2015

The effects on strength, balance and mobility when combining whole body vibration and traditional rehabilitation for stroke patients

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by

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A Thesis

Submitted to the Faculty of Graduate Studies

Through the Faculty of Human Kinetics

In Partial Fulfillment of the Requirements for

the Degree of Master of Human Kinetics at the

University of Windsor

Windsor, Ontario, Canada

2015

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Abstract

Whole-body vibration (WBV) training is a viable option for stroke rehabilitation in improving balance, mobility and muscle strength, with a major focus to date on the lower body. This study evaluated the effectiveness of WBV training on stroke survivor's to include upper body and lower body strength, balance and mobility. 11 stroke survivors were recruited from the outpatient rehabilitation department of HDGH and were put into the WBV training group, training twice a week for 8 weeks. Participants were assessed at baseline (T1), after 8 sessions (T2), and after 16 sessions (T3). 12 participants from a database at HDGH acted as the control group and were assessed at the beginning of outpatient rehabilitation (T1) and upon discharge (T3). There were significant improvements for both the WBV training and control groups BBS and 6-minute walk. The WBV training group also experienced significant improvements on upper-extremity strength.

Acknowledgments

I would like to express my sincere appreciation to my advisor, Dr. Patti Weir, who has provided me with countless amounts of guidance and support throughout my academic career. Thank you for all your words of encouragement and for allowing me to grow as an individual throughout these past few years. I would also like to thank my committee members, Dr. Kenji Kenno, Dr. Nancy McNevin, and Dr. Debbie Kane. I truly appreciate your contributions to my thesis.

This project would not have been possible without my stroke participants, the co-operation of the outpatient rehabilitation department at Hôtel-Dieu Grace Healthcare, Mr. Jason Petro, Miss. Lisa Halley, and my research assistances, Mr. Evan Gammon, Miss. Kristy Smith, and Miss. Kelly Carr. I would also like to thank Dr. Nancy McNevin for the statistics assistance.

Thank you to my friends and lab mates for your assistance and words of encouragement throughout these past few years. Lastly, to my parents, Joanne and Steve, the person I am and the things I have accomplished are because of you. Your endless support, guidance and unconditional love are never overlooked and I am truly grateful to have you in my life.

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List of Abbreviated Terms

α MN = alpha motor neurons

ADLs = activities of daily living

ANOVA = analysis of variance

BBS = Berg Balance Scale

BL = baseline

BP = blood pressure

DBP = diastolic blood pressure

EMG = electromyography

FIN = functional independence

Hz = hertz

ICH = intracerebral hemorrhage

mm = millimeters

MS = multiple sclerosis

PD = Parkinson's disease

SAH = subarachnoid hemorrhage

SBP = systolic blood pressure

SPSS = Statistical Package for Social Sciences

TIA = transient ischemic attack

tPA = tissue plasminogen activator

TUG = timed up-and-go test

WBV = whole-body vibration

Chapter One

Introduction

Throughout the years, a shift in the world's population demographics has developed. In Canada, this increase in the aging community is beginning to accelerate. As the population continues to age, it is expected for the number of seniors aged 65+ to rise substantially by 23 – 25% in 2036 (Statistics Canada, 2010). This upsurge is due to both the improvement in mortality rates and the rise in birth rates after the Second World War, which introduced the world to the baby boomer generation (Phillipson, 2007). Although there has been an average increase of three months per year in human life expectancy, this does not mean that people are living these additional years in a state of optimal health (Fries, 1980; Jette & Branch, 1981; Oeppen & Vaupel 2002; Baker, Meisner, Logan, Kungl, & Weir, 2009). In fact, more than 70% of Canadians over the age of 60 report having at least one chronic condition and 49% of those 65+ years having two or more chronic illnesses (Broemeling, Watson, & Prebtani, 2008). This high rate of chronic conditions among the older population is not surprising since many are associated with aging.

Two of the most prevalent chronic conditions for individuals over the age of 65 years are heart disease (25%) and stroke (5%) (Gilmour & Park, 2006). In particular, stroke is currently the third leading cause of death in Canada and is a major cause of acquired disability (Public Health Agency of Canada, 2011). Each year there are an estimated 50,000 Canadians who suffer a stroke, with over 14,000 resulting in death. With these statistics, there are approximately 315,000 Canadians living with the effects of stroke (Public Health Agency of Canada, 2011). Since the effects of a stroke can be severely detrimental, it is important to know the risk factors as well as signs and symptoms of stroke in order to reduce the prevalence.

When a stroke takes place one of two risk factors must be present; either arterial degeneration (thickening of the inner arterial lining caused by plaque formation) or severe high blood pressure (BP - hypertension) (Carter, 1968). In terms of arterial degeneration, elevated blood cholesterol, in particular atherosclerosis, is a major contributor. Once the formation of plaque is initiated, an individual with atherosclerosis can experience narrowing of the artery which impedes blood flow (Carter, 1968; Edlow, 2008; Silva, Koroshetz, González, & Schwamm, 2011). The condition of hypertension can double or even triple the likelihood of the individual to experience a stroke and is measured as the force of blood against the walls of blood vessels (Hodgson, 1998; Caplan, 2007; Public Health Agency of Canada, 2009). When a stroke does take place, the identification of symptoms is essential for timely treatment. The time passed from the onset of symptoms and delivery of treatment directly influences the degree of damage. Therefore, being able to identify symptoms associated with a stroke is imperative for recovery. The three primary warning signs are the sudden onset of: (1) difficulty with or loss of speech; (2) loss of vision in one eye or on one side of visual field; and (3) weakness or loss of strength or power in the face, arm or leg (Canadian Stroke Network, 2011). Other symptoms include sudden loss of sensation in face, arm or leg, a sudden, severe and unusual headache, and a sudden loss of balance or sense of vertigo, especially when accompanied with other symptoms (Heart and Stroke, 2011; Canadian Stroke Network, 2011). These symptoms vary depending on the type and the location where the stroke takes place.

A stroke occurs when the brain is abruptly deprived of blood and unable to function properly, resulting in neurological deficits (Edlow, 2008). There are two categories of strokes, each with their own list of subtypes: ischemic and hemorrhagic. Ischemic strokes take place in nearly 80% of all strokes and involves blockage of blood supply and energy caused by a clot (Edlow, 2008; Canadian Stroke Network, 2011; Heart and Stroke, 2011). The subtypes of ischemic strokes are: embolic, atherosclerosis, and lacunar (Carter 1968, Edlow, 2008, Silva et al., 2011). The remaining 20% of strokes are classified as hemorrhagic, where uncontrolled bleeding takes place in the brain and leaks out to accumulate and compress tissue, killing brain cells (Heart and Stroke, 2008). There are two subtypes of hemorrhagic stroke: intracerebral and subarachnoid. The strokes pathophysiology is not only important for classification, but for determining the outcomes following the stroke.

The consequences of a stroke range from cognitive to physical impairments. Motor weakness or impairment, either isolated or with other symptoms, is the most common problem (Bohannon, 2007; Langhorne, Bernhardt, & Kwakkel, 2011). One outcome of stroke that impacts the ability for proper gait technique is spasticity. This condition induces an increase in tonic stretch reflexes and exaggerated tendon jerks that result in uncontrollable muscle spasms (Chan et al., 2011). With major physical implications, stroke patients often engage in a more sedentary lifestyle, contributing to secondary complications. For this reason, it is important for stroke survivors to engage in a rehabilitation or physical activity program to regain proper function.

Whole body vibration (WBV) training is an alternative form of resistance training and typically involves performing static and/or dynamic exercises on a vibrating platform

(Lorenzen, Maschette, Koh, & Wilson, 2009). There are two styles of vibration platforms: side-altering and synchronous. Synchronous platforms have a vertical (up and down) stimulus, while the side altering platform has an asynchronous (teeter totter) stimulus while balancing around a central point (Cardinale & Wakeling, 2005; Lorenzen et al., 2009; Rauch et al., 2010). Typically vertical oscillations (frequency [Hz] x amplitude [mm]) are transferred through the legs towards the body, activating the neuromuscular system (Roelants, Delecluse, & Verchueren, 2004; Lachance, Weir, Kenno, & Horton, 2012). Exposure to the vibration causes alterations in the body's tissues, by providing both musculoskeletal and neural overloads (Signorile, 2006). In response to the oscillations, muscles experience a tonic excitatory effect (Torvinen et al., 2002; Signorile, 2006). This reaction to the vibration stimulus in the muscles has been termed the tonic vibration reflex (Signorile, 2006). Interestingly, when WBV is paired with a common task, such as squatting, the amplitude of muscle activity, as reflected in electromyographic (EMG) recordings, increases significantly (Signorile, 2006; Hazell, Jakobi, & Kenno, 2007). This elevated EMG activity can be explained by the fact that vibration is most effective when the targeted muscles are stretched or lengthened (Nordin & Hagbarth, 1996). When comparing this WBV training to traditional forms of exercise, WBV is superior in terms that it requires less time to administer and less stress or effort of the participant (Signorile, 2006).

To date there are only a few studies that used WBV training on stroke patients. In these studies, WBV was performed independently of any traditional rehabilitation however, positive benefits were reported following as few as one session of training. It has been shown that with the use of WBV, those who are living with the effects of stroke can receive improvements in walking performance. Such improvements were seen in ankle spasticity, gait speed, balance, and overall mobility (Chan et al., 2011; Merkert, Butz, Niecza, Steinhagen-Thiessen, & Echardt, 2011; Lau, Yip, & Pang, 2012; Miyara et al., 2014). Often following a stroke, patients experience weakened lower extremities, making weight bearing movements more difficult. However, WBV training has shown to strengthen lower limbs through heightened EMG activity during sessions (Tihanyi et al., 2007; Lau et al., 2012; Tankisheva et al., 2013; Liao, Lam, Pang, Jones, & Ng, 2013). Due to these benefits, WBV training should be further investigated to identify if it is indeed a feasible therapeutic alternative.

Therefore, the purpose of the current study was to evaluate the effectiveness of combining WBV training with traditional rehabilitation therapy on upper and lower body strength, balance, and functional movement in stroke patients. The effectiveness of the intervention was analyzed during two measurement periods, the first half (T1-T2) and the second half of the study (T2-T3). It is hypothesized that both the traditional rehabilitation and the traditional rehabilitation + WBV training groups would show improvements in balance, and mobility. However, it is speculated that the supplementary WBV training will be superior in generating improvements. Furthermore, it is hypothesized that the WBV training group will also experience improvements in strength.

Methods

Participants.

Upon receiving approval from both the University of Windsor Research (REB # 10-021) and Hôtel-Dieu Grace Healthcare (HDGH) Ethics Boards, the investigator visited the outpatient rehabilitation facility at HDGH. This department was chosen as their program supports the recovery stages of stroke from inpatient through outpatient rehabilitation. Patients attending the outpatient rehabilitation program were targeted because in order to be considered eligible, patients must have completed their prescribed inpatient rehabilitation before moving onto outpatient rehabilitation. Following a summary of what the research study entailed, the physician in charge of stroke rehabilitation identified and recruited suitable participants from the outpatient rehabilitation department. Those who were interested in participating were informed verbally and in a letter of information, which outlined the training and measurement protocols, as well as the possible risks and benefits of the study. Eligible individuals then completed a consent to participate in research form (please see Appendix A).

Eleven volunteer stroke survivors (3 males and 8 females; age range: 40-85 years; mean age: 65.3 ± 12.4 years) were recruited from the outpatient rehabilitation department of HDGH, in Windsor, Ontario. Apart from completing their prescribed inpatient rehabilitation (average of 32.3 days), participants were required to be able to stand independently for one minute in order to qualify for the study. Participants must also have been free of the following conditions: cancer, pregnancy, have an active infection, suffer from gall or kidney stones, or have a recent (less than 6 months) joint replacement. These eleven participants were then asked if they would be interested in supplementing their regular rehabilitation with WBV training and were assigned into the traditional rehabilitation + WBV training group.

Due to recruitment problems, the control group was created using anonymized data from a database kept by the physician in charge of stroke rehabilitation at HDGH. A traditional rehabilitation control group could not be created for two primary reasons: First, there was a large waitlist for patients to be enrolled into the outpatient rehabilitation programs at HDGH (i.e., ~3 months for physiotherapy and ~6 months for occupational therapy). These long waitlists could have been attributed to a shortage in staff as one therapist was often catering to more than one patient at a time. Second, at the time of the study, a lot of the strokes that had happened were very severe and patients were physically unable to stand independently for one minute. Therefore, twelve participants from the database were matched on sex and age, and had met the requirement to stand independently for one minute upon discharge from inpatient rehabilitation.

Equipment.

The WBV exercises were done using the WAVE Pro® (Wave Manufacturing Inc, Windsor, Ontario, Canada), which is a vertically oscillating vibration platform (36" X 30") with a maximum load of 1500 lbs. The WAVE Pro® automatically calibrated to the individual's size and weight, which resulted in consistent vibration effects each session. The WAVE machine had two options for amplitude (2 mm =low; 4 mm = high), and an adjustable frequency ranging from 20 to 50 Hz which increased in 1 Hz intervals (WAVE Pro-WAVE Manufacturing, 2006). The WAVE machine was also equipped with a wraparound handle that participants were able to hold onto (either with one of both hands) while on the vibrating platform (please see Figure 1).

Those in the WBV group were required to use a fitted harness which was worn around their waist while on the vibration platform. The fitted harness was attached to the ceiling's supportive steel frame with a metal chain. During the training, if a participant were to ever become off balance, the harness would have caught and prevented them from falling. In between each set, participants sat on a bench to rest before beginning the next set.

WBV Training + Traditional Rehabilitation Group.

On days of training, the traditional rehabilitation + WBV training group participated in their regular outpatient rehabilitation program at the hospital. Participants were enrolled in either physiotherapy which heavily focused on lower body strength, or occupational therapy which focused more on upper body strength and coordination. Some of the participants were enrolled in both occupational therapy and physiotherapy. Both outpatient rehabilitation options were one hour sessions. Once the traditional rehabilitation was completed, participants did an additional 15 minute session using vibration training. To help control for variability among participants, training sessions were performed at the same time of day, under same conditions, and with the same training investigators. For safety precautions, two investigators were always at each session.

The WBV training program involved participants receiving 16, 15 minute training sessions two times per week as part of their normal rehabilitation schedule, for a total of eight weeks. The participants performed all exercises as dynamically as possible. Dynamic exercises result in greater muscle activation with WBV training than static exercises (Hazell et al., 2007; Hazell, Kenno & Jakobi, 2010), and were chosen to be representative of natural movement performed in activities of daily living. The exercises participants performed were squats, heel raises, bicep curls, and tricep extensions (please see Figures 2 – 5). Participants were required to wear the same pair of running shoes during each session in order to control for any vibration discrepancies.

Prior to performing any exercises, the WAVE automatically calibrated to the participant's weight, and participants performed a 30 second hamstring stretch for each leg. To perform the hamstring stretch, one foot was placed onto the platform with the leg straight and toes pointing towards the ceiling. With the opposite leg slightly bent, participants leaned towards their foot, flexing at the hips. In this position, participants experience a stretch in the hamstring muscle (Bissonnette et al., 2010). In order to ensure proper technique, each exercise was explained and demonstrated by the investigator. Once the participant was in the proper exercise position, the platform is set to the desired duration, frequency, and amplitude before turning it on.

During each dynamic exercise, participants performed two trials for 30 seconds each at the respective frequency and amplitude. For the first two weeks of training, each exercise was performed at a frequency of 35Hz and a low amplitude of 2mm. The next four sessions continued to be performed at a low amplitude however, the frequency will increase to 40Hz. Sessions 9-12 remained at a low amplitude and the frequency will be further increased to 45 Hz. Finally, sessions 13-16 were performed with a high amplitude of 4mm at a frequency of 35 Hz.

Lower body exercises:

Squat. Participants performed the squat with feet placed shoulder-width apart, knees slightly bents at approximately 60˚, back as straight as possible, and head facing forward (Verschueren et al., 2004; Tankisheva et al., 2013). Once this position was achieved, participants returned to an upright standing position (please see Figure 2). This movement was repeated throughout the 30s. While performing this movement, participants held onto the support bar of the machine so balance and proper technique was maintained.

Heel Raise. Heel raises were performed by participants standing up on their toes, back straight, and knees slightly bent (please see Figure 3). The slight bend in the knees allowed for the vibration to not resonate throughout the subject's body (Bissonnette et al., 2010). The heel raise was complete once the participant returned their heels back down to the platform and this movement continued for the entire 30s. During upper body exercises, participants stood beside the platform or sat in a chair and held a pair of nylon straps that were directly attached to the vibrating surface of the platform. While holding the straps, subjects were instructed to perform, to the best of their abilities, dynamic bicep curls and tricep extensions.

Bicep Curls. To perform the bicep curls, participants grasped the two handles of the straps. To complete this exercise, arms were first straight and down beside the participants sides (please see Figure 4). Participants then proceed to flex the arms so that the elbow are bent at 90 ˚ and close to their sides (Bissonnette et al., 2010; Lachance et al., 2012a). Once this was achieved, participants returned their arms back to the starting position. This movement was repeated throughout the allocated time interval.

Tricep Extensions. Participants grasped the two straps by the handles with both arms straight and down at their sides, and palms facing forward (please see Figure 5). To perform the tricep extensions, participants extended both arms posteriorly until a there is a 30˚ angle between torso and upper arms (Bissonnette et al., 2010; Lachance et al., 2012a). Once this was achieved, arms were brought back anteriorly to be in line with the sides of their body. This motion was repeated throughout the prescribed time.

Functional Assessment.

The investigator evaluated the participants on the following measures at baseline (T1), after 8 training sessions (T2), and then finally after 16 sessions (T3).

BERG Balance Score (BBS). The BBS is a 14-item scale that quantitatively assessed balance and risk for falls in the older community-dwelling adults, and patients with acute stroke. Assessments were done through direct observation of performance and required 10 to 20 minutes to complete and measure patient's ability to maintain balance (please see Figure 6). The BBS measured both static and dynamic characteristics of balance and items were scored on a 5-point ordinal scale ranging from 0 to 4 (0 = inability to complete task; 4 = independent item completed). The highest possible score is 56 and scores of 0-20 signify balance impairments, 21-40 represent acceptable balance, and 41- 56 good balance (Berg, Wood-Dauphinée, Williams, & Maki, 1992). When using BBS for the stroke population, the BBS has been reported to have excellent internal consistency, inter and intra-rater reliability, test-retest reliability, construct validity, and excellent correlations with other measures of impairment (Mao, Hsueh, Tang, Sheu, & Hsieh, 2002; Usuda et al., 1998; Blum & Korner-Bitensky, 2008).

8-foot Timed Up-and-Go Test (TUG). Assessed mobile agility and dynamic balance (Rikli & Jones, 2001). Participants were instructed to raise from an armless chair walk as quickly as possible around a pylon located 8 feet away, turn, walk back to the chair, and return to a seated position (please see Figure 7). Prior to the two test trial, participants were allowed one practice trial for familiarization. Of the two test trails, the faster trial (to the nearest tenth of a second) was used for evaluation purposes (Rikli & Jones, 2001).

Arm Curl Test. Measured upper-body strength (Rikli & Jones, 2001). A chair, without armrests was placed against a wall to provide stability and prevent slipping. Participants sat on the chair with their backs straight and feet flat on the floor. Participants held a dumbbell down by their side, palm facing their body. To perform the bicep curl, participants gradually rotated their forearm so the dumbbell was facing forward during flexion. The dumbbell was then returned to the starting position (please see Figure 8). Participants were allowed practice this movement for one or two repetitions without the weight to ensure proper form. Scoring was based on the total number of arm curls performed in 30 seconds and only one trial is administered. Both arms were tested. Women used a 5-lb dumbbell and men an 8-lb dumbbell. If participants are unable to safely carry out the movement, the weight of the dumbbell was dropped to 3-lbs and 5-lbs.

Tricep Extension Test. (Adapted from the arm curl test). Evaluated upper-body strength and endurance. The participants were required to perform as many tricep extensions as possible in 30 seconds. While standing in front of a chair for support, participants held a dumbbell in their hand, palm facing their body (please see Figure 9). Beginning with their arm at 90˚, participants extended their hand posteriorly to straighten the arm (Lachance et al, 2012a). Both arms were tested. Women will use a 5-lb dumbbell and men an 8-lb dumbbell and the score reflects the total number of extensions completed within the 30 seconds (Rikli & Jones, 2001).

***6-minute Timed Walk*.** Assessed mobility in terms of aerobic endurance and therefore, was performed after all other tests were completed (Rikli & Jones, 2001). Once the "go" signal was initiated, participants begin to walk as fast as possible, to cover as much distance as possible within the 6-minute limit. Distance was recorded using a measuring wheel which the investigator held as walked beside the participant (please see Figure 10). If needed, participants were allowed to stop and rest however, the time continued to run. Once the 6-minutes were finished, participants slowly march in place for a one minute cool down.

Traditional Rehabilitation Control Group.

Those in the traditional rehabilitation control group were measured on the BBS and 6-minute timed walk test at the beginning of outpatient rehabilitation (T1) and upon discharge (T3).

Qualitative Assessment.

Upon completing the study, participants in the traditional rehabilitation + WBV training group were given a questionnaire that looked at how physical health and quality of life before, directly after the stroke (inpatient rehabilitation), and now (outpatient rehabilitation) (please see Figure 11). The questionnaire also asked how the participants' experience was with using the WAVE and if they would recommend it to other. Each question was measured on a 5-point likert scale ranging from 0 (poor) to 4 (excellent).

Statistical Analyses.

In order to determine the effects of WBV training and traditional rehabilitation, all data was analyzed using the Statistical Package for Social Sciences (SPSS) for Windows, version 21 (Chicago, IL). To examine differences in strength and dynamic balance, pre-planned comparisons were performed on all dependent measures for T1 vs T2 and T2 vs T3. In order to determine if there was a difference between the traditional rehabilitation + WBV training group and the traditional rehabilitation group, a mixed ANOVA with repeated measures on time was performed on the BERG balance score and the 6-minute timed walk test. Main effects and interactions were considered significant at an alpha level of 0.05.

Results

Participant Characteristics and Adherence.

Demographic data on the 23 participants can be found in Table 1. Eleven participants were in the traditional rehabilitation + WBV training group, (3 males and 8 females, mean age of 65.3 ± 12.4 years). Two of the eleven participants were unable to complete the last four weeks of the intervention due to completion of their outpatient rehabilitation; however, their data up to that point was included in the analysis. Two additional participants were physically unable to perform any of the upper body exercises as their affected arm had to be in a sling at all times to support the shoulder joint. For this reason, these two participants only took part in exercises and tests associated with the lower limbs. The traditional rehabilitation control group was comprised of twelve participants chosen from an anonymized database kept by the physician in charge of stroke rehabilitation at HDGH, (6 males and 6 females, mean age of 65.1 ± 13.1 years). This group's scores for the BERG balance scale and 6-minute timed walk test were done at the beginning (T1) of outpatient therapy and at discharge (T3). These scores were included in the analysis. Table 1 shows a summary of the participants' characteristics as well as the number of participants per measure for each testing interval.

Participant Outcome Measures.

Performance scores of the traditional rehabilitation + WBV training and traditional rehabilitation control groups control at measurement periods are shown in Table 2. Pre-planned comparison results for strength, balance and mobility for the traditional rehabilitation + WBV training group are shown in Table 3.

8-Foot Timed Get Up and Go Test (TUG). The WBV training group did not experience any statistically significant improvements in their TUG test.

Bicep Curl Test. After 16 sessions, the WBV training group did not experience any statistically significant improvements in their right bicep curl tests. The WBV training group did however have a statistically significant improvement in their left bicep curl tests. Pre-planned comparison revealed a significant increase during T1-T2 (3.0 ± .764 curls) (see Table 3).

Tricep Extension Test. Both left and right arms experiences significant improvements in strength following WBV training. However, through pre-planned contrasts, it was discovered that these improvements were seen at the T2-T3 time intervals (see Table 3). Participants experienced a significant increase in their right arm (2.41 ± .77 extensions) and in their left arm (2.46 ± .65 extensions).

The results comparing the traditional rehabilitation + WBV training and traditional rehabilitation control groups for balance and mobility are shown in Table 4.

BERG Balance Scale (BBS). After 16 sessions, the WBV training group experienced significant improvements of 17.4% in their BBS. This trend from T1 – T3 was also seen in the traditional rehabilitation group with an improvement of 10.3%. Therefore, this suggests that there was a significant time main effect as both groups improved ($F(1, 21) = 28.38$, $p < .001$). When looking at the two groups individually, there was no significant group main effect, ($F(1, 21) = 1.67$, $p = .210$), or no interaction between time and group ($F(1, 21) = 1.29$, $p = .268$).

Six Minute Walk Test. Both the WBV training group and the traditional rehabilitation group saw a significant improvement in mobility between T1-T3. The mixed ANOVA revealed a significant main effect for time ($F(1, 21) = 25.18$, $p < .001$). Although both groups saw improvements, no group was superior ($F(1, 21) = .451$, $p < .509$), and there was no interaction between group and time ($F(1, 21) = 2.93$, $p < .102$).

Table 1

A) Participant Characteristics; B) Total Number of Participants per Measure at Each Testing Interval

A) Characteristic	**Total (*n*= 23)**	**WBV (*n* = 11)**	**Control (*n* = 12)**
Male / Female (*n*)	9 / 14	3 / 8	6 / 6
Age (mean / SD)	65.2 (12.5)	65.3 (12.4)	65.1 (13.1)
Affected Side			
Left (*n*)		5	
Right (*n*)		6	
Duration of Inpatient Rehab (days / SD)		32.3 (17.6)	
Outpatient Rehab Enrollment			
Physiotherapy (*n*)		4	
Occupational Therapy (*n*)		6	
Both (*n*)		1	
Chedoke-McMaster Score			
Leg (mean / SD)		3.1 (1.5)	
Foot (mean / SD)		3.0 (1.5)	
Arm (mean / SD)		4.4 (1.7)	
Hand (mean / SD)		3.7 (1.6)	
B) Measure	**T1**	**T2**	**T3**
BBS (*n*)	11	11	9
TUG (*n*)	11	11	9
Bicep Curl Test (*n*)	9	9	7
Tricep Extension Test (*n*)	9	9	7
Six Minute Walk Test (*n*)	11	11	9

Table 2

Performance Scores for both WBV Training and Control Groups across the Measurement Periods

Measure	**T1**		**T2**	**T3**	
	WBV (n = 11)	Control *(n = 12)*	WBV (*n* = 11)	WBV (*n* = 11)	Control *(n = 12)*
BBS (# out of 57)	41.6 (9.5)	45.8 (5.2)	47.6 (5.4)	48.9 (5.2)	50.5 (1.7)
TUG Test (seconds)	18.5 (13.8)		15.4 (11.7)	15.7 (11.2)	
Right Bicep Curl Test (# of curls)	15.9 (5.8)		18.7 (5.7)	18.9 (1.8)	
Left Bicep Curl Test (# of curls)	16.9 (4.7)		19.9 (3.7)	20.4 (3.5)	
Right Tricep Extension Test (# of extensions)	16.6 (5.9)		17.5 (2.7)	19.9 (2.4)	
Left Tricep Extension Test (# of extensions)	16.4 (4.3)		18.2 (2.4)	20.9 (2.2)	
Six Minute Walk Test (meters)	246.4 (129.7)	199.5 (69.3)	274.2 (132.1)	284.1 (130.9)	276.2 (60.3)

Note: Values are mean (standard deviation). The two participants in the WBV groups that dropped out, the groups average was used for T3 on all measures so that they could be included in the analysis.

Table 3

Pre-Planned Comparison Results for Strength and Dynamic Balance

	T1-T2			**T2-T3**		
Measure	Mean Difference	Standard Error	*p*-Value	Mean Difference	Standard Error	*p*-Value
TUG (seconds)	- 3.16	1.27	.09	- .31	.83	1.00
Right Bicep Curl (# of curls)	2.78	1.16	.13	.19	1.84	1.00
Left Bicep Curl (# of curls)	3.00	.76	.01*	.54	1.85	1.00
Right Tricep Extension (# of extensions)	.89	1.63	1.00	2.41	.77	.04*
Left Tricep Extension (# of extensions)	1.78	1.59	.84	2.64	.67	.01*

Note: * represents statistically significant, p <0.05.

Table 4

Results of Comparing WBV Training vs Control Group for Balance and Mobility during T1-T3

	Time Main Effect		**Group Main Effect**		**Group x Time Interaction**	
Outcome Measure	*F* Statistic	*p* – Value	*F* Statistic	*p* – Value	*F* Statistic	*p* – Value
BBS (# out of 57)	(1, 21) = 28.36	.00 *	(1, 21) = 1.67	.21	(1, 21) = 1.29	.27
6-Minute Walk Test (meters)	(1, 21) = 25.18	.00 *	(1, 21) = .45	.51	(1, 21) = 2.93	.10

Note: * represents statistically significant, p <0.05.

Effects of WBV training from Qualitative Perspective.

All 11 participants from the WBV training group were asked to complete a questionnaire upon completion of the exercise sessions (please see Figure 11). The two participants who were unable to complete the intervention filled out the questionnaire after their last session (T2). In terms of physical health, 54.5% believed they had "very good" physical health prior to their stroke however, this rating diminished to "poor" (81.8%) once they had their stroke and were in inpatient rehabilitation. On a positive note, 54.5% would rate their physical health as "good" now that they are in outpatient rehabilitation. Similarly, a majority of participants ranked their quality of life as "very good" (45.5%) or "excellent" (36.4%) prior to their stroke. This feeling however plummeted to "poor" (45.5%) once they had their stroke but rose to "very good" (54.5%) now enrolled in the program.

All 11 participants rated their experience with using the WAVE as either "excellent" (54%) or "very good" (45.5%) and believed that they had gained improvements to their physical functioning (81.8%). Lastly, all 11participants stated that they would indeed recommend the WAVE to others.

Overall, participants believed that the WAVE was a positive experience. Some of the comments included: "it helped me feel again in areas that were numb after the stroke", "it helped me mentally, physically in the leg/arm, decreased my pain and improved walking", and "the WAVE was relaxing". Several of the participants also vocalized how they enjoyed using the WAVE as it was something new and that it was a nice change to the repetitive physiotherapy or occupational therapy routines. Participants also stated that they were able to do everyday activities a lot easier at home.

Discussion

Traditionally, the aim of whole-body vibration (WBV) research was to investigate the effects on strength and power for athletes. Due to a progressive shift to understand the available benefits to those with motor impairments, WBV research has begun to look at clinical populations such as multiple sclerosis, Parkinson's disease, and more recently, stroke (Wood, Bilclough, Bowron, & Walker, 2002; Turbanski et al., 2005; Schuhfried, Mittermaier, Jovanovic, Pieber, & Paternostro-Sluga, 2005; Novak & Novak, 20 06; Wunderer, Schabrun, & Chipchase, 2010; Chan et al., 2011; Merkert et al., 2011; Lau et al., 2012; Tankisheva et al., 2013). Therefore, the purpose of this study was to examine the effects of combining traditional rehabilitation with WBV training on upper and lower body strength, balance and mobility for individuals living with the effects of stroke.

Throughout the study, the traditional rehabilitation control group and traditional rehabilitation + WBV training group generated positive results. Both groups saw significant improvements in balance and mobility through the BBS and 6-minute timed walk test. Our data supported the hypothesis that both the control and the traditional rehabilitation + WBV training group would show improvements in balance and mobility. Although both groups saw improvements, no group was superior, therefore, not supporting a priori hypothesis that supplementary WBV training would be better in generating improvements. During the 16 sessions of WBV training, significant improvements in upper body strength was experienced and reflected in the left bicep curls both left and right tricep extensions. These results therefore support the hypothesis that the traditional rehabilitation + WBV training group would obtain enhancements in upper body strength.

The measurement tests used for this current study were part of the Seniors Fitness Manual which allows investigators to identify whether an older adult may be at risk for loss of functional ability. Although participants did not achieve statistical significance on some tests, their scores can be compared to the manuals performance standards. Throughout the entire intervention (T1, T2, T3), both the traditional rehabilitation + WBV training and the traditional rehabilitation control group were severely under the normal range for the 6-minute times walk test. As Table 2 depicts, scores ranged from 199.5 – 284.1 meters where the normal range for those 60-89 years is between 340 – 700 meters. Furthermore, both of these groups fall in the “risk” zone as they walked less than 320 meters (Rikli & Jones, 2001). Participants in the traditional rehabilitation + WBV training group also landed drastically under the normal range for TUG times. These participants scored between 15.4 – 18.5 seconds, where the normal range is 4.4 – 8.9 seconds for those between the ages of 60-89 years. Again, these scores put the traditional rehabilitation + WBV training group into the “risk” zone as they had a time of more than 9 seconds (Rikli & Jones, 2001). Since the targeted population in this study were already impaired, the use of the Senior Fitness Manual tests could have not been sensitive enough to detect changes in physical performance. What the results do suggest however, is that these participants may still be at risk of falls and mobility problems.

Many studies have examined the effects of WBV training on muscle strength. The theory behind this phenomenon states that through vibration exposure, a change in muscle length can be observed by stimulating the muscle spindles (Cardinale & Bosco, 2003; Cardinale & Lim, 2003; Rittweger, 2010; Hazell et al., 2010). This stimulation ultimately leads to an upsurge in muscle activity. This increase in muscle activity is heightened further during activities in which the muscle is stretch or lengthened (Nordin & Hagbarth, 1996). It is this upsurge in muscle activation that is believed to be responsible for enhancing muscle strength. Often researchers target the lower limbs when investigating muscle loss following stroke (Tihanyi et al., 2007; Lau et al., 2012; Tankisheva et al., 2013). However, it is the bimanual control of the upper extremities, in combination with the lower limbs that are required in order to perform many activities of daily living (ADL).

To this date, there are no studies that have examined the effectiveness of using WBV training to improve muscle strength on the upper extremities for stroke survivors. Nevertheless, studies such as Bissonnette et al. (2010) and Lachance et al. (2012a) have used this protocol (two 15 minute training sessions per week for 8 weeks) on older adults to inquire about the impact of WBV training on upper body strength. In both studies, the WBV groups showed improvements in the number of times the weight could be lifted in the arm curl test, supporting positive changes in biceps strength enhancement. With the exception of this study, Lachance et al. (2012a) was the only other study to incorporate tricep extensions to test upper limb strength. Although significant improvements in upper body strength were obtained in the current study, the time period in which these gains occurred differ from previous research. In the studies of Bissonnette et al. (2010) and Lachance et al. (2012a), the healthy older adults saw upper body strength improvements for both bicep curls and tricep extension tests across all time periods (T1-T2 and T2-T3). In contrast, in the current study improvements in upper body strength only occurred during one time period for each test. The improvements in bicep curls was only significant for the left arm and during T1-T2, while both arms received significant increases for tricep extension test during T2-T3. Causation to why the improvements were only seen during certain time intervals could have been attributed to using stroke survivors as participants.

Since stroke survivors are often left with one weakened side, it could be expected for this side to have fewer muscle strength gains. More than half (55%) of participants in the traditional rehabilitation + WBV training group stated that their right side was affected from the stroke therefore, this could explain the heightened improvements to the left arm. Participants could have had more mobility, flexibility and strength in the unaffected left side following the stroke, especially if they are now relying on that limb to fulfil everyday tasks. These reasons could be the contributing factors behind the strength gains. As for the timing in which these gains were observed, a delay in muscle activation is often exhibited during the first few months post-stroke (Wagner, Dromerick, Sahrmann, & Lang, 2007). Following this initial time period, the onset of muscle activation was improved, leading to performance enhancements and could account for why the traditional rehabilitation + WBV training group experienced upper body strength gains later on. While significant improvements were found, it cannot be said if these gains were solely due to WBV training as the control group was not measured on upper body strength.

Participants can take the strength improvements obtained through the WBV training back into their everyday lives as upper extremity strength is important for being able to perform many ADL. Upper limb, particularly tricep strength is especially important for tasks such as your arms to push and rise from a seated position. Although there was not a retention period to investigate whether the strength improvements were maintained, previous research indicates that such gains were preserved four-weeks after WBV training (Carr et al., 2012).

Following a stroke, individuals often adopt a more sedentary lifestyle due to major physical impairments which contribute to secondary complications. A secondary complication which is often associated with the older population are falls. Following a stroke, individuals experience change in their gait patterns and balance which increase the risk of falls (Eng et al., 2003; Gordon et al., 2004; Tankisheva et al., 2013). Since one of the strategies of many outpatient rehabilitation services is to implement a fall prevention and management program, the use of WBV training should be considered as it significantly improved both balance (BBS) and mobility (6-minute walk test) in the present study. Even though the results of the present study reflected significant improvements in the BBS, participants in the control group improved at the same rate. These results are consistent with the study by van Nes et al., (2006), where the WBV training and exercise therapy on music had similar balance recovery profiles in the post-acute phase of stroke.

Outpatient and community-based stroke rehabilitation often focus on person-centered re-engagement in and attainment of the patient's desired life which includes activities and roles (Canadian Stroke Best Practices, 2013). This is an important part of recovery since many stroke survivors have multiple physical impairments which restrict their ability to interact in their community. Without this constant engagement, individuals can experience a loss of identity and reduced quality of life (QOL). In the present study, participants in the traditional rehabilitation + WBV training group were asked to rate their QOL before the stroke, while in inpatient rehabilitation and now while in outpatient rehabilitation. It did not come as a surprise that the ratings of QOL plummeted while in inpatient rehabilitation. However it is encouraging that 54.5% stated their QOL to be "very good" now enrolled in the traditional rehabilitation + WBV training program.

Although the WBV training could be not be addressed as the sole causation of the improvements observed, the use of this training left a positive note for those who experienced it. Following study completion, all 11 participants in the traditional rehabilitation + WBV training group were given the chance to rate their own physical health. Although their ratings for physical health suffered during the time they were in inpatient rehabilitation, their scores greatly improved once in outpatient rehabilitation and using WBV training. These changes to their self-reported physical health could have been due to a heightened self-efficacy, defined as a judgment of one's ability to execute types of performances (Salbach et al., 2006). Self-efficacy has been considered as important as physical ability to influence the decision of engaging in various activities. Therefore, participants might have rated their physical health higher because they believed the supplementary WBV training produced an increase in physical functioning.

Since the availability of rehabilitation services seem to be less than optimal, initiatives need to be done in order to improve funding. Understaffing of trained personnel was most likely the contributing reason behind the long outpatient rehabilitation waitlists as therapists must divide their attention among patients. Since it is not uncommon for physiotherapists in Southwestern Ontario to be responsible for 10 or more rehabilitation patients, therapists are set up for failure in providing the allocated amount of time of treatment (Teasell,, Foley, Salter & Jutai, 2008). This is a key example of why funding needs to be improved for rehabilitation departments. Without improvements in the availability, those who are in dire need of rehabilitation will slip through the healthcare cracks and will continue to decline in their recovery journey.

In summary, this study provided additional evidence as to the effectiveness of WBV training on increasing upper body strength, balance and overall mobility for stroke survivors. This study however cannot associate these improvements solely to the WBV training as the control group did not have data for three (bicep curls, tricep extensions, and TUG) of the five measures. Of the two measures that were able to be compared between the groups, the traditional rehabilitation + WBV training was just as effective as the traditional rehabilitation.

Limitations and future research.

Due to the clinical setting of the study, randomization of the participants became problematic. Initially, this study was intended to be a randomized control trial. However, in order to obtain a large enough sample size, eligible participants from the outpatient rehabilitation department of HDGH were automatically assigned into the traditional rehabilitation + WBV training group. Issues such as waitlists to get into outpatient rehabilitation (~ 3 months for physiotherapy and ~ 6 months for occupational therapy) and other patients having too sever of strokes (unable to stand independently for one minute) were major causes for the low number of participants. These recruitment issues were the reasons why the control group was ultimately created by using anonymized data from a database kept by the physician in charge of stroke rehabilitation at HDGH. Using this database, information pertaining to BBS and 6-minute timed walk test were gathered. Participants were unable to be matched on the Chedoke-McMaster Score as this information was not available for most patients in the database. For these reasons, we were unable to create a true control group.

A concern with using clinical populations is that the measurements used to test any progress may not be sensitive enough to catch smaller improvements. For instance, the BBS is great for measuring balance for those in acute stages of stroke (< 3 months post stroke). However, since there was such backlog for getting into outpatient rehabilitation, patients are often entering these programs after this time period. The four other measurements used for this study were taken from the Seniors Fitness Manual and are used to identify whether an older adults may be at risk for loss of functional ability (Rikli & Jones, 2001). These tests, therefore may not be sensitive enough to track progress for people who already have significant physical impairments. For example, all participants in the current study did show improvements in their TUG times (not significant), however, their best performances were still severely outside of the normal range for their age group. Therefore, future studies should consider using other measurement tools that are more sensitive to detecting changes in physical function for the stroke population.

Since this is the first study to evaluate the effectiveness of WBV training on upper body strength for stroke survivors, more research is needed in this area. Future research should look into alternative forms of hand grips as the straps used in the present study could have caused vibration dampening. Additionally, this is the first study of its kind that looks at both upper and lower dynamic exercises. This is also an area of research that needs to be looked more thoroughly as there is evidence to suggest heightened muscle activation during these types of exercises. In future studies, investigators should consider implementing a more aggressive treatment (60 second trails instead of 30 seconds) as there have research using these protocols for upper and lower body strength however, they are only single sessions (Bosco et al., 1999a; Bosco, Cardinal, Tsarpela, 1999b).

Although there are many studies looking at the effects of WBV training, there is currently not a gold standard for either measurement protocols or WBV training programs. Multiple tests have been used to assess muscle strength, mobility and balance throughout the literature. Additionally programs have differed in terms of incidence of sessions, level of frequency and amplitude for optimal performance, and duration of intervention (Lachance et al., 2012). Therefore, it is important for researchers to come together and generate the goal standard for implementing and evaluating WBV training for both the “healthy” and “clinical” populations.

Lastly, studies to this date have compared the effects of WBV to conventional therapy (i.e., resistance training). However, from a clinical standpoint, future studies should be investigating the results when both of these therapies are paired as WBV training can be a great alternative for therapists who are working with many patients as it requires less time. There was only one study by Tihanyi et al. (2007) that has combined WBV with conventional physiotherapy. Although improvements in muscle strength were observed in this study, participants only received one session of WBV, making the effects of a prolonged program unknown. Therefore, future research should be conducted to determine the effects of multiple WBV sessions coupled with conventional treatment to discover if there are indeed added benefits.

References

Baker, J., Meisner, B., Logan, J., Kungl, A. & Weir, P. (2009). Physical activity and successful aging in Canadian older adults. *Journal of Aging and Physical Activity*, *17*, 223-235.

Berg, K.O., Wood-Dauphinée, S.L., Williams, J.I. & Maki, B. (1992). Measuring balance in the elderly: validation of an instrument. *Canadian Journal of Public Health. 83*(2): S7–S11.

Bissonnette, D., Weir, P., Leigh, L. & Kenno, K. (2010). The effects of a whole-body advanced vibration exercise program on flexibility, balance, and strength in seniors. *Physical and Occupational Therapy in Geriatrics, 28*(3): 225-234.

Blum, L. & Korner-Bitensky, N. (2008). Usefulness of the Berg balance scale in sroke rehabilitation: A systematic review. *Physical Therapy*, *88*, 559-566.

Bohannon, R.W. (2007). Muscle strength and muscle training after stroke. *Journal of Rehabilitation Medicine, 39*, 14-20.

Bosco, C., Cardinale, M. & Tsarpela, O. (1999b). Influence of vibration on mechanical power and electromyogram activity in human arm flexor muscles. *European Journal of Applied Physiology*, *79*, 306-311.

Bosco, C., Colli, R., Introini, E., Cardinale, M., Tsarpela, O., Madella, A., Viru, A. (1999a). Adaptive responses of human skeletal muscle to vibration exposure. *Clinical Physiology*, *19*(2): 183-187.

Broemeling, A., Watson, D. & Prebtani, F. (2008). Population patterns of chronic health conditions, co-morbidity and healthcare use in Canada: Implications for policy and practice. *Healthcare Quarterly*, *11*(3): 70-76.

Canadian Stroke Best Practices. (2013). Stroke Rehabilitation. Retrieved from: http://strokebestpractices.ca/wpcontent/uploads/2013/07/SBP2013_StrokeRehabilitation Update_July-10_FINAL.pdf

Canadian Stroke Network. (2011). Quality of Stroke Care in Canada 2011. Retrieved from: http://www.canadianstrokenetwork.ca/wp-content/uploads/2011/06/QoSC-EN1.pdf

Caplan, L. R. (2007). Stroke Subtypes and Rationale for Their Separation. In T. Munsat (Ed.), *Stroke: Selected Topics* (pp. 9-26). New York: Demos Medical Publishing, LLC.

Cardinale, M. & Bosco, C. (2003). The use of vibration as an exercise intervention. *Exercise and Sport Science Reviews*, *17*, 621-624.

Cardinale, M. & Lim, J. (2003). Electromyography activity of vastus lateralis muscle during whole-body vibration of different frequencies. *Journal of Strength and Conditioning Research*, *17*(3): 621-624.

Cardinale, M. & Wakeling, J. (2005). Whole body vibration exercise: are vibrations good for you? *British Journal of Sports Medicine, 39*, 585-589. doi: 10.1136/bjsm.2005.016857

Carr, K., Lachance, C. & Kenno, K. (2012). Whole-body vibration training in older adults: Retention of the strengthening effects. *Critical Reviews in Physical and Rehabilitation Medicine*,*24*(1-2): 51-67.

Carter, A. B. (1968). *All about Strokes.* London: Thomas Nelson and Sons Ltd.

Chan, K., Liu, C., Chen, T., Weng, M., Huang, M. & Chen, C. (2011). Effects of a single session of whole body vibration on ankle plantarflexion spasticity and gait performance in patients with chronic stroke: a randomized controlled trial. *Clinical Rehabilitation, 26*(12): 1087-1095.

Edlow, J. A. (2008). *Stroke.* Westport, CT: Greenwood Press.

Eng, J., Chu, K., Kim, M., Dawson, A., Carswell, A. & Hepburn, K. (2003). A community-based group exercise program for persons with chronic stroke. *Medicine and Science in Sports and Exercise, 35*(8): 1271-1278.

Fries, J. (1980). Aging, natural death, and the compression of morbidity. *The New England Journal of Medicine, 303*(3): 130-135.

Gilmour, H. & Park, J. (2006). Dependency, chronic conditions and pain in seniors. *Supplement to Health Reports, 14,* 21-31.

Gordon, N., Gulanick, M., Costa, F., Fletcher, G., Franklin, B., Roth, E. & Shephard, T (2004). Physical activity and exercise recommendations for stroke survivors: An American Heart Association scientific statement from the Council on Clinical Cardiology, Subcommittee on Exercise, Cardiac Rehabilitation, and Prevention; the Council on Cardiovascular Nursing; the Council on Nutrition, Physical Activity, and Metabolism; and the Stroke Council. *Circulation, 109,* 2031-2041.

Hazell, T., Jakobi, J. & Kenno, K. (2007). The effects of whole-body vibration on upper- and lower-body EMG during static and dynamic contractions. *Applied Physiology, Nutrition, and Metabolism, 32,* 1156-1163.

Hazell, T., Kenno, K. & Jakobi, J. (2010). Evaluation of muscle activity for loaded and unloaded dynamic squats during vertical whole-body vibration. *The Journal of Strength and Conditioning Research, 24*(7): 1960-1865.

Heart and Stroke (2008). *Hemorrhagic Stroke.* Retrieved from http://www.heartandstroke.com/site/c.ikIQLcMWJtE/b.3484153/k.7675/Stroke__Hemorrhagic_stroke.htm

Heart and Stroke (2011). *Stroke warning signs.* Retrieved from http://www.heartandstroke.com/site/c.ikIQLcMWJtE/b.3483937/k.ED98/Stroke__Stroke_Warning_Signs.htm

Hodgson, C. (1998). Prevalence and disabilities of community-living seniors who report the effects of stroke. *Canadian Medical Association Journal, 159*(6): S9-S14.

Jette, A. & Branch, L. (1981). The Framingham disability study: II physical disability among the aging. *American Journal of Public Health, 71*(11): 1211-1216.

Lachance, C., Kenno, K., Weir, P., Carr, K., McNevin, N. & Horton, S. (2012a). The effects of whole-body-vibration training on upper and lower body strength in older adults. *Physical and Rehabilitation Medicine, 24*(1-2): 35-50.

Lachance, C., Weir, P., Kenno, K. & Horton, S. (2012). Is whole-body vibration beneficial for seniors? *European Review of Aging and Physical Activity, 9*(1): 51-62.

Langhorne, P., Bernhardt, J. & Kwakkel, G. (2011). Stroke rehabilitation. *Lancet, 377,* 1693- 1702

Lau, R., Yip, S. & Pang, M. (2012). Whole-body vibration has no effect on neuromotor function and falls in chronic stroke. *Medicine and Science in Sport and* Exercise. doi:10.1249/MSS.0b013e31824e4f8c

Liao, L., Lam, F., Pang, M., Jones, A. & Ng, G. (2013). Leg muscle activity during whole- body vibration in individuals with chronic stroke. *Medicine and Science in Sports and Exercise. doi:* 10.1249/MSS.0b013e3182a6a006

Lorenzen, C., Maschette, W., Koh, M. & Wilson, C. (2009). Inconsistent use of terminology in whole body vibration exercise research. *Journal of Science and Medicine in Sport, 12*, 676-678.

Mao, H., Hsueh, I., Tang, P., Sheu, C. & Hsieh, C. (2002). Analysis and comparison of the psychometric properties of three balance measures for stroke patients. *Stroke, 33*, 1022-1027.

Merkert, J., Butz, S., Niecza, R., Steinhagen-Thiessen, E. & Echardt, E. (2011). Combined whole body vibration and balance training using Vibrosphere. *Gerontology and Geriatrics Journal, 44*, 256-261.

Miyara, K., Matsumoto, S., Uema, T., Hirokawa, T., Noma, T., Shimodozono, M., Kawahira, K. (2014). Feasibility of using whole body vibrations as a means for controlling spasticity in post-stroke patients: A pilot study. *Complementary Therapies in Clinical Practice, 20*, 70-73.

Nordin, M. & Hagbarth, K. (1996) Effects of preceding movements and contractions on the tonic vibration reflex of human finger extensor muscles. *Acta Physiologica Scandinavia, 156*, 435–440.

Novak, P. & Novak, V. (2006). Effect of step-synchronized vibration stimulation of soles on gait in Parkinson's disease: a pilot study. *Journal of NeuroEngineering and Rehabilitation, 3*(9). doi:10.1186/1743-0003-3-9

Oeppen, J., & Vaupel, J.W. (2002). Broken limits to life expectancy. *Science, 296:* 1029–1031.

Phillipson, C. (2007). Understanding the baby boom generation: Comparative perspectives. *International Journal of Ageing and Later Life, 2*(2): 7-11.

Public Health Agency of Canada (2009). Tracking heart disease and stroke in Canada.

Public Health Agency of Canada. (2011). Tracking heart disease and stroke in Canada – Stroke Highlights 2011.

Rauch, F., Sievanen, H., Boonen, S., Cardinale, M., Degens, H., Felsenberg, D., Rittweger, J. (2010). Reported whole-body vibration intervention studies: Recommendations of the International Society of Musculoskeletal and Neuronal Interactions. *Journal of Musculoskeletal and Neuronal Interactions, 10*(3): 193-198.

Rikli, R., & Jones, C. (2001). Senior fitness test manual. Champaign, IL: Human Kinetics.

Rittweger, J. (2010). Vibration as an exercise modality: how it may work, and what its potential might be. *European Journal of Applied Physiology, 108*, 877-904.

Roelants, M., Delecluse, C. & Verschueren, S. (2004). Whole-body-vibration training increases knee-extension strength and speed of movement in older women. *Journal of the American Geriatrics Society,*52, 901-908.

Salbach, N., Mayo. N., Robichaud-Ekstrand, S., Hanley, J., Richards, C. & Wood-Dauphinee, S. (2006). Balance self-efficacy and its relevance to physical function and perceived health atatus after stroke. *Archives of Physical Medicine and Rehabilitation*, *87*, 364-370.

Schuhfried, O., Mittermaier, C., Jovanovic, T., Pieber, K. & Paternostro-Sluga. T. (2005). Effects of whole-body vibration in patients with multiple sclerosis: a pilot study. *Clinical Rehabilitation*, *19*, 834 -842.

Signorile, J. (2006). Whole body vibration training: a new wave in exercise intervention for older adults? *The Journal on Active Aging*, *5*, 30-37.

Silva, G., Koroshetz, W., González. & Schwamm, L. (2011). Causes of ischemic stroke. In G. González, J. Hirsch, M. Lev, P. Schaefer & L. Schwann (Eds.), *Acute Ischemic Stroke: Imaging and Intervention* (pp. 25-42). Springer-Verlag Berlin Heidelberg.

Statistics Canada. (2010). Population Projections for Canada, Provinces and Territories (catalogue no. 91-520-X). Ottawa, ON: Canada. Minister of Industry.

Tankisheva, E., Bogaerts, A., Boonen, S., Feys, H. & Verschueren, S. (2013). Effects of Intensive whole-body vibration training on muscle strength and balance in adults with chronic stroke: A randomized controlled pilot study. *American Congress of Rehabilitation Medicine*, 1-8.

Teasell, R., Foley, N., Salter, K. & Jutai, J. (2008). A blueprint for transforming stroke rehabilitation care in Canada: The case for change. *Archives of Physical Medicine and Rehabilitation. 89*, 575-578.

Tihanyi, T., Horváth, M., Fazekas, G., Hortobágyi, T. & Tihanyi, J. (2007). One session of whole body vibration increases voluntary muscle strength transiently in patients with stroke. *Clinical Rehabilitation, 21*, 782-793.

Torvinen, S., Kannus, P., Sievanen, H., Jarvinen, T., Pasanen, M., Kontulainen, S., … Vuori, I. (2002). Effect of a vibration exposure on muscular performance and body balance. Randomized cross-over study. *Clinical Physiology and Functional Imaging, 22*, 145-152.

Turbanski, S., Haas, C.T., Friedrich, A. & Schmidtbleicher, D. (2005). Effects of random whole- body vibration on postural control in Parkinson's disease. *Research in Sports Medicine*, 243-256.

Usuda, S., Araya, K., Umehara, K., Endo, M., Shimizu, T. & Endo, F. (1998). Construct validity of functional balance scale in stroke inpatients. *Journal of Physical Therapy Science, 10,* 53-56.

van Nes, I., Latour, H., Schils, F., Meijer, R., van Kuijk, A. & Geurts, A. (2006). Long-term effects of 6-weeks whole-body vibration on valance recovery and activities of daily living in the postacute phase of stroke: A randomized, controlled trial. *Stroke, 37*, 2331-2335.

Verschueren, S., Roelants, M., Delecluse, C., Swinnen, S., Vanderschueren, D., & Boonen, S. (2004). Effect of 6-month whole body vibration training on hip density, muscle strength and postural control in postmenopausal women: A randomized controlled pilot study.*Journal of Bone and Mineral Research, 19*(3): 352–359.

Wagner, J., Dromerick, A., Sahrmann, S. & Lang, C. (2007). Upper extremity muscle activation during recovery of reaching in subjects with post-stroke hemiparesis. *Clinical Neurophysiology*, *118*(1): 164-176.

WAVE Pro [apparatus]. Windsor, Ontario, Canada: WAVE Manufacturing; 2006.

Wood, B., Bilclough, J.A., Bowron, A., Walker, R.W., (2002). Incidence and prediction of falls in Parkinson's disease: a prospective multidisciplinary study. *Journal of Neurology, Neurosurgery and Psychiatry*, *72*(6): 721–725.

Wunderer, K., Schabrun, S. & Chipchase, L. (2010). Effects of whole body vibration on strength and functional mobility in multiple sclerosis. *Physiotherapy Theory and Practice*, *26*(6): 374-384.

Chapter Two

Literature Review

Introduction.

Around the world, population demographics are currently in a state of change. In Canada, the growth in seniors aged 65+ is beginning to accelerate. As this age group continues to increase, Canada is expected to see an increase between 23 – 25 % by 2036 (Statistics Canada, 2010). The main reasons for this growth are from the improvements in mortality rates and the rise in birth rates after the Second World War (Phillipson, 2007). This increase in birth rates appeared in North America between the years of 1946 and 1965 and introduced the world to the baby boomer generation (McKay, 1997; Statistics Canada, 2012). The first baby boomers in Canada reached the age of 65 years in 2011 (Riley, 2001; Statistics Canada, 2012). Enhancements in nutrition, sanitation, education, medicine and income are the underlying reasons for the decreased mortality rates. Although there has been an average increase of 3 months per year in human life expectancy, this does not mean that people are living these additional years in a state of optimal health (Baker, Meisner, Logan, Kungl, & Weir, 2009; Fries, 1980; Jette & Branch, 1981; Oeppen & Vaupel 2002). In fact, more than 70% of Canadians over the age of 60 report having least one chronic condition and 49% of those 65+ years have two or more chronic illnesses (Broemeling, Watson, & Prebtani, 2008). This high rate of chronic conditions among the older population is not surprising since many are associated with aging. The most prominent condition seen in the aging population is arthritis/rheumatism (47%), followed by cataracts/glaucoma (25%), back problems (24%), and cardiovascular disease (25%) (Gilmour & Park, 2006). Cardiovascular disease can be further broken down into two conditions: heart disease and stroke. Of those over the age of 65 years, heart disease (20%) and stroke (5%) are highly prevalent (Gilmour & Park, 2006).

Stroke.

Among the various diseases, stroke is the third leading cause of death in Canada and is a leading cause of acquired disability in adults (Public Health Agency of Canada, 2011). Each year there are an estimated 50,000 strokes in Canada, which equates to one stroke every ten minutes (Hakim, Silver, & Hodgson, 1998). Of the strokes that occur, over 14,000 result in death, leaving approximately 315,000 Canadians who are currently living with the effects of stroke (Public Health Agency of Canada, 2011). Due to the fact that strokes can leave people in a state of dependence and disability, there is an economic burden associated with the condition. Each year the effects of living with a stroke cost the Canadian economy $3.6 billion in physician services, hospital costs, lost wages, and decreased productivity (Public Health Agency of Canada, 2009). Expressed in more immediate terms, in 2005/2006 stroke was the main reason for hospitalization with patients spending more than 639,000 acute care days in hospitals and 4.5 million days in resident care facilities (Canadian Stroke Network, 2011). As the prevalence of stroke remains high and complications following are severely detrimental, it is important to understand the causes in order to prevent and reduce the number of victims.

Risk Factors.

Cardiovascular disease is a leading cause of death in Canada and worldwide, therefore, it is imperative to understand how to prevent a stroke from happening. There are both modifiable and non-modifiable risk factors associated with stroke that determine an individual's likelihood of experiencing one. In order for a stroke to occur one of two factors must be present; either arterial degeneration (thickening of inner arterial lining caused by plaque formation) or severe high blood pressure (BP) (Carter, 1968). Both of these conditions have underlying modifiable risk factors that affect the development and occurrence of a stroke. High blood cholesterol is major contributing factor to arterial degeneration, especially atherosclerosis, the most common form. Atherosclerosis is a condition in which elevated level of cholesterol and triglycerides in the blood leads to a buildup of plaque on the artery walls. This accumulation ultimately causes the narrowing of the artery which impedes blood flow (Carter, 1968; Edlow, 2008; Silva, Koroshetz, González, & Schwamm, 2011). Another risk factor that can be adjusted through diet, exercise, and drug therapy is high BP (hypertension). An individual with hypertension is at double or triple the risk of developing a stroke, illustrating the importance of BP management (Caplan, 2007; Hodgson, 1998; Public Health Agency of Canada, 2009). Blood pressure is a measure of the pressure or force of blood that is exerted against the walls of the blood vessels and is expressed as BP $=\frac{SBP}{DBP}$. In the BP reading, the top number refers to the systolic pressure (SBP), created by the heart as it pumps blood out of the body. Diastolic pressure (DBP) represents the bottom number and is the remaining pressure in the blood vessels between heart pumps (Carter, 1986; Edlow, 2008; Public Health Agency of Canada, 2009). In order for an individual to be classified as having high BP, their SBP must be 140 or higher and DBP 90 or higher. Another risk factor to stroke is atrial fibrillation which is characterized as irregular and often rapid heart rate that commonly causes poor blood flow throughout the body. Atrial fibrillation is unique to stroke when compared with other vascular diseases as it is the most common cardiac arrhythmia detected during a stroke. Individuals with atrial fibrillation have a 3 to 5 times greater risk of experiencing a stroke then those without (Adams et al., 2003). Other manageable risk factors include diabetes, overweight, physical inactivity, smoking and stress (Carter, 1986; Edlow, 2008; Canadian Stroke Network, 2011; O'Donnell et al., 2010).

Although many risk factors can my managed, there are some that are inherited and permanent. Examples of non-modifiable risk factors for stroke include age, sex, family history, ethnicity and history of previous stroke or transient ischemic attack (TIA) (Edlow, 2008; O'Donnell et al., 2010). While strokes can occur at any age, two-thirds of strokes occur in people over the age of 70 years, with the risk doubling every decade over the age of 50 years (Canadian Stroke Network, 2011). In Western countries, 88% of strokes that result in death occur in people over the age of 65 years and 7.1% of Canadians living with the effects of stroke are beyond the age of 75 years (Donnan, Dewey, Thrift & Sturm, 2007; Public Health Agency of Canada, 2009). Since age has an influential role in stroke development, it is interesting to note that until women hit menopause, they have a lower risk of stroke compared to men. However, when women do experience a stroke, they occur at an older age (Public Health Agency of Canada, 2009). In terms of gender differences, both genders are generally equal in terms of the types of stroke experienced, not including subarachnoid hemorrhage, which women experience more (60% vs. 40%) (Canadian Stroke Network, 2011; Public Health Agency of Canada, 2009). Lastly, previous stroke or TIA is a non-modifiable risk factor where individuals with prior incidents are ten times more likely to have a stroke than those who have not (Canadian Stroke Network, 2011). When a TIA occurs there is a short-term reduction of blood flow to the brain, where symptoms last less than twenty-four hours

(Edlow, 2008). The differences between a TIA and an actual stroke is in the timeframe in which the symptoms occur and disappear, and a TIA is often seen as a warning sign of a real stroke. While most TIAs do not cause permanent brain damage and symptoms pass quickly, doctors recognize that there is a heightened risk of a stroke occurring within the following year. This amplified risk is at its peak during the first two days after a TIA (as high as 5%) (Canadian Stroke Network, 2011; Edlow, 2008). All of these risk factors are important to consider when developing prevention strategies, however, identifying the symptoms associates with a stroke is vital in order to get treatment in a timely manner. Please refer to Table 1 for an overview of stroke risk factors.

Table 1

Risk factors and subtypes of stroke

Risk Factor	**Ischemic Stroke**			**Hemorrhagic Stroke**	
	Embolic	*Large-vessel atherosclerosis*	*Lacunar*	*Intracerebral*	*Subarachnoid*
Modifiable					
Hypertension	X	X	X	X	X
Arterial fibrillation	X				
Hyperlipidemia	X	X	X		
Diabetes mellitus			X		
Smoking		X			X
Alcohol consumption		X		X	
Anti-coagulant or thrombolytic therapy				X	
Non-Modifiable					
Previous Stroke/TIA	X	X	X	X	X
Amyloid angiopathy				X	
Advanced age	X	X	X	X	X
Aneurysm					X

(Carter, 1968; Canadian Stroke Network, 2011; Donnan et al., 2007; Edlow, 2008; Ihle-Hansen, Thommessen, Bruun Wyller, Engedal, & Fure, 2012; Kolominsky-Rabas, Weber, Gefeller, Neundoerfer, & Heuschmann, 2001; O'Donnell et al., 2010; Public Health Agency of Canada, 2009; Silva et al., 2011; Steiner et al.,2006).

Signs and Symptoms.

The degree of damage from a stroke is directly dependent upon the time elapsed from the onset of symptoms, to the delivery of treatment. The phrase "time is brain" emphasizes that the human nervous tissue is rapidly and irreversibly damaged as the stroke progresses in the absence of therapeutic interventions (Gomez, 1993; Saver, 2006). The longer an individual waits for treatment is related to the amount of damage that will occur. For example, for every minute delay in treating a stroke, the average patient will lose about 1.9 million neurons, 14 billion synapses and 12 km of axonal fibers. Even more surprising, after each hour in which treatment is withheld, the brain loses as many neurons as it would in almost 3.6 years of regular aging (Saver, 2006). With this in mind, the general public needs to be aware of the signs and symptoms associated with stroke. The three primary warning signs are the sudden onset of: (1) difficulty with or loss of speech; (2) loss of vision in one eye or on one side of visual field; and (3) weakness or loss of strength or power in the face, arm or leg (Canadian Stroke Network, 2011). Other symptoms include sudden loss of sensation in face, arm or leg, a sudden, severe and unusual headache, and a sudden loss of balance or sense of vertigo, especially when accompanied with other symptoms (Canadian Stroke Network, 2011; Heart and Stroke, 2011). Once any of these symptoms occur calling for emergency medical services must take place as soon as possible to increase the likelihood of arriving at a hospital that is equipped for emergency stroke care (Canadian Stroke Network, 2011). In order for a hospital to be prepared for the arrival of a stroke patient they must have access to brain-scanning equipment such as CT or MRI scans and tissue plasminogen activator (tPA) which is a clot-dissolving drug) (Canadian Stroke Network, 2011). The importance of providing a brain scan is to determine the type and nature of the stroke in order to evaluate possible treatment options, including eligibility for tPA. Under ideal circumstances, this process should be completed within 60 minutes of the patient's arrival to the hospital. If a patient is assessed and diagnosed with an ischemic stroke, the recommended practice is to administer tPA within the suggested therapeutic window of 4.5 hours from symptom onset for best possible outcomes (Canadian Stroke Network, 2011).

Types and Pathophysiology.

The human brain is the most demanding organ in terms of blood flow. In order for the brain to work effectively and efficiently, 15% of the body's blood is required for the adequate delivery of oxygen, glucose, and essential nutrients to the brain (Edlow, 2008). A stroke is a condition in which a part of the brain is abruptly suspended of blood and all of its benefits. Without this blood supply, the brain is unable to function properly which results in neurological deficits. Cerebrovascular circulation involves the four main arteries and their branches which are responsible for the delivery of oxygen and glucose rich blood to the brain. Of these arteries, the carotid arteries are the largest and are located in the front of the neck to supply blood to the anterior part of the brain. The smaller pair of arteries located at the back of the neck are called the vertebral arteries and deliver blood to the posterior portion of the brain (Carter, 1968; Edlow, 2008). All four of these arteries join at the base of the brain in a circular fashion, demonstrating collateral circulation and are known as the Circle of Willis (Carter, 1968). This web of blood vessels allows the arteries to support one another. In times when an artery becomes blocked or damaged, one of the other communicating arteries will take over to bypass the blockage so that blood flow to that portion of the brain is preserved (Edlow, 2008). However, when blood flow is unable to be returned in a timely manner or other artery abnormalities are present, a stroke takes place.

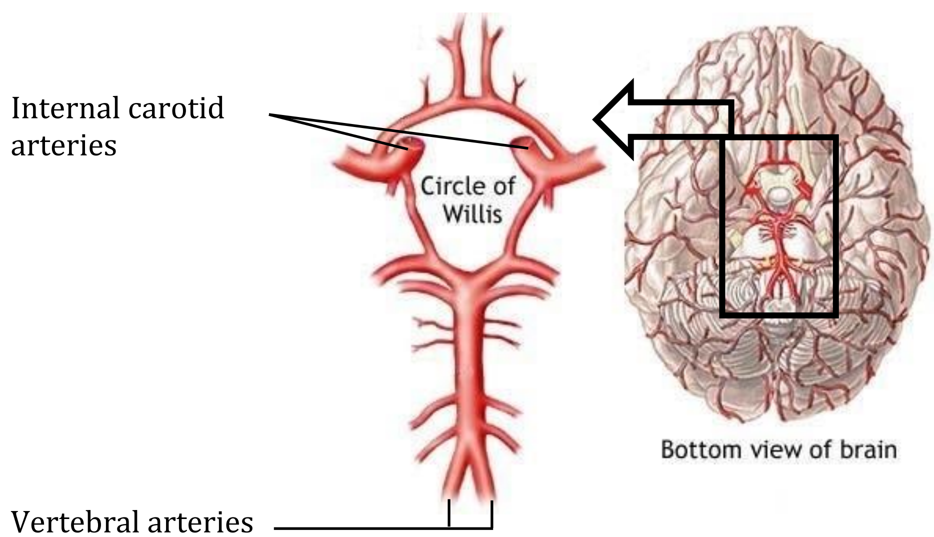

Figure 1: Circle of Willis - Formation of the Circle of Willis with the carotid arteries forming the front and the two vertebral arteries creating the back of the circle. The front and back are then joined by the communicating arteries. (http://www.nlm.nih.gov/medlineplus/ency/imagepages/18009.htm)

Strokes are categorized into two main types, each with their own list of subtypes.

Ischemic strokes are the most common type and account for nearly 80% of all strokes (CNS, 2011; Edlow, 2008; Heart and Stroke, 2011). An ischemic stroke involves blockage of blood supply and energy to the brain caused by a clot. This lack of blood triggers a 5 step process that results in cell death: (1) excitotoxicity and ionic imbalance, (2) oxidative/nitrosative stress, (3) inflammation, (4) apoptosis, and (5) peri-infract depolarization (Singhal, Lo, Dalkara, & Moskowitz, 2011). Following an ischemic stroke, cellular energy metabolism becomes impaired and energy-dependent processes begin to fail. Due to this loss of energy, ionic imbalance begins to develop with the release and inability to reabsorb excitatory neurotransmitters such as glutamate (Bretón & Rodríguez, 2012; Singhal et al., 2011). This surplus of neurotransmitters excessively stimulates nerve cells to the point of damage and even death. Oxidative/nitrosative stress represents the body’s inability to balance the production and elimination of reactive oxygen and nitrogen species with various antioxidant systems that destroy reactive species to prevent or repair damage (Klandorf & Van Dyke, 2012). Reactive oxygen species have been shown to mediate reperfusion-related tissue damage in a multitude of organs including the brain (Bretón & Rodríguez, 2012; Chan, 2001). Following an ischemic stroke, an influx of intracellular chemicals such as Ca^{++}, Na^{+}, and ADP, induce dangerous production levels of oxygen free radical due to mitochondria dysfunction (Bretón & Rodríguez, 2012; Chan, 2001; Singhal et al., 2011). This elevated production is particularly harmful to the injured brain since levels of antioxidant enzymes and vitamins are very low and therefore, cannot match the excess radical formation. This overwhelming production of radicals directly damages lipids, proteins, nucleic acids, and carbohydrates (Chan, 2001; Klandorf & Van Dyke, 2012; Singhal et al., 2011). In the event of an ischemic stroke, cells begin a process of programmed death which is mediated by intracellular factors. This type of cell death is referred to as apoptosis and is triggered through increases in oxygen free radicals and ionic imbalances (Singhal et al., 2011). After an ischemic stroke brain tissue depolarization occurs and can be potentially harmful to the brain tissue. In areas surrounding the direct stroke site (penumbral regions), spreading depression amplifies tissue damage due to comprised blood flow and energy supplies needed to restore ionic equilibrium (Singhal et al., 2011). These spreading depression waves are referred to peri-infarct depolarization. These pathophysiological mechanisms develop in a series of spatial and temporal events which are carried out over hours and days. The areas with sever blood restriction (the ‘core’), excitotoxicity and localized cell death occurs within minutes and tissue experiences irreversible damage in the absence of reperfusion. In the surrounding areas, blood flow to the tissue is maintained by collateral circulation and the severity of damage to these sites depend on the degree of ischemia and the timing of reperfusion (Singhal et al., 2011).

There are many different subtypes of ischemic stroke which are categorized by their pathophysiology. Embolic strokes are a subtype in which a stroke is the result of heart disease. The most common cause of embolism develops from a cardiac condition called “atrial fibrillation” and account for nearly 14% of strokes (Edlow, 2008). In atrial fibrillation, electrical impulses are not synchronized which causes uncoordinated mechanical pumping of the blood in the atria. As an individual lives with this condition, clots begin to develop in the upper chambers of the heart due to pooling of the blood along the walls (Carter, 1968; Edlow, 2008). In time, these clots run the chance of dislodging from the walls of the arteries and travel from the heart into the aorta and ultimately up to the carotid or vertebral artery. As the clot reaches its destination, there runs a risk of the clot becoming caught in one of these arteries or their branches, blocking blood flow and causing a stroke (Carter, 1968; Edlow, 2008). Other cardiac conditions that can cause clot formation are cardiomyopathy, left ventricular aneurysm and congestive heart failure. One common factor associated with these conditions is that the heart becomes swollen or dilated and blood flow is sluggish which together promote clot development (Edlow, 2008). As outlined earlier, atherosclerosis is an important risk factor to strokes. With this in mind, another common ischemic stroke is large-vessel atherosclerosis, where plaque containing cholesterol and other blood components begin to form in arteries (Carter, 1968). As the plaque continues to build up, partial or complete blockages of the arteries can develop which impinges blood flow distally (Carter, 1968; Edlow, 2008). However, the most important site for atherosclerosis to develop is the carotid artery where it splits at the neck and branches off into external and internal (supplies the brain with blood). Atherosclerosis typically develops at these branch points in arteries and when more plaque builds up, a larger percentage of the lumen in the blood vessel is blocked (Edlow, 2008). As the plaque increases, blood flow begins to decrease not until there is a 50-60% obstruction in the vessel (Cater, 1968). Another category of ischemic strokes are lacunar strokes, or lipohyalinosis, which involve the smaller arteries that penetrate into the base of the brain. When this kind of stroke is fatal, autopsies will discover a tiny “lake” embedded into normal tissue, giving to the name “lacune”, which is Latin for lake (Edlow, 2008). Hypertension is practically the sole reason behind these small-vessel occlusions because elevated BP causes the vessel walls to thicken and luminal diameter to decrease, producing small infracts (Silva et al., 2011). Effects of lacunar stroke can cause abrupt motor and sensory deficits with pure sensory stroke being the most common lacunar classification (Silva et al., 2011). A pure sensory stroke is associated with numbing in the face, arm and leg on one side, in the absence. The second most common classification is pure motor hemiparesis and refers to a pure motor paralysis of the face, arm and leg (Edlow, 2008; Silva et al., 2011).

Aside from ischemia, hemorrhagic strokes are the second type of stroke that takes place in the remaining 20% of patients. During a hemorrhagic stroke, the patient experiences uncontrolled bleeding in the brain that leaks out to accumulate and compress tissue, killing brain cells (Heart and Stroke, 2008). While hemorrhages only account for a smaller portion, this type has a higher mortality rate compared to ischemic strokes. Encased under the umbrella term of hemorrhagic stroke are two types: intracerebral hemorrhage (ICH) and subarachnoid hemorrhage (SAH). Although both types involve the rupture of an artery, this degradation of the artery occurs within the brain in ICH, whereas SAH takes place around the brain, within the skull (Canadian Stroke Network, 2011).The pathophysiology of hemorrhagic strokes dictate the classification. One of the major causes of hemorrhages is amyloid angiopathy which means disease of blood vessels that is caused by amyloid beta protein deposition (Edlow, 2008; Tatemichi, 1995). Deposition of amyloid penetrates the walls of leptomeningeal and cortical brain vessels where it replaces some of the vessels contractile components. This accumulation weakens the sites where amyloid is present and allows for blood to leak out and spill onto brain substance, especially if blood pressure is elevated (Tatemichi, 1995). The incidence of amyloid infiltration is common in the elderly population which is why as the population ages, this type of hemorrhage will become more prevalent (Edlow, 2008). As one of the main risk factors for stroke, hypertensive bleeds are another common cause of hemorrhagic strokes. The longer an individual lives with untreated elevated blood pressure the worse the weakening of the blood vessel walls which leads to rupture and bleeding into the brain (Edlow, 2008). Arteries undergo changes due to the effects of hypertension. Such changes consist of fibrinoid necrosis (tissue death), lipohyalinosis (wall thickening and decreased luminal diameter), medial degeneration and microaneurysm formation (Han, Bae, & Wong, 2011). All of these degenerative alterations make blood vessels more prone to rupture. Fortunately, with the improvement in high blood pressure care, hypertensive bleeding is becoming less common (Edlow, 2008; Han, Bae, & Wong, 2011). Although hypertensive bleeds are decreasing in occurrence, another type of hemorrhage is becoming more common due to medical improvements. In recent years doctors have begun to prescribe anticoagulant drugs to thin the blood so that clots are unlikely to form. Ironically, this treatment is used to prevent ischemic strokes, however, intracranial hemorrhage is the most serious and lethal complication of anticoagulants. (Edlow, 2008; Steiner, Rosand, & Diringer, 2006). Researchers have speculated multiple hypotheses responsible for this phenomenon, however, there has not been a definite answer. One hypothesis proposed by Hart (2000), states that the use of anticoagulant drugs reveals intracerebral bleeding that would otherwise remain asymptomatic. This bleeding is particularly apparent in patients with underlying hypertension or cerebrovascular disease (Hart, 2000). Another hypothesis claims that anticoagulants interfere with the production of clotting factors, resulting in low levels. Therefore, it is essential to have sufficient levels and functionality of these clotting factors to respond to the stress placed on blood vessel from daily activities and to prevent bleeding (Steiner et al., 2006). The last cause of a hemorrhagic stroke that will be discussed are those that occur as a result of a burst aneurysm. An aneurysm takes its form on abnormal blood vessels where a weak spot in the artery balloons out (Edlow, 2008). Aneurysms can form in any artery throughout the body, but typical locations are on the aorta and cerebral blood vessels where brain arteries branch, as well as near the Circle of Willis (Edlow, 2008). Once an aneurysm bursts, the patient experiences a sudden and severe headache that is often paired with vomiting and about half of patients will experience a loss of consciousness (Carter, 1968). All of the explained stroke examples have different underlying pathophysiology, however, it is important for the individual to obtain treatment as soon as possible for optimal outcomes.

Outcomes.

The area in the brain that is no longer working properly is directly related to how symptoms will present themselves following a stroke. For this reason, individuals who have experienced a stroke may have completely different outcomes, depending on the location of the stroke. Strokes can have a major impact on an individual's everyday life. Consequences that can come from a stroke range from cognitive to physical impairments. A cognitive effect that a stroke can cause is memory loss. Damage to any part of the cerebral hemispheres, whether from an infarction or hemorrhage, can cause memory loss (Schnider & Landis, 1995). However, it is the physical limitations that are of particular interest. In terms of stroke outcomes, motor weakness or impairment, either isolated or with other symptoms, is the most common problem that stroke patients experience (Bohannon, 2007; Langhorne, Bernhardt, & Kwakkel, 2011). This widely recognized impairment restricts function in both muscle movement and mobility due to a reduced maximum voluntary force (Eng et al., 2003; Langhorne et al., 2011; Tankisheva, Bogaerts, Boonen, Fewys, & Verschueren, 2013). As indicated by Bonita & Beaglehole (1988), at the time of stroke onset, 88% of patients reported a motor deficit. Although this number declined with time, six months following the onset, 62% of patients were still living with these impairments. Muscle strength is imperative for everyday activities and is required for the initiation and control of movements (Wagner, Dromerick, Sahrmann & Lang, 2007; Tankisheva et al., 2013).

Not only is muscle strength important on its own but it is essential for many other bodily functions. Postural control or balance is one function that relies on muscle strength especially in terms of coordinating muscle force during movement. Muscle spindle sensitivity and kinaesthetic information from the central nervous system both influence balance to ensure proper modifications to movement and reflex activity are made (Turbanski, Haas, Friedrich, Duisberg, & Schmidtbleicher, 2005). Once a decrease in balance takes place, stroke patients demonstrate an increase in postural sway, asymmetrical force production, and their center of mass is shifted to their unaffected lower extremity (Eng & Chu, 2002). This shift in center of mass is particularly important for both balance and mobility. Inability to transfer weight onto affected limbs decreases functional mobility and is recognized as a common impairment following cerebrovascular incidences. In fact, those who live with the effects of stroke only bear 20-40% of their body weight on the paretic limb (Eng & Chu, 2002). This transfer of body weight to the affected limb is more difficult for stroke patients when moving in the forward direction and can compromise gait patterns. Functional mobility is dependent upon many factors working together effectively.

As one consequence of stroke, spasticity impacts the ability for proper gait technique. Spasticity is caused by the dissociation of motor responses from sensory input which leads to hyperexcitability. This hyperexcitability induces an increase in tonic stretch reflexes and exaggerated tendon jerks that result in excessive contraction of the muscles due to a lack of inhibition (Chan et al., 2011). These muscle spasms can be referred to as an unusual “tightness”, “stiffness” or “pull” of the muscles and can cause pain in stroke patients, negatively impacting walking ability. Spasticity in the limbs has been shown to have an adverse effect on gait by reducing step length and cadence (walking rate) (Chan et al., 2011). Ankle spasticity is of certain interest to gait pattern as ankle plantar flexors provide as much as 50% of the mechanical work necessary for a single walking stride (Eng & Winter, 1995). As well, an increased swing time and double-leg support time in gait cycles could also be caused by decreased ankle dorsiflexion (Eng & Winter, 1995). Consequently, spastic ankles may be a large factor to decreases in walking velocity and mobility (Chan et al., 2011).

With stroke having such major physical implications, patients often engage in a more sedentary lifestyle which contributes to secondary complications. Changes in gait patterns and balance following a stroke often increase the risk of falls in the older adults (Eng et al., 2003; Gordon et al., 2004; Tankisheva et al., 2013). In fact, the incidence of falls in people living with stroke has been reported to be as high as 50-73% of individuals falling within six months after hospital discharge (Forster & Young, 1995; Harris, Eng, Marigold, Tokuno, & Louis, 2005). Furthermore, the most common activity at the time of the fall was walking, which shows the importance of these individuals regaining proper gait, balance and muscle function (Harris et al., 2005).

Traditional Stroke Treatment.

Inpatient Rehabilitation.

Initial stroke rehabilitation typically entails a process involving (1) assessment, to classify and measure patient's needs; (2) goal setting, to create realistic and achievable goals for improvement; (3) intervention, to contribute to the accomplishment of goals; (4) reassessment, to evaluate progress against original goals (Langhorne et al., 2011). Organized inpatient care takes place in a stroke-unit of the hospital where the rehabilitation structure has been evaluated in randomized trials and systematic reviews. Hospital stroke units are multidisciplinary in nature with an objective of having more patients who survive, return home, and ultimately regain independence in daily activities (Langhorne et al., 2011; Canadian Stroke Best Practices, 2013). While there has been no consensus on the content, timing, duration and intensity of rehabilitation therapies, the Canadian Best Practice Recommendations for Stroke Care is *"stroke patients should receive, through an individualized treatment plan, a minimum of 1 hour of direct therapy by the inter-professional stroke team for each relevant core therapy, for a minimum of 5 days per week based on individual need and tolerance, with duration of therapy being dependent on stroke severity"* (Lindsay et al., 2008, p. S15). The core therapies these recommendations are referring to are occupational therapy, physiotherapy and speech-language therapy. However, as discovered by Foley et al., (2012), therapists often fail to provide the minimum standard of one-hour per day as suggested by the Canadian Best Practice Recommendations. Therapist shortages are mainly responsible for this decreased treatment time as it is not uncommon for physiotherapists in Southwestern Ontario to be responsible for 10 or more rehabilitation patients (Teasell,, Foley, Salter & Jutai, 2008).

Additionally, it has been observed that 3 hours or more of these combined core therapies was associated with improved functional outcomes when compared to patients who received less (Wang et al., 2013). From the onset of stroke to the time when therapy has begun is very influential for patient outcomes. Craig, Bernhardt, Langhorne, & Wu (2010) assessed the impact of an early mobilization intervention that was applied within 24 hours following stroke. When patients started walking 24 hours after a stroke, their chance of being independent at three months post-stroke greatly increased. Additionally, it has been identified that strokes rated moderate and severe are able to benefit from early therapy administration with respect to total functional independence (FIN) gain and motor FIN gain (Wang, Camicia, Terdiman, Hung, & Sandel, 2011). Therefore, it is imperative that national groups come together to create a standardized program that all sectors abide by to provide the best possible care for those who experience a stroke.

Outpatient Rehabilitation.

Once the initial stroke-unit treatment is completed, patients are often prescribed outpatient therapy upon discharge. This type of therapy may be in the form of a hospital based "day" program, community-based programs, or home based rehabilitation and may be required several month or years following the stroke (Lindsay et al., 2008). In Canada, a typical outpatient stroke rehabilitation program would involve 8 weeks of therapy 3 days per week or 2 days a week for 12 weeks (Teasell et al., 2008).It has been shown that individuals who partake in outpatient rehabilitation, particularly occupational therapy, are significantly more independent in instrumental activities and experience improved outdoor mobility (Logan et al., 2004; Legg et al., 2007). Although outpatient treatment can take many different forms, there is some evidence which suggests that patients who receive such treatment in their homes may have better short-term outcomes (3-6 months) compared to day programs or clinical settings (Hillier & Inglis-Jassiem, 2010).

Another form of outpatient rehabilitation is community-based programs which highly promote the involvement of exercise for those living with stroke. Due to the fact that many survivors are left with moderate to severe impairments, indulging in conventional community fitness programs may be a struggle. However, there is strong evidence that supports the notion that stroke survivors can benefit from partaking in regular exercise (Eng et al., 2003; Gordon et al., 2004; Pang, Eng, Dawson, McKay, & Harris, 2005). According to Canadian Best Practice Recommendations for Stroke Care, moderate levels of exercise (accumulation of 30-60 minutes) 4 – 7 days a week, in addition to performing activities of daily living (ADL), promotes a healthy lifestyle and risk management for stroke prevention (Lindsay et al., 2008). Despite these recommendations and available research, there are a limited number of community based exercise programs that cater to the specific needs of stroke survivors.

Resistance Training.

Often patients are left with reduced muscle strength (ability to generate force or torque) following a stroke. This diminished ability predominantly affects the paretic side, with a mild weakness on the non-paretic side (Eng, 2004). A sedentary lifestyle is typically adopted by individuals post-stroke and may contribute to further reductions in muscle strength. However, there have been many studies done evaluating the potential of resistance training for improving muscle strength in the stroke population. For instance, Oulette et al. (2004) demonstrated that dynamic resistance training 3 times per week for 12 weeks produced an increase in lower extremity strength in both the paretic and non-paretic limbs. Additionally, enhanced lower extremity strength, particularly in hip flexors, knee extensions, and ankle plantarflexors, has been observed following resistance training (Bohannon, 2007; Eng, 2004). Gaining lower limb strength is particularly important as it has been associated with functional abilities such as walking speed (Bohannon, 2007; Weiss, Suzuki, Bean, & Fielding, 2000). Although traditional forms of exercise and rehabilitation offer stroke patients the opportunity to regain function, some patients are physically unable to participate. Therefore, alternative forms of training needs to be available for low functioning individuals.

Whole Body Vibration.

An alternative form of resistance training is the use of whole body vibration (WBV).Historically, the use of vibration training was believed to have detrimental effects and was primarily looking at the workforce population. Kitazaki & Griffin (1998) stated that frequencies between 1 and 20 Hz cause the pelvis and spine to resonate, leading to structural damage and health problems including lower-back pain, spinal degeneration, headaches, sleep problems and other occupation-related diseases. A systematic review by Lings & Leboeuf-Yde (2000) investigated the link between WBV and low back pain. Although there are many publication addressing the question, evidence still remains weak whether there is even a relationship between vibrations and low-back pain and if it is causal. However, recent exercise and physical therapy literature has begun to suggest the use of vibration for beneficial outcomes. (Cardinale & Lim, 2003; Cardinale & Wakeling, 2005; Lachance, Weir, Kenno, & Horton, 2012; Rittweger, 2010; Verschueren et al., 2010). WBV training typically consists of performing static and/or dynamic exercises on a vibrating platform (Lorenzen, Maschette, Koh, & Wilson, 2009). Using this type of training offers both physical and neural loads that produce tissue modifications (Signorile, 2006). While WBV demonstrates comparable results to conventional exercise, it is superior in terms that it generally requires less time and effort (Signorile, 2006). As such, researchers in stroke rehabilitation should understand the mechanics of vibration and how they can be used with the stroke population.

About Vibration.

Vibration is described as the mechanical oscillatory motion about an equilibrium point, involving the periodic alteration of force, acceleration and displacement over time (Rauch et al., 2010; Rittweger, 2010). In terms of exercise, the energy from the oscillation (cycles of motion) is transferred from an actuator (vibration platform) to a resonator (part of the body). Furthermore, these oscillations take a sinusoidal form and involve magnitude, frequency (in hertz [Hz]), and phase angle (Rittweger, 2010; Lachance et al., 2012). Vibration frequency (Hz) is consistent throughout the literature and is measured by the number of oscillations per second (Lorenzen et al., 2009). However, it is the magnitude of vibration that is inconsistent as there are a number of different ways it can be described. Both “amplitude” and “peak-to-peak displacement” are commonly used terms in research to describe the magnitude of vibration. Ultimately, peak-to-peak displacement is preferred as it describes total vibration excursion of a point between its positive and negative extremes (Lorenzen et al., 2009; Rauch et al., 2010).

Types of Vibration Platforms.

There are two styles of vibration platforms that are typically used in research. One type transfers the vibrations to both feet synchronously, while the other functions in a side altering manner so that one foot is always lower than the other (Cardinale &

Wakeling, 2005; Ritteger et al., 2010). Figure 2 illustrates how both kinds have a unique way in delivering the vibrating perturbations. Synchronous platforms have a vertical (up and down) stimulus, while the side altering platform has an asynchronous (teeter totter) stimulus while balancing around a central point (Cardinale & Wakeling, 2005; Lorenzen et al., 2009; Rauch et al., 2010). While using a synchronous device, participants experience a slight downward shift of the platform with each vibration (vertical displacement ~ 1-10 mm). This downward motion results in an involuntary contraction of the lengthened muscle. Once this is finished, the platform then returns to its original position where the process is then repeated, harmonizing with the vibration frequency (Bissonnette, Weir, Leigh, & Kenno, 2010; Cardinale & Wakeling, 2005; Lachance et al., 2012). All whole body vibration (WBV) devices offer varying amounts of frequency and magnitude, therefore, it is imperative to know the proper amounts in order to create the desired outcome.

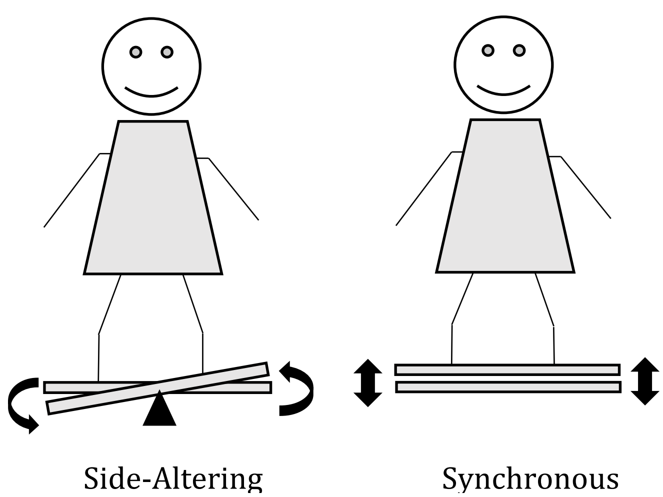

Figure 2: Types of WBV Platforms - Direction of the vibration stimulus in synchronous and side-altering platforms. Adapted from Rittweger et al., 2010.

***Oscillation Frequency and Magnitude*.**

Prior to the use of WBV treatment, it is important to determine the ideal combination of stimuli frequency and magnitude that are needed to generate adaptations. In terms of frequency, Cardinale & Lim (2003) discovered that a vibration frequency of 30 Hz was responsible for generating the largest reflex response in the targeted muscles during WBV. However, although these high frequencies (30-40 Hz) are generating the greatest response, when coupled with a low magnitude (1 mm), these conditions can cause the affected muscle to fatigue (Torvinen et al., 2002; Cardinale & Lim, 2003). Fatiguing the muscle can also be caused by prolonged exposure to the vibrations and can result in repressed neuromuscular performance. Other collective neuromuscular deficits brought on by prolonged exposure are reduced motor unit firing rates and muscle contraction force, depressed nerve conduction velocity, and weakened perception (Cardinale & Wakeling, 2005). For this reason, researchers need to become aware of how long the stimulus is administered to avoid such defects. Torvinen et al. (2002) observed that a shorter session of WBV can lead to improvements in force and power generating capacity in lower limbs. Furthermore, a single session exposing participants to vibration 10 times for a duration of 60 s with a 60 s rest between each treatment, has been shown to induce such improvements (Bosco et al., 1999a). Shorter WBV session of five 1-minute bouts followed by 1-minute rest times have also generated improvements in power in the upper limbs (Bosco, Cardinale, & Tsarpela, 1999b).

WBV Training.

Typically oscillations are transferred through the legs towards the body, activating the neuromuscular system (Roelants, Delecluse, & Verchueren, 2004; Lachance et al., 2012). Due to the movement patterns of the platform, WBV offers both physical and neural (nerve-related) overloads, producing alterations to the body's tissues, particularly the muscles (Signorile, 2006). This exposure to vibration causes the muscles to experience a tonic excitatory effect (Torvinen et al., 2002). The muscle tissue response to the oscillations is termed the tonic vibration reflex (Signorile, 2006). During a vibration stimulus, changes in muscle length are observed. These gain in muscle tension are due to the oscillations stimulating the nerves of the receptors in the muscle spindles (Cardinale & Bosco, 2003). The primary sensory receptors in muscle spindles are the most sensitive to the vibration stimulus and therefore, are able to detect any change in muscle length (Signorile, 2006). Once a change in length is sensed, the primary sensory receptors send information to the spinal cord using Ia sensory neurons (Matthews, 1966). These Ia sensory neurons use both mono- and poly-synaptic pathways for signal transmission (Mester, Spitzenfeil, Schwarzer, & Seifriz, 1999). Directly, Ia sensory receptors excite the alpha motor neurons (α MN) of the same muscle from which they arise. This ultimately causes the agonist muscle to carry out an involuntary reflexive contraction (Burke & Shiller, 1977; Cardinale & Lim, 2003; Mester et al., 1999; Signorile, 2006). Ia sensory neurons can also poly-synaptically excite an inhibitory interneuron to relax the antagonist muscle, complimenting the agonist contraction. Lastly, the Ia sensory neurons are able to excite intrafusal fibre on the agonist muscle so sensitivity and receptiveness is maintained for future oscillations (Cardinale & Bosco, 2003). Please refer to Figure 3 for a depiction of the tonic vibration reflex. Through these mechanisms, WBV training is able to elicit an upsurge in muscle activity.

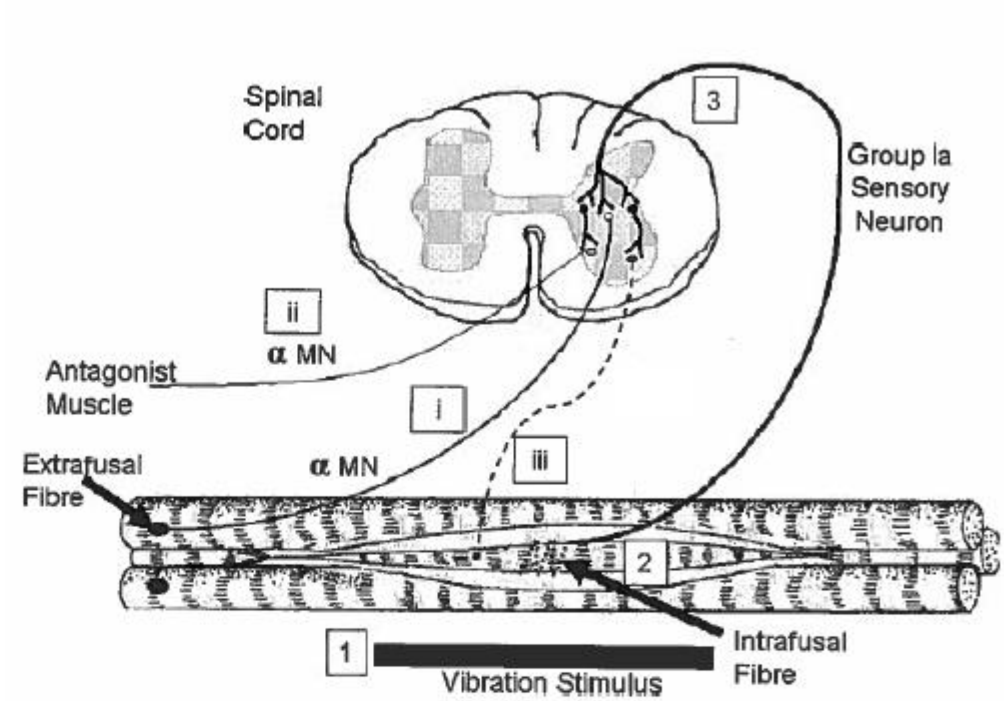

Figure 3: Tonic Vibration Reflex – The vibration stimulus (1) causes changes to muscle length which is detected by the muscle spindles (2) and send Ia sensory neurons to the spinal cord (3). While in the spinal cord, Ia sensory neurons can: (i) mono-synaptically excite α MN to stimulate reflexive muscle contraction of the agonist muscle (extrafusal fibre), (ii) poly-synaptically inhibit α MN to relax antagonist muscle, (iii) poly-synaptically excite intrafusal muscle fibres of agonist muscle to maintain sensitivity to future oscillations. (Hazell, 2006).

When WBV is paired with a common task, such as squatting, the amplitude of EMG signal increases significantly (Hazell, Jakobi, & Kenno, 2007; Signorile, 2006). This elevated EMG activity can be explained by the fact that vibration is most effective when the targeted muscles are stretched or lengthened (Nordin & Hagbarth, 1996). With a crouched or squatted position the quadriceps muscle's involvement is amplified and the transmission of vibration waves to the head is dramatically reduced (Tihanyi, Horváth, Fazekas, Hortobágyi, & Tihanyi, 2007). Therefore, having participants in a half squat position while standing on the vibrating platform is an effective posture to train the lower extremities (Nordin & Hagbarth, 1996).

An important area to consider when using WBV training is proper body positioning. As discussed by Giminiani, Masedu, Tihanyi, Scrimaglio & Valenti (2012), the posture of the body while performing exercises influences the degree of muscle activation. In terms of the squat position, differences in the knee and ankle angles are responsible for the alterations in muscle activity. Changing the joint angle allows for an increase in pre-activation and muscle length, enhancing muscle sensitivity (Giminiani et al., 2012). Therefore, when using this type of training, researchers and participants must be aware of proper exercise techniques in order to generate the best possible results.

While vibrating individual muscles would allow for specific muscle targeting, WBV actively involves the patient, requires balance, and engages several muscles in the lower extremities. One benefit to using WBV is that it minimizes the need for physical exertion and stress on many structures of the body, including the musculo-skeletal, respiratory, and cardiovascular systems (Rittweger et al., 2010). By decreasing the amount of actual stress and effort, WBV can be a viable alternative for training for at-risk populations as WBV has been shown to create comparable results to resistance and explosive strength training (Roelants et al., 2004).

WBV and Healthy Populations.

Initially, the effects of WBV training were observed in healthy populations. It has been identified that performing both static and dynamic exercises while on the WBV platform induce positive effects. However, when the WBV stimuli is added to dynamic exercises, there is an increase in EMG activity, superior to that of static exercises (Hazell, et al., 2007). The same research group identified that adding an additional light external load, while performing dynamic squat exercises on the WBV platform, does not further increase the magnitude of EMG activity (Hazell, Kenno, & Jakobi, 2010). Although positive effects are achieved with healthy populations, research has begun to look at more "at-risk" populations to see if the benefits to WBV training can be obtained.

WBV and Older Adults.

Normal aging processes result in many functional declines including muscular strength and mobility. Experiencing such deficits increases the likelihood of the aging individual obtaining additional diseases and injuries, as well as become more dependent on others. Recently WBV has been introduced as an intervention to reduce and/or reverse the adverse effects of aging. Some of the most fundamental impairments that the aging population are presented with have to do with gait and mobility, balance and flexibility. All of these capabilities affect the way the individual is able to function in everyday tasks, therefore, it is essential for older adults to maintain their competencies.

Gait.

Although majority of available research pertaining to WBV therapy was done on trained, healthy young adults, the aging population is beginning to generate some impact in the field. WBV has been shown to improve many aspects of walking in the older population. For instance, Bogaerts et al. (2011) demonstrated that walking speed had clinically meaningful improvement in elderly women which was likely due to the improved muscle coordination and lower limb strength. In order to have improvements in gait there must be alterations to the underlying mechanisms. After about 2 months of

WBV treatment, a significant improvement was shown in step length, knee extension and ankle plantar flexor strength and speed (Kawanabe et al., 2007; Roelants et al., 2004; Machado, García-López, González-Gallego, & Garatachea, 2010; Rees, Murphy, & Watsford, 2008). Of particular interest is that strength gains from WBV are maintained for 4 weeks following a 16-session training protocol (Carr et al., 2012). These findings are important as older adults are able to retain strength gains, decreasing their risk of secondary health conditions.

Balance.

One of the most influential components of mobility is balance. Maintaining proper balance decreases an aging individual's risk of experiencing a potentially harmful or fatal fall. Each year approximately 30% of community-dwelling adults over 65 years of age have at least one fall, leaving 50% of those fallers never regaining functional walking ability (Liu-Ambrose, Khan, Eng, Lord, & McKay, 2004). These numbers outline the urgency of retaining balance into later life. In institutionalized elderly fallers, postural sway velocity is often heightened. However, with the use of WBV, both sway velocity and fall risk were found to decrease (Bogaerts et al., 2011). In general, WBV training has been shown throughout literature to improve overall body balance through reduced postural sway and improved balance recovery (Bissonnette et al., 2010; Bogaerts, Verschueren, Delecluse, Claessens, & Boonen, 2007; Kawanabe et al., 2007; Lachance et al., 2012a; Rees et al., 2009; Verschueren et al., 2004). As one of the main consequences of stroke, WBV training could have the ability to help those with compromised balance.

WBV and Clinical Populations.

Parkinson's disease and multiple sclerosis.

WBV has recently gained some popularity due to the diverse populations it is able to assist. WBV is believed to be a safe and effective alternative for individuals suffering from many types of disease related motor impairments and postural instabilities such as multiple sclerosis (MS) and Parkinson's disease (PD). For example, patients who are living with the effects of MS often experience incapacitating problems in balance and ataxia which result in disturbances in postural control and mobility. It has been identified that following WBV, these patients are able to achieve enhancements in postural control and walking ability (Schuhfried, Mittermaier, Jovanovic, Pieber, & Paternostro-Sluga, 2005; Wunderer, Schabrun, & Chipchase, 2010). One of the main contributors to the improvement in functional mobility was due to WBV's effect on strengthening lower limb muscles (Jackson, Merriman, Vanderburgh, & Brahler, 2008; Wunderer et al., 2010). Another clinical population that has seen benefits from WBV are patients with PD. Individuals with PD are at approximately double the risk of falling compared to other older individuals (Wood, Bilclough, Bowron, & Walker, 2002). Additionally, these same patients often report a heightened postural instability when pharmacological therapies are involved, highlighting the importance of administering alternative treatments. In recent research, patients with PD have experienced enhanced postural control and gait steadiness following vibration therapies (Haas, Turbanski, Kaiser, & Schmidtbleicher, 2004; Novak & Novak, 2006; Turbanski et al., 2005). WBV was also found to have therapeutic effects on PD motor symptoms, with largest improvements seen in rigidity and tremor (Haas, Turbanski, Kessler, & Schmidtbleicher, 2006). With both of these populations, the effects generated with the WBV treatments appeared to remain stable 2-4 weeks following treatment termination (Ebersbach, Edler, Kaufhold, & Wissel, 2008; Schuhfried et al., 2005). All of these findings are significant and illustrate the potential initial and long lasting effects of WBV for individuals experiencing motor impairments and postural instabilities.

WBV and Stroke.

Exploring the possible effects of WBV training has just begun to develop within the stroke community. Although there are a limited number of studies available addressing this area, there have been some benefits observed from the use of such therapy. As discussed previously, functional mobility is imperative for independence and overall quality of life. Likewise, it has been shown that with the use of WBV, those who are living with the effects of stroke can receive improvements in walking performance. Such contributing improvements were seen in ankle spasticity, gait speed and overall mobility (through the TUG test) (Chan et al., 2011; Lau, Yip, & Pang, 2012; Merkert, Butz, Niecza, Steinhagen-Thiessen, & Echardt, 2011; Miyara et al., 2014). The improvement in the ankle is particularly important as the plantarflexors influence the stepping motion tremendously. Balance is another area that has been shown to benefit from WBV in the stroke population. The lower extremities often become weakened following a stroke, making weight bearing movements difficult. With the use of WBV, individuals living with strokes have experienced enhanced lower limb strength (Lau et al., 2012; Tankisheva et al., 2013; Tihanyi et al., 2007). Liao, Lam, Pang, Jones, & Ng (2013) support this strength increase as heightened EMG activity was observed during a WBV session. Increased ankle range of motion and lower limb strength could possibly be responsible for the increase in weight loading to affected side during WBV (Chan et al., 2011; van Nes, Geurts, Hendricks, & Duysens, 2004). This improved weight-shifting capacity was also paired with enhancements in postural control following WBV training (Merkert et al., 2011; van Nes et al., 2004). Due to the presented benefits, WBV training should be further investigated to identify if it is indeed a viable therapeutic alternative.

Although there have been documented benefits to using WBV training in stroke patients, there have also been studies identifying no added benefits to WBV. A study by van Nes et al. (2006) analyzed the effects of 6 weeks (5 days per week) of WBV training on balance recovery and ADL. However, at both 6 weeks and 12 weeks follow up, researchers found no clinically relevant or statistical differences in balance recovery or ADL performance (van Nes et al., 2006). One possible explanation for this null effect could be that there was not enough time to recover between sessions as they took place 5 times per week. Also, the frequency at which participants performed their exercises at was 30 Hz and other research has discovered that WBV at higher frequencies (40-45 Hz) result in significantly greater muscle activation (Hazell et al., 2007; Hazell et al., 2010).

Limitations and future research.

WBV research has traditionally investigated the effects of treatment on healthy individuals; however, there has been a progressive shift to understand the available benefits for those with motor impairments. Examining the effects of WBV specifically on stroke survivors has only recently started to appear and there are only a few studies that have been conducted as of late. Of the studies that have been done, the evidence suggests WBV training as a possible option for increasing muscle strength, improving balance, and improving overall mobility. However, these findings should be looked at critically as often studies without statistically significant findings are incorporated into the literature.

A limitation that presents itself throughout the literature are that many studies are testing participants who are in the chronic stage of stroke (<6 months post stroke). Future research should be done on patients who are still within the acute stage and have recently finished inpatient rehabilitation. If benefits are found by investigating acute stroke patients, rehabilitation coordinators can implement WBV training during the inpatient treatment to optimize their functional recovery.

Lastly, studies to this date have compared the effects of WBV to conventional therapy (i.e., resistance training). However, from a clinical standpoint, future studies should be investigating the results when both of these therapies are paired. There is only one study by Tihanyi et al. (2007) known to the researchers that has combined WBV with conventional physiotherapy. Although improvements in muscle strength was observed in this study, participants only received one session of WBV, making the effects of a prolonged program unknown. Therefore, future research should be conducted to determine the effects of multiple WBV sessions coupled with conventional treatment to discover if there are indeed added benefits.

References

Adams, H., Adams, R., Brott, T., del Zoppo, G., Furlan, A., Goldstein, L., Hademenos, G. (2003). Guidelines for the early management of patients with ischemic stroke: A scientific statement from the stroke council of the American Stroke Association. *Stroke, 34*: 1056-1083.

Baker, J., Meisner, B., Logan, J., Kungl, A. & Weir, P. (2009). Physical activity and successful aging in Canadian older adults. *Journal of Aging Physical Activity, 17*, 223-235.

Berg Balance Scale. Retrieved January 10, 2014 from: http://www.aahf.info/pdf/Berg_Balance_Scale.pdf

Bissonnette, D., Weir, P., Leigh, L. & Kenno, K. (2010). The effects of a whole-body advanced vibration exercise program on flexibility, balance, and strength in seniors. *Physical and Occupational Therapy in Geriatrics, 28*(3): 225-234.

Bogaerts, A., Delecluse, C., Boonen, S., Claessens A., Milisen, K. & Verschueren, S. (2011). Changes in balance, functional performance and fall risk following whole body vibration training and vitamin D supplementation in institutionalized elderly women. A 6 month randomized controlled trial. *Gait and Posture,* 33, 466-472.

Bogaerts, A., Verschueren, S., Delecluse, C., Claessens, A. & Boonen, S. (2007). Effects of whole body vibration training on postural control in older individuals: A 1 year randomized controlled trial. *Gait and Posture, 26*, 309-316.

Bohannon, R.W. (2007). Muscle strength and muscle training after stroke. *Journal of Rehabilitation Medicine, 39*, 14-20.

Bonita, E. & Beaglehole, R. (1988). Recovery of motor function after stroke. *Stroke, 19*, 1497- 1500.

Bosco, C., Cardinale, M. & Tsarpela, O. (1999b). Influence of vibration on mechanical power and electromyogram activity in human arm flexor muscles. *European Journal of Applied Physiology, 79*, 306-311.

Bosco, C., Colli, R., Introini, E., Cardinale, M., Tsarpela, O., Madella, A., Viru, A. (1999a). Adaptive responses of human skeletal muscle to vibration exposure. *Clinical Physiology,19*(2): 183-187.

Bretón, R. R. & Rodríguez, J. C. (2012). Excitotoxicity and oxidative stress in acute ischemic stroke. In J. Rodríguez (Ed.), *Acute Ischemic Stroke* (pp. 29-58). Croatia: InTech.

Broemeling, A., Watson, D. & Prebtani, F. (2008). Population patterns of chronic health conditions, co-morbidity and healthcare use in Canada: Implications for policy and practice. *Healthcare Quarterly*, *11*(3): 70-76.

Burke, D. & Schiller, H. (1976). Discharge pattern of single motor units in the tonic vibration reflex of human triceps surae. *Journal of Neurology, Neurosurgery, and Psychiatry, 39*, 729-741.

Canadian Stroke Best Practices. (2013). Stroke Rehabilitation. Retrieved from: http://strokebestpractices.ca/wp-ontent/uploads/2013/07/SBP2013_Stroke-Rehabilitation-Update_July-10_FINAL.pdf

Canadian Stroke Network. (2011). Quality of Stroke Care in Canada 2011. Retrieved from: http://www.canadianstrokenetwork.ca/wp-content/uploads/2011/06/QoSC-EN1.pdf

Caplan, L. R. (2007). Stroke Subtypes and Rationale for Their Separation. In T. Munsat (Ed.*), Stroke: Selected Topics* (pp. 9-26). New York: Demos Medical Publishing, LLC.

Cardinale, M. & Bosco, C. (2003). The use of vibration as an exercise intervention. *Exercise and Sport Science Reviews, 17*, 621-624.

Cardinale, M. & Lim, J. (2003). Electromyography activity of vastus lateralis muscle during whole-body vibration of different frequencies. *Journal of Strength and Conditioning Research, 17*(3): 621-624.

Cardinale, M. & Wakeling, J. (2005). Whole body vibration exercise: are vibrations good for you? *British Journal of Sports Medicine, 39,* 585-589. doi: 0.1136/bjsm.2005.016857

Carr, K., Lachance, C. & Kenno, K. (2012). Whole-body vibration training in older adults: Retention of the strengthening effects. *Critical Reviews in Physical and Rehabilitation Medicine, 24*(1-2): 51-67.

Carter, A. B. (1968). *All about Strokes.* London: Thomas Nelson and Sons Ltd.

Chan, P.H. (2001). Reactive oxygen radicals in signaling and damaging in the ischemic brain. *Journal of Cerebral Blood Flow and Metabolism, 21,* 2-14.

Chan, K., Liu, C., Chen, T., Weng, M., Huang, M. & Chen, C. (2011). Effects of a single session of whole body vibration on ankle plantarflexion spasticity and gait performance in patients with chronic stroke: a randomized controlled trial. *Clinical Rehabilitation, 26*(12): 1087-1095.

Circle of Willis: MedlinePlus Medical Encyclopedia Image. (2013). Retrieved February 13, 2014 from: http://www.nlm.nih.gov/medlineplus/ency/imagepages/18009.htm

Craig, L., Bernhardt, J., Langhorne, P. & Wu, O. (2010). Early mobilization after stroke: An example of an individual patient data meta-analysis of a complex intervention. *Stroke, 42*, 2632-2636.

Donnan, G. A., Dewey, H. M., Thrift, A. G. & Sturm, J. (2007).Epidemiology of Stroke. In T. Munsat (Ed.), *Stroke: Selected Topics* (pp. 1-8). New York: Demos Medical Publishing, LLC.

Ebersbach, G., Edler, D., Kaufhold, O. & Wissel, J. (2008). Whole body vibration Versus conventional physiotherapy to improve balance and gait in Parkinson's Disease. *Archives of Physical Medicine and Rehabilitation, 89*, 399-403.

Edlow, J. A. (2008). *Stroke.* Westport, CT: Greenwood Press.

Eng, J. (2004). Strength training in individuals with stroke. *Physiotherapy Canada*, *56*(4): 189–201.

Eng, J. & Chu, K. (2002). Reliability and comparison of weight-bearing ability during standing tasks for individuals with chronic stroke. *Archives of Physical Medicine and Rehabilitation*, *83*(8): 1138-1144.

Eng, J., Chu, K., Kim, M., Dawson, A., Carswell, A. & Hepburn, K. (2003). A community-based group exercise program for persons with chronic stroke. *Medicine and Science in Sports and Exercise*, *35*(8): 1271-1278.

Eng, J. & Winter, D. (1995). Kinetic analysis of the lower limbs during walking: what information can be gained from a three-dimensional model? *Journal of Biomechanics, 28*, 753–758.

Foley, N., McClure, A., Meyer, M., Salter, K., Bureau, Y. & Teasell, R. (2012). Inpatient rehabilitation following stroke: amount of therapy received and associations with functional recovery. *Disability & Rehabilitation, 34*(25): 2135-2138.

Forster, A. & Young, J. (1995). Incidence and consequences of falls due to stroke: a systematic inquiry. *British Medical Journal, 311*, 83-86.

Fries, J. (1980). Aging, natural death, and the compression of morbidity. *The New England Journal of Medicine, 303*(3): 130-135.

Gilmour, H. & Park, J. (2006). Dependency, chronic conditions and pain in seniors. *Supplement to Health Reports*, *14,* 21-31.

Giminiani, R., Masedu, F., Tihanyi, J., Scrimaglio, R. & Valenti, M. (2012). The interaction between body position and vibration frequency on acute response to whole body vibration. *Journal of Electromyography and Kinesiology, 23*, 245-251.

Gomez, C. (1993). Time is brain. *Journal of Stroke and Cerebrovascular Disease, 3*, 1–2.

Gordon, N., Gulanick, M., Costa, F., Fletcher, G., Franklin, B., Roth, E. & Shephard, T (2004). Physical activity and exercise recommendations for stroke survivors: An American Heart Association scientific statement from the council on clinical cardiology, subcommittee on exercise, cardiac rehabilitation, and prevention; the Council on Cardiovascular Nursing; the Council on Nutrition, Physical Activity, and Metabolism; and the Stroke Council. *Circulation, 109*, 2031-2041.

Haas, C.T., Turbanski, S., Kaiser, I. & Schmidtbleicher, D. (2004). Effects of whole-body vibration on postural control in Parkinson’s disease. *Movement Disorders Society, 5*, 185.

Haas, C.T., Turbanski, S., Kessler, K. & Schmidtbleicher, D. (2006). The effects of random whole-body-vibration on motor symptoms in Parkinson's disease. *NeuroRehabilitation, 20, 29-36.*

Hakim, A., Silver, F. & Hodgson, C. (1998). Organized stroke care: A new era in stroke prevention and treatment. *Canadian Medical Association Journal 159*(6):S1.

Han, J., Bae, H. & Wong, L. (2011). Pathophysiology and Mechanisms Whereby Hypertension May Cause Stroke. In Aiyagari, V. & Gorelick, P. (Eds.), *Hypertension and Stroke* (pp. 77-94). New York: Springer Science+Business Media, LLC.

Harris, J., Eng, J., Marigold, D., Tokuno, C. & Louis, C. (2005). Relationship of balance and mobility to fall incidence in people with chronic stroke. *Physical Therapy, 85*, 150-158.

Hart, R.G. (2000). What causes intracerebral hemorrhage during warfarin therapy? *Neurology, 55*, 907–908.

Hazell, T. (2006). *The effects of whole body vibration on muscle activity.* Unpublished Masters Thesis, University of Windsor, Windsor, Canada.

Hazell, T., Jakobi, J. & Kenno, K. (2007). The effects of whole-body vibration on upper- and lower-body EMG during static and dynamic contractions. *Applied Physiology, Nutrition, and Metabolism, 32*, 1156-1163.

Hazell, T., Kenno, K. & Jakobi, J. (2010). Evaluation of muscle activity for loaded and unloaded dynamic squats during vertical whole-body vibration. *The Journal of Strength and Conditioning Research, 24*(7): 1960-1865.

Heart and Stroke (2008). *Hemorrhagic Stroke.* Retrieved from: http://www.heartandstroke.com/site/c.ikIQLcMWJtE/b.3484153/k.7675/Stroke__Hemorrhagic_stroke.htm

Heart and Stroke (2011). *Stroke warning signs.* Retrieved from: http://www.heartandstroke.com/site/c.ikIQLcMWJtE/b.3483937/k.ED98/Stroke__Stroke_Warning_Signs.htm

Hillier, S. & Inglis-Jassiem, G. (2010). Rehabilitation for community-dwelling people with stroke: home or centre based? A systematic review. *International Journal of Stroke*, 5, 178-86.

Hodgson, C. (1998). Prevalence and disabilities of community-living seniors who report the effects of stroke. *Canadian Medical Association Journal, 159*(6): S9-S14.

Ihle-Hansen, H., Thommessen, B., Bruun Wyller, T., Engedal. K. & Fure, B. (2012). Risk factors for and incidence of subtypes of ischemic stroke. *Functional Neurology, 27*(1): 35-40.

Jackson, K., Merriman, H., Vanderburgh, P. & Brahler, J. (2008). Acute effects of whole-body vibration on lower extremity muscle performance in persons with multiple sclerosis. *Journal of Neurologic Physical Therapy, 32*(4): 171-176.

Jette, A. & Branch, L. (1981). The Framingham disability study: II physical disability among the Aging. *American Journal of Public Health, 71*(11): 1211-1216.

Kawanabe, K., Kawashima, A., Sashimoto, I., Takeda, T., Sato, Y. & Iwamoto, J. (2007). Effects of whole-body vibration exercise and muscle strengthening, balance, and walking exercises on walking ability in the elderly. *The Keio Journal of Medicine, 56*(1): 28-33.

Kitazaki, S., & Griffin, M. (1998). Resonance behaviour of the seated human body and effects of posture. *Journal of Biomechanics, 31*, 143-149.

Klandorf, H. & Van Dyke, K. (2012). Oxidative and Nitrosative Stresses: Their Role in Health and Disease in Man and Birds. In V. Lushchak (Ed.), *Oxidative Stress – Molecular Mechanism and Biological Effects* (pp. 47-60). Croatia: InTech.

Kolominsky-Rabas, P., Weber, M., Gefeller, O., Neundoerfer, B. & Heuschmann, U. (2001). Epidemiology of ischemic stroke subtypes according to TOAST criteria: Incidence recurrence, and long-term survival in ischemic stroke subtypes: A population-based Study. *Stroke*, 32, 2735-2740.

Lachance, C., Weir, P., Kenno, K. & Horton, S. (2012). Is whole-body vibration beneficial for seniors? *European Review of Aging and Physical Activity*, *9*(1): 51-62.

Lachance, C., Kenno, K., Weir, P., Carr, K., McNevin, N. & Horton, S. (2012a). The effects of whole-body-vibration training on upper and lower body strength in older adults. *Physical and Rehabilitation Medicine, 24*(1-2): 35-50.

Langhorne, P., Bernhardt, J. & Kwakkel, G. (2011). Stroke Rehabilitation. *Lancet*, *377,* 1693-1702.

Lau, R., Yip, S. & Pang, M. (2012). Whole-body vibration has no effect on neuromotor function and falls in chronic stroke. *Medicine and Science in Sport and* Exercise. doi:10.1249/MSS.0b013e31824e4f8c

Legg, L., Drummond, A., Gladman, J.R.F., Corr, S., Donkervoort, M., Edmans, J., Langhorne, P. (2007).Occupational therapy for patients with problems in personal activities of daily living after stroke: systematic review of randomised trials. *British Medical Journal*, 1-8. doi:10.1136/bmj.39343.466863.55

Liao, L., Lam, F., Pang, M., Jones, A. & Ng, G. (2013). Leg muscle activity during whole- body vibration in individuals with chronic stroke. *Medicine and Science in Sports and Exercise. doi:*10.1249/MSS.0b013e3182a6a006

Lindsay, P., Bayley, M., Hellings, C., Hill, M., Woodbury, E. & Phillips, S. (2008). Canadian best practice recommendations for stroke care: Summary. *Canadian Medical Association Journal, 179*(12): S1-S25.

Lings, S. & Leboeuf-Yde, C. (2000). Whole-body vibration and low back pain: a systematic critical review of the epidemiological literature 1992-1999. *International Archives of Occupational and Environmental Health, 73*: 290-297.

Liu-Ambrose, T., Khan, K.M., Eng, J.J., Lord, S.R. & McKay, H.A. (2004) Balance confidence improves with resistance or agility training. Increase is not correlated with objective changes in fall risk and physical abilities. *Gerontology, 50*(6): 373–383

Logan, P.A., Gladman, J.R.F., Avery, A., Walker, M.F., Dyas, J. & Groom, L. (2004). Randomized controlled trial of an occupational therapy intervention to increase outdoor mobility after stroke. *British Medical Journal,* 1-4. doi: 10.1136/bmj.38264.679560.8F

Lorenzen, C., Maschette, W., Koh, M. & Wilson, C. (2009). Inconsistent use of terminology in whole body vibration exercise research. *Journal of Science and Medicine in Sport, 12*, 676-678.

Machado, A., García-López, D., González-Gallego, J. & Garatachea, N. (2010). Whole-body vibration training increases muscle strength and mass in older women: a randomized-controlled trial. *Scandinavian Journal of Medical and Science in Sports, 20*, 200-207.

Matthews, P. (1966). The reflect excitation of the soleus muscle of the decerebrate cat caused by vibration applied to its tendon. *Journal of Physiology, 184,* 450-472.

McKay, H. (1997). Generations: Baby Boomers, their Parents and their Children. Sydney: *Macmillan Publishing.*

Merkert, J., Butz, S., Niecza, R., Steinhagen-Thiessen, E. & Echardt, E. (2011). Combined whole body vibration and balance training using Vibrosphere. *Gerontology and Geriatrics Journal, 44,* 256-261.

Mester, J., Spitzenfeil, P., Schwarzer, J. & Seifriz, F. (1999). Biological reaction to vibration implications for sport. *Journal of Science and Medicine in Sport, 2,* 211-226.

Miyara, K., Matsumoto, S., Uema, T., Hirokawa, T., Noma, T., Shimodozono, M., Kawahira, K. (2014). Feasibility of using whole body vibrations as a means for controlling spasticity in post-stroke patients: A pilot study. *Complementary Therapies in Clinical Practice*, *20*, 70,73.

Nordin, M. & Hagbarth, K. (1996) Effects of precedeng movements and contractions on the tonic vibration reflex of human finger extensor muscles. *Acta Physiologica Scandinavia, 156*, 435–440.

Novak, P. & Novak, V. (2006). Effect of step-synchronized vibration stimulation of soles on gait in Parkinson's disease: a pilot study. *Journal of NeuroEngineering and Rehabilitation, 3*(9). doi:10.1186/1743-0003-3-9

O'Donnell, M., Xavier, D., Liu, L., Zhang, H., Lim Chin, S., Rao-Melacini, P., … Yusuf, S. (2010). Risk factors for ischaemic and intracerebral haemorrhagic stroke in 22 countries (the INTERSTROKE study): a case-control study. *Lancet*, *376*, 112-123

Oeppen, J., & Vaupel, J.W. (2002). Broken limits to life expectancy. *Science, 296:* 1029–1031.

Ouellette, M., LeBrasseur, N., Bean, J., Phillips, E., Stein, J., Frontera, W. & Fielding, R. (2004). High-intensity resistance training improves muscle strength, self-reported function, and disability in long-term stroke survivors. *Stroke,* 35, 1404-1409.

Pang, M., Eng, J., Dawson, A., McKay, H. & Harris, J. (2005). A Community-based fitness and mobility exercise (FAME) program for older adults with chronic stroke: a randomized controlled trial. *Journal of the American Geriatrics Society*, *53*(10): 1667- 1667.

Phillipson, C. (2007). Understanding the baby boom generation: Comparative perspectives. *International Journal of Ageing and Later Life, 2*(2): 7-11.

Public Health Agency of Canada. (2011). Tracking Heart Disease and Stroke in Canada – Stroke Highlights 2011.

Public Health Agency of Canada (2009). Tracking Heart Disease and Stroke in Canada.

Rauch, F., Sievanen, H., Boonen, S., Cardinale, M., Degens, H., Felsenberg, D., … Rittweger, J. (2010). Reported whole-body vibration intervention studies: Recommendations of the International Society of Musculoskeletal and Neuronal Interactions. *Journal of Musculoskeletal and Neuronal Interactions, 10*(3): 193-198.

Reese, S., Murphy, A. & Watsford, M. (2009). Effects of whole body vibration on steadiness in an older population. *Journal of Science and Medicine in Sport, 12,* 440-444.

Reese, S., Murphy, A. & Watsford, M. (2008). Effects of whole-body vibration exercise on lower-extremity muscle strength and power in an older population: A randomized clinical trial. *Physical Therapy, 88*(4): 462-470.

Riley, J. (2001). *Rising Life Expectancy: A Global History*. Cambridge University Press.

Rittweger, J. (2010). Vibration as an exercise modality: how it may work, and what its potential might be. *European Journal of Applied Physiology, 108*, 877-904.

Roelants, M., Delecluse, C. & Verschueren, S. (2004). Whole-body-vibration training increases knee-extension strength and speed of movement in older women. *Journal of the American Geriatrics Society,*52, 901-908.

Saver, J. L. (2006). Time is brain – Quantified. *Stroke, 36*, 263-266.

Schnider, A., & Landis, T. (1995) Memory Loss. In J. Bogousslavsky & L. Caplan (Eds.), *Stroke Syndromes* (pp. 145-150). Cambridge: Cambridge University Press.

Schuhfried, O., Mittermaier, C., Jovanovic, T., Pieber, K. & Paternostro-Sluga. T. (2005). Effects of whole-body vibration in patients with multiple sclerosis: a pilot study. *Clinical Rehabilitation, 19,* 834 -842.

Signorile, J. (2006). Whole body vibration training: a new wave in exercise intervention for older adults? *The Journal on Active Aging,* 5, 30-37.

Silva, G., Koroshetz, W., González. & Schwamm, L. (2011). Causes of ischemic stroke. In G. González, J. Hirsch, M. Lev, P. Schaefer & L. Schwann (Eds.), *Acute Ischemic Stroke: Imaging and Intervention* (pp. 25-42). Springer-Verlag Berlin Heidelberg

Singhal, A.B., Lo., E. H., Dalkara, T. & Moshowitz, M. (2011). Ischemic Stroke: Basic Pathophysiology and Neuroprotective. In G. González, J. Hirsch, M. Lev, P. Schaefer & L. Schwann (Eds.), *Acute Ischemic Stroke: Imaging and Intervention* (pp. 1-24). Springer-Verlag Berlin Heidelberg

Statistics Canada. (2010). Population projections for Canada, provinces and territories (catalogue no. 91 520-X). Ottawa, ON: Canada. Minister of Industry.

Statistics Canada. (2012). The Canadian population in 2011: Age and sex structure (catalogue no. 98311- X2011001). Ottawa, ON: Canada. Minister of Industry.

Steiner, T., Rosand, J. & Diringer, M. (2006). Intracerebral hemorrhage associated with oral anticoagulant therapy: Current practices and unresolved questions. *Stroke 37,* 256-262.

Surveyors Use Reed Sensors to Accurately Measure Linear Distance. Retrieved December 18, 2014, from: http://www.meder.com/us_linear_distance.html

Tankisheva, E., Bogaerts, A., Boonen, S., Feys, H. & Verschueren, S. (2013). Effects of intensive whole-body vibration training on muscle strength and balance in adults with chronic stroke: A Randomized Controlled Pilot Study. *American Congress of Rehabilitation Medicine*, 1-8.

Tatemichi, T. K. (1995) Dementia. In J. Bogousslavsky & L. Caplan (Eds.), *Stroke Syndromes* (pp. 169-181). Cambridge: Cambridge University Press.

Teasell, R., Foley, N., Salter, K. & Jutai, J. (2008). A blueprint for transforming stroke rehabilitation care in Canada: The case for change. *Archives of Physical Medicine and Rehabilitation. 89*, 575-578.

Tihanyi, T., Horváth, M., Fazekas, G., Hortobágyi, T. & Tihanyi, J. (2007). One session of whole body vibration increases voluntary muscle strength transiently in patients with stroke. *Clinical Rehabilitation*, *21*, 782-793.

Torvinen, S., Kannus, P., Sievanen, H., Jarvinen, T., Pasanen, M., Kontulainen, S., … Vuori, I. (2002). Effect of a vibration exposure on muscular performance and body balance. Randomized cross-over study. *Clinical Physiology and Functional Imaging, 22*, 145-152.

Turbanski, S., Haas, C.T., Friedrich, A. & Schmidtbleicher, D. (2005). Effects of random whole- body vibration on postural control in Parkinson’s disease. *Research in Sports Medicine*, 243-256.

van Nes, I., Geurts, A., Hendricks, H. & Duysens, J. (2004). Short-term effects of whole-body vibration on postural control in unilateral chronic stroke patients. American Journal of Physical Medicine and Rehabilitation, *83,* 867-873.

van Nes, I., Latour, H., Schils, F., Meijer, R., van Kuijk, A. & Geurts, A. (2006). Long-term effects of 6-weeks whole-body vibration on balance recovery and activities of daily living in the postacute phase of stroke: A randomized, controlled trial. *Stroke, 37*, 2331-2335.

Verschueren, S., Bogaerts, A., Delecluse, C., Claessens, A., Haentjens, P., Vanderschueren, D. & Boonen, S. (2010). The effects of whole-body vibration training and vitamin D supplementation on muscle strength, muscle mass, and bone density in institutionalized elderly women: A 6-month randomized, controlled trial. *Journal of Bone and Mineral Research, 26*(1): 44-49.

Verschueren, S., Roelants, M., Delecluse, C., Swinnen, S., Vanderschueren, D., & Boonen, S. (2004). Effect of 6-month whole body vibration training on hip density, muscle strength and postural control in postmenopausal women: A randomized controlled pilot study. *Journal of Bone and Mineral Research*, *19*(3): 352–359.

Wagner, J., Dromerick, A., Sahrmann, S. & Lang, C. (2007). Upper extremity muscle activation during recovery of reaching in subjects with post-stroke hemiparesis. *Clinical Neurophysiology*, *118*(1): 164-176.

Wang, H., Camicia, M., Terdiman, J., Hung, Y.Y. & Sandel, M.E. (2011). Time to inpatient rehabilitation hospital admission and functional outcomes of stroke patients. *Academy of Physical Medicine and Rehabilitation, 3*, 296-304.

Wang, H., Camicia, M., Terdiman, J., Mannava, M.K., Sidney, S. & Sandel, M.E. (2013). Daily treatment time and functional gains of stroke patients during inpatient rehabilitation. *Academy of Physical Medicine and Rehabilitation, 5*, 122-128.

Weiss, A., Suzuki, T., Bean, J. & Fielding, R. (2000). High intensity strength training improves strength and functional performance after stroke. *American Journal of Physical Medicine and Rehabilitation*, *79*, 369–376.

Wood, B., Bilclough, J.A., Bowron, A., Walker, R.W., (2002). Incidence and prediction of falls in Parkinson's disease: a prospective multidisciplinary study. *Journal of Neurology, Neurosurgery and Psychiatry*, *72*(6): 721–725.

Wunderer, K., Schabrun, S. & Chipchase, L. (2010). Effects of whole body vibration on strength and functional mobility in multiple sclerosis. *Physiotherapy Theory and Practice*, *26*(6): 374-384.

Appendix A

University of Windsor

CONSENT TO PARTICIPATE IN RESEARCH

Title of Study: **The effects on balance and mobility when combining whole body vibration (WBV) and traditional rehabilitation for acute stroke patients.**

You are asked to participate in a research study conducted by **Ms. Brittany Becker, Dr. K. Kenno, Dr. P. Weir, and Dr. N. McNevin** from the **Department of Kinesiology** at the University of Windsor, and Dr. S. Naaman from Hôtel-Dieu Grace Healthcare.

If you have any questions or concerns about the research, please feel to contact **Ms. Brittany Becker**: *Primary Investigator. (519) 981-8037*

PURPOSE OF THE STUDY

The purpose of the study is to investigate whether a combination of traditional rehabilitation and whole body vibration (WBV) exercise provide superior improvements in balance and mobility than traditional rehabilitation alone for stroke patients.

PROCEDURES

If you volunteer to participate in this study, we would ask you to do the following things:
1. Be assigned to either the traditional rehabilitation or the rehabilitation/WBV exercise group.
2. Complete the following assessments prior to the start of WBV training, following 8 therapy sessions, and following 16 sessions
    a. 6-minute timed walk – For this test, you will walk a predefined course for 6-minutes, at which time the total distance walked will be recorded. If you are unable to complete the 6-minute timed walk, we will record the distance walked and the duration of the walk.
    b. BERG balance scale – The purpose of the BERG balance scale is to measure balance among older adults with impairments in balance function by assessing performance on functional tasks.
    c. Timed "Up & Go"-test – The test assesses functional mobility. You will be asked to rise from a chair, walk to a marker, located 8 feet away, turn, walk back to chair and sit down again. The individuals' score is timed in seconds.
    d. Arm Curl Test: You will be asked to perform as many complete bicep curls as possible in 30 seconds. Women will hold a 5lbs dumbbell, whereas men will hold an 8lbs dumbbell.

e. Tricep Extension Test: You will be asked to complete as many tricep extensions as you can in 30 seconds. Women will hold a 5lbs dumbbell, whereas men will hold an 8lbs dumbbell.

3. If you are assigned to the WBV group, in addition to your traditional therapy, you will participate in two, 15-minute sessions of WBV per week which will require you to stand on a vibration platform and perform exercises for your biceps, triceps, hamstrings and quadriceps.

Subjects will be randomly assigned to the two therapy groups, but will be age matched, and matched on their Chedoke-McMaster stroke scale score.

All therapy will take place in the Rehabilitation Department of Hôtel-Dieu Grace Healthcare under the supervision of Dr. Naaman.

POTENTIAL RISKS AND DISCOMFORTS

With any exercise, there is the possibility of abnormal responses to occur. However, there are minimal risks associated with this study. An assistant will stand by your side throughout testing to ensure that you do not fall should you become unbalanced, and you will be supported by a LiteGait® system. Slight discomfort and/or muscle soreness, may be experienced following the initial training regimen. This study has been created allowing for slight variations to be made to the exercise program, thus minimizing possibility of discomfort.

POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

As a participant, it is expected that you will experience positive improvements in balance function from partaking in your regular therapy sessions.

The scientific community/society will benefit from the publication of this research study, furthering the knowledge base on the effects of vibration training on stroke rehabilitation and balance performance.

PAYMENT FOR PARTICIPATION

Subjects in the traditional therapy control group will be offered WBV exercise training at the completion of the study. All subjects will receive a “Kinesiology Research” t-shirt for their participation.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. All subjects will be supplied a number which will be associated with their data during collection and analysis. As we are interested in the results of the group as a whole, individual data will not be reported in any public forum. At the time of publication and/or presentation, no reference will be made to any individual participant number. Only the Primary and Co-investigator will be able to access the data. The data will also be kept in a secure, locked location for 7 years after which time the data collection forms will be shredded.

PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you do not want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so. If upon completion of the participant profile any one of the following contraindications are met (cancer, pregnancy, active infection, gall or kidney stones, recent [less than 6 months] joint replacement) the investigator will remove the subjects from the study. Final approval for participation will be made by Dr. Naaman based on information provided in the Par-Q and participant profile.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE SUBJECTS

Individual results will be provided after every assessment procedure. A copy of the results of the study will be posted at the hospital in the Rehabilitation Department, and a verbal presentation of the group findings may be made.

Date when preliminary results are available: September 2014

SUBSEQUENT USE OF DATA

This data may be used in subsequent studies.

RIGHTS OF RESEARCH SUBJECTS

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

SIGNATURE OF RESEARCH SUBJECT/LEGAL REPRESENTATIVE

I understand the information provided for the study The effects on balance and mobility when combining whole body vibration (WBV) and traditional rehabilitation for acute stroke patients as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____

Name of Subject

Signature of Subject Date

SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

Signature of Investigator Date

Revised February 2014

LETTER OF INFORMATION FOR CONSENT TO PARTICIPATE IN RESEARCH

Title of Study: **The effects on balance and mobility when combining whole body vibration (WBV) and traditional rehabilitation for acute stroke patients.**

You are asked to participate in a research study conducted by **Ms. Brittany Becker,Dr. K. Kenno, Dr. P. Weir, and Dr. N. McNevin,** from the **Department of Kinesiology** at the University of Windsor, and Dr. S. Naaman from Hôtel-Dieu Grace Healthcare

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Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. All subjects will be supplied a number which will be associated with their data during collection and analysis. As we are interested in the results of the group as a whole, individual data will not be reported in any public forum. At the time of publication and/or presentation, no reference will be made to any individual participant number. Only the Primary and Co-investigator will be able to access the data. The data will also be kept in a secure, locked location for 7 years after which time the data collection forms will be

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SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

_______________________________ ____________________

Signature of Investigator Date

Revised February 2014

Appendix B

Figure 1 - WAVE Pro® vibration platform

Figure 2 – Dynamic Squat

Figure 3 – Dynamic Heel Raise

Figure 4 – Dynamic Bicep Curls

Figure 5 – Dynamic Tricep Extensions

Figure 6- Berg Balance Scale

Berg Balance Scale

The Berg Balance Scale (BBS) was developed to measure balance among older people with impairment in balance function by assessing the performance of functional tasks. It is a valid instrument used for evaluation of the effectiveness of interventions and for quantitative descriptions of function in clinical practice and research. The BBS has been evaluated in several reliability studies. A recent study of the BBS, which was completed in Finland, indicates that a change of eight (8) BBS points is required to reveal a genuine change in function between two assessments among older people who are dependent in ADL and living in residential care facilities.

Description:
14-item scale designed to measure balance of the older adult in a clinical setting.

Equipment needed:
Ruler, two standard chairs (one with arm rests, one without), footstool or step, stopwatch or wristwatch, 15 foot walkway

Completion:

Time: 15-20 minutes

Scoring: A five-point scale, ranging from 0-4. “0” indicates the lowest level of function and “4” the highest level of function. Total Score = 56

Interpretation:
41-56 = low fall risk
21-40 = medium fall risk
0 –20 = high fall risk

A change of 8 points is required to reveal a genuine change in function between 2 assessments.

Berg Balance Scale

Name: ________________________________ Date: __________________

Location: ______________________________ Rater: __________________

ITEM DESCRIPTION	SCORE (0-4)
Sitting to standing	________
Standing unsupported	________
Sitting unsupported	________
Standing to sitting	________
Transfers	________
Standing with eyes closed	________
Standing with feet together	________
Reaching forward with outstretched arm	________
Retrieving object from floor	________
Turning to look behind	________
Turning 360 degrees	________
Placing alternate foot on stool	________
Standing with one foot in front	________
Standing on one foot	________

Total ________

GENERAL INSTRUCTIONS
Please document each task and/or give instructions as written. When scoring, please record the lowest response category that applies for each item.

In most items, the subject is asked to maintain a given position for a specific time. Progressively more points are deducted if:

- the time or distance requirements are not met
- the subject's performance warrants supervision
- the subject touches an external support or receives assistance from the examiner

Subject should understand that they must maintain their balance while attempting the tasks. The choices of which leg to stand on or how far to reach are left to the subject. Poor judgment will adversely influence the performance and the scoring.

Equipment required for testing is a stopwatch or watch with a second hand, and a ruler or other indicator of 2, 5, and 10 inches. Chairs used during testing should be a reasonable height. Either a step or a stool of average step height may be used for item # 12.

SITTING TO STANDING

INSTRUCTIONS: Please stand up. Try not to use your hand for support.

( ) 4 able to stand without using hands and stabilize independently
( ) 3 able to stand independently using hands
( ) 2 able to stand using hands after several tries
( ) 1 needs minimal aid to stand or stabilize
( ) 0 needs moderate or maximal assist to stand

STANDING UNSUPPORTED

INSTRUCTIONS: Please stand for two minutes without holding on.

( ) 4 able to stand safely for 2 minutes
( ) 3 able to stand 2 minutes with supervision
( ) 2 able to stand 30 seconds unsupported
( ) 1 needs several tries to stand 30 seconds unsupported
( ) 0 unable to stand 30 seconds unsupported

If a subject is able to stand 2 minutes unsupported, score full points for sitting unsupported. Proceed to item #4.

SITTING WITH BACK UNSUPPORTED BUT FEET SUPPORTED ON FLOOR OR ON A STOOL

INSTRUCTIONS: Please sit with arms folded for 2 minutes.

( ) 4 able to sit safely and securely for 2 minutes
( ) 3 able to sit 2 minutes under supervision
( ) 2 able to able to sit 30 seconds
( ) 1 able to sit 10 seconds
( ) 0 unable to sit without support 10 seconds

STANDING TO SITTING

INSTRUCTIONS: Please sit down.

( ) 4 sits safely with minimal use of hands
( ) 3 controls descent by using hands
( ) 2 uses back of legs against chair to control descent
( ) 1 sits independently but has uncontrolled descent
( ) 0 needs assist to sit

TRANSFERS

INSTRUCTIONS: Arrange chair(s) for pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrests. You may use two chairs (one with and one without armrests) or a bed and a chair.

( ) 4 able to transfer safely with minor use of hands
( ) 3 able to transfer safely definite need of hands
( ) 2 able to transfer with verbal cuing and/or supervision
( ) 1 needs one person to assist
( ) 0 needs two people to assist or supervise to be safe

STANDING UNSUPPORTED WITH EYES CLOSED
INSTRUCTIONS: Please close your eyes and stand still for 10 seconds.
( ) 4 able to stand 10 seconds safely
( ) 3 able to stand 10 seconds with supervision
( ) 2 able to stand 3 seconds
( ) 1 unable to keep eyes closed 3 seconds but stays safely
( ) 0 needs help to keep from falling

STANDING UNSUPPORTED WITH FEET TOGETHER
INSTRUCTIONS: Place your feet together and stand without holding on.
( ) 4 able to place feet together independently and stand 1 minute safely
( ) 3 able to place feet together independently and stand 1 minute with supervision
( ) 2 able to place feet together independently but unable to hold for 30 seconds
( ) 1 needs help to attain position but able to stand 15 seconds feet together
( ) 0 needs help to attain position and unable to hold for 15 seconds

REACHING FORWARD WITH OUTSTRETCHED ARM WHILE STANDING
INSTRUCTIONS: Lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. (Examiner places a ruler at the end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the fingers reach while the subject is in the most forward lean position. When possible, ask subject to use both arms when reaching to avoid rotation of the trunk.)
( ) 4 can reach forward confidently 25 cm (10 inches)
( ) 3 can reach forward 12 cm (5 inches)
( ) 2 can reach forward 5 cm (2 inches)
( ) 1 reaches forward but needs supervision
( ) 0 loses balance while trying/requires external support

PICK UP OBJECT FROM THE FLOOR FROM A STANDING POSITION
INSTRUCTIONS: Pick up the shoe/slipper, which is in front of your feet.
( ) 4 able to pick up slipper safely and easily
( ) 3 able to pick up slipper but needs supervision
( ) 2 unable to pick up but reaches 2-5 cm (1-2 inches) from slipper and keeps balance independently
( ) 1 unable to pick up and needs supervision while trying
( ) 0 unable to try/needs assist to keep from losing balance or falling

TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS WHILE STANDING

INSTRUCTIONS: Turn to look directly behind you over toward the left shoulder. Repeat to the right. (Examiner may pick an object to look at directly behind the subject to encourage a better twist turn.)

( ) 4 looks behind from both sides and weight shifts well
( ) 3 looks behind one side only other side shows less weight shift
turns sideways only but maintains balance
( ) 1 needs supervision when turning
( ) 0 needs assist to keep from losing balance or falling

TURN 360 DEGREES

INSTRUCTIONS: Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.

( ) 4 able to turn 360 degrees safely in 4 seconds or less
( ) 3 able to turn 360 degrees safely one side only 4 seconds or less
( ) 2 able to turn 360 degrees safely but slowly
( ) 1 needs close supervision or verbal cuing
( ) 0 needs assistance while turning

PLACE ALTERNATE FOOT ON STEP OR STOOL WHILE STANDING UNSUPPORTED

INSTRUCTIONS: Place each foot alternately on the step/stool. Continue until each foot has touched the step/stool four times.

( ) 4 able to stand independently and safely and complete 8 steps in 20 seconds
( ) 3 able to stand independently and complete 8 steps in > 20 seconds
( ) 2 able to complete 4 steps without aid with supervision
( ) 1 able to complete > 2 steps needs minimal assist
( ) 0 needs assistance to keep from falling/unable to try

STANDING UNSUPPORTED ONE FOOT IN FRONT

INSTRUCTIONS: (DEMONSTRATE TO SUBJECT) Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. (To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject's normal stride width.)

( ) 4 able to place foot tandem independently and hold 30 seconds
( ) 3 able to place foot ahead independently and hold 30 seconds
( ) 2 able to take small step independently and hold 30 seconds
( ) 1 needs help to step but can hold 15 seconds
( ) 0 loses balance while stepping or standing

STANDING ON ONE LEG

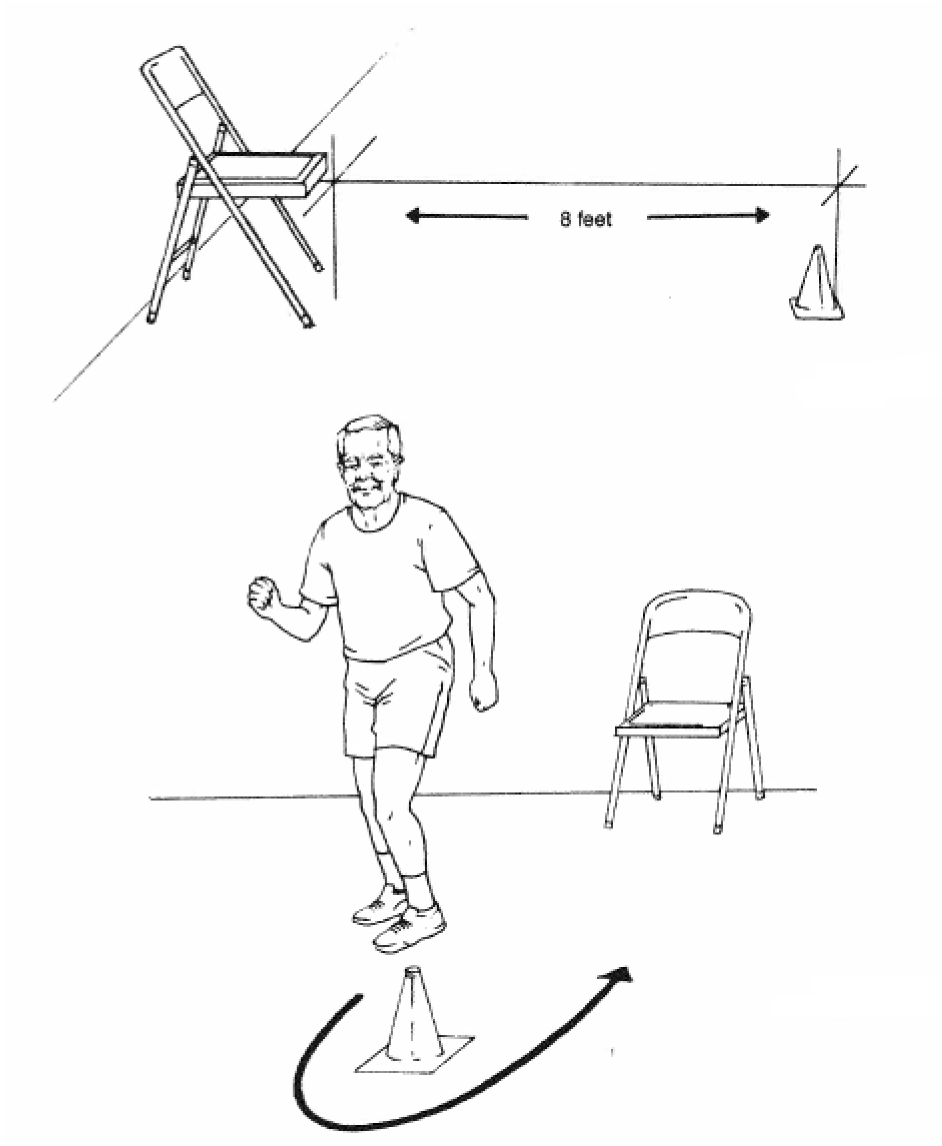
INSTRUCTIONS: Stand on one leg as long as you can without holding on.

( ) 4	able to lift leg independently and hold > 10 seconds
( ) 3	able to lift leg independently and hold 5-10 seconds
( ) 2	able to lift leg independently and hold L 3 seconds
( ) 1	tries to lift leg unable to hold 3 seconds but remains standing independently.
( ) 0	unable to try of needs assist to prevent fall

(   ) TOTAL SCORE (Maximum = 56)

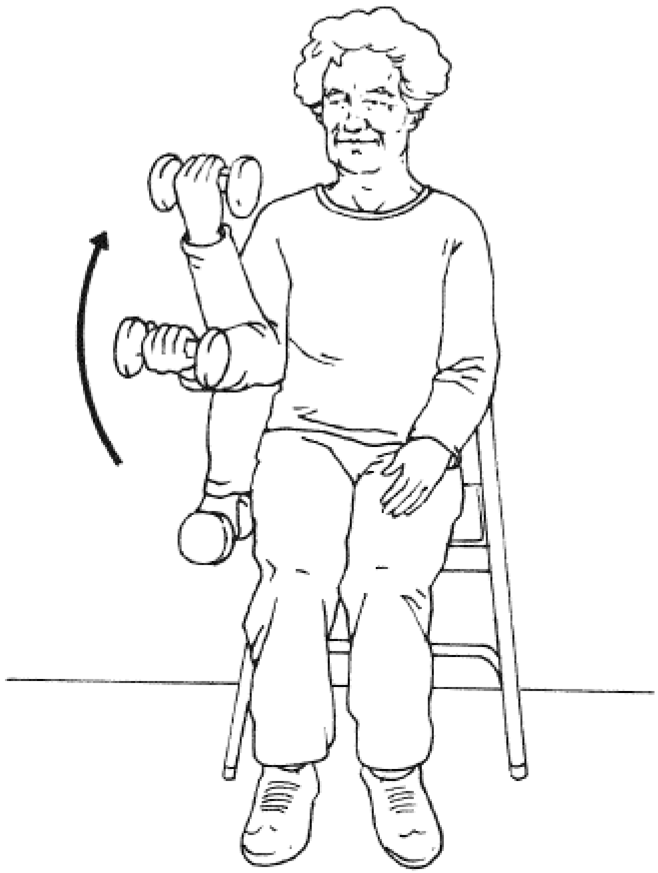
(Retrieved January 10, 2014 from: http://www.aahf.info/pdf/Berg_Balance_Scale.pdf)

Figure 7– 8-foot Timed Up-and-Go Test



(Rikli & Jones, 2001).

Figure 8 – Arm Curl Test



(Rikli & Jones, 2001).

Figure 9 – Tricep Extension Test

Figure 10 – 6-minute Timed Walk

(Retrieved December18, 2014 from: http://www.meder.com/us_linear_distance.html)

Appendix C

Figure 11 – T3 Questionnaire Participant ID _______

Please Rate the Following:
0= Poor 1= Fair 2 = Good 3 = Very Good 4 = Excellent

1. Physical health before stroke:	0	1	2	3	4
2. Physical health directly after stroke (inpatient):	0	1	2	3	4
3. Physical health now (outpatient):	0	1	2	3	4
4. Quality of life before stroke:	0	1	2	3	4
5. Quality of life after stroke (inpatient):	0	1	2	3	4
6. Quality of life now (outpatient):	0	1	2	3	4
7. How was your experience with the WAVE:	0	1	2	3	4

1. Did you see improvements in your physical functioning?
   YES_____ NO ____ I DON'T KNOW _____

a. If yes, what do you feel like you improved on the most??
____
____
____

2. What did you enjoy most about using the WAVE??
____
____
____
____

3. Would you recommend the WAVE to others? YES _____ NO____

Vita Auctoris

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