise programmes are in their infant stage of development and require further scientific conformation.

Effects of WBV, and specifically, chronic WBV effects in a community dwelling older adult population are basically unknown. Few studies have recruited such a sample, and fewer have quantified neuromuscular performance. Furthermore, effects of detraining after a WBV intervention on such a sample are unknown.

This study was designed to investigate the effectiveness of variations in WBV training protocols. The clarification of such issues is significantly important to the field of Exercise Science because the prescription of any exercise programme must have boundaries within which the practitioner can safely advise the clientele. Any form of exercise that purports to elicit health benefit must be thoroughly researched and understood in order to gain maximum health effect. As yet, such knowledge of WBV protocols remains unknown.

This study is important because of knowledge gaps within the scientific literature. The gaps in knowledge, for example, include the appropriate vibration platform dynamics (frequency and amplitude), the appropriate number of WBV sessions per week and, in turn, effects of WBV on quality of life in a community dwelling older adult population to elicit beneficial WBV effects. This study was unique since it specifically focused on those gaps by drawing a community dwelling older adult sample with the aim of scientifically developing a beneficial WBV intervention.

1.5 Definition of Terms

Acute:	Effects of neuromuscular performance that are quantified immediately after, or within 30 minutes of a WBV bout.
Agonist:	Prime mover of skeletal muscle for movement.
Amplitude:	To describe the vibration oscillation magnitude, from the equilibrium position of the wave form, quantified in millimetres.
Antagonist:	Muscle opposed to the direction of movement, thus, muscle lengthens due to the movement.
Bout:	Single WBV treatment lasting for 60 seconds.
Chronic:	Measured at least 24 hours after a WBV bout and after at least six weeks of intervention.
Community Dwelling:	An individual that is functionally independent within the community and does not rely solely upon Public Health.
EMG:	Electromyography, activity within the muscle and an indicator of neuromuscular performance.
Frequency:	The repetition rate of vibration oscillation, quantified in Hz.
HRQOL:	Health Related Quality of Life as qualified by the SF-36 Health Survey.
Isokinetic:	Muscle contraction in which the maximum tension is generated in the muscle as it contracts at a constant speed over the full range of motion of the joint.
Isometric:	Muscle contraction without movement at the joint.

Isotonic:	Both eccentric muscular contraction (muscle lengthens) and concentric contraction (muscle shortens).
Neurogenic Adaptation:	Manipulation of neural pathways to improve neuromuscular performance.
Neuromuscular Efficiency:	Recruitment of larger motor units to perform muscular work.
Neuromuscular Performance:	Components include muscular strength (the force generated by muscular contraction and the leverage of the muscle at the joint) and muscular power (the product of force and velocity, thus, a measure of the time taken to perform a task about a joint).
Reciprocal Inhibition:	Process by which muscles on one side of a joint relax to accommodate contraction on the other side of that joint.
Sarcopenia:	The condition where muscular strength and muscular mass are lost.
Session:	Period of five WBV bouts.
Stretch Reflex:	Reflex contraction of a muscle when an attached tendon is stretched.
Vibration:	Occurs when an object is moved rapidly and continuously to and fro.
Whole Body Vibration (WBV):	Is transmitted to the entire body of an individual rather than vibration one specific area of the body.

CHAPTER 2. LITERATURE REVIEW

Whole body vibration can be used as a form of exercise, training or treatment when an individual stands on a vibration platform. The literature describing such use of WBV was reviewed in this section. Initially, vibration and WBV were defined. The subsequent subsections reviewed effects of WBV, effects of WBV upon older adults, methods used to determine neuromuscular performance of older adults and effects of sarcopenia upon older adults. Subsequently, a case for the manner in which WBV can be prescribed as an exercise intervention for community dwelling older adults was designed.

2.1 Vibration

Vibration can be beneficial and detrimental to the health of an individual. In industry, vibration occurs when an object is moved rapidly and continuously to and fro (Knight, 2000). The movement of such objects, however, may be ‘pure’ (i.e. the objects create vibration by moving in a periodic, sinusoidal oscillatory motion) or more ‘shock’ like (i.e. the objects create vibrations that are discontinuous and random) (Mester, Spitzenpfeil & Yue, 2002). Specifically, vibration of a periodic, sinusoidal oscillatory nature was used in this study (figure 1). Sinusoidal vibration is characterised by repetitive wave form oscillations of movement over a period of time.

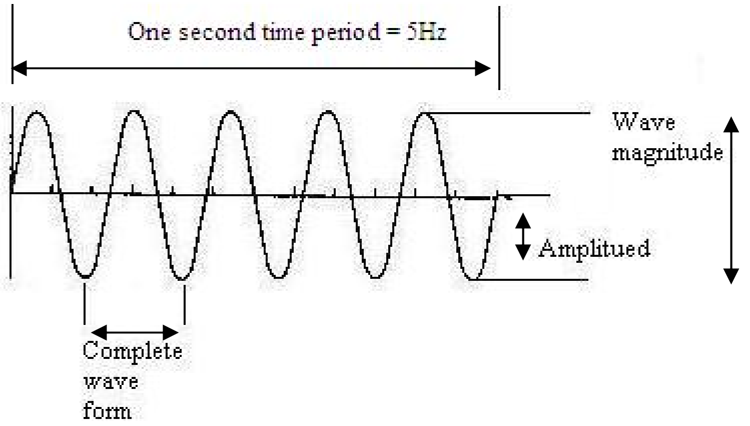


Figure 1 Typical sinusoidal vibration showing repetitive wave form oscillations.

Vibration is varied depending upon the size of the vibration oscillation (magnitude) and the repetition rate of the oscillation (frequency) (Jordan, Norris, Smith & Herzog, 2005). The frequency and amplitude are the quantifiers of vibration. The magnitude of the oscillatory movement is quantified by the amplitude (mm) of a half wave form (Mester, Spitzenpfeil & Yue, 2002). Amplitude of 1.0 mm, for example, equates to wave magnitude of 2.0 mm. The repetition rate of the oscillations is quantified by the frequency (Hz) of the repetitions (Cardinale & Bosco, 2003). Sinusoidal oscillation of 5 Hz, for example, equates to 5 complete wave forms in a one second time period.

Past studies have used several terms to describe the magnitude of vibration oscillation. Magnitude has been described synonymously as amplitude, displacement and peak to peak displacement (Cardinale & Lim, 2003; Delecluse, Roelants & Verschueren, 2003). One study, for example, initially reported vibration oscillation magnitude as amplitude of 2.5 mm to 5.0 mm, only later to describe vibration oscillation magnitude as peak to peak displacement of the same magnitude (Delecluse, Roelants & Verschueren, 2003).

Such differences in the nomenclature can make it difficult to interpret research findings and replicate methods. Furthermore, such oversights may lead to confusion and a general idea that standards have not been established within the field.

Amplitude, by definition, is “the maximum extent of vibration from the equilibrium position” (Knight, 2000, p. 26). Figure 1 best displays the equilibrium position at the point where the wave form begins. The equilibrium position, however, is also shown as a horizontal line (i.e. the *x*-axis). For the purpose of this study, therefore, the aforementioned definition of amplitude was used to describe the vibration oscillation magnitude in an effort to reduce confusion.

2.1.1 Vibration Effects

Vibration may be transmitted to an individual through specific devices. A hammer strike, for example, transmits shock vibration through the arm while a specifically designed vibration platform transmits pure vibration though the whole body. Vibration, therefore, has both beneficial and contra-indicated effects on individuals and their health (Lundström, Holmlund, & Lindberg, 1998; Lundström, Holmlund, 1998; Mester, Spitzenpfeil & Yue, 2002; Crewther, Cronin & Keogh, 2004; Jordan et al., 2005). Vibration, for example, has been used as a therapeutic tool for rehabilitation and pain management (Cronin, Oliver & McNair, 2004). Specifically, vibration can be used to relieve spasticity in rigid muscles (Marieb, 1995).

Conversely, high frequency, long duration vibration is necrotic to exposed muscles (Necking, Dahlin, Fridén, Lundborg, Lundström & Thornell, 1992). The influence of vibration for an individual can vary according to the factors that quantify vibration and the duration of the vibration exposure. Some areas of vibration research, therefore, had been directed at effects of different forms of vibration (i.e. pure or shock) on muscular function and neuromuscular performance. One such form of pure vibration research focuses on whole body vibration (WBV).

2.1.2 Whole Body Vibration

Whole body vibration may be observed in a variety of occupational and recreational environments (i.e. operators of heavy vehicles and hand held chain saws, skiers and horse riders). WBV has also been created in laboratory and field settings by researchers. As a specific form of vibration, WBV is transmitted to the entire body of an individual rather than vibrating one specific area of the body, hence the terms 'whole body vibration'.

In laboratory settings, a platform that rotates about a sagittal axis is generally used to create vibrations (figure 2). Such platforms may allow for frequency and amplitude to be manipulated. An individual will experience pure WBV when standing on the platform with both feet equidistant, on either side of the rotation axis (Rittweger, Beller & Felsenberg, 2000; Roelants, Delecluse & Verschueren, 2004). WBV, therefore, is a means to indirectly apply periodic, sinusoidal oscillatory vibration to a whole body (Luo, McNamara & Moran, 2005).

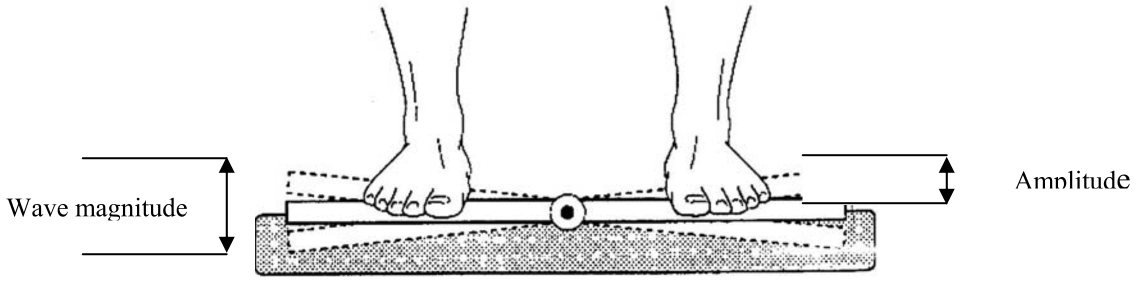


Figure 2 A typical vibration platform used to deliver WBV to an individual.

2.1.2.1 WBV Effects in all Environments

The beneficial effects of WBV in laboratory conditions have been reported. WBV improved muscular strength and muscular power, body balance, gait, blood circulation and growth hormone levels (Bosco et al., 2000; Torvinen, Kannus, Sievänen, Järvinen, Pasanen, Kontulainen, Järvinen, Järvinen, Oja & Vuori, 2002; Roelants, Delecluse & Verschueren, 2004).

Contra-indicated effects (i.e. damage to biological structures) of WBV have also been reported in occupational environments involving heavy vehicle operators and men who use, for example, chain saws (Carlsöö, 1982; Blűthner, Seidel & Hinz, 2001; Ishitake, Miyazaki, Noguch, Ando & Matoba, 2002). Heavy vehicle operators are exposed to WBV whilst seated. In those situations shock WBV is created from the vibration of the vehicle and the terrain the vehicle encounters during its journey. Gastrointestinal symptoms increased after WBV for those operators. Chain saw operators are exposed to WBV whilst standing, with the hands the first point of contact with the vibrating device.

With such knowledge, the International Standards Organisation constructed strict guidelines governing the safe and effective use of machines that create WBV. Such standards are established to reduce injury and maintain productivity since effects of WBV to human health are dependent on the quantifiers of vibration and duration of the vibration (Ishitake et al., 2002). Such WBV standards (e.g. laws stating the length of time an individual can use a jack hammer), however, do not exist for recreational environments since WBV may be unavoidable and/or expected. Unavoidable WBV, for example, occurs in sports where the surface encountered contains undulations.

In recreational environments individuals are exposed to WBV in a variety of sports such as surfing, skiing, running and horse riding (Mester, Spitzenpfeil & Yue, 2002). Athletes are exposed to WBV during track running and other sports that involve a flight and landing phase. Medial tibial stress syndrome, for example, may partly be caused by vibration transmitted to the tibialis anterior muscle during running on firm surfaces (Marieb, 1995).

2.1.2.1.1 Gravity

During WBV, changes in gravitational conditions are produced by the vibrations of machinery (i.e. vehicles and vibration platforms) (Bosco, Cardinale, Tsarpela, Colli, Tihanyi, Duvillard & Viru, 1998). Gravity is a component of WBV since the product of amplitude and frequency is acceleration (equation 1). Manipulations of amplitude or frequency can affect the rate of change of the WBV (i.e. acceleration) acting upon an individual. Thus, the gravitational forces acting upon the body are varied in most WBV environments (i.e. recreational and occupational).

$$g = \frac{A.(2\pi f)2}{9.81} \qquad \text{Equation 1}$$

Where g = gravitational force; $A.(2\pi f)^2$ = acceleration maximum (product of frequency and amplitude); 9.81 = the acceleration of gravity.

When, for example, amplitude (0.5 mm) and frequency (15 Hz) are manipulated the gravitational force is equal to 0.45 g. When frequency is increased to 25 Hz the gravitational force is equal to 1.26 g. Thus, during WBV the gravitational forces acting upon the body were, for example, between almost one half and one and a quarter times greater than that of a period of inactivity.

In an occupational environment, vehicle operators, especially bus and truck drivers are exposed to WBV and these drivers experience both positive and negative vertical and horizontal gravitational forces as the vehicle travels. Carpenters, however, experience WBV of a much larger frequency but smaller amplitude from power tools to the aforementioned drivers.

In a recreational environment the frequency of WBV a skier experiences will depend, for example, on the number of undulations encountered per second. The amplitude of WBV will depend on the size of the undulation. The gravitational conditions the skier experiences will change as he/she moves up, over and down each undulation, thus affecting the position of the body in space (i.e. proprioception).

Whole body vibration in occupational and recreational environments may vary in frequency and amplitude, therefore, gravitational variation occurs. Since the position of the whole body in space is changing, the role of the neuromuscular system during WBV must be to perceive and attenuate changes in body position for optimum performance and/or comfort. Furthermore, it is noteworthy that vibration affecting the whole body may be generated by more than one source, thus, multiple forms of vibration may affect the whole body simultaneously. It is this phenomenon that makes WBV research difficult since field conditions are difficult to replicate in laboratory settings (e.g. reproducing downhill skiing conditions in a laboratory). Controlled WBV, however, can be created in the laboratory with vibration platforms and used to help elicit various biologic responses within participants.

2.1.2.2 WBV Specific to the Laboratory and the Field

During typical laboratory conditions, WBV has been transmitted to participants in both sitting and standing positions upon a prototype vibration platform or commercial vibration platforms (Torvinen et al., 2002; Rubin, Pope, Fritton, Magnusson, Hansson & McLeod, 2003; Crewther, Cronin & Keogh, 2004). The frequency and amplitude of most vibration platforms can be manipulated. This study used a calibrated (i.e. amplitude and frequency) prototype vibration platform (figure 3) (Appendix K). The design of this unique vibration platform allows changes in frequency and/or amplitude without a participant having to change stance. Other platforms require the person to change stance where the width of the feet is increased to increase the amplitude (e.g. Galileo 2000; Novotec, Pforzheim, Germany).

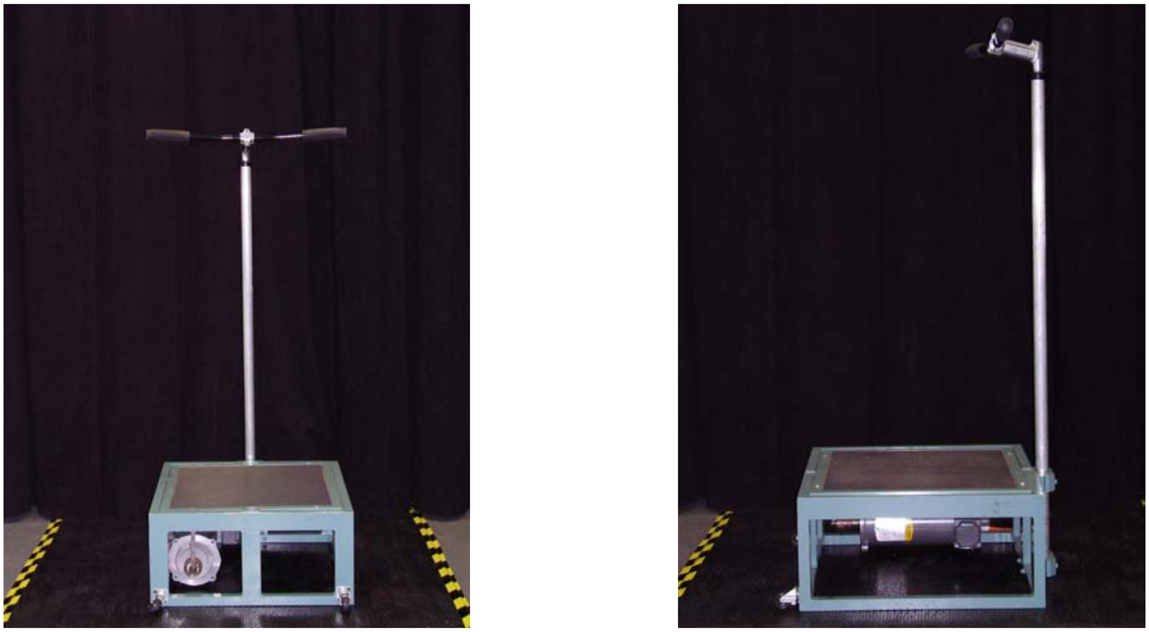


Figure 3 Prototype vibration platform used in this study. Posterior and lateral view.

2.1.2.2.1 Recommended Range for Safety and Health Benefit

Contra-indicated effects of WBV have been reported (Carlsöö, 1982; Blűthner, Seidel & Hinz, 2001; Ishitake et al., 2002). Researchers, therefore, have found that to avoid injury, the most common range of frequency and amplitude of WBV platforms are between 26 Hz and 44 Hz and 1.0 mm to 10.0 mm (Crewther, Cronin & Keogh, 2004; Cronin, Oliver & McNair, 2004). Vibration platform frequency less than 12 Hz and amplitude as high as 3.0 mm have caused chronic tendonitis and muscle soreness of the lower limbs in healthy participants (Mester, Spitenfeil, Schwarzer & Seifriz, 1999; Cronin, Oliver & McNair, 2004).

The apparent contradiction between the aforementioned facts regarding amplitude suggests that high amplitude and low frequency is more injurious than low amplitude and high frequency. Researchers need to identify the most appropriate vibration platform amplitude and frequency to achieve maximum health and/or fitness/performance benefit for the participant. Specifically, achieving adequate vibration platform frequency may be of clinical importance in preventing disc degeneration or low back pain (Cheung, Zhang & Chow, 2003). Vibration platform dynamics are one method to elicit beneficial health affects, however, the action of the participant on the platform can also influence health.

The body posture adopted on the vibration platform can affect the health benefit for the participant (Mansfield & Griffin, 2002). The position of the spine and the degree of tension in the muscles of the trunk and lower extremities changes the elastic and dampening properties of the body (Harazin & Grzesik, 1998). Since bony structures and tissue structures are affected by WBV, the posture adopted can change the vibration about different body sections of the individual (i.e. different WBV effects between the lower and upper extremities).

The amount of WBV affecting an area of the body (the transmission) has been quantified using accelerometers attached to various landmarks of participants. Transmission at the ankle, knee and hip in the sinusoidal vibration platform frequency range of 20 Hz to 30 Hz was larger than at the shoulder and head. However, in different postures (standing feet apart, knees bent to 110°) transmission was similar through all landmarks (Harazin & Grzesik, 1998). That finding suggests that WBV with knees bent (110°) creates a more even transmission of WBV. Functionally, the elastic and dampening properties of the body changed due to the posture adopted and the subsequent transmission. That may also explain why, in many WBV studies, participants stood in a squat position to enable a more even transmission of vibration (i.e. possibly less potential for injury at the knee) while isometrically contracting the quadriceps muscle group.

2.1.2.3 WBV Exercise Effects

Whole body vibration has been used as a form of exercise in controlled conditions. In various studies, participants standing on vibration platforms have maintained static positions or performed dynamic movements such as squats and squats with an additional load (Rittweger, Schiessl & Felsenberg, 2001; Roelants, Delecluse & Verschueren, 2004; Rønnestad, 2004). Subsequently, many different effects of WBV have been reported. Furthermore, given the relative ease in which vibration platforms can be transported, WBV effects have also been reported from the field.

The exercise effects of WBV on the body are numerous and considered beneficial to health. The VO_2 of participants standing on a WBV platform increased 4.5 $ml.kg^{-1}.min^{-1}$, above those that did not receive WBV, equating to the equivalent of moderate walking (Rittweger, Schiessl & Felsenberg, 2001; Rittweger, Ehring, Just, Mutschelknauss, Kirsch & Felenberg, 2002). Similarly, small increases in heart rate, blood pressure and rate of perceived exertion (RPE) were reported (Rittweger, Beller & Felsenberg, 2000). Also, WBV has been reported to increase growth hormone and testosterone levels and reduce body fat (Bosco et al., 2000; Roelants, Delecluse, Goris & Verschueren, 2004). From a functional aspect, WBV increased leg muscular force and muscular power (Bosco et al., 2000).

Through the act of standing on a vibration platform, an individual tended to attenuate the imposed WBV by physical activity, thus, the muscular contractions elicited may be beneficial in counteracting muscular loss due to the lack of other physical exercise such as resistance training (Kerschan-Schindl, Grampp, Henk, Resch & Preisinger, 2001). Such findings validate the role of WBV as a form of exercise leading some authors to suggest WBV as an effective alternative for resistance training (Roelants, Delecluse & Verschueren, 2004). Furthermore, WBV is a safe and effective method to improve muscular strength, body balance and mechanical competence of bone (Torvinen et al., 2002; Yue & Mester, 2002).

Whole body vibration research findings drew attention to the importance of WBV as a research area for exercise scientists. Findings implied that WBV may be an alternative mode of exercise for individuals who are, for example, less inclined to participate in gym classes or individuals who have trouble walking (Roelants, Delecluse & Verschueren, 2004). Further research conducted by exercise scientists needs to identify the most appropriate methods of WBV interventions to achieve desired health benefit since the aforementioned research findings used different methods to elicit WBV effects.

2.1.2.3.1 Effects on Muscles

Electromyography (EMG) measurements have shown that WBV significantly improved isometric and isokinetic neuromuscular performance (i.e. muscular strength and muscular power) for the knee extensor and forearm flexor muscles. Vibration improved the force-velocity relationship in the upper and lower limbs as well as increased moving blood volume (Bosco et al., 1999; Bosco, Cardinale, Tsarpela, 1999; Runge, Rehfeld & Resnicek, 2000; Kerschan-Schindl et al., 2001; Cardinale & Lim, 2003; Delecluse, Roelants & Verschueren, 2003). That is, the ability of the muscle to contract more forcefully in a reduced amount of time.

Whole body vibration has been reported to enhance neuromuscular adaptation, synchronisation and coordination, also to elicit central motor excitability, rhythmical muscle contraction and proprioceptive responses (Bosco et al., 1999; Rittweger, Beller & Felsenberg, 2000; Kerschan-Schindl et al., 2001; Delecluse, Roelants & Verschueren, 2003; Rittwegwe, Mutschelkanuss & Felsenberg, 2003). Functional measures of neuromuscular performance such as vertical jump height, leg press average velocity, average power and average force significantly improved after WBV (Bosco et al., 1999; Rønnestad, 2004).

Other studies have shown, however, that WBV did not improve functional strength of the knee extensors, change muscle performance or improve body balance (Torvinen et al., 2002; de Ruiter et al., 2003; Torvinen, Kannus, Sievänen, Järvinen, Pasanen, Kontulainen, Nenonen, Järvinen, Paakkala, Järvinen & Vuori, 2003). Specifically, vertical jump height and maximal voluntary contraction did not significantly improve after WBV (Torvinen et al., 2002; de Ruiter et al., 2003; Torvinen et al., 2003).

The different methods used during WBV interventions may partly explain the contradiction between studies. Effects of WBV on body balance, for example, may not be significant for young adults, but body balance had significantly improved for older adults (age range 60-90 years, *n* = 213) (Runge, Rehfeld & Resnicek, 2000). Furthermore, acute effects of WBV had shown improvement in knee extensor strength, while chronic WBV had shown no effect (Torvinen et al., 2002a; Torvinen, Kannus, Sievänen, Järvinen, Pasanen, Kontulainen, Järvinen, Järvinen, Oja, & Vuori, 2002b). The chronic increase in vertical jump height found by Delecluse, Roelants & Verschueren (2003) and Torvinen et al. (2003) contradict those findings since the knee extensors are the prime movers in jumping.

The mechanisms governing effects of WBV are yet to be clearly understood. It was suggested that WBV had been designed to elicit spinal reflexes (i.e. the stretch reflex) and/or the tonic vibration reflex/response (Rittweger, Mutschelknauss & Felsenberg, 2003). WBV, therefore, had been regarded as a neuromuscular training tool (Delecluse, Roelants & Verschueren, 2003). Since neural changes are the first within muscle with the commencement of strength training, WBV may be an effective alternative to resistance training, as WBV appeared to elicit neural changes (Bosco, Cardinale & Tsarpeal, 1999; Roelants, Delecluse & Verschueren, 2004).

Whole body vibration is thought to elicit neuromuscular activity due to the repetitive oscillation of the pelvis (Rittweger, Schiessl & Felsenberg, 2001). The contraction of the muscle is brought about by the body trying to attenuate the imposed vibration. Spinal reflexes create rhythmic muscle contraction, thus, without much effort by the recipient (Rittweger, Beller & Felsenberg, 2000). Furthermore, WBV stimulated greater synchronisation of motor units, thus, the aforementioned improvements are most probably due to an increased sensitivity of the stretch reflex (Issurin & Tenenbaum, 1999).

Whole body vibration may be more effective when coupled with additional training load (de Ruiter et al., 2003). Performing the squat exercise during a WBV bout chronically increased counter movement vertical jump height (Delecluse, Roelants & Verschueren, 2003). Also, muscular fatigue was reached more rapidly with WBV, and EMG frequency indicated the recruitment of larger motor units (Rittweger, Mutschelknauss & Felsenberg, 2003). WBV, therefore, may be more effective as an aid to training in younger adults where additional load is not as uncomfortable as compared to older adults (i.e. stability). Current research, however, had not extended that theory to older adult samples.

In most cases WBV affected neuromuscular performance in some way. Improvement in muscular strength and muscular power have been explained by neuromuscular adaptation to the vibration stimulus. To further understand the potential effects of WBV, the processes of muscular function must be understood. Since WBV was said to affect neuromuscular performance, the succeeding subsections detailed muscular contraction, muscular strength, muscular power and the spinal reflex loop of the stretch reflex.

2.1.2.3.1.1 Muscular Contraction

The major functions of skeletal muscle are to produce body movement and maintain body posture. Such functions occur when skeletal muscle lengthens or shortens under contraction or maintains muscle tone without changing length (i.e. eccentric, concentric and isometric contractions). Specifically, movement and posture are affected when a motor unit is stimulated by an alpha (ά) motoneuron. The contractile proteins of skeletal muscle, actin and myosin, are stimulated to adjust or maintain the length and thus, the tension of the muscle. This procedure, termed the ‘sliding filament theory of contraction’ was first discovered by Huxley in the 1950’s and remains in the contemporary Exercise Science lexicon.

Contraction of skeletal muscle depends upon the number of motor units innervated, the conduction velocity of the nerve, the duration of the innervation and the metabolic capabilities of the motor unit (Robergs & Roberts, 1997). A skeletal muscle may be innervated by several ά-motor nerves. Each ά-motor nerve may contain hundreds of ά-motoneuron axons which branch into axon terminals that form a neuromuscular junction with a muscle fibre (i.e. the motor unit) (Marieb, 1995; Saladin, 2001). A muscle, therefore, will not contract without motor unit stimulation.

2.1.2.3.1.2 Neuromuscular Performance

The term neuromuscular performance is used to describe the interaction of nerves and muscles. The successful interaction between the two is important for functional aspects of daily living as well as athletic achievement. Muscular strength and muscular power are the quantifiers of neuromuscular performance (Luo, McNamara & Moran, 2005).

Muscular strength is determined by both the force generated by muscular contraction and the leverage of the muscle at the joint (Abernethy, Kippers, Mackinnon, Neal & Hanrahan, 1996). Functionally, it is the maximum force produced by a muscle and can be best quantified by one repetition maximum (1 RM) through a single range of motion (Hamill & Knutzen, 1995; Robergs & Roberts, 1997). The 1 RM is the maximum weight an individual can lift for a single repetition.

Muscular strength is needed, for example, to lift a box off the ground. Using correct technique, the trunk in an upright position, the quadriceps skeletal muscle group contract to produce extension about the knee (i.e. the leverage about a joint). Full extension will occur if the muscular force generated is greater than the weight of the box. Consider a similar technique for weight lifting. Again extension about the knee is needed. Since athletes may lift in excess of 200 kg, much larger muscular strength is needed (figure 4).

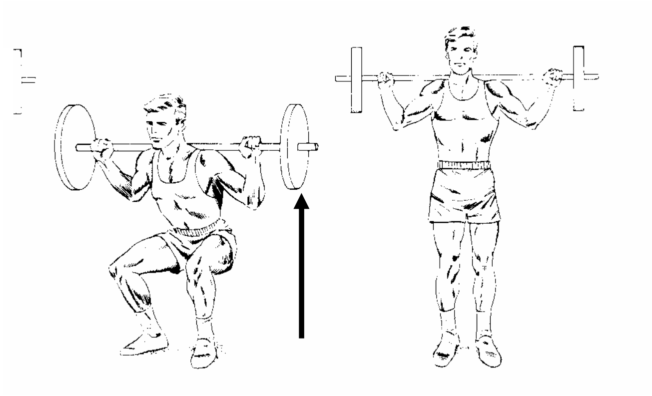


Figure 4 Weight lifting using quadriceps for extension about the knee (Luttgens & Hamilton, 1997, p. 648).

Muscular power is the product of force and velocity, thus, a measure of the time taken to perform a task about a joint (Hamill & Knutzen, 1995). Functionally, such tasks may include joint flexion and extension. The power of a muscle will determine how quickly an object can be moved about the joint range of motion. Muscular power is best observed as a force-velocity time curve (figure 5).

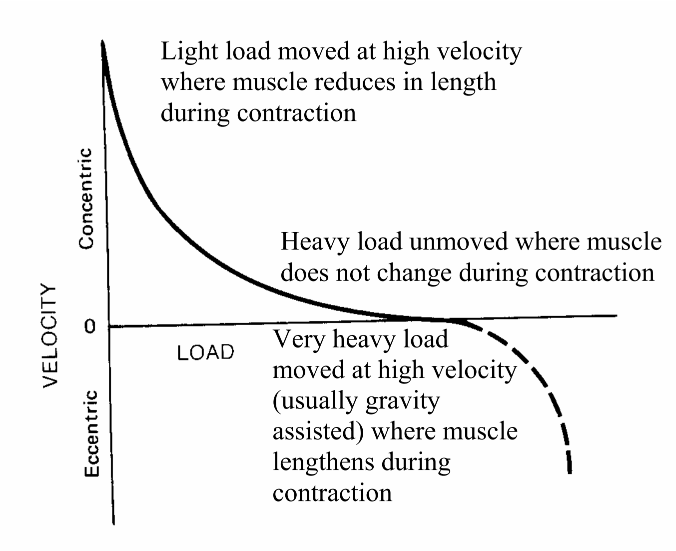


Figure 5 Force-velocity time-curve; heavy loads are moved at small velocity (Luttgens & Hamilton, 1997, p. 62).

The velocity of movement of a heavy load about a joint will be less than that of a light load. Therefore, as the velocity of muscular contraction increases, the force production decreases (Luttgen & Hamilton, 1997). Functionally, as the load increases the amount of actin/myosin cross-bridging must increase. Since large force is required to move a heavy load, more motor units are recruited, subsequently, the time taken to complete the task increases.

Neuromuscular performance (i.e. neuromuscular actions) has other functional roles. The ability of the individual to quickly contract (specifically concentric and eccentric contractions) skeletal muscles in order to, essentially, overcome the force of gravity and the weight of the body is important during the mishap of falling. Since muscular strength is linked to bone strength and falling, neuromuscular performance is a risk factor for falls and hip fractures for older adults (Runge, Rehfeld & Resnicek, 2000). Tripping and the ability to stumble and regain body balance, therefore, rely partly on muscular power. When muscle moves a limb, power and velocity of force development are critical components that prevent a stumble becoming a fall. Neuromuscular performance, therefore, must be quantified to assess appropriateness of, for example, rehabilitation interventions and research methods.

Neuromuscular performance can be quantified using a variety of procedures and equipment. During typical laboratory conditions a participant may ride a cycle ergometer, or perform maximal voluntary contractions using modified machines (Bosco et al., 1999; Torvinen et al., 2003; McBride, Porcari & Scheunke, 2004). Neuromuscular performance is quantified by, for example, industrial or prototype force platforms (i.e. reaction forces), or by measuring EMG signals (i.e. rate of electrical signal) (Cardinale & Lim, 2003; Lindemann, Claus, Stuber, Augat, Muche, Nikolaus, Becker, 2003).

Isokinetic movement is perhaps the ideal method to quantify neuromuscular performance. Using the Cybex (Cybex$^{®}$, Bay Shore, New York) or KIN-COM Isokinetic Dynamometer (Chettecx Corp, Chattanooga, TN), for example, a participant will perform a concentric contraction about a joint at a set angular velocity. Isokinetic, literally meaning 'equal movement', is a useful method since speed is controlled and maximum force may be produced. Many researchers have measured muscular strength and muscular power in laboratories using such devices (Skelton, Kennedy & Rutherford, 2002; Roelants, Delecluse & Verchueren, 2004).

In the field, neuromuscular performance may be quantified with simpler instruments. Since field research often requires manageable, transportable equipment, larger devices such as the aforementioned are not practical. Muscular strength and muscular power have been quantified using, for example, hand held dynamometers and various tests such as the 'Timed Up and Go test' (TUG) (Bohannon, 1986; Mathias, Nayak & Isaacs, 1986; Podsiadlo & Richardson, 1991; Bruyere, Wuidart, Di Palma, Gourlay, Ethgen, Richy, & Reginster, 2005).

The TUG test has confirmed inter-rater and intra-rater reliability and correlates with other field tests with known reliability (Podsiadlo & Richardson, 1991). The advantages of some field methods over laboratory methods are that they are time and cost effective. The TUG test, for example, requires minimal equipment (i.e. a stop watch) and is completed within two minutes.

Laboratory tests and equipment, when used correctly, will remain the ultimate method to quantify neuromuscular performance. Field testing, however is a more practical method in many circumstances. Field tests were judged the most practical method to quantify the neuromuscular performance of participants in this study. That decision was made for three reasons; (1) there were a large number of community dwelling individuals within the desired age range in the locale; (2) the location of the field testing was central to all participants, and; (3) the sample was located approximately one hour from the laboratories of Australian Catholic University, Victoria.

2.1.2.3.1.3 Reflex Loop

The maintenance of body posture is dependent on the ability of skeletal muscle to maintain muscle tone. Skeletal muscles maintain a slightly toned state in preparation for quick contraction required to attenuate changes in body position (Luttgens & Hamilton, 1997). When a skeletal muscle experiences a brief, unexpected increase in length the reflex response is to shorten the muscle to avoid, for example, injury or unstable body posture. This reflex, known as the ‘stretch reflex’ may be completed (from stimulation to effector) in less than 40 milliseconds (Sinkjaer, 1974; Abernethy et al., 1996; Martini, 1998). The mechanisms of the stretch reflex originate, for example, at the patella tendon of the knee and the Achilles’ tendon of the ankle. A role of the stretch reflex is to maintain muscle tone, thus, it is the neural pathway by which skeletal muscle contract to maintain or adjust body posture (Luttgens & Hamilton, 1997).

The stretch reflex is a monosynaptic reflex. The reflex loop requires an afferent ά-motoneuron to send signals from the muscle to the spinal cord and an efferent ά-motoneuron to send signals to the muscle from the spinal cord (figure 6).

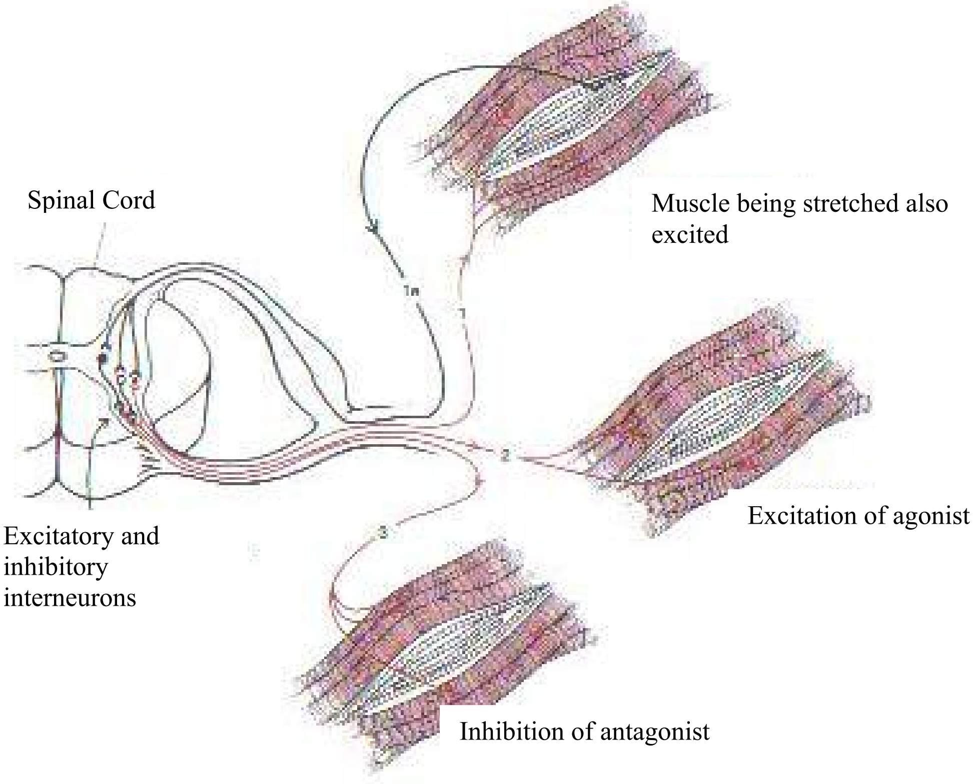


Figure 6 The stretch reflex loop showing agonist and antagonist muscles for reciprocal inhibition (Hamill & Knutzen, 1995, p. 128).

Skeletal muscle proprioceptors, the muscle spindles, initiate the stretch reflex. Muscle spindles detect stretch in the muscle-tendon complex. Typically, type Ia and type II afferent fibres of the muscle spindle detect the rate, amount and degree of stretch. The muscle spindle converts changes in muscle length and tension to nerve impulses that enter the spinal cord (Hamill & Knutzen, 1995). The fibres also play an inhibitory role since they stimulate the antagonistic muscle to relax, thus allowing the agonist to be the prime mover (Shumway-Cook & Woollacott, 2001). This function is called 'reciprocal inhibition' (Marieb, 1995).

Activation of the afferent fibres excites the ά-motoneuron where impulses are sent to the dorsal root of the spinal cord. At the spinal cord, the afferent ά-motoneuron synapses with the efferent ά-motoneuron. The efferent ά-neuron then stimulates the motor unit and that results in the sliding filament theory of contraction (Shumway-Cook & Woollacott, 2001; Enoka, 2002; McBride, Porcari & Scheunke, 2004; Jordan et al., 2005).

When standing on a vibration platform the skeletal muscles of the lower limbs, for example, will contract (lengthen and shorten) according to the amplitude and frequency of the platform. The mechanical action of vibration mediates fast and short changes in the length of the muscle-tendon complex (i.e. type Ia and type II afferent fibres stimulation) (Cardinale & Bosco, 2003; Rønnestad, 2004). Muscle proprioceptors detect the changes in length and the reflex is activated accordingly. Finally, involuntary muscular contraction occurs. This knowledge is supported by research noting the increase of EMG activity (Bosco, Cardinale, Tsarpela, 1999; Cardinale & Lim, 2003; McBride, Porcari & Schunke, 2004). WBV, therefore, evokes spatially oriented postural responses (Kasi, Yahagi & Shimura, 2002).

A tonic vibration response (TVR) and/or the tonic vibration reflex (TVR) are acronyms used interchangeably within the WBV literature to describe the neural effects of WBV. The TVR occured when vibration is applied to the muscle belly or tendons (Cardinale & Bosco, 2002; Cardinale & Lim, 2003; Rønnestad, 2004; McBride, Porcari & Schunke, 2004). Specifically, the TVR is elicited when the vibration is localised at a selected muscle or tendon (Issurin, Liebermann, Tenenbaum, 1994). The reflex is thought to activate muscle spindles and elicit ά-motoneuron response. Since the TVR, by definition, is impractical in sporting and exercise environments where the whole body may be vibrated, it was not considered to be a feasible explanation as to effects of WBV in this study.

2.1.2.3.2 WBV Acute Effects

Many studies have examined acute effects of WBV (e.g. Cardianle & Lim, 2003; Humphries, Warman, Purton, Doyle & Dugan, 2004). Typically, data were collected during, immediately after, or within 30 minutes of the WBV session. Acute effects include increased EMG activity, enhanced neuromuscular excitability and performance, improved flexibility (Bosco, Cardinale & Tsarpela, 1999; Issurin & Tenenbaum, 1999; Bosco et al., 2000; Cardianle & Lim, 2003) and increased vertical jump height (Cochrane, & Stannard, 2005). Other studies have shown that WBV did not improve muscle activation or enhance force production (de Ruiter, van der Linden, van der Zijden, Hollander & de Haan, 2003a; Humphries et al., 2004).

Acute effects of WBV are yet to be formally established since conjecture exists between studies. Finding the exact WBV method that will improve acute neuromuscular performance may be beneficial in countless athletic and rehabilitation environments. For short duration sporting events that require power, such as 100 metre sprinting and weightlifting, WBV may, for example, acutely improve neuromuscular recruitment, thus eliciting greater motor unit recruitment and ultimately superior performance. In elite events where the difference between first and fifth placing can be measured in milliseconds, a small performance advantage elicited by WBV may prove the difference in performance.

Although acute effects of WBV require further research and ultimate understanding, they are not the focus of this study. Chronic effects of WBV were of particular interest here since few studies (e.g. Delecluse, Roelants & Verschueren, 2003; Roelants, Delecluse, & Verschueren, 2004) had examined such effects. Furthermore, less had examined chronic effects on community dwelling older adult samples (Luo, McNamara & Moran, 2005).

Chronic effects (measured at least 24 hours after a WBV session and after at least six weeks of intervention) of WBV were of particular interest to this investigator since, as with any exercise, the beneficial effects of the exercise are the reason the exercise occurred. Since the potential benefit of chronic WBV are still rather unknown, this study focussed on neuromuscular performance effects after a six week WBV intervention period. Chronic effects were recorded and documented. Chronic WBV effects were considered more valid since, for older populations who may not desire sporting performance improvement, the chronic effects of WBV are more desirable for health and quality of life than the acute WBV effects.

2.1.2.3.3 WBV Chronic Effects

Chronic effects of WBV are of importance for a number of populations such as community dwelling and dependent individuals who may derive some benefit from WBV. In rehabilitation settings, individuals recovering from surgery or other muscular injuries may benefit from WBV since it is easily administered (i.e. simply standing on a vibration platform) as opposed to resistance training. Muscle atrophy is common in post operative situations or in other periods of inactivity (i.e. bed-ridden). WBV could be used as a rehabilitation tool to reduce muscle atrophy. Furthermore, athletes may increase muscular strength and muscular power when WBV is added to their exercise programme. WBV may also play a role in cross training and motivation for athletes since it adds a new dimension to exercise.

Chronic effects of WBV are a largely unknown phenomenon. One reason for the lack of research may be that the area of WBV investigation has only recently become more prevalent. The relative difficulty in obtaining a vibration platform may be one such cause. WBV platforms are manufactured by a small number of companies (i.e. Galileo 2000; Novotec, Pforzheim, Germany and Power Plate; Badhoevedorp, The Netherlands) and are expensive.

Only limited knowledge exists that is related to chronic WBV effects. Furthermore, some authors suggested a clear lack of research into the area (Luo, McNamara & Moran, 2005). However, it is known that WBV improved chronic knee extension maximal voluntary contraction and rate of force development (Runge, Rehfeld, & Resnicek, 2000; Bruyere et al., 2005). Functionally, improvement in vertical jump height were also found (Delecluse, Roelants & Verschueren, 2003; Torvinen et al., 2003).

More recent research has reported eight months of WBV did not significantly improve serum markers of bone turnover, shuttle run scores, grip strength or body balance (Torvinen et al., 2003). The lack of improvement in body balance is interesting. Since muscle proprioceptors are stimulated during WBV, it would be expected that body balance, as a result, would improve. One reason for the finding may be that the young participants had good balance before the intervention. The methods used in the aforementioned study, as with all studies, must be scrutinised in order to progress WBV knowledge and research direction.

2.1.2.4 WBV Chronic Methods

Chronic effects of WBV are recorded after a series of sessions over an extended period (Luo, McNamara & Moran, 2005). The methods used for chronic WBV research are similar and therefore, do not vary considerably. The methods used, however, may have led to the different findings between studies. Most notably, the findings of Delecluse et al. (2003) (significant lower limb maximal voluntary contraction increase and counter movement vertical jump height increase) differ from those of Torvinen et al. (2003) (no WBV effect on bone mass, body balance or maximal voluntary contraction, but, increased counter movement vertical jump height) and de Ruiter et al. (2003a) (no WBV effect).

The three investigation teams recruited young adults and had them stand or perform dynamic movements on a vibration platform at least three times per week. The intensities (i.e. amount of work performed by participants) of the Delecluse et al. (2003) and Torvinen et al. (2003) studies were greater since participants performed dynamic movements (such as squats) during WBV, rather than standing with the legs at 110º knee extension (i.e. de Ruiter et al. 2003a). Those methods may account for the larger increase in knee extension maximal voluntary contraction (MVC) (Delecluse et al., 2003) and improved vertical jump height (Delecluse et al, 2003; Torvinen et al., 2003). The contradiction between the two dynamic movement studies, however, is interesting since Torvinen et al. (2003) did not report increased MVC.

Both Delecluse et al. (2003) and Torvinen et al. (2003) used dynamometers to test MVC but the participant posture was different between the two studies. The former used a standard dynamometer with the participant sitting in the chair, while the latter used a leg press position. Since an improvement in vertical jump height would suggest an increase of MVC perhaps the leg press dynamometer, on that occasion, was not sensitive to neuromuscular performance change elicited by WBV. Of note, the reported improvements after WBV were not related to the placebo effect (Delecluse et al., 2003).

Participants examined in the three studies were healthy young adult females and males. The examination of such participants may partly explain a lack of bone development. Torvinen et al. (2003) reported no significant change in bone mass, structure or estimated mechanical strength. According to the authors, those findings may be due to the fact that the basic physical performance of the participants was relatively good and their bones were probably in good condition and could cope well with the WBV (Torvinen et al., 2003). Furthermore, pervious explanations suggest that the musculoskeletal tissue of young healthy participants has no physiological need to adapt to the WBV (Rubin, Xu & Judex, 2001). Also, the Torvinen et al. (2003) study was brief, considering the duration of other bone studies, since the intervention was eight months (Rubin, Recker, Cullen, Ryaby, McCabe & McLeod, 2004).

Whole body vibration, therefore, may be beneficial for older adults whose bones are not as strong as that of younger adults. There is no doubt that the effect of exercise to the skeleton is beneficial in that it can reduce loss of bone and increase bone mass (Skerry, 1997; Eisman, 2001; Kohrt, Bloomfield, Little, Nelson, & Yingling, 2004). Furthermore, WBV has been shown to reduce bone loss in postmenopausal adult females (Rubin, Recker, Cullen, Ryaby, McCabe & McLeod, 2004).

Whole body vibration has typically been transmitted to older adults standing on a vibration platform. Platform frequency ranged between 10 Hz and 40 Hz, while platform amplitude ranged between 2.5 mm and 5.0 mm. The duration of each WBV intervention varied between 30 seconds and up to 2 minutes bouts with 90 seconds rest. Participants performed dynamic leg exercises, such as the squat, or were asked to stand (posture not reported) on a vibrating platform. The overall duration of the studies varied and data were collected after six, eight and 24 weeks of intervention. The age range of participants ranged between 58 years and 98 years (Runge, Rehfeld, & Resnicek, 2000; Roelants, Delecluse & Verchueren, 2004; Bruyere et al., 2005).

Whole body vibration improved neuromuscular performance, body balance and HRQOL in older adults (Runge, Rehfeld, & Resnicek, 2000; Roelants, Delecluse & Verchueren, 2004; Bruyere et al., 2005). Furthermore, WBV was reported to be a safe and valid form of exercise and reduced the rate of bone loss in the elderly (Rittweger, Beller & Felsenberg, 2000; Rubin et al., 2004). WBV exercise, therefore, may be thought of as a tool to safely administer physical activity to a broader range of older adults.

Knowledge of certain modes of exercise that are most likely to increase bone mass enables sound decision making regarding recommendations for lifestyles that will maximise peak bone mass and minimise bone loss in later life. Since WBV is conducted with an individual standing on a vibration platform, the chance of developing injuries associated with other exercises such as falls and stress fractures are reduced, possibly making WBV a more attractive exercise method for older adults.

The lack of published data investigating chronic effects of WBV in older adults is surprising since physical activity and exercise offers an opportunity to extend years of active independent life, thus improving quality of life (Stewart, 2001; Cress, Buchner, Prohaska, Rimmer, Brown, Macera, DePietro & Chodzko-Zajko, 2004). Furthermore, the methods used in studies to determine chronic effects of WBV exposes a lack of knowledge in the area.

Significant questions such as the number of WBV sessions per week and the vibration platform dynamics required to elicit health benefit are yet to be answered. Since the benefits of WBV are known, the method used to achieve specific benefit must be established. In support, Cardinale and Lim (2003) suggested there was a lack of information on the effectiveness of different WBV platform frequency on neuromuscular performance. Conversely the American College of Sports Medicine (2000) suggests that two to three sets of 10 to 12 repetitions is the optimal amount of resistance training for increasing muscular strength. Such guidelines for WBV interventions and/or programmes are unknown.

2.2 Older Adults

The steady growth of the median age of the global population is possibly the most significant change impacting upon health care for this century (Bean, Vora & Frontera, 2004). Since advancing age is synonymous with decline in performance of a majority of body functions such as neuromuscular ability, body balance and gait, researchers have focused on developing methods to change the manner in which individual's age (Nigg, Fisher & Ronsky, 1994). Such advancements in knowledge are necessary to combat the growing list of issues facing an older population. Issues such as Government spending on Health Care Systems (i.e. Hospital waiting lists and bed numbers and funding for Medicare in Australia), aged accommodation and the pension could potentially be compounded by a larger number of retirees. Comments about such issues are far ranging and unending.

Media outlets relentlessly comment on the issue of under-funding for the Public Health Care System. Given that the majority of the Australian Commonwealth Government's annual budget is dedicated to the health sector, it appears there is never enough money to satisfy all areas. An advancing age population will, it is widely considered, place additional strain on the Public Health Care System.

Australia has developed seven areas of national health concern. Injury prevention is one such area. In Australia, fall related injuries, for example, constitute a public health problem that has led to 486,448 hospital bed days annually at an estimated cost of $AUD498 million (Forinsky, Iannuzzi-Sucich, Baker, Gottschalk, King, Brown & Tinetti, 2004; Hill & Schwarz, 2004; McFarlane-Kolb, 2004; Melzer, Benjuya & Kaplanski, 2004). Since falls are generally a problem for older adults, the predicted increase within the population of such individuals will lead to an escalation of these costs.

While some injuries are unavoidable, others are preventable. A role of exercise scientists could be to identify such preventable injury issues in the older adult population and develop methods and programmes to combat the deleterious effects. Sarcopenia, for example, is one such older adult issue that has been addressed by exercise scientists since it is determined as deleterious to health.

2.2.1 Sarcopenia

Sarcopenia, the condition where muscular strength and muscular mass are lost, is considered in many cases to be preventable (Janssen, Heymsfield & Ross, 2002; Mühlberg & Sieber, 2004). The cost to the community of sarcopenia in monetary value is unknown, however, the costs to the individual insofar as reduced physical activity are well documented. Sarcopenia is consistent with ageing, creates neuromuscular impairment and affects quality of life which may lead to the dependence upon supportive services. Functionally, sarcopenia can lead to gait and body balance disorders, thus to falls and fractures, thus to immobilisation, thus to increased sarcopenia. For that reason sarcopenia is described as a vicious loop (Mühlberg & Sieber, 2004).

Sarcopenia occurs in older adults and is associated with a decline in quantity and intensity of daily physical activity (Häkkinen, Pakarinen, Kraemer, Häkkinen, Valkeinen & Alen, 2001). Functionally, sarcopenia limits the ability of older adults to rise from a chair and changes gait patterns, thus impairing neuromuscular performance (Nigg, Fisher & Ronsky, 1994; Gross, Stevenson, Charette, Pyka & Marcus, 1998). Such losses in activities of daily living are deleterious to the quality of life of older adults (Luo, McNamara & Moran, 2005).

Exercise reduced effects of sarcopenia in older adults (Bean, Vora & Frontera, 2004). Furthermore, exercise reduced fall risk factors such as impaired body balance, gait and mobility (Cho, Scarpace & Alexander, 2004; Dite & Temple, 2002; Nitz & Choy, 2004; Stel, Smit, Pluijm & Lips, 2004). For older adults, it is crucial that spinal reflexes are maintained since they provide the initial response to sudden destabilising forces applied to the body (Marigold, Eng, Dawson, Inglis, Harris & Gylfadóttir, 2005). Given the known effects of WBV on neuromuscular performance and specifically, spinal reflex activation, WBV may have a role in this area.

2.2.1.1 Detraining

Detraining is a specified period of time after an exercise intervention where no exercise was performed, or a specified period of time after which an exercise programme was ended (Telxeira-Salmela, Santiago, Lima, Lana, Camargos & Cassiano, 2005). Some detraining effects are known (Ivey, Tracy, Lemmer, NessAiver, Metter, Fozard & Hurley, 2000; Toraman, 2005). After a detraining period, neuromuscular performance regressed to levels below baseline (Telxeira-Salmela et al., 2005; Fatouros, Kambas, Katrabasas, Leontsini, Chalzinikolaou, Jamurtas, Douroudos, Aggelousis & Taxildaris, 2006).

Further investigation is required to comprehensively understand detraining effects in older adults and the resulting effect upon sarcopenia. Specifically though, for the target population and the WBV intervention of this study, detraining data are unknown. Furthermore, effects of detraining after a WBV intervention have not been reported after a three week detraining period.

Ultimately the goal of any exercise programme is to improve or maintain functional processes. To reduce Public Health spending, preventable injuries should be a major research focus for exercise scientists. A goal of exercise scientists could be to maintain the number of community dwelling older adults. WBV may prove to be one such tool to achieve that goal. Furthermore, Cardianle and Bosco (2003) are convinced that WBV could be an effective intervention to reduce effects of ageing on musculoskeletal structures. Deleterious effects of sarcopenia, therefore, may be mitigated by WBV.

While it was not possible to measure muscle mass in this study, neuromuscular performance (i.e. muscular strength and muscular power) was measured. Examining effects of WBV on neuromuscular performance of community dwelling older adults may provide knowledge that can be used to combat effects of sarcopenia in the older adult population and, ultimately, reduce the burden on the Public Health Care System created by preventable injuries.

2.3 Summary

Since some forms of vibration are deleterious to health, the theory of using vibration to improve health requires careful and concise consideration. One such area of vibration research uses WBV to elicit health benefit. The theory of WBV upon vibration platforms is to elicit muscular contraction via spinal reflex. Specifically the stretch reflex is activated.

A role of skeletal muscles is to dampen and absorb the general vibrations caused in day to day living, thus, effects of vibration are determined by the degree of muscle stretch (i.e. stretch reflex). When standing on a WBV platform, one attenuates the imposed vibration by physical activity, thus rhythmic muscle contraction constantly occurs.

Whole body vibration is a safe form of exercise since only small increases in heart rate, blood pressure, RPE and VO_2 were found (Rittweger, Beller & Felsenberg, 2000; Rittweger, Schiessl & Felsenberg, 2001; Rittweger et al., 2002). Since WBV can be performed without the risk of, for example, falling or shin splints, it may become an attractive form of exercise for community dwelling older adults.

Chronic effects of WBV are relatively unknown. While some studies have examined chronic effects, significant questions remain. The ideal exercise programme for WBV is unknown. The number of WBV sessions per week, the adequate frequency and amplitude of the vibration platform to elicit health benefit also remains unknown. Furthermore, effects of detraining upon an older population are unknown after a WBV intervention.

Sarcopenia reduces quality of life for older adults. Since older adults predominantly suffer sarcopenia, methods to reduce its effect are important for an ageing global population. Effects of sarcopenia can be quantified by methods that determine neuromuscular performance. Since WBV may be an adequate replacement to resistance training for older adults, which is known to improve neuromuscular performance, WBV, therefore, may be an appropriate exercise programme for that age group.

The objectives of the study were established to; (1) quantify neuromuscular performance and body balance of community dwelling older adults; (2) quantify effects of WBV upon neuromuscular performance and body balance; (3) quantify HRQOL of community dwelling older adults; (4) examine effects of WBV on HRQOL; (5) determine the appropriate number of sessions per week of WBV to improve neuromuscular performance, body balance and HRQOL of community dwelling older adults, and; (6) quantify effects of a three week detraining period upon neuromuscular performance within the target sample.

This study was the first to examine the number of sessions per week required to elicit chronic health change from WBV for the target population. Furthermore, by maintaining amplitude and manipulating frequency it was anticipated that an understanding of WBV method could be developed and later, further investigated. Since larger WBV amplitudes are known to cause injury, it was an aim to discover if frequency alone could be appropriately manipulated to elicit changes. This study is also the first to combine the 5-Chair Stands test, the TUG test, the Tinetti test, and the SF-36 Health Survey to examine effects of WBV on community dwelling older adults in the field.

CHAPTER 3. METHODS

3.1 Participants

Participants were provided with an information letter and consent form to retain for their personal records (Appendix A). Participants were also given an information letter and screening questionnaire to pass on to their physician (Appendix B). A letter of introduction and an information letter were sent to the Chelsea RSL as the intended venue for data collection (Appendix C). The Australian Catholic University Human Research Ethics Committee approved this procedure. Seventy-three community dwelling older adult females and males (mean age = 72.0 ± 7.6 years, mean stature = 1.66 ± 0.10 metres, mean weight = 74.5 ± 14.9 kilograms) freely consented to participate in the study. The cohort was drawn from a population of community dwelling older adults residing in the Chelsea locale, Victoria, Australia.

3.2 Selection Criteria

Each participant was asked to pass an information letter and questionnaire to their physician. The participant was asked to return the completed physician questionnaire to the investigator. The physicians were asked to perform a medical screening of the participant and thus, provide medical consent. Furthermore, the physicians were asked to list medication that the participant used that effects balance and/or to record any comments or recommendations regarding the health of the participant. Individuals who were not given medical consent were not invited to participate in the study. Once medical consent had been obtained each participant was asked to sign the consent form and subjected to screening and questionnaire by the investigator. The screening questionnaire consisted tests of cognition and vestibular function (Mini-Mental State Examination, Vestibular Stepping test and Romberg test) and tests of visual acuity (Snellen Eye Chart and Melbourne Edge test).

Each participant was asked to detail previous fall or joint replacement procedures. Participants who had fallen in the past 12 months or had undergone any form of lower limb joint replacement procedure were excluded from the study. Furthermore, participants who suffered from reactive arthritis, had vascular disease, suffered from vertigo or were at high risk of thromboembolism (as described by the physician) were excluded from the study (Runge, Rehfeld & Resnicek, 2000; Roelants, Delecluse & Verschueren, 2004; Bruyere et al., 2005). This position was taken by the investigator, even if medical consent had been granted by the physician since it complied with other selection criteria implemented in similar investigations of WBV.

3.3 Criteria Protocol

The tests of cognition and vestibular function included the Mini-Mental State Examination (MMSE), the Vestibular Stepping test and the Romberg test. Tests of visual acuity included the Snellen Eye Chart (six metres) and the Melbourne Edge test. The tests were always conducted in that order for every participant. Participants unable to pass all tests were not invited to participate further in the study (Appendix D). The investigator conducted all tests.

3.3.1 Tests of Cognition and Vestibular Function

The MMSE was administered to assess mental status (Appendix E). The test covered five areas of cognitive function: orientation, registration, attention and calculation, recall and language (Kurlowicz & Wallace, 1999). The examination was specific for community dwelling older adults and was completed in less than ten minutes. A score of less than 23 out of 30 was considered unacceptable (Dite, & Temple, 2002; Hill & Schwarz, 2004; Melzer, Benjuya & Kaplanski, 2004).

The Vestibular Stepping test was administered to assess alterations in the gait motor program (Gordon, Fletcher, Jones & Block, 1995) (Appendix F). Each participant stood with their eyes closed and arms outstretched. The participant marched in place at the pace of a self-assessed brisk walk while keeping their eyes closed (Gordon et al., 1995). Rotation of the body, as indicated by the position of the feet, was noted. The investigator observed any rotation that occurred. Rotation of 30º or more was considered an unacceptable test. The participant was asked to take 50 steps.

The Romberg test was administered to identify distorted proprioception (Khasnis & Gokula, 2003). Each participant stood with their feet together and eyes closed for 30 seconds. The investigator was close at hand in case the participant began to sway or fall, at which time the test was ended. A test less than 30 seconds was unacceptable.

3.3.2 Tests of Visual Acuity

The Snellen Eye Chart was administered to establish how well each eye saw printed letters (Gerdhem, Ringsberg, Åkesson & Obrant, 2005) (Appendix G). Each participant was asked to read letters of the chart at six metres distance. The participant sat in a chair and read, one eye at a time, the chart as accurately as possible. If the participant normally wore glasses for reading, he/she was permitted. For an acceptable test the participant had to score at least 0.2 on the chart for the set distance.

The Melbourne Edge test was administered to examine the contrast sensitivity of each participant (Hill & Schwarz, 2004) (Appendix H). The participant was asked to use both eyes (glasses optional) to detect the varying contrast between two colours. A score below 11 on the test, was considered unacceptable.

3.4 Test Procedure

Data were collected at the Chelsea RSL, Chelsea, Victoria. The room provided by the RSL was well lit with natural light and far removed from other amenities of the RSL. Each participant was randomly assigned to one of four sample groups: zero sample group, one WBV session per week sample group, two WBV sessions per week sample group and three WBV sessions per week sample group. The zero sample group did not participate in any WBV sessions. The WBV intervention sample groups attended WBV sessions for six weeks (i.e. 18 sessions, 12 sessions or 6 sessions).

All participants were asked to perform a battery of tests for data collection. The battery consisted of the 5-Chair Stands test, the TUG test and the Tinetti test (in that order) for pre-test and post-test. For the retention-test the 5-Chair Stands test and the TUG test were used (table 1). Only the three WBV sessions per week sample group completed the retention-test. Those tests were the dependent variables. Participants were also asked to complete the SF-36 Health Survey before the first WBV bout and at least 48 hours after the final WBV bout (i.e. after the six week intervention). The investigator conducted all test batteries.

Table 1

Time-line of WBV intervention

Intervention	Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk9
Zero	pre-test					post-test	
1/Week	pre-test & WBV	WBV	WBV	WBV	WBV	WBV & post-test	
2/Week	pre-test & WBV	WBV	WBV	WBV	WBV	WBV & post-test	
3/Week	pre-test & WBV	WBV	WBV	WBV	WBV	WBV & post-test	retention-test

pre-test; test battery and SF-36 Health Survey
post-test; test battery and SF-36 Health Survey
retention-test; 5-Chair Stands test and the TUG test

The pre-test battery was completed before the first vibration session. The post-test battery was completed at least 48 hours after the final vibration session (Cochrane, Legg & Hooker, 2004). These batteries included the 5-Chair Stands test, the TUG test, the Tinetti test and the SF-36 Health Survey. The retention-test (detraining) was completed exactly three weeks (21 days) after the final vibration session. That battery included the 5-Chair Stands test and the TUG test.

A minimum 24 hour rest period was observed between each vibration session (Roelants, Delecluse & Verschueren, 2004). Participants assigned to the one WBV session per week sample group completed a WBV session on the same day every week. Participants of the two WBV sessions per week sample group completed WBV sessions on Tuesdays and Thursdays. Participants of the three WBV sessions per week sample group completed WBV sessions on Mondays, Wednesdays and Fridays.

The amplitude of the vibration platform was controlled at 0.5 mm, while the frequency of the platform was increased in standard with procedures of other WBV studies (Cardinale & Lim, 2003; Torvinen et al., 2003; Bruyere et al., 2005; Lou, McNamara & Moran, 2005). The frequency of the vibration platform for the first WBV session in week one was 15 Hz ($g = 0.45$) and increased to 25 Hz ($g = 1.26$) by the last WBV session in week six (table 2). Each WBV bout lasted one minute with a one minute rest period between bouts (Cardinale & Bosco, 2003; Cronin, Oliver & McNair, 2004; Bruyere et al., 2005). Thus, for one WBV session, a participant received five minutes of WBV.

Table 2

Vibration platform frequency for the six weeks of WBV intervention

Intervention	Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk9
Zero							
1/Week 1 min WBV 1 min rest	5×15 Hz	2×15 Hz 3×20 Hz	5×20 Hz	2×20 Hz 3×25 Hz	5×25 Hz	5×25 Hz	
2/Week 1 min WBV 1 min rest	5×15 Hz	2×15 Hz 3×20 Hz	5×20 Hz	2×20 Hz 3×25 Hz	5×25 Hz	5×25 Hz	
3/Week 1 min WBV 1 min rest	5×15 Hz	2×15 Hz 3×20 Hz	5×20 Hz	2×20 Hz 3×25 Hz	5×25 Hz	5×25 Hz	

Zero, zero vibration bouts
1/Week, 30 vibration bouts
2/Week, 60 vibration bouts
3/Week, 90 vibration bouts

Shod (flat sole shoes) participants were asked to stand with legs at 110º knee extension during each WBV bout (Harazin & Grzesik, 1998; de Ruiter et al., 2003a). The angle was set using a goniometer and tested at the beginning, after 30 seconds and at the end of each WBV bout. Participants were to maintain the posture as accurately as possible for the duration of the WBV bout. Participants stood with their feet equidistant (16 cm) from the axis of rotation on the vibration platform. Participants were told to hold the handlebars for support if required with instructions not to lean on the handlebars so as not to reduce potential WBV effect.

The data for the pre-test, post-test and retention-test batteries were recorded in a spreadsheet of a notebook computer. The data collected for each test battery were hidden from the investigator after the pre-test battery to reduce bias error.

3.4.1 The 5-Chair Stands Test

Each participant was asked to sit in a standard height (46 cm, including back rest) chair with their arms crossed. The test is most commonly used in field settings to quantify neuromuscular performance (Moreland, Richardson, Goldsmith & Clase, 2004). The participant was then asked to stand and sit five times (Brill, Cornman, Davis, Lane, Mustafa, Sanderson & Macera, 1999; Runge, Rehfeld & Resnicek, 2000; Visser, Pluijm, Stel, Bosscher & Deeg, 2002; Runge, Rittweger, Russo, Schiessi & Felsenberg, 2004).

The test began when the investigator said “go” and ended when the participant sat with their back against the back rest of the chair. Participants were told their back must make contact with the back rest for all five chair stands. The time taken was recorded with a stopwatch and noted by the investigator. Participants were told the procedure to complete the test and were given one familiarisation test. The timed test occurred 5 minutes after the familiarisation test to ensure recovery. Participants were asked to complete the test as they felt comfortable. The instruction was stated as such since it was the intention to measure data while older adults were performing simulated activities of daily living.

3.4.2 The Timed Up and Go Test

The Timed Up and Go test (TUG) is a modified version of the Get-Up and Go test (GUG). Developed by Mathias, Nayak and Isaacs (1986) the GUG was thought to be ambiguous since performance was rated on a scale (Podsiadlo & Richardson, 1991). Thus, variance between different observers was common. Regardless, the GUG test was shown to be a simple practical guide of body balance function of older adults.

Presented by Podsiadlo and Richardson (1991) the TUG test eliminated observer variance by examining the time taken to complete the test. The TUG test is a useful practical measure of body balance, gait speed, and functional ability of older adults. It is reliable and has concurrent and content validity (Isles, Low Choy, Steer & Nitz, 2004). The test correlates well with more extensive measures of body balance, gait speed and functional ability and involves a well recognised series of events used in active daily living (Podsiadlo & Richardson, 1991)

For this study, the participant was asked to sit in a standard height (46 cm) arm (63 cm) chair. The participant was then asked to stand, walk three metres to a marker on the floor, turn, return and sit on the chair (Brill et al., 1999; Dite & Temple, 2002; Cho, Scarpace & Alexander, 2004). The test began when the investigator said "go" and ended when the participant sat with their back against the back rest of the chair. Participants were told their back must make contact with the back rest in order to complete the test.

The time taken was recorded with a stopwatch and noted by the investigator. Participants were told the procedure to complete the test and were given one familiarisation test. The timed test occurred 5 minutes after the familiarisation test to ensure recovery. Participants were asked to complete the test as they felt comfortable.

3.4.3 The Tinetti Test

The Tinetti test was used to assess body balance and gait (Tinetti, 1986; Tinetti, Speechley & Ginter, 1988; Bruyere et al., 2005) (Appendix I). Specifically, each participant was assessed on their ability to, for example, rise from a chair, turn 360º and walk in a straight line. A score of zero was awarded if the participant was at the lower end of ability, while a score of 2 was awarded if the participant showed no signs of inconvenience (Bruyere et al., 2005). A global score of 28 was awarded for 12 measures of gait and 16 measures of body balance.

Studies have shown the Tinetti test as a reliable tool for the assessment of body balance and gait of community dwelling older adults (Tinetti, 1986; Tinetti & Ginter, 1988; Raîche, Hébert, Prince & Corriveau, 2000). Reliability among physicians, nurses and medical students was high. Tinetti test scores were identical between 85% and 95% of data collection occasions. The difference between scorers was not larger than 10% for the total of the body balance score and the gait score.

The investigator, an Exercise scientist, collected all data for the Tinetti test. Data were recorded to a notebook spreadsheet for the pre-test condition. The data were hidden from the investigator after the pre-test battery to reduce bias error.

3.4.4 The SF-36 Health Survey

The SF-36 Health Survey was used to assess Health Related Quality Of Life (HRQOL) of all participants (Appendix J). The survey consisted of eight health concepts of life; physical functioning, bodily pain, role limitations due to physical health problems and personal or emotional problems, emotional well being, social functioning, energy or fatigue and general health perceptions (Ware & Sherbourne, 1992; RAND Corporation, 2006). Participant scores were graded on a Likert scale.

Studies have shown the SF-36 Health Survey as a reliable tool for the assessment of HRQOL (Hays & Shapiro, 1992; Ware & Sherbourne, 1992; RAND Corporation, 2006). Based on the Medical Outcome Study (n = 2471), no significant differences were found between any components of each health concepts (i.e. $p > 0.77$). The result indicated that the SF-36 Health Survey was a reliable tool to examine HRQOL.

Each participant completed the SF-36 Health Survey for the pre-test and post-test battery. Each participant was not aware of the result of the survey in order to reduce bias error.

3.5 Instrumentation

Whole body vibration was created with a prototype vibration platform (Appendix K). The frequency of the platform was manipulated as the weeks of the WBV exercise intervention increased. The amplitude of the vibration was controlled at 0.5 mm for the duration of the WBV study.

Anthropometric data were collected with a stadiometer and scales. Data were recorded to a notebook computer.

3.5.1 Tests of Cognition and Vestibular Function

The MMSE was conducted with the ‘paper and pen’ method documented in pervious investigations (Kurlowicz & Wallace, 1999; Dite, & Temple, 2002; Hill & Schwarz, 2004; Melzer, Benjuya & Kaplanski, 2004). Tape was placed on the floor of the testing room to create the field of rotation for the Vestibular Stepping test. A protractor was used to create the angle of the test. No instruments were required to complete the Romberg test.

3.5.2 Tests of Visual Acuity

The Snellen Eye Chart was used as a test of visual acuity. The chart was placed on a chair (46 cm high) six metres from the participant. The participant read the chart from an identical chair. A tape measure was fixed to a point on the floor (directly below the chart) and drawn six metres from the chart. The centre of the participant’s seat was placed at that point.

The Melbourne Edge test was placed on a table directly in front of the participant. The participant sat on the same chair used for the Snellen Eye Chart assessment.

3.5.3 Test Procedures

A standard height chair (46 cm, including back rest) was used for the 5-Chair Stands test. The chair did not have ‘arms’. A standard height chair with ‘arms’ (arm height 63 cm) was used for the TUG test and the body balance component of the Tinetti test. Time taken was recorded with a stopwatch to a notebook computer.

3.6 Data Collection

Anthropometric data were collected for all participants. The anthropometric measures included; (1) age (years); (2) stature (metres) and; (3) mass (kilograms). Dependent variables were measured to determine effects of the independent variables. The independent variables were both controlled and manipulated. Table 3 shows the study design. Data were recorded only for participants who had completed greater than 90% of the possible WBV sessions.

Table 3

Study design

Sample group	Pre-test battery	Post-test battery	Retention-test battery
Zero	TUG test 5-Chair Stands test Tinetti test SF-36 Health Survey	TUG test 5-Chair Stands test Tinetti test SF-36 Health Survey	
One WBV session per week	TUG test 5-Chair Stands test Tinetti test SF-36 Health Survey	TUG test 5-Chair Stands test Tinetti test SF-36 Health Survey	
Two WBV sessions per week	TUG test 5-Chair Stands test Tinetti test SF-36 Health Survey	TUG test 5-Chair Stands test Tinetti test SF-36 Health Survey	
Three WBV sessions per week	TUG test 5-Chair Stands test Tinetti test SF-36 Health Survey	TUG test 5-Chair Stands test Tinetti test SF-36 Health Survey	TUG test 5-Chair Stands test

3.6.1 Dependent Variables

Dependent variables of the test procedure (i.e. test batteries) for ratio data are listed in table 4. Dependent variables of the test procedure (i.e. test batteries) for ordinal data are listed in table 5.

Table 4

Description of dependent variables (ratio data) collected during the test procedure

Dependent Variable	Description
5-Chair$_{\text{Pre}}$ (sec)	The 5-Chair Stands test, quantified in time (seconds to complete). The data were collected before the WBV intervention commenced. The datum value was the mean for all participants or sample group specific (as specified).
5-Chair$_{\text{Post}}$ (sec)	The 5-Chair Stands test, quantified in time (seconds to complete). The data were collected at least 48 hours after the final WBV session. The datum value was the mean for all participants or sample group specific (as specified).
5-Chair$_{\text{Retention}}$ (sec)	The 5-Chair Stands test, quantified in time (seconds to complete). The data were collected three weeks after the final WBV session. The datum value was the mean for all participants or sample group specific (as specified).
TUG$_{\text{Pre}}$ (sec)	The Timed Up and Go test, quantified in time (seconds to complete). The data were collected before the WBV intervention commenced. The datum value was the mean for all participants or sample group specific (as specified).
TUG$_{\text{Post}}$ (sec)	The Timed Up and Go test, quantified in time (seconds to complete). The data were collected at least 48 hours after the final WBV session. The datum value was the mean for all participants or sample group specific (as specified).
TUG$_{\text{Retention}}$ (sec)	The Timed Up and Go test, quantified in time (seconds to complete). The data were collected three weeks after the final WBV session. The datum value was the mean for all participants or sample group specific (as specified).

Table 5

Description of dependent variables (ordinal data) collected during the test procedure

Dependent Variable	Description
Tinetti Test_{Pre}	The Tinetti test. The data were collected before the WBV intervention commenced. The score of the test was recorded for all participants or sample group specific (as specified).
Tinetti $\text{Test}_{\text{Post}}$	The Tinetti test. The data were collected at least 48 hours after the final WBV session. The score of the test was recorded for all participants or sample group specific (as specified).
PF_{Pre}	Physical Functioning ^{1,2}
PF_{Post}	Physical Functioning ^{1,3}
LPH_{Pre}	Limitation due to Physical Health ^{1,2}
LPH_{Post}	Limitation due to Physical Health ^{1,3}
LEH_{Pre}	Limitation due to Emotional Health ^{1,2}
LEH_{Post}	Limitation due to Emotional Health ^{1,3}
E_{Pre}	Energy ^{1,2}
E_{Post}	Energy ^{1,3}
W_{Pre}	Wellbeing ^{1,2}
W_{Post}	Wellbeing ^{1,3}
SF_{Pre}	Social Functioning ^{1,2}
SF_{Post}	Social Functioning ^{1,3}
BP_{Pre}	Bodily Pain ^{1,2}
BP_{Post}	Bodily Pain ^{1,3}
GH_{Pre}	General Health ^{1,2}
GH_{Post}	General Health ^{1,3}

^{1}; Data were collected for all participants and reported as sample total. Data were reported as a percentage.

$^{2;}$ Data were recorded before the commencement of the WBV intervention.

$^{3;}$ Data were recorded at least 48 hours after the final WBV session.

3.6.2 Independent Variables

The controlled independent variables were group (zero, one, two and three WBV sessions per week), test occasion (pre-test, post-test and retention-test), vibration platform amplitude, WBV bout duration and rest duration. Vibration platform frequency, however, was manipulated to affect the dependent variables of the test procedure.

3.7 Data Analysis

The raw data were imported to a SPSS 14.0 for Windows spreadsheet. All participant data were stored anonymously in accordance with the Ethical standard set by the Human Research Ethics Committee of the Australian Catholic University.

3.7.1 Descriptive Statistics

Descriptive statistics were calculated for all participants and all intervention sample groups. All data were checked for normality according to an established standard (Bluman, 1997; Macellari, Giacomozzi & Saggini, 1999; Vincent, 1999; Portney & Watkins, 2000; Coakes, Steed & Dzidic, 2006). The assumptions of normality were; (1) the participants were randomly selected from the population of interest; (2) the distribution of the population data scores were normal; (3) homogeneity of variance should not be violated; (4) the data should not exceed ± 2 for skewness and kurtosis, and; (5) the data were ordinal (Macellari, Giacomozzi & Saggini, 1999; Vincent, 1999; Portney & Watkins, 2000; Coakes, Steed & Dzidic, 2006). Data that did not meet normality assumptions (i.e. skewness and kurtosis) were transformed or analysed with non-parametric statistical methods (i.e. ordinal data).

3.7.2 Inferential Statistics

Both parametric and non-parametric statistical methods were used to calculate inferential statistics. Parametric statistical methods were used when the assumptions of normality were met. When the assumptions were not met, data transformation or non-parametric statistical methods were used.

When data violated skewness and or kurtosis values, reciprocal transformation was used to meet the assumption of normality (equation 2). Where RT was the datum value of the reciprocal transformation and *x* was the raw datum value. All ratio data were transformed with this method.

$$RT = \frac{1}{\chi} \qquad \text{Equation 2}$$

4.7.2.1 Parametric Statistical Methods

Reciprocal transformed data were used for the parametric analysis of the ratio data. Data reported in Chapter 5 were raw data, while data reported in Appendix L had undergone reciprocal transformation. A mixed design (between-within) MANOVA with Post-hoc analysis was calculated to view effects of the independent variables (test occasion and group) for both the 5-Chair Stands test and the TUG test. A one-way ANOVA, with Post-hoc analysis was also calculated using the difference scores of the 5-Chair Stands tests since the groups were different at the pre-test occasion. Paired-sample tests were calculated to determine within group differences. The retention-test data were not analysed with the ANOVA since the number of participants was too low ($n = 10$).

4.7.2.2 Non-Parametric Statistical Methods

Ordinal data were analysed with non-parametric statistical methods. These data were from the Tinetti test and the SF-36 Health Survey. Friedman's two-way ANOVA was used as the non-parametric equivalent of the mixed design MANOVA.

To avoid a 10% range (i.e. body balance maximum score 12, gait maximum score 16) of difference in scores for the Tinetti test, mean data were rounded to the nearest whole number.

CHAPTER 4. RESULTS

Both descriptive and inferential statistics were calculated to describe and determine effects of WBV on neuromuscular performance of community dwelling older adults. Section 4.1 lists the sample descriptors. Section 4.2 lists both the descriptive and inferential statistics of the study calculated with parametric methods. Section 4.3 lists both the descriptive and inferential statistics of the study calculated with non-parametric methods.

4.1 Sample Descriptors

Table 6 shows some descriptors of participants in the study. The minimum age was controlled at 65 years, while there was no restriction on weight or stature. The mean age of participants was 72.0 years. The mean weight of participants was 74.5 kilograms.

Table 6

Descriptors of participants in the study

	Age (years)	Height (m)	Weight (kg)
Mean	72.0	1.66	74.5
standard deviation	7.6	0.10	14.9
Minimum	65	1.50	48.9
Maximum	86	1.88	100.0
N	73	73	73

4.1.1 Compliance

Participants randomly selected to receive WBV were asked to attend at least 90% of all WBV sessions during the six week intervention. That level was set based on the findings of past research (Suzuki, Kim, Yoshida & Ishzaki, 2004; Means, Rodell & O'Sullivan, 2005). Compliance was 100% for all three WBV sample groups (*n* = 55). For the retention-test, however, data for 10 participants were analysed due to participant dropout.

4.2 Parametric Statistics

Table 7 shows the results of the 5-Chair Stands test. For all sample groups combined, the mean time to complete the test significantly reduced from 5-Chair$_{Pre}$ to 5-Chair$_{Post}$ (F(1,69) = 29.45, $p < .05$) (Appendix L). After a three week detraining period, mean time to complete the 5-Chair Stands test increased to 12.77 seconds.

Table 7

Statistics of the 5-Chair Stands test for all participants

	5-Chair$_{Pre}$ (sec)	5-Chair$_{Post}$ (sec)	5-Chair$_{Retention}$ (sec)
All sample groups	13.98	12.76	12.77
	s = 3.25	*s* = 2.41	*s* = 2.05

5-Chair$_{Pre}$; mean and standard deviation 5-Chair Stands test time for all participants before commencement of WBV intervention, 5-Chair$_{Post}$; mean and standard deviation 5-Chair Stands test time for all participants after WBV intervention. 5-Chair$_{Retention}$; mean and standard deviation 5-Chair Stands test time for three WBV sessions per week sample group three weeks after final WBV session. All sample groups (*n* = 73) for 5-Chair$_{Pre}$ and 5-Chair$_{Post}$. Only the three WBV sessions per week sample group completed 5-Chair$_{Retention}$ (*n* = 10).

Table 8 shows the statistics of the 5-Chair Stands test for each sample group. There was a significant group*time interaction (F(3,69) = 6.74, $p < .05$). The zero group was significantly slower than the one and three WBV sessions per week groups (Appendix L). The largest mean change was found for the three WBV sessions per week sample group (pre-test to post-test mean difference = 2.63 sec). For that sample group, the time to complete the 5-Chair Stands test reduced after the WBV intervention was completed.

There were significant differences within the two WBV sessions per week group and the three WBV sessions per week group. After a three week detraining period, mean time to complete the 5-Chair Stands test increased (5-Chair$_{\text{Post}}$ to 5-Chair$_{\text{Retention}}$ mean difference = 0.89 second).

Table 8

Statistics of the 5-Chair Stands test for each sample group

Sample group	5-Chair$_{\text{Pre}}$ (sec) (mean & standard deviation)	5-Chair$_{\text{Post}}$ (sec) (mean & standard deviation)	Mean Difference (sec)	p value	5-Chair$_{\text{Retention}}$ (sec) (mean & standard deviation)
Zero	13.85	13.53	0.32	.38	
$n = 18$	$s = 3.45$	$s = 1.12$			
1/Week	13.33	13.04	0.29	.48	
$n = 18$	$s = 2.79$	$s = 3.01$			
2/Week	14.29	12.77	1.52	.02*	
$n = 18$	$s = 4.13$	$s = 2.92$			
3/Week	14.51	11.88	2.63	.01*	12.77
$n = 19$	$s = 2.47$	$s = 1.95$			$s = 2.05$ $n = 10$

Zero; zero WBV intervention, 1/Week; one WBV session per week, 2/Week; two WBV sessions per week, 3/Week; three WBV sessions per week. Only the 3/Week sample group completed the retention tests for 5-Chair Stands test.
*; significant difference $p < .05$

Table 9 shows the results of the TUG test. For all sample groups combined, the mean time to complete the test significantly reduced from TUG_{Pre} to TUG_{Post} ($F(1,69) = 16.31$, $p < .05$) (Appendix L). After a three week detraining period, mean time to complete the TUG test increased ($TUG_{Retention}$ mean = 8.65 sec).

Table 9

Statistics of the Timed Up and Go test for all participants

	TUG_{Pre} (sec)	TUG_{Post} (sec)	$TUG_{Retention}$ (sec)
All sample groups	8.83	8.29	8.65
	$s = 2.05$	$s = 1.74$	$s = 1.66$

TUG_{Pre}; mean and standard deviation Timed up and Go test time for all participants before commencement of WBV intervention, TUG_{Post}; mean and standard deviation Timed up and Go test time for all participants after WBV intervention. $TUG_{Retention}$; mean and standard deviation Timed up and Go test time for three WBV sessions per week sample group three weeks after final WBV session. All sample groups ($n = 73$) for TUG_{Pre} and TUG_{Post}. Only the three WBV sessions per week sample group completed $TUG_{Retention}$ ($n = 10$).

Table 10 shows the statistics of the TUG test for each sample group. There was a significant between group difference (F(3,69) = 2.81, $p < .05$). The three WBV sessions per week group was significantly faster than the two WBV sessions per week group. The largest mean change was found for the two WBV sessions per week sample group (mean difference = 1.03 sec). For that sample group the time to complete the TUG test reduced after the WBV intervention.

There were significant differences within the two WBV sessions per week group and the three WBV sessions per week group. After a three week detraining period, mean time to complete the TUG test increased (TUG_{Post} to $\text{TUG}_{\text{Retention}}$ mean difference = 1.01 sec increase).

Table 10

<u>Statistics of the Timed Up and Go test for each sample group</u>

Sample group	TUG_{Pre} (sec) (mean & standard deviation)	TUG_{Post} (sec) (mean & standard deviation)	Mean Difference (sec)	p - value	$\text{TUG}_{\text{Retention}}$ (sec) (mean & standard deviation)
Zero	8.61	8.57	0.04	.81	
$n = 18$	$s = 1.65$	$s = 0.89$			
1/Week	9.10	8.49	0.61	.16	
$n = 18$	$s = 1.59$	$s = 1.83$			
2/Week	9.68	8.65	1.03	.01*	
$n = 18$	$s = 2.98$	$s = 2.52$			
3/Week	8.12	7.57	0.55	.03*	8.65
$n = 19$	$s = 1.41$	$s = 0.92$			$s = 1.66$
					$n = 10$

Zero; zero WBV intervention, 1/Week; one WBV session per week, 2/Week; two WBV sessions per week, 3/Week; three WBV sessions per week. Only the 3/Week sample group completed the retention tests for TUG ($n = 10$).
*; significant difference $p < .05$

4.3 Non-parametric Statistics

Table 11 shows the statistics of the Tinetti test. For all sample groups combined, the mean test score for Tinetti Total increased from $\text{Tinetti}_{\text{Pre}}$ (mean = 24) to $\text{Tinetti}_{\text{Post}}$ (mean = 25). The Balance score for the Tinetti test improved more than the Gait score. There was a significant difference between pre-test and post-test Tinetti Total score $X^2(1, \underline{N} = 73) = 37.23$, $p < .05$ (Appendix M).

Table 11

Statistics of the Tinetti test for all participants

All sample groups	Tinetti test_{Pre}	Tinetti $\text{test}_{\text{Post}}$
Tinetti Total	24	25
	$s = 2$	$s = 2$
Balance Score	13	14
	$s = 2$	$s = 1$
Gait Score	11	11
	$s = 1$	$s = 1$

Tinetti test_{Pre}; mean and standard deviation Tinetti test score for all participants before commencement of WBV intervention. Tinetti $\text{test}_{\text{Post}}$; mean and standard deviaiton Tinetti test score for all participants after WBV intervention ($n = 73$).

Table 12 shows the statistics of the Tinetti test for each sample group. The largest mean score increase was found in the three WBV sessions per week sample group (Tinetti$_{\text{Pre}}$ mean = 23, Tinetti$_{\text{Post}}$ mean = 26). There was a significant difference within all sample groups except the zero sample group (e.g. 3/Week, $X^2(1, N = 19) = 17.00$, $p < .05$) (Appendix M).

Table 12

Statistics of the Tinetti test for each sample group

Sample group		Tinetti test$_{\text{Pre}}$	Mean Rank	Chi-Square	Tinetti test$_{\text{Post}}$
Zero	Tinetti Total	24	Pre 1.33	2.57	25
$n = 18$		$s = 2$	Post 1.67		$s = 1$
	Balance Score	13			14
		$s = 2$			$s = 1$
	Gait Score	11			12
		$s = 1$			$s = 0$
1/Week	Tinetti Total	24	Pre 1.31	7.00*	25
$n = 18$		$s = 2$	Post 1.69		$s = 1$
	Balance Score	13			13
		$s = 2$			$s = 1$
	Gait Score	12			12
		$s = 1$			$s = 0$
2/Week	Tinetti Total	23	Pre 1.11	14.00*	25
$N = 18$		$s = 2$	Post 1.89		$s = 2$
	Balance Score	12			14
		$s = 2$			$s = 2$
	Gait Score	11			11
		$s = 1$			$s = 1$
3/Week	Tinetti Total	23	Pre 1.05	17.00*	26
$n = 19$		$s = 3$	Post 1.95		$s = 2$
	Balance Score	13			14
		$s = 2$			$s = 1$
	Gait Score	10			11
		$s = 1$			$s = 1$

Tinetti test$_{\text{Pre}}$; mean and standard deviation Tinetti test score for specific sample group before commencement of WBV intervention. Tinetti test$_{\text{Post}}$; mean and standard deviation Tinetti test score for specific sample group after WBV intervention. Zero; zero WBV intervention, 1/Week; one WBV session per week, 2/Week; two WBV sessions per week, 3/Week; three WBV sessions per week.

*: significance $p < .05$

Table 13 shows the statistics of the SF-36 Health Survey. For all sample groups combined, the mean score increased from the pre-test to the post-test. Limitation due to physical health, for example, was 70 at the pre-test occasion and increased to 77 at the post-test occasion, limitation therefore, was less due to the six week WBV intervention (Appendix N).

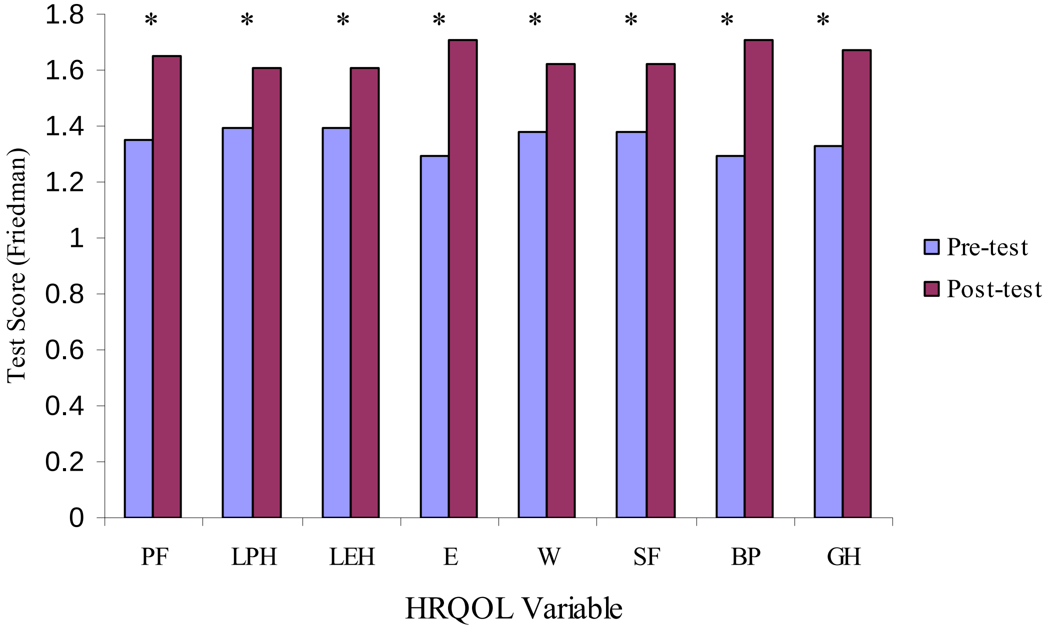
Table 13

Statistics of the SF-36 Health Survey for all participants

Variable	Pre-test		Post-test	
	mean	standard deviation	mean	standard deviation
Physical Functioning	64	22	70	18
Limitation due to Physical Health	70	32	77	23
Limitation due to Emotional Health	75	33	84	21
Energy	63	17	69	12
Wellbeing	75	16	78	12
Social Functioning	84	20	87	14
Bodily Pain	73	20	81	14
General Health	69	17	72	11

Score of 100; no limitation in physical functioning, physical health, emotional health, energy, wellbeing, social functioning, bodily pain or general health.
Score of 0; complete limitation in physical functioning, physical health, emotional health, energy, wellbeing, social functioning, bodily pain or general health. (*n* = 73)

Figure 7 shows the statistics of the SF-36 Health Survey. For all sample groups combined, the mean score was significantly higher from the pre-test to the post-test for all measured variables (e.g. PF, $X^2(1, \underline{N} = 73) = 7.56, p < 0.05$). Limitation due to emotional health, for example, was 75 at the pre-test occasion and increased to 84 at the post-test occasion, limitation therefore, was less after the six week WBV intervention (Appendix N).



<u>Figure 7</u> Statistics of the SF-36 Health Survey for all sample groups combined. *; significant difference, $p > .05$ for the Friedman test. PF: Physical Functioning, LPH: Limitation due to Physical Health, LEH: Limitation due to Emotional Health, E: Energy, W: Wellbeing, SF: Social Functioning, BP: Bodily Pain and GH: General Health.
$n = 73$ for each variable.

Table 14 shows the within sample groups analysis of the SF-36 Health Survey. Significant differences were found within some groups for some variables. Energy, for example was significantly increased after the WBV intervention within the three WBV sessions per week group ($X^2(1, \underline{N} = 19) = 5.56$, $p < 0.05$) and the zero WBV sessions per week group($X^2(1, \underline{N} = 18) = 8.00$, $p < 0.05$).

Table 14

Statistics of the SF-36 Health Survey within sample groups

Sample group	PF	LHP	LEH	E	W	SF	BP	GH
Zero *n* = 18				*			*	*
1/Week *n* = 18	*							
2/Week *n* = 18								
3/Week *n* = 19			*	*				

*; significant difference, *p* < .05 for the Friedman test. PF: Physical Functioning, LPH: Limitation due to Physical Health, LEH: Limitation due to Emotional Health, E: Energy, W: Wellbeing, SF: Social Functioning, BP: Bodily Pain and GH: General Health.

CHAPTER 5. DISCUSSION

5.1 Focus Area

As an exercise intervention, WBV is an increasingly researched area of exercise science. WBV, by which sinusoidal vibration of various frequency and amplitude are transmitted to an individual, is created in both occupational and recreational environments. Moreover, effects of WBV are measured and analysed in both rehabilitative and performance enhancement domains.

Whole body vibration has been shown to improve muscular strength and muscular power, body balance, gait, blood circulation and growth hormone levels in healthy samples (Bosco, et al., 2000; Torvinen et al., 2002; Roelants, Delecluse & Verschueren, 2004). Functionally, WBV improved vertical jump height in healthy, non-athletic young adults (Torvinen et al., 2003).

Typically, WBV research focused on young adults. Effects of WBV on a community dwelling older adult population, therefore, are not thoroughly investigated. Since the proportion of older adults in the population is increasing, the exercise science field can contribute to the body of WBV knowledge by focusing upon said population.

The cost of incapacitation (e.g. fall related injuries due in part to sarcopenia) to the community is significant in Australia (Forinsky, et al., 2004). Injury prevention, therefore, is an area of national health concern. Methods to reduce effects of, for example, sarcopenia, are valuable tools of knowledge to significantly benefit Australian citizens. One such method includes WBV and effects upon neuromuscular performance.

Neuromuscular performance of older adults is measured by tools that quantify muscular strength and muscular power. Data of neuromuscular performance can help show the effect of sarcopenia across populations. Intervention methods that manipulate neuromuscular performance to potentially benefit older adults could be a tool to assail an area of national health concern in Australia.

This study focused on the dearth of knowledge (i.e. appropriate chronic WBV intervention methods to elicit neuromuscular performance improvement) about WBV effects on a community dwelling older adult population. Specifically, a sample of community dwelling older adult Australians was recruited to examine effects of WBV on neuromuscular performance.

5.2 Major Findings

Neuromuscular performance of the community dwelling older adult sample improved after a WBV intervention. Specifically, muscular strength and muscular power significantly improved after six weeks of WBV exercise implemented during this study.

These findings are similar to other studies of muscular strength and muscular power. Using varied methods, researchers reported that WBV effects neuromuscular performance (Bosco et al., 1999; Torvinen et al., 2002a; Torvinen et al., 2003; Rittweger, Mutschelkanuss & Felsenberg, 2003).

Different from this study, those studies recruited young adults of varying athletic ability. Findings from this study, therefore, suggested that WBV can be a useful tool to beneficially affect neuromuscular performance in another population, specifically, the community dwelling older adult population.

5.2.1 Neuromuscular Performance

Muscular strength and muscular power increases in this study were similar to another study using a similar method (Runge, Rehfeld & Resnicek, 2000). The mean percentage reduction in time to complete the 5-Chair Stands test in this study was 8.73 %. Elsewhere, a maximum 36% reduction in time for a community dwelling older adult individual was reported, however, the mean time percentage reduction for all participants (*n* = 39) was approximately 18% (Runge, Rehfeld & Resnicek, 2000). That study incorporated a two month WBV intervention. Raw time data, and/or mean time data were not reported by those authors.

Muscular strength and muscular power increases were also found with the TUG test in this and other studies of community dwelling older adults. Time taken to complete the test has ranged from seven seconds to 13.1 seconds (Podsiadlo & Richardson, 1991; Hughes, Osman & Woods, 1998; Shumway-Cook, Brauer & Woollacott, 2000; Dite & Temple, 2002; Steffen, Hacker & Mollinger, 2002). Another investigation, however, reported a TUG test mean time as high as 36.4 seconds for a 'normal' nursing home older adult sample (Bruyere et al., 2005). The current study found a mean pre-test TUG test time of 8.83 seconds for the entire sample.

Figure 8 shows effects on neuromuscular performance of the WBV intervention at various test-time intervals. The two major observations were; (1) the reduction in time for both neuromuscular performance tests due to a WBV intervention and; (2) the increase in time at the retention-test interval for the three WBV sessions per week sample group. The pre-test to post-test comparison therefore, demonstrated effects of a WBV intervention and the subsequent training effect thought to be caused by the elicitation of the stretch reflex. The post-test to retention-test comparison showed effects of chronic WBV and the subsequent effect of a three week detraining period. The training effect, therefore, was reduced in the retention period.

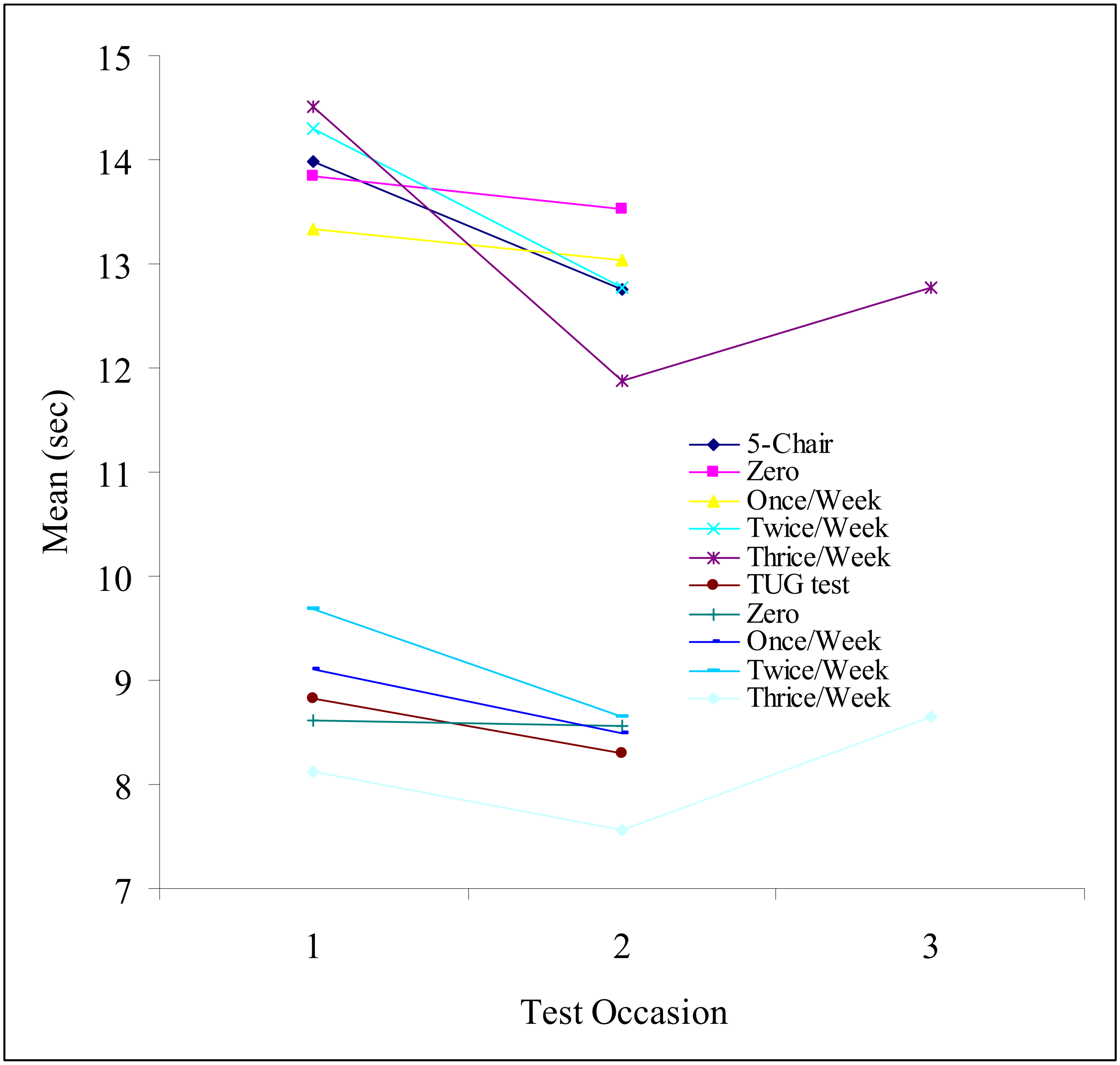


Figure 8 Neuromuscular performance of a community dwelling older adult sample. Data are mean and reported in seconds.

5.2.1.1 Pre-test to Post-test

The test procedure of this study allowed chronic data collection. Uniquely, unlike other studies of chronic effects of WBV, this study drew community dwelling older adults. Past studies found improvement in maximal voluntary contraction and vertical jump height in young adults after a WBV intervention (Delecluse, Roelants & Verschueren, 2003; Torvinen et al., 2003). Those dependent variables were not measured in this study, however, improvement in maximal voluntary contraction and vertical jump height suggested, as was found in this study, an improvement in neuromuscular performance after WBV.

Specific to the dependent variables of this study, a lack of 5-Chair Stands test data makes comparison difficult, however, a significant time reduction was observed in this study as had been reported elsewhere (Runge, Rehfeld & Resnicek, 2000). Both neuromuscular performance tests of this study (5-Chair Stands and TUG) showed a percentage reduction in time between 6 % and 8.83 %. The largest reduction in time was for the 5-Chair Stands test (pre-test to post-test comparison). After a six week WBV intervention combined with a mild intensity physical therapy programme (resistance training, gait and balance exercises), one study reported a 30 % reduction in time to complete the TUG test (Bruyere et al., 2005).

One possible explanation for the observed neuromuscular improvements was, as had been suggested in the literature, increased synchronous motor unit recruitment. WBV increased muscular fatigue quantifiers (RPE and blood lactate levels) (Rittweger, Mutshelknauss & Felsenberg, 2003). Such process caused enhanced neuromuscular excitability and greater motor unit recruitment (Torvinen et al., 2002a). Relative improvements in neuromuscular performance are expected in those circumstances.

Furthermore, the synchronous activity of synergist muscles of the lower limbs or increased inhibition of the antagonistic muscles caused by the activation of the stretch reflex may also explain the observed findings (Torvinen et al., 2002a). For this study, participants stood with knee flexion (110°), thus promoting quadriceps group (agonist) activation, and via the stretch reflex, hamstrings group (antagonist) inhibition. That posture was thought to have elicited neuromuscular improvement through involuntary muscular contraction and increased sliding filament theory (i.e. actin/myosin cross-bridge) activity.

Contrary to this study, a study did not report significant improvement in quadriceps group muscular strength after WBV (110° knee flexion) (de Ruiter et al., 2003a). Using some similar methods as this study, functional neuromuscular activities such as vertical jump height and maximal voluntary contraction did not significantly improve. WBV alone was not enough to elicit significant increases in muscular strength for the quadriceps group of young adults.

That study was, however, poignant, since muscular electrical activity was significantly higher in the WBV group. That finding provided valuable knowledge since the mechanisms of WBV and effects within muscles were partly explained. This study further confirmed the theory of increased motor unit recruitment and stretch reflex elicitation since, unlike de Ruiter et al. (2003a), this study examined community dwelling older adults and found significant functional neuromuscular improvements.

Further evidence of the stretch reflex activation was reported (Rittwegwe, Mutschelkanuss & Felsenberg, 2003). After WBV exercise to exhaustion, patella tendon reflex amplitudes were similar to and sometimes above base line measures whereas control amplitudes were decreased. However, declines in neuromuscular performance were comparable in both exercise groups. Those findings were most likely due to an enhanced central motor excitability resulting in patella tendon reflex activation (i.e. stretch reflex) (Rittwegwe, Mutschelkanuss & Felsenberg, 2003).

Neuromuscular performance, therefore, was affected by a WBV intervention. Specifically, muscular strength and muscular power were improved after a six week WBV intervention. Functionally, participants were able to rise from a chair and perform other simulated daily activities with significantly greater motor speed and motor control. The intervention was successful in eliciting neuromuscular processes that affected performance.

5.2.1.2 Post-test to Retention-test

Retention-test data of this study were consistent (refer to figure 8). The 5-Chair Stands test time increased 7.0 % at the retention-test interval, while, TUG test time increased 12.5 % at the same time interval (three WBV sessions per week group). Such occurrence suggested that a WBV intervention beneficially affected neuromuscular performance and that observed improvements in 5 Chair-stands and TUG tests times were partly or completely lost after a three week detraining period.

The findings of this study, however, are unique since many studies reported contrasting data (Häkkinen, Alen, Kallinen, Newton & Kraemer, 2000; Lemmer, Hurlbut, Martel, Tracy, Ivey, Metter, Fozard, Fleg & Hurley, 2000; Elliott, Sale & Cable, 2002; Toraman, 2005; Toraman & Ayceman, 2005; Fatouros, Kambas, Katrabasas, Nikolaidis, Chatzinikolaou, Leontsini & Taxildaris, 2005; Telxeira-Salmela et al., 2005; Fatouros et al., 2006). That is, detraining (retention-test) data were lower (poorer neuromuscular performance) than baseline (pre-test) data after resistance training interventions. Conversely, other studies reported improvement in neuromuscular performance after a detraining period (Ivey et al., 2000; Toraman, 2005). Specifically, after a six week detraining period, lower limb strength gains were maintained in older adults (Toraman, 2005). Different methods, however may have contributed to those collective findings. Specifically, effects of detraining were measured over a minimum 12 week and maximum 52 week period in those studies.

Lemmer et al. (2000) reported most evident performance losses during a detraining period from week 12 onwards for older adults after resistance training. The findings of the current study identify two issues; (1) that chronic neuromuscular performance gains elicited by a WBV intervention were reduced after a three week detraining period in a community dwelling older adult sample and; (2) that WBV influenced neuromuscular performance gains were lost more rapidly than gains from resistance training.

Findings of this study suggest that WBV should not be seen as a replacement to resistance training in community dwelling older adults as was previously suggested (Roelants, Delecluse & Verschueren, 2004). Resistance training appeared to have a more significant influence in delaying sarcopenia in older adults than WBV when considering detraining data of this study. As previously mentioned, WBV is easy to administer and requires minimal skill. As shown in previous studies, WBV and resistance training positively affected older adults in combination (Bruyere et al., 2005).

Whole body vibration, specifically considering the methods of this study could be implemented in conjunction with resistance training interventions for community dwelling older adults. Those assumptions however, are tentative since further study is required to specifically examine that theory. Previous studies, for example, had found both supportive and contradictory evidence for such a theory (de Ruiter et al. 2003a; Bruyere et al., 2005).

5.2.2 Body Balance, Gait and Health Related Quality of Life

Body balance, gait and HRQOL of the sample examined in this study improved after a six week WBV intervention. Specifically, data collected with the Tinetti test and the SF-36 Health Survey were improved after a WBV intervention.

Body balance and gait were quantified with the Tinetti test (figure 9). There were significant differences for all intervention sample groups that received WBV (Appendix M). Using a similar method Bruyere et al. (2005) also found a significant intervention effect.

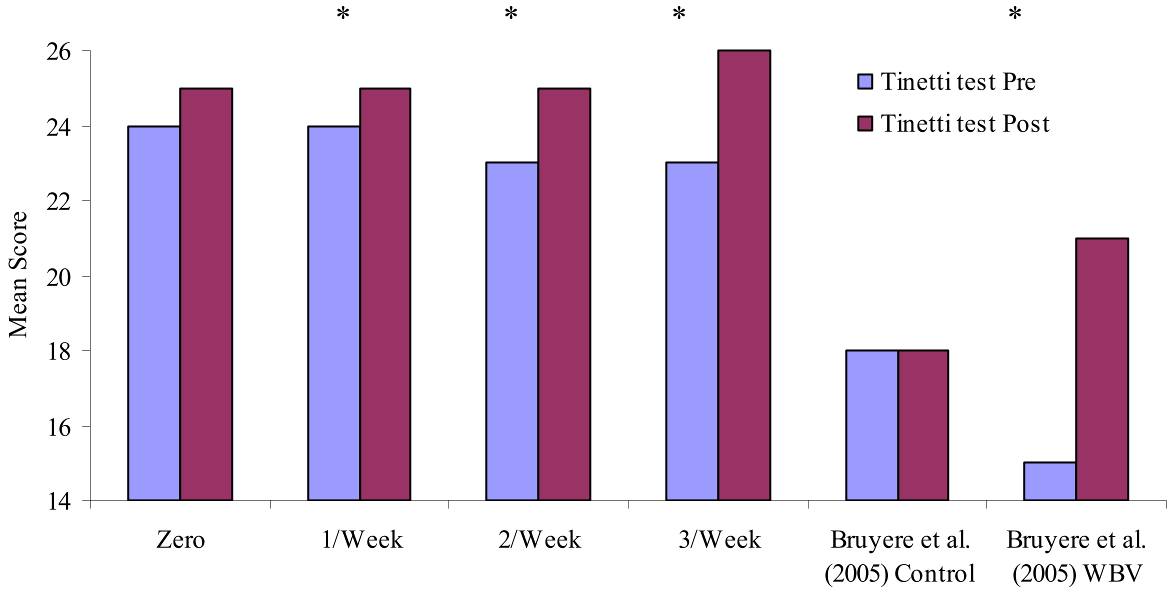


Figure 9 Comparison of pre-test and post-test Tinetti test mean scores for all sample groups of the WBV intervention and Bruyere et al. (2005). The mark (*) signifies a significant difference (*p* <.05) within pre-test and post-test data. The control sample group for the Bruyere et al. (2005) study did not receive WBV, whilst the WBV sample groups attended three WBV sessions per week.

There was a larger effect for the Bruyere et al. (2005) study, as may be expected, since older adults performed resistance training with WBV exercise. Significant emphasis, therefore, may be placed in the addition of WBV to resistance training programmes. Baseline levels of performance, however, were very low and have not been reported at similar levels in other investigations.

The improvements may be attributed to neurogenic adaptation since other studies reported similar trends (Raîche et al., 2000; Cochrane, Legg & Hooker, 2004, Luo, McNamara & Moran, 2005). The findings of this study further inferred that the Tinetti test was a sensitive tool to detect improvement in neuromuscular performance elicited by WBV.

There was a significant difference within pre-test and post-test SF-36 (i.e. HRQOL) means in this study (Appendix N and figure 7). Similar findings were found in another investigation of similar sample (Bruyere et al., 2005). All dependent variables were significantly improved at the post-test interval. Mostly, the findings of this study were similar to that of RAND Corporation (2006) who listed the normative measures of central tendency for the SF-36 Health Survey (*n* = 2471) (figure 10).

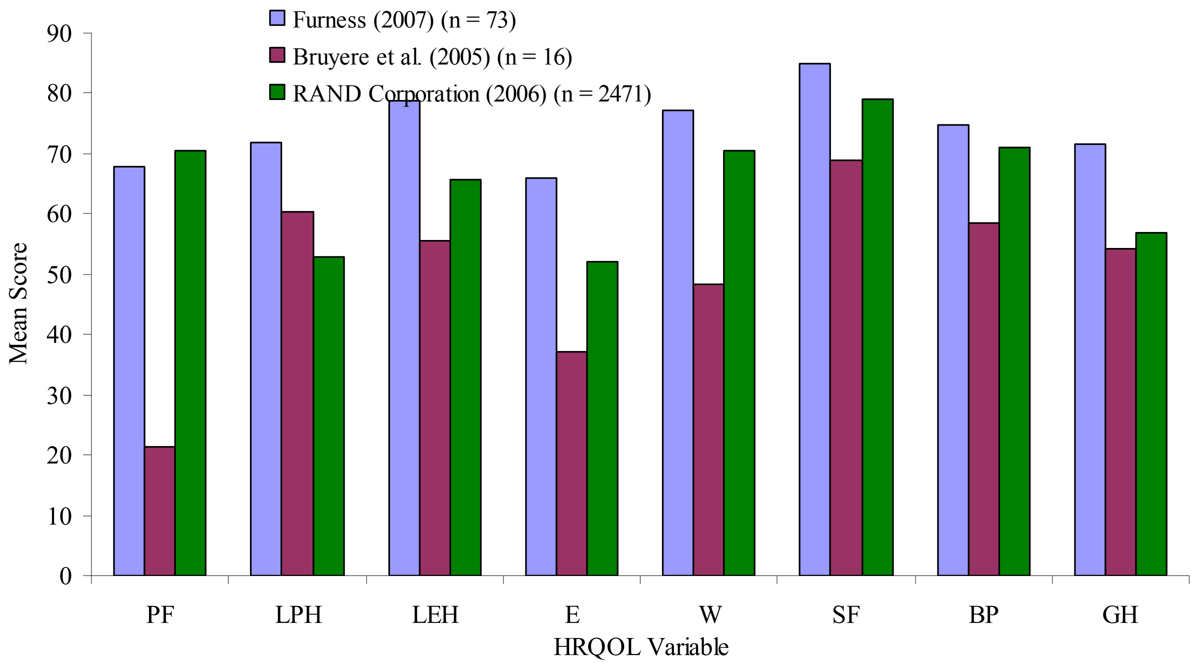


Figure 10 Comparison of post intervention data for this study and Bruyere et al. (2005) and measures of central tendency from RAND Corporation (2006) for HRQOL measured with the SF-36 Health Survey.

These findings were somewhat expected since the beneficial effects of other forms of exercise on psychological health are well known. The findings of this study are unique since a WBV intervention elicited significant improvement in all components of the SF-36 Health Survey. Interestingly, when compared to RAND Corporation (2006) measures of central tendency, only physical functioning (PF) was less. Moreover, PF reported by Bryere et al. (2005) was lower still. That result would suggest that WBV was not effective in improving PF to a normative level.

These findings may be attributed to several causes, particularly methodological differences since participant numbers were lower in this study. These data are useful, however, in identifying the potential benefit of WBV on HRQOL. Since the duration of the WBV intervention was six weeks, it was noteworthy that such large improvements were observed and could not be attributed to the placebo effect, since as previously established, it did not exist in other WBV interventions (Delecluse, Roelants & Verschueren, 2003).

5.3 Specific Intervention Effect

This study was able to distinguish differences between the neuromuscular performance data of the different intervention sample groups. Other investigations have used a standard protocol (i.e. only a three sessions per week WBV intervention sample group). The methods of this study searched for WBV effects on community dwelling older adult sample groups whom attended different exercise programmes.

5.3.1 Sessions per Week

Figure 11 shows 5-Chair Stands test sample group means. The smallest difference within pre-test and post-test means was within the one WBV session per week sample group. The largest improvements were within the two WBV sessions per week and three WBV sessions per week sample groups. A significant difference was not observed between those sample groups, however, the zero WBV sessions per week group was significantly slower than the one and three WBV sessions per week groups (Appendix L). Thus, for a community dwelling older adult to gain significant improvement in neuromuscular performance incorporating the frequency and amplitude adopted in this study, he/she should attend three WBV sessions per week.

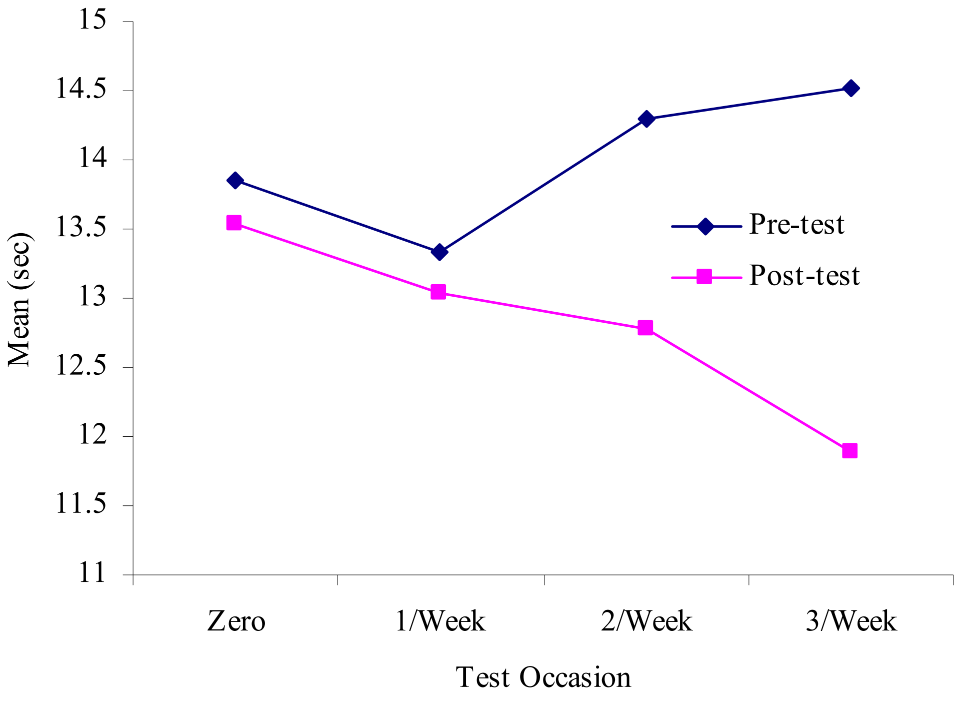


Figure 11 Effect of a six week WBV intervention measured by the 5-Chair Stands test for all intervention sample groups.

Figure 12 shows the TUG test sample group means. The pre-test data for three of the four sample groups were similar. The largest pre-test to post-test difference was within the two WBV sessions per week sample group (1.03 sec; a 12.29 % reduction in time to complete test). A significant difference was found between the two WBV sessions per week and three WBV sessions per week sample groups (Appendix L). Thus, the three WBV sessions per week sample group could complete the test significantly faster than the two WBV sessions per week sample group. However, the three WBV session per week sample group, while not significantly, was faster at the pre-test occasion.

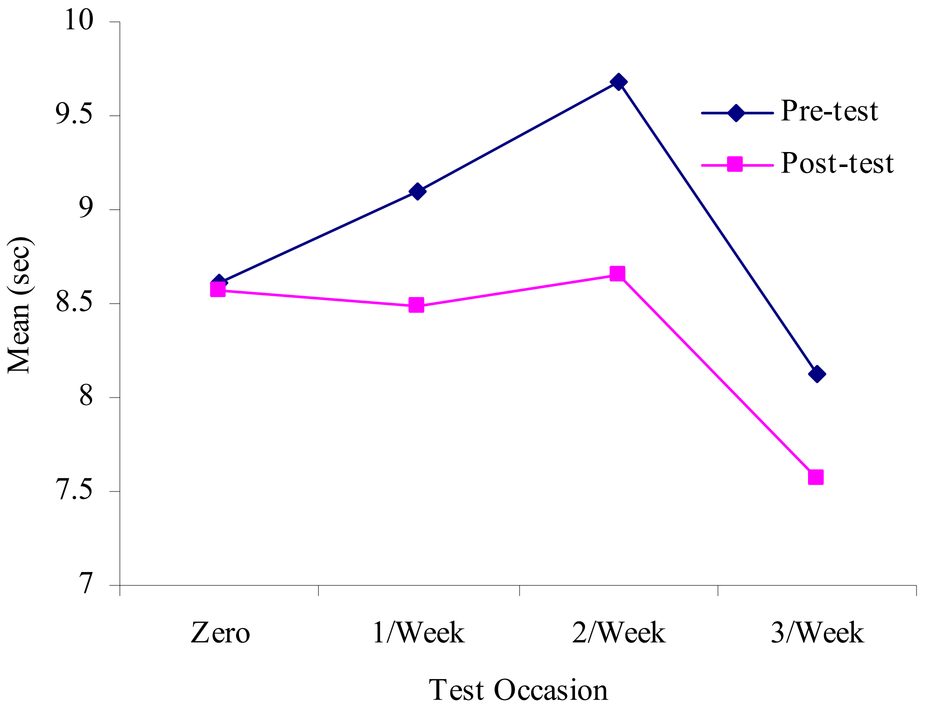


Figure 12 Effect of a six week WBV intervention measured by the TUG test for all intervention sample groups.

Many researchers used a three WBV sessions per week method for an intervention and found improvement in neuromuscular performance of younger and older adults (Runge, Rehfeld & Resnicek, 2000; Delecluse, Roelants & Verschueren, 2003; Torvinen et al., 2003). This study however, was the first to investigate the number of WBV session per week required to affect neuromuscular performance for the target population using fixed amplitude and manipulated frequency.

It was suggested that WBV may be a means to alter central motor control patterns in young adults (Rittweger, Mutschelkanuss & Felsenberg, 2003). WBV was thought to affect the motor function of young adults by manipulating, improving or creating alternate motor programs. Researchers, however, have only tentatively suggested the potential WBV effects upon an older adult population. Findings of this study and the few others that examined effects upon older adults showed that WBV altered central motor patterns. Specifically, the three WBV sessions per week protocol of this study elicited the most beneficial health gains in a community dwelling older adult sample.

5.3.2 Frequency and Amplitude

Kerschan-Schindl, Grampp, Henk, Resch, Preisinger, Fialka-Moser and Imhof (2001) found that frequency and amplitude are the crucial components regarding a positive or negative outcome for muscular strength and blood circulation from vibration exercise. This study showed that WBV with controlled amplitude and manipulated frequency was able to elicit beneficial neuromuscular adaptation in a community dwelling older adult sample.

More uniquely, the maximum gravitational force ($g = 1.26$) generated by the vibration platform of this study, whilst not as large as other studies, elicited neuromuscular performance improvement. Furthermore, the vibration platform dynamics were such that no injuries were associated with the six week WBV intervention.

This study was able to identify the adequate frequency and amplitude of the vibration platform to elicit health benefit. This finding was important since methodological models may now refer to a standard for a community dwelling older adult population. Progressively overloaded vibration platform frequency, initially 15 Hz to 25 Hz and platform amplitude controlled at 0.5 mm were sufficient to elicit neuromuscular performance improvement in the target sample whilst avoiding injuries associated with larger gravitational forces.

5.4 Older Adult Population

The community dwelling older adult population, representing an increasing proportion of the population in Australia, is a target population that can benefit from WBV interventions. Indicators of neuromuscular performance such as chair raising time, body balance and gait have improved in older adults after WBV (Runge, Rehfeld & Resnicek, 2000, Roelants, Delecluse & Verchueren, 2004; Bruyere et al., 2005). With those mentioned, this study found that quantifiers of neuromuscular performance were affected by a six week WBV intervention.

5.4.1 Adaptation to Change

It is universally accepted that exercise should be performed every day (Jassen, Heymsfield & Ross, 2002). The ability of the human body to adapt to exercise (i.e. resistance training and cardiovascular training) is well documented (Whipple, Wolfson & Amerman, 1987). However, the exact mechanisms (i.e. mode, frequency, intensity and duration) are yet to be firmly established (Bean, Vora, & Frontera, 2004; Moreland et al., 2004; Seguin & Nelson, 2003; Skelton & Beyer, 2003).

One area of specific concern to the older adult population is sarcopenia. It was suggested that intervention strategies designed to preserve skeletal muscle mass should be implemented in the fifth decade (Jassen, Heymsfield & Ross, 2002). Thus, resistance training is a proven from of exercise to avoid muscle mass loss in the older adult population (Häkkinen et al., 2001; Lynch, 2004). Furthermore, Visser et al. (2002) showed that over a three year period, older adults who remained physically active did not experience any decline in mobility performance. Older adults who remained inactive or those who stopped sports participation experienced significant mobility decline (Visser et al., 2002).

The findings of this study, which show measurable improvement in mobility performance, are unique. A WBV intervention was shown to be an effective exercise method for a community dwelling older adult sample. Significantly, the WBV intervention was, essentially, very easy for the participant. The ability of one to stand on a vibration platform was considerably easier than performing resistance training. This author is not suggesting WBV over resistance training as the preferred muscle mass preserving exercise. However, given the relative ease of WBV interventions, WBV may be considered a preliminary exercise to resistance training (i.e. three weeks WBV before resistance training is commenced) or as a useful alternate exercise, and/or as a cross-training exercise.

5.4.2 Limiters to Participation

Since sarcopenia may be unavoidable, older adults must retain some level of physical strength so as to potentially recover from injury and regain independence (Harridge, Mangusson, Saltin, 1997; Skelton & Beyer, 2003). As mentioned, exercise is an important component to maintain mobility. Some forms of exercise, however, are limiters to participation for older adults. Resistance training and treadmill walking can be daunting exercise options for older adults.

Other limiters to participation include a loss of confidence in body balance capabilities and a fear of falling (Close, Hooper, Glucksman, Jackson, & Swift, 2003; Marks, & Allegrante, 2004; Kannus, Parkkari, Niemi, & Palvanen, 2005). Both those limiters lead to a proven deterioration in physical functioning, physical health and mental health (Vellas, Cayla, & de Bocquet 1997; Sadigh, Reimers, Andersson, & Laflamme, 2004; Schwartz, Nevitt, Brown, & Kelsey, 2005; Lach, 2005). Since the ability to develop rapid high force contributes to successful performance in many everyday activities involving body balance, and that ability depends upon physical functioning, limiters to participation must be reduced to achieve a healthier community dwelling older adult population.

To improve knowledge, research must be conducted to determine successful exercise methods. Research studies, however, can be limiters to knowledge of older adults. One study recruited 10 participants (mean age = 64 years) and took muscle biopsy to show the effect of the intervention. The intervention greatly improved muscular strength and muscular power in the lower extremities of participants (Häkkinen et al., 2001). The small sample and demanding methods of the study demonstrated the difficulty in collecting an older adult sample. Furthermore, the sample may not be representative of the general population since a rigorous screening protocol was used and considering that all participants, despite age, were regular sport performers.

This study, therefore, is unique since participants were community dwelling older adults of varying age and varying regular exercise endeavour (i.e. ranging from no regular exercise to regular exercise such as golf or walking the family dog). The undemanding methods and large sample size were not limiters to participation. Significant knowledge regarding exercise with a motive to improve physical functioning was obtained without potentially adding to an 'exercise is too hard and too dangerous' perception.

5.4.3 Motive to Improve

The FITTE acronym (Frequency, Intensity, Type, Time and Enjoyment) is commonly used in exercise environments. Generally, the acronym incorporates all important components of an exercise programme (i.e. sets and repetitions, location, exercises, etc.). Perhaps the most important component for older adults is enjoyment since recently, less than 10% of the older adult population in the U.S.A. regularly engaged in resistance training (US DHHS, 2000; Seguin & Nelson, 2003). Resistance training, therefore, was shown to improve emotional health and vitality in older adults (Penninx, Guralnik, Bandeen-Roche, Kasper, Simonsick, Ferrucci & Fried, 2000). Older adults, therefore, should enjoy exercise participation, or the observed participation rates may endure.

Lack of enjoyment may also affect research projects. The attrition rate of three month resistance training research projects ranged from 20% to 37.8% (Suzuki, Kim, Yoshida & Ishzaki, 2004; Means, Rodell & O'Sullivan, 2005). Compliance during research projects has also been problematic. In some instances, compliance was, at best, 79% (Brill et al., 1999) and as low as 75.3% (Suzuki et al., 2004) for resistance training interventions.

The compliance in this study was noteworthy. Every participant had 100% participation levels, thus attended every session as described in the methods. One possible reason was that the community dwelling older adults enjoyed the WBV intervention. As indicated by the SF-36 Health Survey (figure 7), all components of health were significantly improved after the six week WBV intervention.

5.4.4 Suitability to Measurement Instruments and Tools

Some measurement instruments used in research are inconvenient for a number of reasons. Specifically, location, cost and transportability were factors for this study. Laboratory measurement instruments, however, may at times be a hindrance for older adults. The KIN-COM Isokinetic Dynamometer (500H Chattanooga Corp., Chattanooga, TN), for example, is an excellent tool to examine the maximal muscular strength of older adults (Pavol, Owings, Foley, Grabiner & 2002). That devise, however, is expensive and not easily transported from a laboratory to the field.

Another common tool to quantify muscular strength and muscular power is to test one-repetition maximum (1RM). Typically tested in a gymnasium, 1RM demonstrates the absolute amount of weight that can be lifted. For an older adult population, however, the 1RM test is not typically used since there are associated disadvantages (Rogers, Rogers, Takeshima & Islam, 2003). One-repetition maximum has caused higher injury rates than actual resistance training programmes and has poorly defined testing criteria (Pollock, Carroll, Graves, Legett, Braith, Limacher & Hagberg, 1991; Hurley, 1995). Vincent and Braith (2002) experienced a 9.7% reduction in participation of their resistance training programme because of joint discomfort caused by 1RM and a resistance training method.

The measurement instruments used in this study to quantify neuromuscular performance were commonly used in other field investigations of older and young adult populations (Tinetti, 1986; Tinetti, Speechley & Ginter, 1988; Podsiadlo & Richardson, 1991; Hays & Shapiro, 1992; Ware & Sherbourne, 1992; Brill et al., 1999; Runge, Rehfeld & Resnicek, 2000; Dite & Temple, 2002; Visser et al., 2002; Cho, Scarpace & Alexander, 2004; Isles et al., 2004; Bruyere et al., 2005). Since compliance was 100% and no injuries were reported, WBV delivered by a vibration platform and quantified with the 5-Chair Stands test, TUG test and Tinetti test were suitable for a community dwelling older adult sample.

5.5 Limitations

There were limitations that affected the hypotheses testing of this study, namely, participant numbers and measurement instruments. Unfortunately, those limitations were unavoidable.

Participant numbers for the retention test ($n = 10$) of this study were not ideal, therefore the data are simply descriptive rather than inferential. The data however, were useful in illustrating effects of detraining in the sample. Ideally, participant numbers would have been higher, thus increasing observed power.

Neuromuscular performance may have also been quantified with a hand held dynamometer (Vianda, Smit, Pluijm & Lips, 2003). Since the instrument was absent the chosen and validated field tests were used and considered appropriate. Ideally, the test procedures would have been conducted at the laboratories of the Australian Catholic University incorporating instruments such as the KIN-COM Isokinetic Dynamometer (500H Chattanooga Corp., Chattanooga, TN) and the GAITRite measurement system.

5.6 Future Directions

This study has highlighted other areas of potential significance within the Exercise Science field. Further research improving and expanding the methods of this study could assist WBV knowledge and implementation.

Bruyere et al. (2005) conducted a study of WBV intervention effect and neuromuscular performance of older adults. There were some marked differences in the samples of that study and the current study (mean age difference = 12 years, sample size difference = 50 persons more in the current study). The older age of the Bruyere et al. (2005) sample may account for the large mean difference in TUG test time, however, such long times were not reported in other investigations of similar sample ages (Shumway-Cook, Brauer & Woollacott, 2000; Dite & Temple, 2002; Steffen, Hacker & Mollinger, 2002). Such diverse findings suggest that further investigation is required to obtain more comprehensive understanding of age quartiles in older adults.

Furthermore, the reduction in time reported by Bruyere et al. (2005) to complete the TUG test was simultaneously unique and contradictory. Phenomenal since a six week WBV intervention (three WBV sessions per week, four one minute WBV bouts) combined with resistance training reduced time to complete the TUG test by 30%, however, contradictory since a six week resistance training intervention increased TUG test time by 8%. Questions of significance are raised such as; what is the exact method for the combination of the two training types? and/or is the TUG test appropriate to measure changes in neuromuscular performance after resistance training?

Immediate acute post intervention, WBV interventions were found not to damage articular surfaces or joints of the lower limbs while eliciting mild cardiovascular increases (Rittweger, Beller & Felsenberg, 2000; Rittweger, Schiessl & Felsenberg, 2001; Rittweger et al., 2002; Torvinen et al., 2003). Cardiovascular affects were reported to return to homeostasis after 15 minutes. Effects of long term WBV interventions (i.e. three or more month interventions) exist, however there remains a dearth of research recruiting older adults. Furthermore, given the nature of sarcopenia, further investigations may extend exercise programme durations and examine chronic and acute effects in conjunction.

5.7 Conclusion

The stated aims; (1) to identify chronic effects of WBV on a community dwelling older adult sample, and; (2) to identify WBV methods that would elicit such chronic effects in such a sample were answered in this study.

A six week WBV intervention was shown to chronically improve neuromuscular performance of community dwelling older adults as had similar interventions in younger adults. Functionally, participants were able to perform common activities of active daily living with significantly improved speed brought about by improved neural performance. Furthermore, a WBV intervention was shown to significantly improve HRQOL for the sample.

The methods of the intervention were able to elicit chronic changes in neuromuscular performance of community dwelling older adults. Moreover, the methods used were simple for the participant and easily replicable.

Many hypotheses were tested in this study in order to examine effects of WBV on neuromuscular performance of community dwelling older adults. The WBV intervention was shown to improve neuromuscular performance as quantified by the 5-Chair Stands test, TUG test, the Tinetti test in the intervention group. The WBV intervention was also shown to improve HRQOL as qualified by the SF-36 Health Survey in the intervention group.

Specifically, a community dwelling older adult should attend at least three WBV sessions per week to significantly improve neuromuscular performance with the methods used in this study. Furthermore, effects of detraining occurred more rapidly that had been previously reported in similar samples.

Those findings should be interpreted with specific regard to the method applied. This study showed that amplitude may not be manipulated to elicit health benefit in community dwelling older adults. Those findings are important since it was shown that WBV, as an exercise intervention, can be easily administered, with no adverse effects to the individual. Further this study has enabled one to establish, with more scientific confidence, the role of WBV as an exercise intervention and add credibility to the field.

This WBV intervention was shown to mitigate, or at least address, contra-indicators of sarcopenia. While muscular mass was not measured, functional performance improved after the intervention, thus inhibiting the debilitating effects of sarcopenia. Those findings are externally significant since WBV interventions are easy to implement and require little additional skill to perform.

Overall, WBV should be considered as a tool to easily improve neuromuscular performance and HRQOL in community dwelling older adults. Used in conjunction with other training aids, WBV could affect contra-indicators of health in the said population. Furthermore, WBV could be considered as a training aid of muscular strength and muscular power exercise programmes.

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LIST OF APPENDICES

APPENDIX A

Australian Catholic University
Brisbane Sydney Canberra Ballarat Melbourne

ACU National

INFORMATION LETTER FOR PARTICIPANT

TITLE OF PROJECT: EFFECTS OF WHOLE BODY VIBRATION ON NEUROMUSCULAR PERFORMANCE OF OLDER ADULTS

NAME OF SUPERVISORS: DR WAYNE MASCHETTE

NAME OF STUDENT RESEARCHER: TRENTHAM FURNESS

NAME OF PROGRAMME IN WHICH ENROLLED: MASTER OF EXERCISE SCIENCE (RESEARCH)

You are invited to participate is a study to examine the effects of Whole Body Vibration (WBV) on neuromuscular performance of older adults. Low intensity WBV will be conducted over a six week period, followed by a six week follow up period. You will feel WBV when you stand on a horizontal platform (Figure 1, please note you will be asked to wear flat soled shoes on the platform). The sensation of WBV is similar to that experienced when riding a tram. Your neuromuscular performance will be assessed using simple, non-invasive, short duration tests such as standing from a chair and walking.

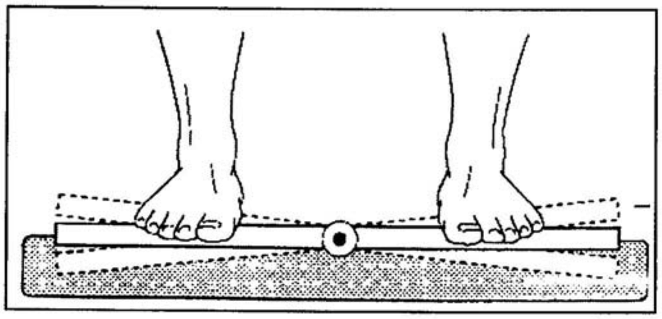

Figure 1. WBV platform during vibration period.

After standing on the WBV platform your legs may feel ‘different’ or ‘alive’. The WBV is specifically designed to evoke such feelings and improve muscular performance. While these possible changes are not considered a risk, inconvenience or discomfort, in order to ensure that you will not be at risk of any muscular injury please obtain a medical clearance from your local practitioner prior to your involvement in the study. Please pass the accompanying forms on to your physician.

During the study you will be asked to complete simple, non-invasive, short duration tests, followed by six weeks of WBV (maximum of three sessions per week). Each WBV session will run for approximately 10 minutes to 15 minutes. At weeks three and six you will also be asked to complete the same simple tests. You will also be asked to complete a six week follow-up period (no WBV). During the follow up period you will be asked to complete the simple tests on weeks one, three and six (i.e. you will only be tested on three occasions over the six week period). Thus, your total involvement will be 12 weeks. Both the simple tests and WBV are very low intensity.

The WBV exercise will be conducted at the Chelsea R.S.L located at 12 Beach Street, Chelsea.

The benefits of WBV have been reported in both older and athletic populations. Research has shown that WBV can improve balance and health related quality of life in older adults. Athletes have also gained strength and power after WBV. NASA is currently investigating if a form of WBV helps reduce muscle loss in astronauts while in space. As such the use of WBV spans many areas of science and is an exciting new area of research. It is hoped that findings of this study will be published in journals such as the *Journal of Biomechanics* in an effort to advance the knowledge of WBV research and more specifically the effects of WBV on older adults.

Personal data such as your age, height, gender and weight will be recorded. These data will only be known by the researcher. All data will be analysed collectively, thus individual differences are not recorded. Any published data will be anonymous and can not in any way be associated with you. You are free, however, to refuse your consent to participate altogether without having to justify that decision, or to withdraw consent and discontinue participation in the study at any time without giving a reason.

You are also offered the opportunity to obtain any information regarding any aspect of the research project.

Any questions regarding this project should be directed to the Supervisor and the Student Researcher:

Dr Wayne Maschette
On telephone number (03) 99533040
In the School of Exercise Science
Campus Address: Australian Catholic University
Locked Bag 4115
FITZROY VIC 3065

OR

Mr Trentham Furness
On telephone number (03) 94158602
In the School of Exercise Science
Campus Address: Australian Catholic University
Locked Bag 4115, FITZROY VIC 3065

You are warmly encouraged to apply for feedback regarding the results of the study by contacting the afore mentioned supervisor and student researcher.

This study has been approved by the Human Research Ethics Committee at Australian Catholic University.

In the event that you have any complaint or concern about the way you have been treated during the study, or if you have any query that the Supervisor and Student Researcher has (have) not been able to satisfy, you may write to the Chair of the Human Research Ethics Committee care of the following address:

VIC: Chair, HREC
C/o Research Services
Australian Catholic University
Locked Bag 4115
FITZROY VIC 3065
Tel: 03 9953 3157
Fax: 03 9953 3315

Any complaint or concern will be treated in confidence and fully investigated. The participant will be informed of the outcome.

Upon agreement to participate in this study please sign both copies of the Consent Form, retain one copy for your own records and return the other copy to the Supervisor or the Student Researcher.

Yours sincerely,

Dr Wayne Maschette
SUPERVISOR

Mr Trentham Furness
STUDENT RESEARCHER

Australian Catholic University
Brisbane Sydney Canberra Ballarat Melbourne

ACU National

CONSENT FORM (Participant Copy)

TITLE OF PROJECT: EFFECTS OF WHOLE BODY VIBRATION ON MUSCULAR PERFORMANCE OF ELDERLY ADULTS

NAMES OF SUPERVISOR: DR WAYNE MASCHETTE

NAME OF STUDENT RESEARCHER: TRENTHAM FURNESS

I .... *(the participant)* have read (*or, where appropriate*, have had read to me*)* and understood the information provided in the Letter to Participants. Any questions I have asked have been answered to my satisfaction. I agree to participate in this activity, realising that I can withdraw at any time. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify me in any way.

NAME OF PARTICIPANT: ....
(block letters)

SIGNATURE .... DATE ....

SIGNATURE OF SUPERVISOR: ....

DATE:……………………………………..

SIGNATURE OF STUDENT RESEARCHER:...

DATE:...................................…………

APPENDIX B

Australian Catholic University
Brisbane Sydney Canberra Ballarat Melbourne

ACU National

INFORMATION LETTER FOR PHYSICIAN

TITLE OF PROJECT: EFFECTS OF WHOLE BODY VIBRATION ON NEUROMUSCULAR PERFORMANCE OF OLDER ADULTS

NAME OF SUPERVISORS: DR WAYNE MASCHETTE
NAME OF STUDENT RESEARCHER: TRENTHAM FURNESS

NAME OF PROGRAMME IN WHICH ENROLLED: MASTER OF EXERCISE SCIENCE (RESEARCH)

The purpose of this study is to examine the effects of Whole Body Vibration (WBV) on neuromuscular performance of older adults. WBV will be used as an exercise intervention over a six week period, followed by a six week follow up period. WBV is transmitted to a participant when he/she stands on a horizontal platform (Figure 1). Neuromuscular performance will be assessed via a range of short duration tests such as standing from a chair and walking. The tests are of a low intensity, i.e. small increases in resting heart rate.

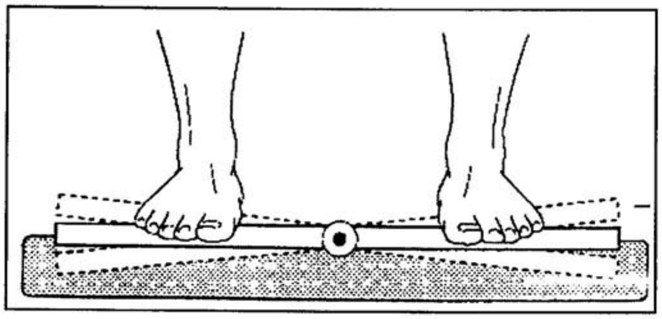

Figure 1. WBV platform during vibration period.

Each participant exposed to the WBV exercise may experience changes/differences in leg function. Changes in leg function will be assessed as neuromuscular performances. Participants will be asked to perform the 'Timed up and Go Test', the 5-chair stands test and the Tinetti test during pre-intervention and post-intervention sessions. The WBV exercise is specifically designed to improve neuromuscular performance (thus changes/differences are expected). While these possible changes/differences are not considered a risk, inconvenience or discomfort, participants are asked to complete a medical screening prior to their involvement in the study.

It is the researcher's intention to exclude participants who do not pass a medical screening or who are using medication that affects balance.

During the study the participant will be required to complete a test battery of neuromuscular performance (tests aforementioned), followed by six weeks of WBV exercise (maximum of three sessions per week). Each WBV session will run for approximately 10 minutes to 15 minutes. During the follow up period participants will be required to complete the test battery on weeks one, three and six (i.e. testing on three occasions over the six week period). Thus, the total involvement for each participant will be 12 weeks. Both the test battery and WBV exercise are very low intensity. Using similar protocols, past studies have found increases in heart rate equivalent to that of slow-moderate walking.

The benefits of WBV exercise have been reported in both older and athletic populations. Research has shown that WBV can improve balance and health related quality of life in older adults. Athletes have also gained strength and power after WBV exercise. NASA is currently investigating if a form of WBV exercise helps reduce muscle loss in astronauts while in space. As such the use of WBV exercise spans many areas of science and is an exciting new area of research. It is hoped that findings of this study will be published in journals such as the *Journal of Biomechanics* in an effort to advance the knowledge of WBV research and more specifically the effects of WBV on older adults.

If your medical approval is granted for this study (i.e. patient passes medical screening and is not taking medicine that effects balance) please sign/stamp the accompanying form and pass it on to your patient. Please also add any comments necessary.

Any questions regarding this project should be directed to the Supervisor and the Student Researcher:

Dr Wayne Maschette
On telephone number (03) 99533040
In the School of Exercise Science
Campus Address: Australian Catholic University
Locked Bag 4115
FITZROY VIC 3065

OR

Mr Trentham Furness
On telephone number (03) 94158602
In the School of Exercise Science
Campus Address: Australian Catholic University
Locked Bag 4115
FITZROY VIC 3065

You are warmly encouraged to apply for feedback regarding the results of the study by contacting the afore mentioned supervisor and student researcher.

This study has been approved by the Human Research Ethics Committee at Australian Catholic University.

Yours sincerely,

Dr Wayne Maschette
SUPERVISOR

Mr Trentham Furness
STUDENT RESEARCHER

Australian Catholic University
Brisbane Sydney Canberra Ballarat Melbourne

ACU National

FOR PHYSICIAN TO COMPLETE

CODE NUMBER: __________

Has your patient satisfactorily passed a medical screening?

YES ☐ NO ☐

Does your patient take medicine that affects balance?

YES ☐ NO ☐

In your medical opinion, is the participant healthy and able to participant in the study?

YES ☐ NO ☐

Comments? (if any)

Please sign/stamp below:

Thank you for your time.

Regards,

Trentham Furness

APPENDIX C

Australian Catholic University
Brisbane Sydney Canberra Ballarat Melbourne

ACU National

To the Manager,

Australian Catholic University, School of Exercise Science is conducting research with the focus upon older adults. The expected outcomes of the research are beneficial to individuals and the broader community. It is expected that individuals participating in this research will experience improvements in strength and power of their legs, thus improving balance.

We are requesting permission to approach residents in your locale and to conduct the research within your grounds. The research will be conducted over a 12 week period in which it is hoped older adults will attend either, one, two or three 15 minute sessions per week. The equipment used is small and easily transportable. It is hoped that you may be able to spare some space in a function room, or similar, for the 12 week period. It is anticipated that the research will not exceed 3 hours per day.

The following letter explains in detail the research and associated benefits and risks of involvement.
If you are interested in further information please contact:

Mr Trentham Furness
On telephone number (03) 94158602
In the School of Exercise Science, Australian Catholic University

OR

Dr Wayne Maschette
On telephone number (03) 99533040
In the School of Exercise Science, Australian Catholic University

Yours faithfully,

Trentham Furness

Australian Catholic University
Brisbane Sydney Canberra Ballarat Melbourne

ACU National

INFORMATION LETTER FOR MANAGER

TITLE OF PROJECT: EFFECTS OF WHOLE BODY VIBRATION ON NEUROMUSCULAR PERFORMANCE OF OLDER ADULTS

NAME OF SUPERVISORS: DR WAYNE MASCHETTE

NAME OF STUDENT RESEARCHER: TRENTHAM FURNESS

NAME OF PROGRAMME IN WHICH ENROLLED: MASTER OF EXERCISE SCIENCE (RESEARCH)

The purpose of this study is to examine the effects of Whole Body Vibration (WBV) on neuromuscular performance of older adults. WBV will be used over a six week period, followed by a six week follow up period. WBV is transmitted to a participant when he/she stands on a horizontal platform (Figure 1). Neuromuscular performance will be assessed via a range of short duration tests such as standing from a chair and walking. The tests are of a low intensity, i.e. small increases in resting heart rate.

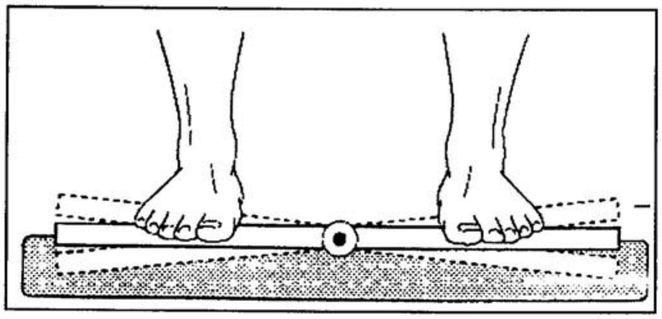

Figure 1. WBV platform during vibration period.

Each participant exposed to WBV may experience changes/differences in leg function. Changes in leg function will be assessed as neuromuscular performances. Participants will be asked to perform the ‘Timed up and Go Test’, the 5-chair stands test and the Tinetti test. The WBV is specifically designed to improve neuromuscular performance (thus changes/differences are expected). While these possible changes/differences are not considered a risk, inconvenience or discomfort, participants are asked to complete a medical screening prior to their involvement in the study.

It is the researcher’s intention to exclude participants who do not pass a medical screening or who are using medication that affects balance.

During the study the participant will be required to complete a tests of neuromuscular performance (tests aforementioned), followed by six weeks of WBV (maximum of three sessions per week). Each WBV session will run for approximately 10 minutes to 15 minutes. During the follow up period participants will be required to complete the tests on weeks one, three and six (i.e. testing on three occasions over the six week period). Thus, the total involvement for each participant will be 12 weeks. Both the tests and WBV are very low intensity. Using similar protocols, past studies have found increases in heart rate equivalent to that of slow-moderate walking.

The benefits of WBV have been reported in both older and athletic populations. Research has shown that WBV can improve balance and health related quality of life in older adults. Athletes have also gained strength and power after WBV exercise. NASA is currently investigating if a form of WBV helps reduce muscle loss in astronauts while in space. As such the use of WBV spans many areas of science and is an exciting new area of research. It is hoped that findings of this study will be published in journals such as the *Journal of Biomechanics* in an effort to advance the knowledge of WBV research and more specifically the effects of WBV on older adults.

Any questions regarding this project should be directed to the Supervisor and the Student Researcher:

Dr Wayne Maschette
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In the School of Exercise Science
Campus Address: Australian Catholic University
Locked Bag 4115
FITZROY VIC 3065

OR

Mr Trentham Furness
On telephone number 0415920158
In the School of Exercise Science
Campus Address: Australian Catholic University
Locked Bag 4115, FITZROY VIC 3065

You are warmly encouraged to apply for feedback regarding the results of the study by contacting the afore mentioned supervisor and student researcher.

This study has been approved by the Human Research Ethics Committee at Australian Catholic University.

Yours sincerely,

Dr Wayne Maschette
SUPERVISOR

Mr Trentham Furness
STUDENT RESEARCHER

APPENDIX D

Australian Catholic University
Brisbane Sydney Canberra Ballarat Melbourne

ACU National

FOR RESEARCHER TO COMPLETE

Physician Approval: YES ☐ NO ☐ Medication affecting balance: YES ☐ NO ☐

Personal Details: **CODE NUMBER: _______________**

Name: ____

Address: ____

Telephone: ______________________(AH) __________________________(MOB)

Date of Birth: ________________________ Gender: M ☐ F ☐

Height: __________(m) Weight: _________(kg) BMI ____________(kg·m^2)

Medical History:

Have you had any falls in the past 12 months? **YES ☐** **NO ☐**

If yes how many falls? _______________

Have you undergone any joint replacement procedures? **YES ☐** **NO ☐**

If yes please provide details: (i.e. year of surgery, location of joint, etc.)

____

____

____

____

____

Are you affected by any of the following?	YES ☐	NO ☐	Please Specify
Musculo-skeletal dysfunction	☐	☐	_________________
Neuromuscular dysfunction	☐	☐	_________________
Overuse injuries	☐	☐	_________________
Vascular disease	☐	☐	_________________
Diabetes	☐	☐	_________________
Arthritis (reactive)	☐	☐	_________________
Vertigo	☐	☐	_________________
Other			_________________ _________________

SCREENING TESTS

Tests of Cognition:

MMSE (Mini Mental State Examination)	PASS ☐	FAIL ☐	Score___________
Vestibular Stepping Test	PASS ☐	FAIL ☐	
Romberg Test	PASS ☐	FAIL ☐	

Tests of Visual Acuity:

Snellen Eye Chart (6 m) Line read ____________________

Melbourne Edge Test Score ______________________

Tests of Data Analysis:

Tinetti Test	PASS ☐	FAIL ☐	Score___________
5-Chair Stands Test	PASS ☐	FAIL ☐	Time________(sec)
TUG test	PASS ☐	FAIL ☐	Time________(sec)

RESULTS

		TUG (sec)	5-Chair (sec)	SF-36		Tinetti Test	
WBV	WEEK 1		1	Completed?		Completed?	
			2	Y	N	Y	N
			3	Returned?			
			4	Y	N		
			5				
	WEEK 6		1	Completed?		Completed?	
			2	Y	N	Y	N
			3	Returned?			
			4	Y	N		
			5				
RETENTION	WEEK 3		1	NA		NA	
			2				
			3				
			4				
			5				

APPENDIX E

The Mini-Mental State Exam (MMSE)

Participant___________________________________ Examiner __________________________
Date____________

Maximum Score

Orientation
5 ( ) What is the (year) (season) (date) (day) (month)?
5 ( ) Where are we (state) (country) (town) (hospital) (floor)?

Registration
3 ( ) Name 3 objects: 1 second to say each. Then ask the patient
all 3 after you have said them. Give 1 point for each correct answer.
Then repeat them until he/she learns all 3. Count trials and record.
Trials ___________

Attention and Calculation
5 ( ) Serial 7’s. 1 point for each correct answer. Stop after 5 answers.
Alternatively spell “world” backward.

Recall
3 ( ) Ask for the 3 objects repeated above. Give 1 point for each correct answer.

Language
2 ( ) Name a pencil and watch.
1 ( ) Repeat the following “No ifs, ands, or buts”
3 ( ) Follow a 3-stage command:

“Take a paper in your hand, fold it in half, and put it on the floor.”
1 ( ) Read and obey the following: CLOSE YOUR EYES
1 ( ) Write a sentence.
1 ( ) Copy the design shown.

_____ Total Score

APPENDIX F

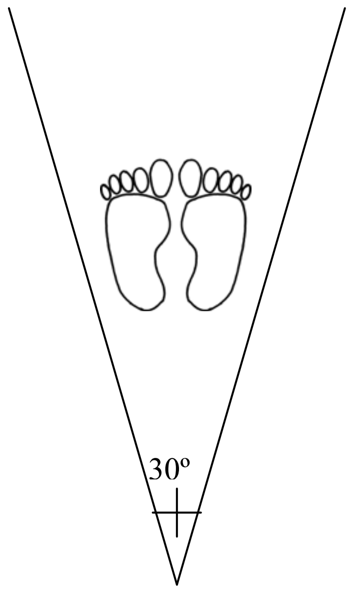
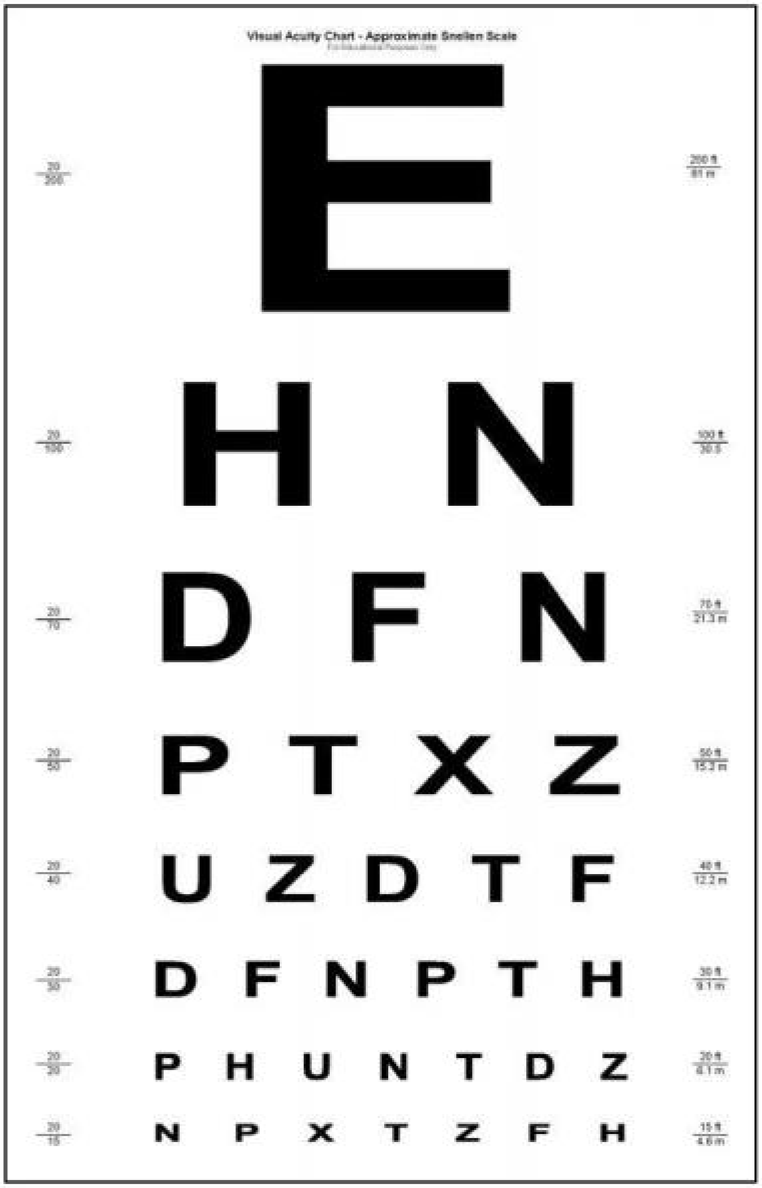


Figure 1 Transverse view of the Vestibular Stepping Test rotation angle.

APPENDIX G



<u>Figure 1</u> The Snellen Eye Chart.

APPENDIX H

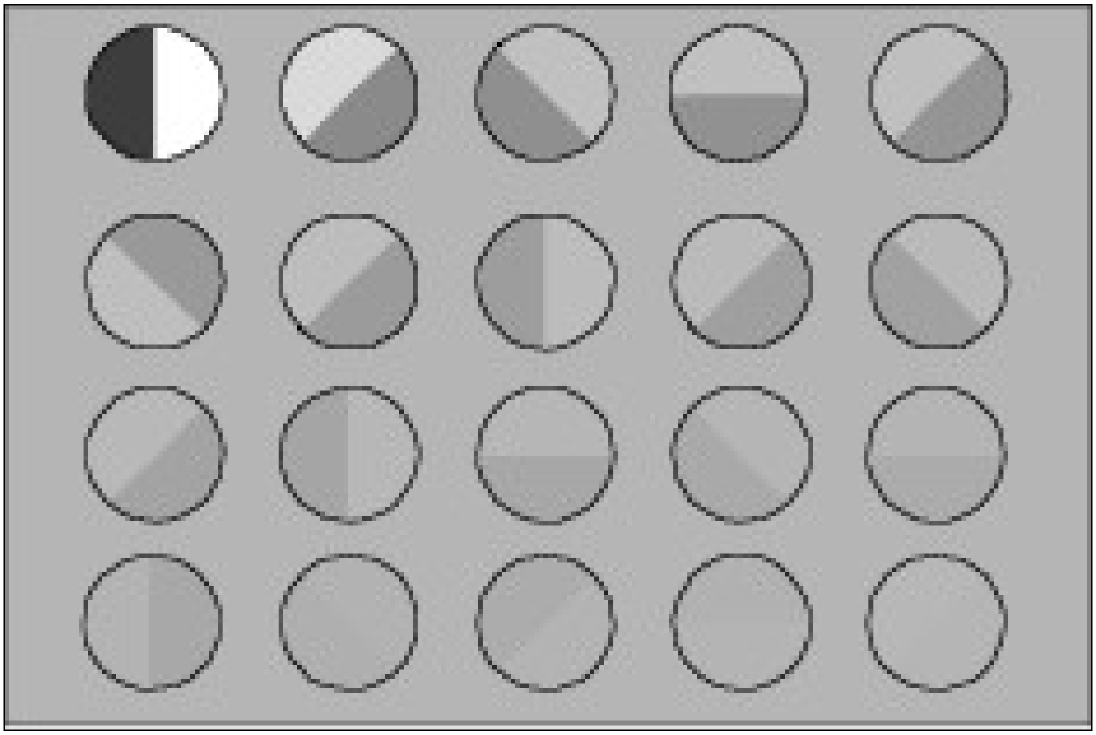


Figure 1 The Melbourne Edge Test.

APPENDIX I

Tinetti Assessment Tool: Description

Participant Name: ____________________ **Date:** _______________________
Location: _________________________ **Rater:** _______________________
Initial Instructions: Subject is seated in a hard, armless chair. The following maneuvers are tested.

Task Description of Balance Possible Score

1. Sitting Balance Leans or slides in chair
Steady, safe
= 0
= 1

2. Arises Unable without help
Able, uses arms to help
Able without using arms
= 0
= 1
= 2

3. Attempts to arise Unable without help
Able, requires > 1 attempt
Able to rise, 1 attempt
= 0
= 1
= 2

4. Immediate standing balance
(first 5 seconds)
Unsteady (swaggers, moves feet, trunk sway)
Steady but uses walker or other support
Steady without walker or other support
= 0
= 1
= 2

5. Standing Balance Unsteady
Steady but wide stance (medial heels > 4 inches apart) and uses cane or other support
Narrow stance without support
= 0
= 1
= 2

6. Nudged (subject at max position with feet as close together as possible, examiner pushes lightly on subject's sternum with palm of hand 3 times.
Begins to fall
Staggers, grabs, catches self
Steady
= 0
= 1
= 2

7. Eyes closed (at maximum position #6)
Unsteady
Steady
= 0
= 1

8. Turning 360 degrees Discontinuous steps
Continuous steps
Unsteady (grabs, swaggers)
Steady
= 0
= 1
= 0
= 1

9. Sitting Down Unsafe (misjudged distance, falls into chair)
Uses arms or not a smooth motion
Safe, smooth motion
= 0
= 1
= 2

Balance Score:

Task Description of Gait Possible Score

10. Initiation of gait (immediately after told to “go”)
Any hesitancy or multiple attempts to start
No hesitancy
= 0
= 1

11. Step length and height
a. Right swing foot does not pass left stance foot with step
b. Right foot passes left stance foot
c. Right foot does not clear floor completely with step
d. Right foot completely clears floor
e. Left swing foot does not pass right stance foot with step
f. Left foot passes right stance foot
g. Left foot does not clear floor completely with step
h. Left foot completely clears floor
= 0
= 1
= 0
= 1
= 0
= 1
= 0
= 1

12. Step Symmetry Right and left step length not equal (estimate)
Right and left step appear equal
= 0
= 1

13. Step Continuity Stopping or discontinuity between steps
Steps appear continuous
= 0
= 1

14. Path (estimated in relation to floor tiles, 12-inch diameter; observe excursion of 1 foot over about 10 feet of the course).
Marked deviation
Mild/moderate deviation or uses walking aid
Straight without walking aid
= 0
= 1
= 2

15. Trunk Marked sway or uses walking aid
No sway but flexion of knees or back, or spreads arms out while walking
No sway, no flexion, no use of arms, and no use of walking aid
= 0
= 1
= 2

16.
Walking Stance Heels apart
Heels almost touching while walking
= 0
= 1

Gait Score:
Balance + Gait Score:

APPENDIX J

SF36 Health Survey

1. In general, would you say your health is: (Please tick **one** box.)

Excellent _
Very Good _
Good _
Fair _
Poor _

2. Compared to one year ago, how would you rate your health in general now?
(Please tick **one** box.)

Much better than one year ago _
Somewhat better now than one year ago _
About the same as one year ago _
Somewhat worse now than one year ago _
Much worse now than one year ago _

3. The following questions are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?
(Please circle one number on each line.)

Activities	**Yes, Limited A Lot**	**Yes, Limited A Little**	**Not Limited At All**
3(a) **Vigorous activities**, such as running, lifting heavy objects, participating in strenuous sports	**1**	**2**	**3**
3(b) **Moderate activities**, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	**1**	**2**	**3**
3(c) Lifting or carrying groceries	**1**	**2**	**3**
3(d) Climbing **several** flights of stairs	**1**	**2**	**3**
3(e) Climbing **one** flight of stairs	**1**	**2**	**3**
3(f) Bending, kneeling, or stooping	**1**	**2**	**3**
3(g) Walking **more than a mile**	**1**	**2**	**3**
3(h) Walking **several blocks**	**1**	**2**	**3**
3(i) Walking **one block**	**1**	**2**	**3**
3(j) Bathing or dressing yourself	**1**	**2**	**3**

4. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?

(Please circle one number on each line.)	**Yes**	**No**
4(a) Cut down on the **amount of time** you spent on work or other activities	1	2
4(b) Accomplished less than you would like	1	2
4(c) Were **limited** in the **kind** of work or other activities	1	2
4(d) Had **difficulty** performing the work or other activities (for example, it took extra effort)	1	2

5. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (e.g. feeling depressed or anxious)?

(Please circle one number on each line.)	**Yes**	**No**
5(a) Cut down on the **amount of time** you spent on work or other activities	1	2
5(b) Accomplished less than you would like	1	2
5(c) Didn’t do work or other activities as **carefully** as usual	1	2

6. During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbours, or groups? (Please tick **one** box.)

Not at all _
Slightly _
Moderately _
Quite a bit _
Extremely _

7. How much physical pain have you had during the past 4 weeks?
(Please tick **one** box.)

None _
Very mild _
Mild _
Moderate _
Severe _
Very Severe _

8. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)? (Please tick **one** box.)

Not at all _
A little bit _
Moderately _
Quite a bit _
Extremely _

9. These questions are about how you feel and how things have been with you during the past 4 weeks. Please give the one answer that is closest to the way you have been feeling for each item. **(Please circle one number on each line.)**

	All of the Time	**Most of the Time**	**A Good Bit of the Time**	**Some of the Time**	**A Little of the Time**	**None of the Time**
9(a) Did you feel full of life?	1	2	3	4	5	6
9(b) Have you been a very nervous person?	1	2	3	4	5	6
9(c) Have you felt so down in the dumps that nothing could cheer you up?	1	2	3	4	5	6
9(d) Have you felt calm and peaceful?	1	2	3	4	5	6
9(e) Did you have a lot of energy?	1	2	3	4	5	6
9(f) Have you felt downhearted and blue?	1	2	3	4	5	6
9(g) Did you feel worn out?	1	2	3	4	5	6
9(h) Have you been a happy person	1	2	3	4	5	6
9(i) Did you feel tired?	1	2	3	4	5	6

10. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives etc.) (Please tick **one** box.)

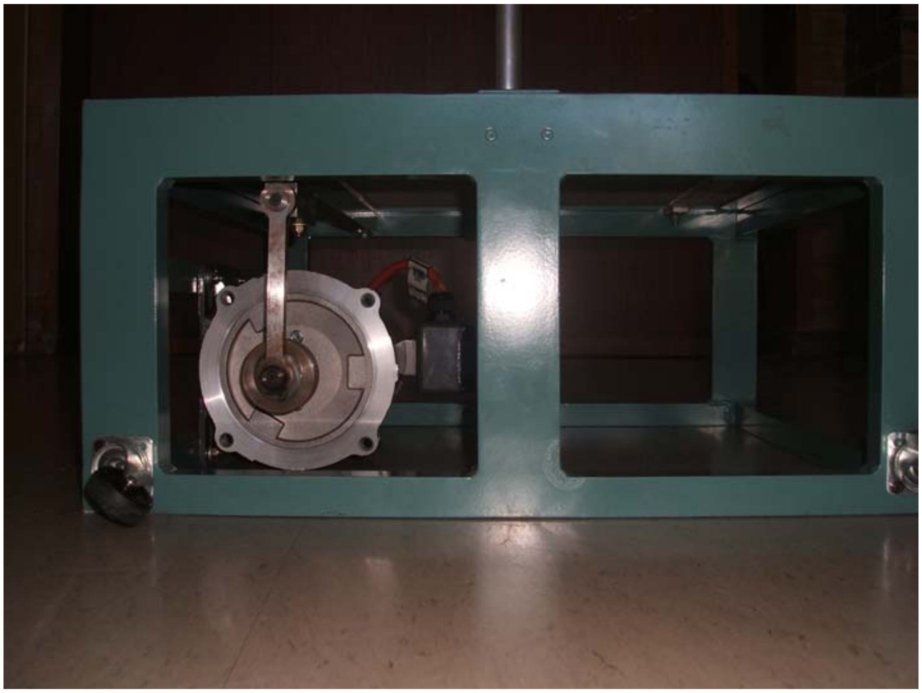
All of the time _
Most of the time _
Some of the time _
A little of the time _
None of the time _

11. How TRUE or FALSE is each of the following statements for you?
(Please circle one number on each line.)

	Definitely True	**Mostly True**	**Don't Know**	**Mostly False**	**Definitely False**
11(a) I seem to get sick a little easier than other people	**1**	**2**	**3**	**4**	**5**
11(b) I am as healthy as anybody I know	**1**	**2**	**3**	**4**	**5**
11(c) I expect my health to get worse	**1**	**2**	**3**	**4**	**5**
11(d) My health is excellent	**1**	**2**	**3**	**4**	**5**

Thank You!

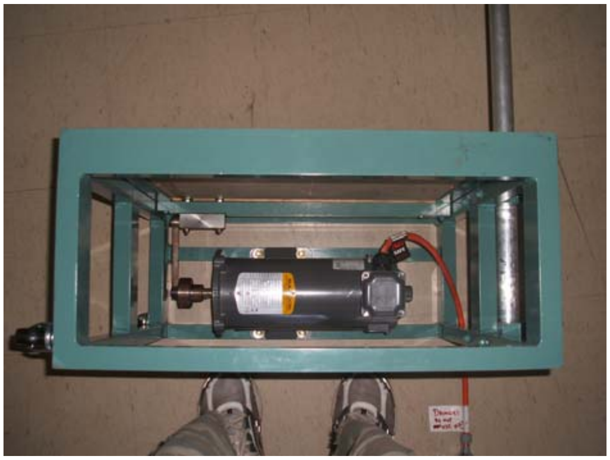
APPENDIX K



Picture 1 View of prototype vibration platform.

Specifications of the prototype vibrating platform:

- Baldor Electrical Co USA
    - Industrial Motor Direct Current
    - 1750 RPM
    - 29.16 Hz
    - 180 V
    - 2.5 Amps
    - Cam wheel/lever arm set for 0.5 mm amplitude
    - Weight ~ 25 kg



Picture 2 Lateral view of platform. Picture 3 View of platform from above.

Dimensions of the prototype vibrating platform:

- Lateral View
    - 55 cm long by 26 cm high
    - Total height (including handle) 130 cm
- From Above
    - 55 cm by 55 cm (78 cm diagonal)

Calibration of the prototype vibrating platform was performed on a weekly basis. A strobe light (X-LED Super Strobe, model 820050) was used to measure the frequency of the platform. Adjustments were made accordingly.

APPENDIX L

Reciprocal transformed data for both the 5-Chair Stands test and the TUG test

Within-Subjects Factors

Measure	test	Dependent Variable
chair	1	chairpre
	2	chairpost
tug	1	tugpre
	2	tugpost

Between-Subjects Factors

		Value Label	N
group	0	zero	18
	1	once per week	18
	2	twice per week	18
	3	thrice per week	19

Descriptive Statistics

	group	Mean	Std. Deviation	N
chairpre	zero	.0722	.01801	18
	once per week	.0750	.01543	18
	twice per week	.0700	.02000	18
	thrice per week	.0689	.01049	19
	Total	.0715	.01613	73
chairpost	zero	.0739	.01614	18
	once per week	.0767	.01749	18
	twice per week	.0783	.01581	18
	thrice per week	.0842	.01071	19
	Total	.0784	.01537	73
tugpre	zero	.1161	.01975	18
	once per week	.1100	.01749	18
	twice per week	.1033	.02590	18
	thrice per week	.1232	.01887	19
	Total	.1133	.02161	73
tugpost	zero	.1167	.02196	18
	once per week	.1178	.02390	18
	twice per week	.1156	.02526	18
	thrice per week	.1321	.01653	19
	Total	.1207	.02269	73

Multivariate Tests(c)

Effect			Value	F	Hypothesis df	Error df	Sig.
Between Subjects	Intercept	Pillai's Trace	.974	1294.459(a)	2.000	68.000	.000
		Wilks' Lambda	.026	1294.459(a)	2.000	68.000	.000
		Hotelling's Trace	38.072	1294.459(a)	2.000	68.000	.000
		Roy's Largest Root	38.072	1294.459(a)	2.000	68.000	.000
	Group	Pillai's Trace	.176	2.214	6.000	138.000	.045
		Wilks' Lambda	.826	2.280(a)	6.000	136.000	.040
		Hotelling's Trace	.210	2.342	6.000	134.000	.035
		Roy's Largest Root	.202	4.655(b)	3.000	69.000	.005
Within Subjects	Test	Pillai's Trace	.344	17.839(a)	2.000	68.000	.000
		Wilks' Lambda	.656	17.839(a)	2.000	68.000	.000
		Hotelling's Trace	.525	17.839(a)	2.000	68.000	.000
		Roy's Largest Root	.525	17.839(a)	2.000	68.000	.000
	test * group	Pillai's Trace	.282	3.769	6.000	138.000	.002
		Wilks' Lambda	.731	3.847(a)	6.000	136.000	.001
		Hotelling's Trace	.351	3.922	6.000	134.000	.001
		Roy's Largest Root	.293	6.741(b)	3.000	69.000	.000

Mauchly's Test of Sphericity(b)

						Epsilon(a)		
Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Huynh-Feldt	Lower-bound	Greenhouse-Geisser
test	chair	1.000	.000	0	.	1.000	1.000	1.000
	tug	1.000	.000	0	.	1.000	1.000	1.000

Multivariate(c,d)

Within Subjects Effect		Value	F	Hypothesis df	Error df	Sig.
test	Pillai's Trace	.344	17.839(a)	2.000	68.000	.000
	Wilks' Lambda	.656	17.839(a)	2.000	68.000	.000
	Hotelling's Trace	.525	17.839(a)	2.000	68.000	.000
	Roy's Largest Root	.525	17.839(a)	2.000	68.000	.000
test * group	Pillai's Trace	.282	3.769	6.000	138.000	.002
	Wilks' Lambda	.731	3.847(a)	6.000	136.000	.001
	Hotelling's Trace	.351	3.922	6.000	134.000	.001
	Roy's Largest Root	.293	6.741(b)	3.000	69.000	.000

Univariate Tests

Source	Measure		Type II Sum of Squares	df	Mean Square	F	Sig.
test	**chair**	**Sphericity Assumed**	**.002**	**1**	**.002**	**29.450**	**.000**
		Greenhouse-Geisser	.002	1.000	.002	29.450	.000
		Huynh-Feldt	.002	1.000	.002	29.450	.000
		Lower-bound	.002	1.000	.002	29.450	.000
	tug	**Sphericity Assumed**	**.002**	**1**	**.002**	**16.313**	**.000**
		Greenhouse-Geisser	.002	1.000	.002	16.313	.000
		Huynh-Feldt	.002	1.000	.002	16.313	.000
		Lower-bound	.002	1.000	.002	16.313	.000
test * group	**chair**	**Sphericity Assumed**	**.001**	**3**	**.000**	**6.741**	**.000**
		Greenhouse-Geisser	.001	3.000	.000	6.741	.000
		Huynh-Feldt	.001	3.000	.000	6.741	.000
		Lower-bound	.001	3.000	.000	6.741	.000
	tug	Sphericity Assumed	.001	3	.000	1.783	.158
		Greenhouse-Geisser	.001	3.000	.000	1.783	.158
		Huynh-Feldt	.001	3.000	.000	1.783	.158
		Lower-bound	.001	3.000	.000	1.783	.158
Error(test)	chair	Sphericity Assumed	.004	69	5.81E-005		
		Greenhouse-Geisser	.004	69.000	5.81E-005		
		Huynh-Feldt	.004	69.000	5.81E-005		
		Lower-bound	.004	69.000	5.81E-005		
	tug	Sphericity Assumed	.008	69	.000		
		Greenhouse-Geisser	.008	69.000	.000		
		Huynh-Feldt	.008	69.000	.000		
		Lower-bound	.008	69.000	.000		

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Type II Sum of Squares	df	Mean Square	F	Sig.
Intercept	chair	.820	1	.820	1868.661	.000
	tug	1.998	1	1.998	2513.053	.000
group	chair	.000	3	9.34E-005	.213	.887
	tug	**.007**	**3**	**.002**	**2.814**	**.046**
Error	chair	.030	69	.000		
	tug	.055	69	.001		

Multiple Comparisons

Tukey HSD

Measure	(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Upper Bound	Lower Bound
chair	zero	once per week	-.0028	.00494	.943	-.0158	.0102
		twice per week	-.0011	.00494	.996	-.0141	.0119
		thrice per week	-.0035	.00487	.887	-.0163	.0093
	once per week	zero	.0028	.00494	.943	-.0102	.0158
		twice per week	.0017	.00494	.987	-.0113	.0147
		thrice per week	-.0007	.00487	.999	-.0136	.0121
	twice per week	zero	.0011	.00494	.996	-.0119	.0141
		once per week	-.0017	.00494	.987	-.0147	.0113
		thrice per week	-.0024	.00487	.960	-.0152	.0104
	thrice per week	zero	.0035	.00487	.887	-.0093	.0163
		once per week	.0007	.00487	.999	-.0121	.0136
		twice per week	.0024	.00487	.960	-.0104	.0152
tug	zero	once per week	.0025	.00665	.982	-.0150	.0200
		twice per week	.0069	.00665	.724	-.0106	.0244
		thrice per week	-.0112	.00656	.324	-.0285	.0060
	once per week	zero	-.0025	.00665	.982	-.0200	.0150
		twice per week	.0044	.00665	.909	-.0131	.0219
		thrice per week	-.0137	.00656	.165	-.0310	.0035
	twice per week	zero	-.0069	.00665	.724	-.0244	.0106
		once per week	-.0044	.00665	.909	-.0219	.0131
		thrice per week	**-.0182(*)**	**.00656**	**.035**	-.0355	-.0009
	thrice per week	zero	.0112	.00656	.324	-.0060	.0285
		once per week	.0137	.00656	.165	-.0035	.0310
		twice per week	**.0182(*)**	**.00656**	**.035**	.0009	.0355

* The mean difference is significant at the .05 level.

ANOVA

Difference Chair

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.002	3	.001	6.741	.000
Within Groups	.008	69	.000		
Total	.010	72			

Multiple Comparisons
Dependent Variable: Difference Chair

Tukey HSD

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
		Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
zero	once per week	.00000	.00359	1.000	-.0095	.0095
	twice per week	-.00667	.00359	.257	-.0161	.0028
	thrice per week	**-.01360(*)**	**.00355**	**.002**	-.0229	-.0043
once per week	zero	.00000	.00359	1.000	-.0095	.0095
	twice per week	-.00667	.00359	.257	-.0161	.0028
	thrice per week	**-.01360(*)**	**.00355**	**.002**	-.0229	-.0043
twice per week	zero	.00667	.00359	.257	-.0028	.0161
	once per week	.00667	.00359	.257	-.0028	.0161
	thrice per week	-.00693	.00355	.216	-.0163	.0024
thrice per week	**zero**	**.01360(*)**	**.00355**	**.002**	.0043	.0229
	once per week	**.01360(*)**	**.00355**	**.002**	.0043	.0229
	twice per week	.00693	.00355	.216	-.0024	.0163

* The mean difference is significant at the .05 level.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	tzpre	.1161	18	.01975	.00465
	tzpost	.1167	18	.02196	.00518
Pair 2	t1pre	.1100	18	.01749	.00412
	t1post	.1178	18	.02390	.00563
Pair 3	t2pre	.1033	18	.02590	.00610
	t2post	.1156	18	.02526	.00595
Pair 4	t3pre	.1232	19	.01887	.00433
	t3post	.1321	19	.01653	.00379
Pair 5	czpre	.0722	18	.01801	.00424
	czpost	.0739	18	.01614	.00380
Pair 6	c1pre	.0750	18	.01543	.00364
	c1post	.0767	18	.01749	.00412
Pair 7	c2pre	.0700	18	.02000	.00471
	c2post	.0783	18	.01581	.00373
Pair 8	c3pre	.0689	19	.01049	.00241
	c3post	.0842	19	.01071	.00246

Paired Samples Test

		Paired Differences						df	Sig. (2-tailed)
					95% Confidence Interval of the Difference			Std. Deviation	Std. Error Mean
		Mean	Std. Deviation	Std. Error Mean	Upper	Lower	t		
Pair 1	tzpre - tzpost	-.00056	.00938	.00221	-.00522	.00411	-.251	17	.805
Pair 2	t1pre - t1post	-.00778	.02238	.00527	-.01890	.00335	-1.475	17	.159
Pair 3	**t2pre - t2post**	**-.01222**	**.01166**	**.00275**	**-.01802**	**-.00642**	**-4.447**	**17**	**.000**
Pair 4	**t3pre - t3post**	**-.00895**	**.01595**	**.00366**	**-.01663**	**-.00126**	**-2.445**	**18**	**.025**
Pair 5	czpre - czpost	-.00167	.00786	.00185	-.00557	.00224	-.900	17	.381
Pair 6	c1pre - c1post	-.00167	.00985	.00232	-.00657	.00323	-.718	17	.483
Pair 7	**c2pre - c2post**	**-.00833**	**.01383**	**.00326**	**-.01521**	**-.00146**	**-2.557**	**17**	**.020**
Pair 8	**c3pre - c3post**	**-.01526**	**.01073**	**.00246**	**-.02044**	**-.01009**	**-6.198**	**18**	**.000**

APPENDIX M

Tinetti test data

Friedman Test

Group Analysis	Mean Rank
Pretotal	1.20
Posttotal	1.80
Zeropre	1.33
Zeropost	1.67
Oncepre	1.31
Oncepost	1.69
Twicepre	1.11
Twicepost	1.89
Thricepre	1.05
Thricepost	1.95

Test Statistics

Group Analysis	Variables	Test Statistic
pretotal-posttotal	N	73
	Chi-Square	37.231
	df	1
	Asymp. Sig.	0.000
zeropre-zeropost	N	18
	Chi-Square	2.571
	df	1
	Asymp. Sig.	0.109
oncepre-oncepost	N	18
	Chi-Square	7.000
	df	1
	Asymp. Sig.	0.008
twicepre-twicepost	N	18
	Chi-Square	14.000
	df	1
	Asymp. Sig.	0.000
thricepre-thricepost	N	19
	Chi-Square	17.000
	df	1
	Asymp. Sig.	0.000

APPENDIX N

SF-36 Health Survey data

Raw data for each group and Friedman significance

	Zero		Once	
Variable	Pre-test (Mean St.Dev)	Post-test (Mean St.Dev)	Pre-test (Mean St.Dev)	Post-test (Mean St.Dev)
	64	64	65	75
Physical Functioning	18	16	17	12
Asymp. Sig.	.157		**.029**	
Limitation due to	70	79	70	77
Physical Health	25	7	31	16
Asymp. Sig.	.059		.796	
Limitation due to	66	82	90	85
Emotional Health	36	6	13	20
Asymp. Sig.	.157		.405	
Energy	60	66	62	70
	14	8	24	11
Asymp. Sig.	**.005**		.346	
Wellbeing	73	75	77	80
	16	10	14	8
Asymp. Sig.	.059		.467	
Social Functioning	79	83	85	92
	24	12	23	6
Asymp. Sig.	.157		.052	
Bodily Pain	70	78	71	79
	19	8	24	19
Asymp. Sig.	**.005**		.071	
General Health	66	72	71	75
	14	1	16	7
Asymp. Sig.	**.001**		.059	

Variable	Twice		Thrice	
	Pre-test (Mean St.Dev)	Post-test (Mean St.Dev)	Pre-test (Mean St.Dev)	Post-test (Mean St.Dev)
Physical Functioning	65	69	62	71
	29	21	24	21
Asymp. Sig.	.796		.109	
Limitation due to Physical Health	68	67	72	83
	37	36	36	24
Asymp. Sig.	.366		.206	
Limitation due to Emotional Health	69	81	74	89
	36	31	38	22
Asymp. Sig.	.083		**.006**	
Energy	69	69	59	70
	13	14	15	16
Asymp. Sig.	..285		**.018**	
Wellbeing	79	80	72	79
	12	11	20	16
Asymp. Sig.	.796		.225	
Social Functioning	83	88	87	86
	18	11	17	21
Asymp. Sig.	.134		.705	
Bodily Pain	72	78	79	88
	24	15	15	11
Asymp. Sig.	.197		.052	
General Health	72	74	66	68
	16	13	21	15
Asymp. Sig.	.617		.782	

Friedman Test; pre-test, post-test analysis

Variable	Mean Rank	Variables	Test Statistic
PF_{Pre}	1.35	N	73
PF_{Post}	1.65	Chi-Square	7.563
		df	1
		Asymp. Sig.	.006*
LPH_{Pre}	1.39	N	73
LPH_{Post}	1.61	Chi-Square	4.741
		df	1
		Asymp. Sig.	.029*
LEH_{Pre}	1.39	N	73
LEH_{Post}	1.61	Chi-Square	5.120
		df	1
		Asymp. Sig.	.024*
E_{Pre}	1.29	N	73
E_{Post}	1.71	Chi-Square	13.235
		df	1
		Asymp. Sig.	.000*
W_{Pre}	1.38	N	73
W_{Post}	1.62	Chi-Square	4.313
		df	1
		Asymp. Sig.	.038*
SF_{Pre}	1.38	N	73
SF_{Post}	1.62	Chi-Square	6.000
		df	1
		Asymp. Sig.	.014*
BP_{Pre}	1.29	N	73
BP_{Post}	1.71	Chi-Square	15.754
		df	1
		Asymp. Sig.	.000*
GH_{Pre}	1.33	N	73
GH_{Post}	1.67	Chi-Square	9.615
		df	1
		Asymp. Sig.	.002*

* = significant difference, $p > .05$