A Comparison of Whole Body Vibration versus conventional training on leg strength

By

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ABSTRACT

Whole Body Vibration (WBV) training is a new addition to the field of Exercise and Sports Science and has been developed for the use in strength and conditioning exercises. With the introduction of this new mode of exercise, the study focused on comparing the strength gaining effect of WBV training versus conventional resistance training.

The study was conducted in a descriptive, exploratory manner utilizing a quasi-experimental approach with a three group comparison pre-test-post-test design consisting of an experimental-, comparison- and control group. Convenience and snowball sampling were used to select 43 male and female healthy, sedentary volunteer participants. The research focused on reviewing the contribution that each mode of training offers to increase strength in the upper leg and underlines the important physiological adaptations that the human body undergoes to bring about an increase in muscle strength.

Both the whole body vibration and land-based resistance groups trained three times a week over an eight week intervention period. Exercises were performed with progressive increments in the frequency, amplitude and duration for the WBV- and in workload, number of sets and repetitions for the conventional resistance training program. The control group remained sedentary throughout the duration of the study.

The dependent variables of peak torque flexion and extension of the knee joint in both legs were analyzed using descriptive and inferential statistics. Analysis of covariance (ANCOVA) was done to determine intra-group differences. Post-hoc analysis in the form of Scheffé's test was done to determine and compare inter-group differences. Practical significance was indicated by means of Partial eta^2.

The analysis of the results revealed significant strength increases in both conventional resistance training and WBV for most of the dependent variables, except for peak torque extension, where the WBV group did not increase significantly.

Based on these results, it can be concluded that both modes of conventional resistance and whole body vibration increased selected dependent variables for upper leg strength in previously inactive individuals.
Keywords: Whole Body Vibration training, Resistance training, Leg strength

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Chapter 1 – PROBLEM IDENTIFICATION

1.1 Introduction

Whole Body Vibration (WBV) therapy is a current neuromuscular training method that is applied to training both the general population as well as elite athletes (Delecluse, Roelants and Verschueren, 2003). WBV exploits the body's innate reflexive response to disruptions in stability in order to stimulate and enhance muscle strength and performance (Delecluse, Roelants, Diels, Koninckx and Verschueren, 2004).

The WBV device produces a vibration through which energy is transferred to the body. This mechanical stimulus produces a stretch reflex which, depending on the frequency, results in rapid and intense muscle contractions 30-50 times per second (Ribot-Ciscar, Rossi-Durand and Jean-Pierre, 1998).

WBV training requires a subject to stand on a vibrating platform, which generates sinusoidal vibrations ranging between 30Hz and 50Hz. The vibration platform simultaneously vibrates through the full range of three-dimensional motions in the horizontal, transverse and saggital plane (Ribot-Ciscar, Rossi-Durand and Jean-Pierre, 1998). The resultant mechanical stimuli are being transmitted to the body targeting sensory receptors. These receptors include the muscle spindle, which is a delicate proprioceptor that is located within the skeletal muscle fibres (Guyton and Hall, 2006). The muscle spindle is activated when the muscle is stretched, sending an impulse to the central nervous system (CNS), indicating the quantity and the rate of change in the muscle fibre length. The CNS then integrates the information causing muscle activity (Drake, Vogl and Mitchell, 2005).

According to Roelants, Delecluse, Goris and Verschueren (2003) the activation of the muscle spindle leads to the activation of the alpha-motor neurons which in turn initiates muscle contractions leading to the tonic vibration reflex. The increase of the tension in the muscle-tendon transition allows the Golgi-sensor to

inhibit the alpha-motor neurons thereby decreasing the tension in the muscle. When training with WBV the stretch reflex is stimulated and thus increases the threshold of the Golgi apparatus. Thus, the muscle tension can be increased to a greater intensity before the Golgi apparatus is inhibited (Delecluse, Roelants, Diels, Koninckx, and Verschueren, 2004).

WBV therapy offers a host of benefits such as considerably improving muscular strength, muscular flexibility and bone density. Vibration training enhances the secretion of hormones that are important in regeneration and repair processes, such as the human growth hormone, IGI-1, and testosterone ([http://www.powerplateusa.com/research/support.aspx]). Furthermore, WBV training increases the release of neurotransmitters, such as serotonin and neurotropine, substances that support positive thinking processes. Other benefits postulated by the power plate research website as mentioned above include, a decrease in cortisol levels, reduction in lower back pain and a decrease in the appearance of cellulite as a result of blood circulation stimulation. WBV training aids the rehabilitation of injuries and ailments, recovery after speed training and accelerates weight loss while bringing about enhanced pain reduction and improved collagen production.

Additionally, studies have proven that this mode of training has the ability to reduce muscular pain and soreness, and expedite the recovery of damaged muscles and tendons (Roelants, Delecluse, Goris and Verschueren 2003). As vibration therapy is a novel mode of training, little research could be found on the impact of WBV as an alternative mode of strength training for the healthy population. It is here where the significance and challenge of this study lies in contributing to the body of knowledge and bridging the existing gap in sound literature pertaining to the field of Exercise and Sport Science with specific application in the field of Biokinetics.

1.2 Problem statement

This dissertation aimed at exploring and comparing the effectiveness of a novel and current exercise training modality, called WBV, as an alternative to a conventional training modality, such as a land based program performed in the gymnasium, specifically pertaining to strength training. WBV therapy eliminates a number of barriers to participation in an exercise program as it requires less time from the individual, the perceived level of difficulty is decreased and the level of enjoyment is amplified, thus making participation and adherence to a regular conventional strength training exercise regime more likely and long term.

1.3 Aim and objectives

The aim of this study was to determine and compare the effect of an eight-week training period of WBV to conventional resistance exercises on leg strength of 18-25- year old participants.

The following objectives were addressed in the pre- and post-test assessments for both experimental- and comparison group, as well as the control group, in order to achieve the aim:

1.3.1 To explore, describe and contrast the following dependent variables, namely; peak torque, work per repetition and average power per repetition for flexion at the knee joint for both legs.

1.3.2 To explore, describe and contrast the following dependent variables, namely; peak torque, work per repetition and average power per repetition for extension at the knee joint for both legs.

1.4 Problem clarification

The evolutionary history of resistance training has been well documented. Kraemer and Häkkinen, (2004) described Milos of Crotona; a Greek strongman who has been credited with the first use of progressive resistance exercises as he has been reported to have carried a young calf across his shoulder every day until the beast was fully-grown. According to Phildin (2004) “strongmen” would travel the country in vaudeville circus acts, performing feats of strength during the late 1800s. They would press and squat large animals, such as cows and horses, and heavy objects in all sorts of shapes and sizes. These men did not follow structured strength training programs, nor did they have access to refined equipment or machines. Aforementioned authors deduced that these men learned the most basic concept of strength training, namely; the overload principle, through trial and error. These men were genetically gifted with a large powerful body type, very similar to that of sumo wrestlers in Asian culture (Kraemer and Häkkinen, 2004).

The historical context of the documentation of resistance training however leaves the question of reliability of studies conducted and challenges the state of current versus previous research. It is therefore warranted that the literature review of strength training be of current and updated status in the quest to supplement inferior study designs and outdated research.

Carpinelli and Otto (1998) stated that resistance training and strength training have often been prescribed for enhancing general health and fitness, athletic conditioning, and the prevention or rehabilitation of muscular and orthopaedic injuries. In support of the evidence documented, the authors continued to prove that resistance training was an effective method for increasing muscular strength and hypertrophy. Cullinen and Caldwell (1998) and Howley and Franks (2003) supported the notion that resistance training is recommended for the development and maintenance of fat free mass (FFM). According to Bosco, Coli, Introini, Cardinale, Lacovellie, Tihanyi, Von Duvillard and Viru (2002) during

WBV strength training, the ‘burn effect’ occurred in addition to a moderate building-up of muscle, resulting in an increase in basal metabolic rate (BMR) which together with a controlled intake of food, resulted in the reduction of body fat.

Rittweger, Schiessel and Felsenberg (2001) stated that WBV training has many advantages for anyone involved in resistance training. Vibration training activates the fast twitch muscle fibres (the muscle fibres engaged in quick, sudden action). Also, the higher release of hormones involved in recovery would ensure a faster and more complete recuperation, especially that of the red muscle fibres as a result of the increased amounts of human growth hormone (HGH).

Rittweger, Mutschelknaus and Felsenberg, (2003) characterized muscular function by the production of force and power, and by the capacity to maintain force and power over a given period of time; defined as muscular endurance. Once again both central and peripheral functioning contributes to the enhancement of the efficacy of muscle contraction.

It has been well documented by Charette, McEvoy, Pyka, Snow-Hater, Guido, Wiswell and Marcus, (1991) that the decrease in muscular strength as a person ages, is partly reversible by a combination of resistance training and aerobic conditioning. These authors further indicated that resistance training promoted muscle fibre hypertrophy, thereby resulting in better established peripheral pathways for the utilization of oxygen.

Earle and Baechle (2003) defined muscular strength as the force or tension a muscle group can exert against a resistance in one maximal effort. According to literature there are three basic types of muscular contractions, namely; isotonic, isometric and isokinetic contractions. Isotonic strength training can be defined when the resistance to movement is constant and the speed of the movement is varied. Isotonic strength training is a commonly utilized strength technique. Isotonic exercises may be concentric (in which the muscle shortens as it

contracts to move a weight) or eccentric (in which the muscle contracts as it lengthens) or utilize a combination movement (Bruckner and Khan, 2005). Isometric exercises occur when a muscle contracts without associated movement of the joint on which the muscle acts. Isometric exercises are often the first form of strengthening exercise used after injury, especially if the region is excessively painful or if the area is immobilized.

Bruckner and Khan (2005) defined isokinetic exercises as exercises that are performed on a device at a fixed speed with a variable resistance that is totally accommodative to the individual, throughout the range of motion. The velocity is, therefore, constant at a pre-selected dynamic rate, while the resistance varies to match the force applied at every point in the range of motion. This enables the individual to perform more work than is possible with either constant or variable resistance isotonic exercise. Tarpenning and Marino (2005) stated that often a combination of eccentric, concentric and isometric contractions can be used in resistance training program design and exercise prescription to bring about an increase in strength and power. For the purpose of this study a combination of concentric and eccentric muscle contraction was utilised.

The Russian cosmonauts were the pioneers who explored WBV training as an extraordinary form of exercise to stay in space for a longer period than ever imagined by the Americans (Rubin, Turner, Bain, Mallinckrodt and McLeod (2001). The weightless environment in space results in a decrease in bone density and leads to muscle dystrophy. Using WBV to stimulate the effect of gravitational force on the body, the negative physical impact of the weightless environment is minimized. According to Rubin, Turner, Bain, Mallinckrodt and McLeod (2001) vibration training utilizes a machine designed to stimulate gravity through exposing the individual to WBV.

According to literature there has been various studies proposing that WBV training was responsible for the increase in the production of isometric torque

(Bosco, Colli, Introini, Cardinale, Tsarpela, Madella, Tihanyi and Viru, 1999; Delecluse *et al*., 2003; Rittweger, Mutschelknaus and Felsenberg, 2003). The most significant results were obtained by a study done by Delecluse, Roelants and Verschueran (2003) which was aimed at comparing knee extensor strength after 12 weeks of WBV training to a resistance training programme of the same duration. The authors found a significant increase in isometric torque after 12 weeks of WBV training and resistance training. A further conclusion drawn was that there was a significant increase in dynamic strength in both the WBV training and resistance training groups. A differentiation in the superiority of one of the modes of strength training could however, not be made.

Research conducted by Bosco *et al.,* (1999) focused on the mechanical behaviour of the human skeletal muscle when it has been exposed to WBV training. During the study the subject's one leg was assigned to a control group while the other leg was subjected to WBV training. During the intervention the subject had to keep the involved leg flexed at 100^0 while standing on the vibration platform. The results indicated an increase in the power output of the involved leg, but unfortunately the effect of the isometric contraction of the involved leg during WBV training was not calculated.

The aforementioned phenomenon begs the question as to the accuracy of results reported. Due to the impact of multiple factors, a direct cause and effect relationship as a result of vibration training had been difficult to establish. The extent to which the isometric contraction of the uninvolved leg contributed to the power output during the performance of the static exercises needed to have been addressed. Thus the isolation and measurement of the force production, caused by the isometric contraction of the quadriceps muscles posed an age old question of accuracy of reported measurement and the selection of valid measuring protocol.

Rittweger *et al.,* (2003) researched the impact of vibration exercise on neuromuscular force and power production in the vastus lateralis muscle of the thigh. Results indicated that WBV training increased not only the isometric peak torque in the vastus lateralis muscle, but also created a significant increase in tendon reflex amplitude.

Issurin and Tenenbaum (1999) contributed to the WBV training studies by researching the effect of WBV training on explosive strength in the biceps brachii muscle in the upper arm. The results of the study showed that there was indeed an increase in explosive power in the test subjects. This finding supported recent research indicating musculoskeletal adaptations after exposure to WBV training (Bosco *et al*., 1999; Cardinale and Lim, 2003; Delecluse *et al*., 2003; De Ruiter, van der Linden, van der Zijden, Hollander and de Haan, 2003; Torvinen, Kannes, Siëvanen, Järvinen, Järvinen, Oja and Vuori, 2002). From the literature acquired it is clear that ambiguity existed regarding the nature of the type of muscle contraction used in WBV training and of that used in the strength assessment measuring protocol. Most of the studies used an isokinetic measure of strength assessment which differed from the training mode, targeting isometric strength in WBV and or dynamic strength in resistance training programmes.

In order to address the above mentioned problem, this study focused on using the same exercises for both vibration training and resistance training interventions. Post-intervention results were based on the increase in strength, thereby adhering to the aim of the study, which was to determine and contrast the changes in strength by comparing WBV and resistance training. WBV strength training takes place in a closed kinetic chain system. Delecluse, Roelants, and Verschueren, (2003) defined this system as an activity where the foot or hand was weight bearing with concomitant co-contraction of agonist and antagonist musculature. Furthermore, advantages of this closed kinetic chain system is the joint-sparing training effect derived from reduced shear forces, improvement of the intermuscular coordination and improvement in the functional

patterns of movement. The continuous initiation of muscle stretch reflexes by pre-tensioned muscles resulted in the intensive activation of greater than 95% of all muscle fibers, commencing the improvement of intermuscular and intramuscular coordination.

Morrissey (2002) and Witvrouw (2003) defined closed kinetic chain exercises by stating that the extremity used in the exercise had to be constantly in contact with an immovable surface. For the purpose of this study the power plate platform served as the immobile surface for the WBV group. For the comparison group performing the resistance training programme, the floor served as the immovable surface. Thus, leading to a uniform intervention program with the primary difference being the use of the WBV platform versus non-vibration training that was land-based.

1.5 Methodology

The study followed a quasi-experimental design with a three group comparison pre-test-post-test design (De Vos, 2002) consisting of an experimental and a comparative experimental group and a control group. The two comparative experimental groups participated in the same eight-week isotonic exercises for the upper leg, whereas the control group remained sedentary throughout the intervention period. The difference was only that the load imposed on the resistance training group was by means of free weights, compared to the load generated by the vibrating platform in the WBV training group. Houglum and Perrin (2005) indicated that eight weeks of strengthening exercises resulted in increased muscle strength and endurance. The study was descriptive and explorative in nature.

A non-randomised sampling technique was employed with an equivalent match-pair design to divide the base of volunteers gathered through a combination of accidental and snowball sampling into either of the two comparative experimental or control groups, respectively.

Standardized tests were used as the evaluation protocol for the dependent variables at the pre- and post-test phases of assessment, with clearly defined exclusion criteria as were discussed in detail in chapter three. The dependant variables of peak torque, work per repetition, and average power per repetition for flexion and extension at the knee joint for both legs were analyzed using descriptive statistics with analysis of co-variance (ANCOVA) to determine if any differences existed in the strength variables due to the specific intervention. Post hoc analysis was computed to determine and compare differences between the three groups in order to address the problem at hand. The statistical analysis of the data was presented in chapter four and the discussion of results subsequently followed in chapter five.

1.6 Limitations

In all studies there are a number of factors that limit the outcome or have an effect on the study's results. The following limitations could have had an impact on the results obtained in the study.

The relative small sample size consisted of participants in total. The researcher was dependent on the number of sedentary volunteers whom presented themselves for participation in the study. This relatively small sample size was then furthermore divided into either an experimental, a comparative or control group.

Due to the high cost and availability of the intervention on a WBV platform and time constraints due to University holidays on behalf of the participants, an eight week intervention period was followed. Ideally according to Roelants, Delecluse and Verschueren (2004) whole body vibration training is most effective in increasing strength benefits after adherence to a 12 week resistance training program.

WBV training is a relatively new development in the field of Exercise and Sport Science and as such there were limited resources available on the topic.

Limitations also existed pertaining to the acquisition of documented evidence of the long-term effect of WBV training on the human body. The benefits were all derived from studies conducted over relatively short periods of time and longitudinal studies were lacking in the literature retrieved.

1.7 Summary

The study explored and described the effects that WBV training had on leg strength when compared to a conventional land-based resistance training protocol. For the purpose of this research, literature pertaining to principles of resistance training and physiological adaptations were discussed in chapter two. Furthermore, the underlying principles of the use of WBV as a mode of resistance training, including the acute, residual and chronic effects were addressed.

A quasi-experimental three group pre-test-post-test design was utilized and descriptive and inferential statistical techniques were implemented to ascertain any changes and significant differences acquired in the dependent variables for leg strength in the experimental-, comparative-, and control group.

The analysis of the results revealed significant increases in both the resistance training and WBV group for most of the dependent variables; namely, peak torque, work per repetition, and average power per repetition for flexion of the knee joint measuring upper leg strength in both legs. However, no significant strength increases for peak torque extension at the knee joint for both legs in the WBV group were obtained. Furthermore, the strength increases recorded in the resistance training group were superior to that of the WBV group for all the

dependent variables. Based on these results and evaluated in the light of the limitations of this study design, the conclusion could be made that conventional resistance training proved to be a superior means of increasing upper leg strength in comparison to WBV training.

Chapter 2 – REVIEW OF LITERATURE

2.1 Introduction

WBV training has recently been introduced in health and fitness centres as an alternative mode of exercise. Documented exercise guidelines for strength enhancement in the leg musculature using vibration therapy as a mode of conditioning, were not available at the time this dissertation was compiled. This being the case, the participants in the WBV training group performed unloaded static and dynamic exercises on a platform that generated three-dimensional vibrations at a pre-determined frequency. Strength exercise prescription guidelines as advocated by the ACSM, (cited in Mahler *et al.,* 1995) were followed to ensure that the WBV intervention programme progressed in a scientifically appropriate manner.

As the aim of the study was to determine and contrast the difference in leg strength using conventional resistance and vibration training as modes of intervention, respectively, rationale in support of the study was predominantly selected from the domains of resistance training for strength gains and vibration training. Aspects included in the literature review pertained to physiological adaptations that occurred in the musculo-skeletal system and allowed for hypertrophy of the relevant muscle fibres, causing an increase in strength. Knowledge of the physiological context underlying muscle strength gain is deemed essential for proper program prescription by a health professional such as a sport scientist and a biokineticist.

Chapter two furthermore explored the theoretical framework that informed this study by highlighting the principles used in program prescription for strength training.

2.2 Rationale of Whole Body Vibration Therapy

Muscle activation by means of vibration produced improvements in strength and power performance similar to those that had been observed in strength training. The similarity of the effect was related to the characteristic of the load imposed by the vibration, which, as with strengthening and plyometric exercises, increased the gravitational load imposed on the neuromuscular system (Bosco, Lacovelli, Tsarpela, Cardinale, Bonifazi, Tihanyi and Viru, 1999).

Vibration exercise induced hyper-gravity activity due to the high accelerations experienced. The mechanical action of vibration produced fast and short changes in the length of the muscle tendon complex. This disturbance was, in turn, detected by the sensory receptors that modulated muscle stiffness through reflex muscular activity. The mechanism responsible for vibration-induced enhancement was different to the effects of vibrations on an active muscle after an application of vibration (Cardinale and Bosco, 2003).

Mechanical vibrations applied to the muscle or the tendon elicited a reflex muscle contraction called the “Tonic Vibration Reflex” (TVR). The deformation of the soft tissues caused by the vibrations was capable of activating the muscle spindle, which led to an enhancement in the stretch reflex loop. The excitatory influx during vibration stimulation was mainly related to the reflex activation of the alpha-motor neurons. There was an increase in electromyograph (EMG) activity during vibration treatment, which resulted in values higher than the ones that had been observed during voluntary muscular activity (Cardinale and Bosco, 2003).

Cardinale and Bosco, (2003) further reported that the acute enhancement of neuromuscular performance after WBV therapy was related to an increase in the sensitivity of the stretch reflex. Vibration therapy inhibited the activation of the antagonist muscles through Ia-inhibitory neurons, thereby leading to an alteration

in the intramuscular coordination patterns and resulting in a decreased braking force around the joints stimulated by the vibration exposure.

In addition to the above, Cardinale and Bosco, (2003) went on to state that vibration applied at different frequencies was capable of producing kinesthetic illusion that activated the supplementary motor area, the caudal cingulate motor area, and area 4a of the brain. The vibration stimulus influenced the excitatory state of the peripheral and central structures, which facilitated subsequent voluntary movements. The greater levels of force after vibration exposure were due to both the enhancement of the stretch reflex and the excitatory state of the somatosensory area.

Naito, Kinomura, Geyer, Kawashima, Roland and Zilles, (2000) reported on the influence of WBV stimulation on the central motor command. These authors concluded that the primary and secondary somatosensory cortex, together with the supplementary motor area, constituted the central processing unit for the afferent signals.

According to Torvinen, Kannus, Sievanen, Jarvinen, Pasanen, Kontulainen, Jarvinen, Jarvinen, Oja and Vuori (2002) the acute neural stimulation observed after WBV therapy was relatively short lasting and was determined by the duration of the exercise. Relatively short exposure (four to five minutes divided into bouts of one minute each, with a rest interval of one minute between bouts) was capable of subsequent enhanced voluntary strength exertions.

In accordance with the above-mentioned study, Rittwegar *et al*., (2000) found that long duration WBV therapy reduced the force generating capacity of the muscle and that this effect was due to either the activation of the inhibitory feedback or the reduced sensitivity of muscle spindles.

Furthermore, Cardinale and Bosco (2003) discovered that the potential mechanism determining an increase in neuromuscular performance resulted from a vibratory stimulus being perceived by the different sensory structures, which stimulated the neuromuscular system to produce reflex muscle activation. These authors supported evidence by Torvinen *et al*., (2002) that if the vibratory stimulus was relatively short, it created the potential for a more powerful voluntary activation of the skeletal muscle.

Bosco, Colli, Introini, Cardinale, Tsarpela, Madella, Tibanyi, Von Duvillard and Viru (1999) investigated the effects of WBV on the mechanical behavior of human skeletal muscle. The authors found that skeletal muscle was specialized tissue that modified its overall functional capacity in response to chronic exercise with loads. Intensive, prolonged strength training induced a specific neuromuscular and hormonal adaptive response in the human body within a few months, whereas a change in morphological structure occurred at a later stage (Earle and Baechle, 2004).

In earlier research Bosco (1992) had found that specific programs for strength and explosive power training were based on exercises performed with rapid and violent variation of gravitational acceleration. These changes in gravitational conditions were produced by the mechanical vibrations applied to the whole body. During WBV, skeletal muscles underwent small changes in the muscle length. Facilitation of the excitability of the spinal reflex was elicited through vibration to the quadriceps muscle as pointed out by Burke, Rymer and Walsh (1996).

Further to the above documented literature, Burke, Schutten, Koceja and Kamen (1996) suggested that the vibration reflex operated predominantly on the alpha motor neurons and did not use the same cortically originating efferent pathways as those used in voluntary muscle contractions. However, in a study by Bosco, Colli, Introini, Cardinale, Tsarpela, Madella, Tihanyi and Viru (1999), the authors

found that neurogenic adaptation occurred in response to WBV treatments. In addition to these findings, the duration of the stimulus seemed to be of importance. The adaptive response of the human skeletal system after having been stimulated by hyper gravity conditions applied for three weeks, resulted in a dramatic enhancement of the neuromuscular functions (Bosco, 1992).

2.3 Resistance training

Resistance training is commonly used to promote muscle fitness by imposing an overload on the muscle which physiologically adapts, resulting in an improvement in muscle strength. It is typically named progressive resistance training because the frequency, intensity and length of time of muscle overload are progressively increased as muscle fitness increases (Corbin *et al*., 2000).

According to Foss and Keteyian, (1998) the mode represented the type of muscle contraction that was generated with a specific movement and defined three modes of muscle contraction, namely; isotonic, isometric, and isokinetic contractions. For the purposes of this study isotonic and isometric modes were discussed in more detail to outline the modes used in the intervention programs for the experimental and comparative groups.

2.3.1 Isotonic exercise

Isotonic exercises are performed when the joint moves through a range of motion against a constant resistance or weight (Brukner and Khan, 2005). Isotonic exercises can be performed using free weights or resistance machines. According to Brukner and Khan (2005) free weights have an added advantage as it results in strengthening of both the primary and synergistic stabilizing muscles, as well as providing stress on ligaments and tendons. Free weights can also simulate athletic activities as the body position can be varied. The strength gains from free weights translate well to the playing field.

Isotonic exercises comprise two types of muscle actions (Powers and Howley, 2001). The first is concentric muscle action, which results from a shortening of muscle fibers. The second is termed eccentric muscle action, which occurs when a muscle is activated and force is produced, but the muscle lengthens. The intramuscular force produced per motor unit during eccentric contraction is larger than that during concentric contraction (Brukner and Khan, 2005).

Cavani, Mier, Musto, and Tummers, (2002) used the isotonic mode of exercise to bring about an increase in muscular strength by including exercises such as, leg press, leg extension, and leg curl, and engaged both the concentric and eccentric contractions during the performance of the exercises. Findings were in support of documented literature by stating that the isotonic mode of exercise was the preferred mode to enhance muscle strength. Henwood and Taaffe, (2005) used isotonic exercises as a means of high velocity training and found significant improvement in the physical performance in older adults.

In a report on the effects of ten weeks of resistance training by Fiatarone, O'Niel, Ryan, Clements, Solares, Nelson, Roberts, Kehayias, Lipsitz, and Evans (1994), the authors found that resistance training had a great potential to improve functional ability. According to them, strength increased by 113%, muscle area of the thigh region increased by 3%, walking speed increased by 12% and stair climbing power increased by 28%. The authors also concluded that impaired mobility was strongly related to muscular weakness. They demonstrated that adult musculature responded very well to resistance training and that the response was accompanied by improvements in functional mobility and overall activity.

In addition, Tesch, Ekberg, Lindquist, and Trieschmann, (2004) focused on improving muscle strength by means of both eccentric and concentric contractions. Over the five week exercise intervention of the study the

physiological adaptations were accredited to an increase in cross-sectional area of the involved muscles, known as hypertrophy. Based on evidence of the aforementioned literature, it could thus be assumed that isotonic exercises were appropriate means of resistance training to bring about a state of hypertrophy in skeletal muscle.

In a comparative study conducted by Mjølsnes *et al.,* 2003 on the effectiveness of eccentric versus concentric hamstring training, well-trained soccer players followed a 10-week intervention period. No significant changes were observed in the concentric training group, but the eccentric training group improved in the hamstring muscles strength. Godard, Williamson, Porter, Rowden, and Troppe, (2001) studied the effect of both concentric and eccentric training on neuromuscular activity over a 12-week period. Findings indicated that muscle activation as recorded by EMG activity reading increased for both modes of exercise. Finally, the researchers concluded that there was neuromuscular alteration as a result of the two varying modes of exercise and subsequent increases in cross-sectional area in the quadriceps muscle as well as increased isometric strength.

For the purposes of this study the experimental and comparative groups were subjected to the same isotonic exercises. The difference was only that the load imposed on the resistance training group was by means of free weights, compared to the load generated by the vibrating platform in the WBV training group. In earlier research Bosco (1992) had found that specific programs for strength and explosive power training were based on exercises performed with rapid and violent variation of gravitational acceleration. These changes in gravitational conditions were produced by the mechanical vibrations applied to the whole body. During WBV, skeletal muscles underwent small changes in the muscle length. Facilitation of the excitability of the spinal reflex was elicited through vibration to the quadriceps muscle as pointed out by Burke, Rymer and Walsh (1996).

In both the experimental and comparison group, the exercises were performed in an isotonic and dynamic mode to ensure that both eccentric and concentric muscle actions were generated during the execution of the respective training programs.

2.3.2 Isometric exercise

An isometric exercise occurs when a muscle contracts without associated movement of the joint on which the muscle acts (Brukner and Khan, 2005). The authors furthermore state that isometric exercises are commonly used in the first rehabilitative phase of muscle strengthening after injury, especially if the specific region is excessively painful. They stated the functions of isometric exercises are to prevent muscular atrophy by increasing static strength, to lesson swelling through providing a pumping action to remove accumulated fluid and may also limit neural dissociation of proprioceptors.

Brukner and Khan (2005) showed that the load imposed on the muscle affecting the joint depends on the force that the muscle itself can produce. The isometric exercises are performed through holding a designated position for five to ten seconds. These exercises are performed in sets of 10 repetitions, and the sets vary depending on the stage of the rehabilitation program. It is therefore important to reiterate the difference between isotonic and isometric exercises so that WBV as a mode of resistance training can be understood.

Russo, Lauretani, Bandinelli, Bartali, Cavazzini, Guralnik and Ferrucc (2003) used isometic exercises on the vibration platform to increase muscle strength. Russo *et al.*, (2003) concluded that combining WBV exercises with isometric exercises brought about an increase in muscle strength. Torvinen *et al.*, (2002) conducted a similar study to determine the effect of WBV training on performance and balance. After the participants stood on the vibration platform

utilizing a static isometric form of resistance training with progression in frequency varying from 25Hz, to 30Hz, to 35Hz, and 40Hz., conclusions were made that neuromuscular adaptations had occurred, but no significant improvement in balance was documented. In utilizing WBV training as an exercise mode, the frequency of the vibration accounts for the intensity of the exercise.

Luo, McNamara and Moran (2005) conducted a review study on documented evidence of neuromuscular and physiological training effects of WBV, especially when conventional training and WBV were combined. No conclusive results could have been found as a lack of strictly controlled studies existed in the meta-analysis and the most effective frequency (Hz) of the vibration to increase muscle strength, yet remained a challenging question. Luo *et al.,* (2005) concluded with recommendations that future studies should focus on the chronic muskulo-skeletal adaptations that occurred as a result of the performance of dynamic resistance training on the vibration platform. Based on aforementioned literature participants were exposed to three-dimensional WBV therapy using the Power Plate® for the purpose of this study. The frequencies of the vibrations in the study were set at 30 Hz, 35 Hz, 40 Hz, and 50 Hz at various stages of the intervention program. The amplitude varied between a 'low' and a 'high' setting with a displacement of between two to eight millimetres, respectively.

2.4 Adaptations to resistance training

Literature revealed both acute and chronic physiological changes in musculature as a result of resistance training. An acute response to exercise usually results in an immediate change in the examined variable. Chronic change has to do with the body's response to a repeated exercise stimulus over the course of a training program. The physiological process by which the body adapts to the exercise is called adaptation to exercise.

According to Fleck and Kraemer (1997) the adaptation to training ultimately determined whether a resistance-training program was effective and whether an athlete was capable of a higher level of physiological function or performance.

2.4.1 Physiological adaptations to resistance training

Whether it be attending the local gym or participating in a recreational or competitive event, the body undergoes changes when introduced to exercise. These changes are the physiological adaptations that the body undergoes.

Hypertrophy is defined as an increase in muscle size in response to resistance training. This increase in the cross-sectional area of existing muscle fibres is attributed to the increased size and number of actin and myosin filaments and the addition of sarcomeres within existing muscle fibres (Goldspink 1992; MacDougall, Sale, Moroz, Elder, Sutton and Howard 1979). However, literature indicated that this depended on the type of muscle fibre and the pattern of recruitment. Not all muscle fibres underwent the same amount of enlargement. Fleck and Kraemer (1997) reported hypertrophy in fast-glycolytic (FG) fibres after eight weeks of heavy resistance training.

Kraemer (2004) conducted a study reviewing the effect that resistance training had on load bearing performance. As a result of a 12 week resistance training program that brought about muscle hypertrophy the load bearing ability of the participants had improved significantly. The assumption could thus be made that hypertrophy was a direct result of heavy resistance training and that muscle hypertrophy improved muscle strength. Hunter, McCarthy, Bamman, (2004) conducted a review study that focused on determining hypertrophy in skeletal muscles. As part of their review various studies showed that engaging in resistance training at least three times a week for a minimum period of nine weeks resulted in hypertrophy that was determined by monitoring the cross-sectional area of both Type I and Type II muscle fibres of the vastus lateralis

muscle. An increase in the cross-sectional area indicated muscle hypertrophy. Another review by Hunter *et al*., (2004) found strength increases associated with the increased cross-sectional area that was furthermore exponentially increased with the increase in training duration (weeks) the participants were exposed to during the resistance training.

Another significant study conducted by O'Neill, Thayler, Taylor, Dzialoszynkis, and Noble (2000) indicated the relationship between muscle fibre size and muscle strength. The authors prescribed an eight week isotonic knee extension resistance training program. Both the peak torque output (180°/s) and the mean power increased when measured at the post-test evaluation. Although a moderate non-significant cross over training effect was observed in the contra-lateral untrained limb, Type I and Type IIb muscle fibres increased in the cross sectional area in the experimental limb. However, the mean cross sectional area for all fibre types in the trained experimental limb was no larger than those observed in the contra-lateral limb before or after training. Findings of aforementioned study therefore suggested that short term resistance training significantly increased isokinetic peak torque, with minimal changes in histo-chemical and biochemical parameters.

Roth *et al.*, (2001) showed by using magnetic resonance imaging (MRI) of the thigh and quadriceps muscle that thigh volume increased after a six-month whole body strength training program. Thus, the assumption was supported that resistance training over an extended period resulted in muscle hypertrophy.

Resistance training has been shown to be the most effective mode to induce anabolic adaptations in older men and women. Advantages in imaging techniques and histo-chemistry have increased the ability to detect such changes, conforming to the high level of adaptability that remained in aging skeletal muscle (Galväo, Newton and Taaffe, 2005). Hyperplasia was first implicated as an adaptive strategy for muscle enlargement in laboratory animals

(Gonyea 1980; Ho, Roy, Tweedle, Heusner, Van Huss and Carrow 1980). Critics of those studies have claimed that methods of evaluation, damage to the muscle sample, and degenerating muscle fibres accounted for the observed hyperplasia.

In a study by Izquierdo, *et al.,* (2004: 435-443), the authors found that prolonged combined resistance and endurance training led to similar muscle mass gains and gains in maximal leg strength and muscle power output as those obtained through resistance training alone. This observation suggested that once-weekly resistance training sessions and once-weekly endurance training sessions might have been instrumental in promoting neuromuscular endurance.

Research conducted by Winett and Carpinelle, (2001) demonstrated that resistance exercise training had profound effects on the musculoskeletal system, contributed to the maintenance of functional abilities, and prevented osteoporosis, sarcopenia, lower back pain, and other disabilities.

Supplementary research by Winett and Carpinelle (2001) demonstrated that resistance training positively affected risk factors such as insulin resistance, resting metabolic rate, glucose metabolism, blood pressure, body fat and gastrointestinal transit time, all of which are associated with heart disease and cancer. Reports by Goldberg, Elliot, Schutz, and Kloster (1984) and Johnson, Stone, Lopez, Herbert, Kilgore, and Byrd (1982) suggested that resistance training had a favorable effect on lipoprotein-lipid profiles, and a survey by Schnabel and Kindermann (1982) indicated good insulin response and glucose ingestion during resistance training, while a study by Hagberg, Ehsani, Goldring, Hernandez, Sinacore and Hollosky, (1984) indicated positive blood pressure alterations.

Vanderhoek, Coupland and Parkhouse (2000) reported increases in strength ranging between 41% and 96% in respect of eight exercises following a 32 week

training regime. The research literature also reported significant improvements in balance, which was associated with an increase in dynamic strength.

2.4.2 Hormonal changes

Ahtiainen, Pakarinen, Kraemer and Hakkinen (2004) conducted a study that monitored the hormonal changes associated with resistance training measuring serum testosterone, free testosterone, cortical and growth hormone concentrations and blood lactate levels. The results showed an immediate significant increase in hormone levels after a heavy resistance exercise bout.

One of the most significant studies on hormonal changes after resistance training was conducted by Kraemer and Ratamess in 2005. According to these authors resistance training had shown to elicit a significant acute hormonal response. The study revealed that acute responses were more critical to tissue growth and remodelling than chronic changes in resting hormonal concentrations. The authors indicated an elevation in anabolic hormones, such as testosterone and human growth hormones, during 15 to 30 minutes of post-resistance exercise provided that an adequate stimulus had been presented.

In addition, Kraemer and Ratamess, (2005) reported that strength training protocols of a high volume, of moderate to high intensity, using short rest intervals and stressing a large muscle mass, produced the greatest acute hormonal elevation. These included the elevation of testosterone, human growth hormone and the catabolic hormone, cortisol. The study also revealed that the anabolic hormones such as insulin and insulin-like growth factor-1 (IGF-1) were critical to skeletal muscle growth. A further conclusion was that IGF-1 elevations followed after resistance exercise, presumably in response to growth hormone stimulated hepatic secretion.

2.4.3 Neural adaptation

Muscle fibre and force production characteristics were monitored during a study conducted by Häkkinen, Kraemer, Newton and Alen (2001). The aim of the study was to monitor the change in neural activation of skeletal muscles in the upper legs with the use of EMG activity after a six month resistance training period. Findings yielded significant neuro-muscular activation of the vastus medialis muscle during the first two months of the study. The aforementioned study supported the role of neural adaptations in strength and power development. A review study conducted by Carrol, Riek, and Carson, (2001) furthermore supported documented evidence that resistance training changed both neural and physiological structure of skeletal musculature.

Similar studies were conducted using WBV to determine the neuromuscular function of skeletal muscle. Rittweger *et al.,* (2003) compared the effect of squatting on a vibration platform to squatting without vibration until fatigued and found that time to exhaustion was significantly shorter in the WBV group compared to the group without the vibrations. Although the subjective perceived rate of exertion recorded indicated comparable levels of fatigue, the EMG frequency recorded was significantly higher for participants subjected to vibration training. The authors concluded that the superimposed 26Hz vibration appeared to elicit an alteration in neuromuscular recruitment patterns, which enhanced neuromuscular excitability in the comparison group.

Judge, Moreau, and Burke, (2003) also used EMG activity readings in a study to determine the effects of variations in volume and intensity of resistance training in highly skilled athletes, to document evidence on neural adaptive mechanisms. These mechanisms were measured as the maximal muscle activation, measured by using a high-resolution sample and hold amplifier to record interpolated twitches. The pattern of the neural drive was measured by analysing isometric

torque-time curves and EMG characteristics during the performance of rapid isometric contractions at maximal effort. The volume and intensity of training were varied at four-weekly intervals to systematically emphasize the development of strength, power and motor performance in 14 highly skilled track and field athletes.

Findings of the study by Judge, Moreau, and Burke, (2003) showed a significant increase in the knee extension strength during steady maximal isometric contractions and rapid isometric contractions at maximal effort after the 16-week training program. There was an increase in EMG amplitude and rate of EMG activation indicated that improvements to the pattern of neural drive occurred with sport specific resistance training.

Griffin and Cafarelli (2005) indicated increased maximal muscle force output during the first few weeks of isometric resistance training that cannot be accounted for by muscle hypertrophy. Aforementioned study proposed that increased excitation occurred at the cortical levels following short-term resistance training. These alterations in synergistic and reductions in antagonist activation are neural factors that have been identified as changing during the early stages of resistance training which could contribute to maximal force generation. The neural adaptations that occurred during the ramp-up phase of isometric contraction included decreases in motor unit recruitment thresholds increased motor unit discharge rates and increases in double discharges. An increase in the maximal rate of force development also occurred during the early stages of resistance training, but whether the neural mechanisms associated with the increase in the rate of rise were also associated with the increase in maximal force production, had not been determined.

2.5 Principles of resistance training

According to the ACSM (cited in Mahler *et al.,* 1995) the principles of resistance training comprised intensity, volume, frequency, overload and rest periods and required training protocols that were precise and time efficient, while Feigenbaum and Pollock (1999) contended that the most basic goal of resistance training was to apply a stimulus to each muscle group for approximately 30 to 90 seconds and to provide a marginal overload compared to the prior training session.

According to Smith (2000) an overload could be a small increase in resistance used for the same duration, or the use of the same resistance for a longer duration, or both. The author added that progressive overload was essential for increasing muscular strength and size, and furthermore, that the requirements for stimulating increases in strength and muscle mass were achieved by surpassing the threshold established in the previous training session.

Exceeding the threshold, set in motion complex physiological responses such as an increase in protein synthesis, resulting in increased strength and muscle mass. However, Earle and Baechle (2004) noted that once the threshold had been passed, any additional volume of exercise was counterproductive. The authors further deduced that physiological adaptations occurred during the recovery time between training sessions, and these provided the basis for subsequent overload in the next training session. Thus, a minimal but very prescriptive dose of resistance training appeared to be the ideal amount required to produce a positive response.

2.5.1 Intensity

Maximal strength is a vital part of athletic performance and has received considerable attention in conditioning programs over the last several decades. The assessment of maximal strength has become a significant part of evaluating

the effects of resistance-training programs on athletes at all levels. The typical method for measuring maximal dynamic strength is the 1RM, which requires an individual to lift as much weight as possible one time through a full range of motion (Mayhew, Kerksick, Lentz, Ware, and Mayhew, 2004).

Earle and Baechle (2003) and Hickson (1980) used 80% of one repetition maximum (1RM) as their starting intensity, respectively, in studies to bring about an increase in muscle strength.
In a study conducted by Mjølsnes, Arnason, Østthagen, Raastad, and Bahr (2004) the intensity was set at 60% of the 1RM prior to the start of the intervention. Hennessy and Watson (1994) used a wide spectrum of 70%-105% of 1RM to determine the intensity during their study. In another study conducted by Henwood and Taaffe (2005) on dynamic muscle strength the authors recorded significant increases in knee extension during an eight week resistance training intervention using 75% of 1RM as training intensity.

Fry, Kraemer, Lynch and Barnes (2001) reported maximal leg strength decreased significantly with participants adhering to a training intensity of 100% of 1RM due to overtraining of the leg muscles. In the same study the isokinetic knee extension strength also decreased significantly. Aforementioned finding is of great importance as the strength in the current study utilised isokinetic knee flexion and extension as the basis of comparison to measure strength increases at pre- and post test phases of the intervention.

2.5.2 Volume

Volume or Volume load describes the total amount of weight lifted in a training session and a set is a group of repetitions sequentially performed before the athlete stops to rest. Single-set training may be appropriate for untrained athletes or during the first several months of training. However, the musculoskeletal system will eventually adapt to the stimulus of one set and require added

stimulus of multiple sets to bring about continued strength gains (Fleck and Kraemer 1997). Moreover, performing three sets of a specific exercise without going to failure enhances strength better than one set to failure (Kramer, Stone, O'Bryant, Conley, Johnson, Nieman, Honeycutt and Hoke 1997). Literature that supports the multiple set training principle include studies conducted by Hickson (1980) who used five repetitions of multiple sets, Hunter, Dermment and Miller (1987) who used three sets of seven to 10 repetitions. Kraemer, Patton and Gordon (1995) similarly used three sets of 10 repetitions in their study to bring about an increase in strength. Based on the aforementioned guidelines, the participants in this study were asked to adhere to a training volume of three sets of six reps, as this would bring about strength increases faster than what single sets' training would have done.

Winett and Carpinelle, (2001) also indicated that virtually all the benefits of resistance training were likely to be achieved in two 15 - 20 minute training sessions per week. Sensible resistance training involved precisely controlled movements for each muscle group and did not require the use of heavy resistance.

Vanderhoek, Coupland and Parkhouse (2000) reported increases in strength ranging between 41% and 96% in respect of eight exercises following a 32 week training regime. The research literature also showed significant improvements in balance, which was associated with an increase in dynamic strength.

2.5.3 Frequency

Training frequency refers to the number of sessions completed in a given period of time. According to Baechle and Earle (2000) the common time period is one week for a resistance-training program. Upon determining the training frequency the following variables were to be considered, namely, the participant's current

muscular fitness status, projected exercise loads, types of exercises, and other concurrent training or activities as these could impact upon the performance related outcomes (Foss and Keteyian. 1998).

According to Baechle and Earle (2000) and Alway, Siu, Murlasits and Butler (2005) the best frequency for resistance training when working with beginners involved two to three sessions per week. In support of aforementioned studies, Mjølsnes *et al.,* (2004) revealed that three training sessions per week were ideal to bring about an increase in strength. Furthermore, studies set the optimal frequency of three days per week for strength gains as a result of resistance training. Studies by Dudley and Djamil (1985) and Hennessey and Watson (1994) supported this notion. This frequency details the number of sessions that the participants would have completed the intervention training program weekly. The frequency contributed tremendously to the success of the study to bring about a statistically significant increase in the two experimental groups. Mjølsnes *et al.,* (2004) showed that by using a frequency of three sessions per week in well-trained soccer athletes was sufficient enough to bring about an increase in strength.

On the contrary, Kraemer *et al.,* (1995) documented a four day a week training frequency in their studies, whilst Bird, Tarpenning and Marino (2005) revisited the training frequency and found that a training frequency of two to three days per week was to be most beneficial for previously novice trainers. A frequency of one to two days per week was prescribed as the effective maintenance frequency for novice trainers. It was observed that competitive lifters adhered to a frequency of five to seven days per week to maximize muscle strength gains and to improve muscle size.

As the inclusion criteria for the current study stated that the participants should not have been involved in strength training prior to the study, the initial muscle fitness level was set to be at a beginners level. Therefore, a frequency of three

times a week was prescribed to allow for a rest day between each training session and ensured to set a resistance training program which was easy to follow.

2.5.4 Rest Periods

The time dictated to recover between sets and exercise is termed the rest period (Bird *et al.,* 2005). The length of the rest period between sets and exercises is highly dependent on the goal of the training, the relative load, and the participant's training status. According to Earle and Baechle (2001) rest periods for strength training was set at two to five minutes between each set. Bird *et al*., (2005) described the rest period as a primary determinant of the overall intensity, as the rest period length was strongly related to the load lifted. Moreover it affected metabolic and hormonal demands, as well as the performance of subsequent sets. The rest period length not only determined how much of the adenosine triphoshate (ATP)-phosphocreatine (PCr) energy source was recovered, but also how high lactate concentrations increased in the blood. Both ATP and PCr resynthesis should be completed in 3-5 minutes. Write out in full

Chiu, Schilling, Fry, and Weiss (2004) similarly conducted a study that used five minute rest periods between sets during their resistance training intervention program and found five minutes to be the maximum time allowed for rest periods. On the contrary a study conducted by Hortobdgyi, Money, Zheng, Dudek, Fraser and Dohm (2002) only used a rest period of three minutes between exercise bouts. This indicated the minimum rest period according to Bird *et al.,* (2005). Typically these rest periods were applicable to strength training intensities, meaning that 6-8 repetitions at 80% of 1RM were performed prior to the rest period.

In a WBV study conducted by Roelants *et al.,* (2004) the starting rest period between each WBV exercise was set at 60 seconds. This rest period was

decreased to five seconds over 12 weeks of training and kept at this rest period for the remainder of the 24 week intervention period. The decrease in rest period served as a means of progression in the training intensity for resistance training. The other method involved the increase in amplitude of the WBV training apparatus as a means of progression in intensity.

2.5.5 Overload and Progression

The number of times an exercise can be performed is inversely related to the load lifted; the heavier the load, the fewer the number of repetitions that can be performed (Earle and Baechle, 2004). The implication of this resistance training principle is that the use of a specific workload and number of repetitions were prerequisites to an effective resistance training intervention for strength increases to occur in specific sites.

According the Earle and Baechle (2001) the optimal repetitions to be used in conjunction with the training load to achieve an increase in strength and bring about an increase in muscle diameter (muscle hypertrophy) was six repetitions. As the participant adapted to the training program it was important to progress in the intensity of the exercise program in terms of training load. The conservative method of the 2-for-2 rule was used for progression in the study as advocated by Baechle and Groves, (1998). A study conducted by Bird *et al.,* (2005) concurred that the training load be increased by 2-10% if the participant could perform the current load for one to two repetitions in the desired number of repetitions. Based on a study by Mjølsnes *et al.,* (2004) the intensity progressed by a set weight once the participant could conduct three sets of 12 repetitions during the intervention phase. However the goal for a training program utilizing 12 repetitions is to improve muscle endurance and not muscle strength and hypertrophy as it was desired in this study. The participants increased the load by 2.5kg and started again at eight repetitions until three sets of 12 repetitions could be managed, prior to subsequent loading. For the purpose of this study,

the goal was to improve leg strength over an eight-week training period. With this goal in mind the specific load and repetitions could be assigned by using the standardized one repetition maximum. Based on the results of the pre-test 1RM, 80% of the 1RM was calculated according to the method proposed by Earle and Baechle (2003) to predict the training load at the onset of the study.

2.6 The use of WBV as a mode for resistance training

Cardinale and Bosco (2003) defined WBV as a mechanical stimulus characterized by oscillatory motion. The biomechanical parameters in WBV training to determine intensity are the amplitude, frequency and magnitude of the oscillations of the mechanical stimulus provided by the vibration platform. The extent of the oscillatory motion determined the amplitude (displacement in mm) of the vibration, the repetition rate of the cycles of oscillation denoted the frequency of the vibration (measured in Hz), and the acceleration indicates the magnitude of the vibration.

According to Drake, Vogl and Mitchell (2005) the elasticity and plasticity of the musculoskeletal and articular system is capable of absorbing and dampening mechanical vibration without damage, providing the vibration level is within tolerable limits. The design and fit of the cranial bones, the s-shaped spinal column with shock absorbing intervertebral discs, the external shape of the femur and pelvis, the arch shape of the foot, and the trabecular system within these bones are examples of elastically deformable skeletal designs. The structure and consistent position of the joint surfaces sheathed in articular cartilage also contribute to the body's ability to absorb jolting and vibration.

Bosco *et al.,* (1999) studied the effects of vibration training with participants exercising on vibrating plates that produced a sinusoidal vibration. The frequency used for exercise ranged from 15Hz to 44Hz and the displacement ranged from three mm to ten mm. The acceleration ranged from 3.5 to 15g

(where g is the earth's gravitational force or $9.81 m.s^{-2}$), thus the vibration provided a perturbation of the gravitational field during the time course of the intervention.

In earlier research, Bosco, Cardinale, Colli, Tihanyi, Von Duvillard and Viru (1998) advocated that low amplitude; low frequency mechanical stimulation of the human body was a safe and effective way to improve muscular strength. These authors also reported a significant improvement in muscular strength and power in individuals who exercised with the specially designed WBV exercise equipment. In a study by Roelants, Delecluse and Verschueren (2004) the starting frequency was set at 35Hz and was increased to 40Hz after 12 weeks of intervention. The amplitude was started at 2.5mm and was increased to 5mm after 12 weeks. Both these increases were maintained for another 12 weeks of the study as the intervention period was conducted over 24 weeks. Findings indicated significant knee extension strength increases.

Winett and Carpinelle, (2001) also indicated that virtually all the benefits of resistance training were likely to be achieved in two 15 - 20 minute training sessions per week. Sensible resistance training involved precisely controlled movements for each muscle group and did not require the use of heavy resistance.

The initial frequency used in this study started at 30Hz and set at low amplitude of 2.5mm. The frequency was increased by 5Hz for the following two weeks maintaining the same amplitude. In the fourth week the frequency was increased by 10Hz maintaining the same amplitude. From week five to eight the frequency progression was repeated as it was progressed in the first four weeks, but the amplitude for the last four weeks was set at high (5mm) for the last four weeks. This progression is unique to this study, although the study by Roelants, Delecluse and Verschueren (2004) followed a similar progression. The focus was to progress the WBV intensity to simulate the progression that the resistance

training group underwent. The duration of exposure to WBV did not form part of the prescription of the WBV training program. The exposure lasted for as long as it took for the participant to complete six repetitions. No vibration exposure was present between exercises or during the rest periods between sets.

2.7 The effect of WBV on human performance

WBV is a mode of exercise that had been developed for the prevention and treatment of osteoporosis (Rittweger, Beller and Felsenberg, 2000). Vibration therapy involved neuromuscular training and in addition to the positive skeletal effects in the prevention of loss of bone mineral density, positive training effects on type II muscle fibers had been indicated according to the relative frequency selection of the vibration.

Literature pertaining to WBV, proposed different time effects, such as acute effects, which occurred during the vibration application; acute residual effect, which happened immediately after the application of the vibration, and the chronic training effect, which was defined as the impact of the vibration after a series of training sessions over an extended period.

2.7.1 The acute effects of vibration on strength during isometric contractions

Five studies have investigated the acute affects of vibration exposure on maximal isometric contraction. These studies were conducted by Bongiovanni, Hagbarth, and Stjernberg (1990) on prolonged muscle vibration reducing motor output in maximal voluntary contractions in man; Curry and Clelland (1981) on the effects of asymmetric tonic neck reflex and high frequency muscle vibration on isometric wrist extension strength in adults; Humphries, Warman and Purton (2004) on the influence of vibration on muscle activation and the rate of force development during maximal isometric contractions; and Samuelson, Jorfeldt and Ahlborg

(1989) on the influence of vibration on endurance of maximal isometric contraction.

In the abovementioned studies, measurements of neuromuscular performance were made in a fatigued and an unfatigued state. Findings indicated that when the neuromuscular system was unfatigued, vibration had a significant facilitatory effect on maximal force production. Furthermore, when neuromuscular force was measured in a fatigued state, the findings indicated that vibration could accentuate the muscle fatigue of sustained maximal contraction. The authors concluded that it was unlikely that prolonged vibrations accentuated fatigue by the recruitment of more motor units during the early stage of the muscle contraction.

Aforementioned authors suggested that vibration had a suppression effect that increased gradually with sustained vibration on motor output of maximal voluntary contraction. The suppression effect decreased the ability to generate high firing rates in high threshold motor units. They concluded that prolonged vibration decreased the neuromuscular performance of maximal voluntary contractions by inhibiting motor units from recruitment, rather than by fatiguing the motor units by recruitment.

Kihlberg, Atterbrant and Gemne (1995) studied the acute effects of vibration from a chipping hammer and a grinder on the hand-arm system and found that applied vibration was likely to enhance the submaximal muscular force production. Maximal dynamic contractions and the subsequent effects on strength and power was investigated and reported on by Issurin and Tenenbaum (1999) and Liebermann and Issurin (1997). They concluded that the effects were greater in elite athletes, however, a significant improvement in sedentary individuals had been found as well.

In a study by Rittweger, Mutschelknaus and Felsenberg (2003) subjects performed exhaustive squatting with an additional load of 40% of the body mass, both with and without WBV. It was found that the time to exhaustion was significantly shorter with vibration than without vibration. Oxygen consumption during the squatting exercise was also enhanced significantly by WBV, leading the authors to suggest that the shorter time to fatigue could be due to greater muscle activity during squatting on the vibration platform.

Based on the exploration of available literature, the conclusion could thus be made that prolonged vibration induced more muscle fatigue in both maximal and submaximal isometric and dynamic muscle contractions. This intensified muscle fatigue was due to a facilitatory effect of vibration on muscle contraction force and activity during the early part of the exercise and due to the suppression effect of vibration on neuromuscular performance.

Acute effects had been documented by Bosco *et al.,* (1999) in a study to determine the hormonal response in males when subjected to WBV training. Blood samples were collected and plasma concentrations of testosterone, growth hormone and cortisol were measured indicating a significant increase in the testosterone and growth hormone levels, after a single session of WBV training, the cortisol levels decreased. The latter findings indicated that WBV training brought about similar hormonal adaptations as resistance training with the exception of the cortisol level.

2.7.2 The residual effect of vibration on force and isometric actions

A study by Rittweger, Mutschelknaus and Felsenberg (2003) on the maximal voluntary isometric contraction force found that the maximal voluntary contraction was significantly reduced following a 30 minute vibration treatment at intensity of

30Hz, compared with the control group. These findings suggested that vibrations elicited greater neuromuscular fatigue.

Three studies have examined the effects of vibration on power during dynamic actions. Torvinen, Sievanen and Jarvinen (2002) found that the facilitatory effect of vibration therapy during dynamic movements was transient. This facilitatory effect on muscle strength and power performance was observed in an un-fatigued state and was due to an enhanced central motor excitability to recruit predominately large motor units during both isometric and dynamic movements. However the vibration amplitude and duration needed to be of significant magnitude to elicit this effect, thus leading to the conclusion that a bout of prolonged vibration training exacerbated muscle fatigue, which decreased subsequent muscle performance (Torvinen, Kannu and Sievanen. 2002).

2.7.3 Chronic effect of vibration on neuromuscular performance

Literature pertaining to the chronic effect of vibration training on isometric strength revealed that after 12 weeks of WBV therapy there was a significant increase in knee extensor strength, in contrast to the placebo group (Delecluse, Roelants and Verschueren, 2003). However, in a study by Ruiter, Van Raak and Schilperoort (2003) the authors reported no significant difference in knee extensor isometric strength between the experimental and control groups after an 11 week intervention period. The vibration frequency was similar in the two studies; however the amplitude differed, with higher amplitude being implemented in the latter study. Another difference between the two studies was exercise intensity and the total duration of each training program. Exercise intensity and volume was greater in the study by Delecluse, Roelants and Verschueren (2003), thereby indicating that these parameters were of importance to induce chronic benefits associated with WBV training.

Issurin, Lieberman and Tenenbaum (1994) found that the chronic effects of vibration on dynamic strength and power enhanced the gain of dynamic strength and power, substantiating the long term effects of vibration training. The findings indicated that vibration training induced chronic adaptations, provided that the exercise intensity and volume was sufficient and that the higher the exercise intensity and volume, the greater the strength gains achieved. This finding highlighted the dose-response relationship of exercise.

A study conducted by Torvinen *et al.,* (2002) on the chronic effects of WBV training focused on muscle performance and balance. Findings indicated an increase in vertical jump height, and lower leg extension strength after a four month intervention program. No effect was recorded for grip strength, shuttle run or any of the balance tests. The authors concluded that the increase in jumping height could be attributed to neuromuscular adaptation as a result of the vibrations.

2.8 Summary

After viewing the physiological adaptation that WBV training and resistance training are responsible for, it is logical to want to compare the two modes of exercise to one another. The challenge to be addressed is whether one of these modes should be more superior when increasing muscular strength in comparison to the other.

Resistance training has been used for generations to improve muscular strength and improve performance. The physiological adaptations and principles are well known to the fitness industry. It has been the preferred means of improving human performance. WBV therapy has only recently been introduced to the field of Exercise Science. The adaptations have also been documented through research studies and there is evidence that WBV training can be compared to resistance training based on the benefits that can be derived from the results.

Researchers have indicated guidelines for using the resistance training principles to the best means possible in order to ensure that the goals of the training program can be achieved. The principles for WBV training are not yet scientifically founded and this study explores the potential thereof when compared to resistance training and furthermore, the physiological adaptations when comparing the two modes of exercise.

Chapter 3 – METHODS AND PROCEDURES

3.1 Introduction

The purpose of this study was to determine, contrast and document subsequent evidence of the effect of an eight week WBV and conventional land- based resistance training on peak torque strength and related variables in the upper leg.

3.2 Research Design

The research design incorporated in the study utilized a descriptive, exploratory study with a quasi-experimental approach. According to De Vos, Strydom, Fouche and Delport (2002) the advantage for using this approach lies in the experimental design employing a three group pre-test – post-test design. The design employed was equivalent to the comparison group pre-test – post-test design, in which an experimental and comparative group were utilized with the control group having received both the pre-test and the post-test but remained sedentary for the treatment duration. The purpose of a three group pre-test – post-test design was to gain insight into possible statistical differences that may be apparent between the experimental and comparison group which could potentially be attributed to participation in the WBV training programme or the conventional land-based resistance training programme.

The comparison group were restricted to the gymnasium resistance training program in an attempt to ensure that should any statistically significant differences between the experimental and comparison groups occurred, most of the dependent variables had been controlled for. The results could then be contributed to the independent variable, namely, participation in the whole-body vibration plate or resistances exercise program, and not to the initial gains from a specific exercise regime.

3.3 Sampling technique

Accidental sampling was used to identify and obtain a base of volunteers. De Vos *et al.,* (2002) defined accidental sampling as including any case that happens to cross the researcher's path and is relevant to the phenomenon in the sample until the desired number has been obtained. The participants were volunteers that were recruited from the Nelson Mandela Metropolitan University (NMMU) student population. Volunteers were additionally obtained by means of snowball sampling in which participants already involved in the study found other participants relevant to the study. De Vos *et al.,* (2002:336) defined snowball sampling as the collection of data on the few members of the target population that could be located, then sought information from these individuals that enabled the location of other members of that population.

Furthermore, a non-randomised technique for participant selection was used and participants were matched paired into either the experimental or comparison or control group following completion of the initial assessment. Research completed by Myers (1998:114) stated that this type of quasi-randomization technique minimized differences that might have existed between the experimental, comparison and control groups prior to the intervention.

3.4 Participants

Healthy, sedentary participants of both genders between the ages of 18 and 25 years were included in the study. In an attempt to obtain volunteers an advertisement was placed on the Nelson Mandela Metropolitan University student e-mail portals, inviting them to participate in the study on a voluntary basis. The inclusion and exclusion criteria were clearly formulated in an attempt to identify volunteers who may have met the contra-indications of exercise using whole-body vibration equipment.

All participants had a medical history clear of any recent illnesses, injuries or disease symptomatology. A prerequisite for inclusion in the study was that the participants were not to be involved in any form of resistance training as the effect could impact on the significance of the results. All recruits completed a medical history questionnaire and gave informed consent prior to participation.

Following the pre-test isokinetic leg strength measurement, the forty-three participants were ranked from the strongest to the weakest based on the average isokinetic peak torque acquired for the left and right knee extensors. A matched pair design was used to assign the participants to one of the three groups, namely; the experimental-, the comparison- or the control group to ensure equivalence of leg strength in all three groups prior to the onset of the intervention. The strongest participant was assigned to group one, the second participant to group two and the third participant to group three. The process was then repeated for the rest of the participants. The whole-body vibration therapy group consisted of 15 participants, while the comparison group and control group consisted of 12 and 16 respectively, thereby requiring that use be made of non-parametric statistics to determine if significant differences existed between these groups.

3.5 Exclusion criteria:

According to the researchers Reid and Smith (1981) and Sarantakos (2000) in De Vos *et al.,* (2002), a complete coverage of the total population is seldom possible, and all the members of a population of interest cannot possibly be reached. However, a large sample needs to be drawn as a certain degree of participant mortality and drop-out occurs in any research (De Vos *et al.,* 2002). The latter proved to be a limitation of the current design as forty-three participants only volunteered to participate in the study.

Pregnant individuals were excluded from the study as the safety considerations in the use of WBV therapy during pregnancy had not been determined at the

onset of this research. Furthermore, the effect of whole-body vibration training on the development of the foetus has not been established.

Preventative contra-indications were stated as exclusion criteria due to the unknown effects that vibration training may have had on various conditions or symptoms. These conditions included serious cardiac conditions or vascular disease, including recent bypass surgery, primarily due to the increase in body temperature and blood circulation, and the use of a pacemaker as a result of unknown effects of vibration training on the frequency setting and placement of the pacemaker.

Participants with orthopaedic conditions, including severe osteoporosis, rheumatoid arthritis or any other generalized bone disease were excluded, as the exercise programme selected could potentially aggravate the existing conditions and their relevant signs and symptoms.

Recent fractures of the axial skeleton, or recent orthopaedic surgery, such as joint replacements, metal or pin implantations as well as chronic conditions including severe epilepsy, tumours and acute migraine, were among those conditions listed as having unknown results from vibration training and hence were excluded due to safety considerations.

A thorough medical history and fitness evaluation for each participant was documented to ensure a state of good health prior to and during participation in the intervention programs. The medical history questionnaire acted as a screening test for contra-indications to both the resistance mode of training and the vibration training. All participants were at an untrained level at the onset of the intervention as none were currently, nor for a period of six months prior to the study, involved in any form of resistance training, with the aim to improve upper leg strength.

3.6 The Assessment Instrument

The CYBEX NORM 770 Isokinetic Dynamometer was utilized to determine leg strength of the following dependent variables; evaluating the knee flexor and extensor peak torque, work per repetition and average power per repetition at $60^0.s^{-1}$. In a study conducted by Delecluse, Roelants and Verschueran (2003), knee extensor strength was assessed using an isokinetic dynamometer. The CSMI Humac software package was used to display the results of the isokinetic test. The leg strength was assessed using the concentric measuring capability of the NORM 770. The machine was calibrated before testing and the software was setup to provide numeric data indicating peak torque, power output and Watts.

3.7 Testing protocol

During the isokinetic testing the participants were required to contract the quadriceps and the hamstring muscle group alternatively and consecutively to produce maximum force output against the dynamometer. A warm-up phase consisted of a five minute cycle on a cycle ergometer at an intensity of 25 watts to prevent potential injury. The participants were placed in a seated position the CYBEX NORM 770 testing chair. The leg being test was strapped in with the knee joint aligned with the axis of rotation of the dynamometer. An extension of the warm-up protocol followed once the participant was placed in the appropriate position on the CYBEX isokinetic dynamometer to perform a trial consisting of five sub-maximal repetitions, which additionally served as familiarization with the isokinetic equipment. Following the five repetition trial the participants performed five repetitions at maximal force application which served as the assessment phase where data was computer recorded. During the test the participants received verbal encouragement from the researcher to ensure the performance of maximum effort, was recorded.

3.8 The training programs

Designed according to the principles of resistance training as prescribed by the ACSM and The National Strength and Conditioning Association (NSCA) as detailed by Earle and Baechle (2004) with emphasis on upper leg muscle strength. Participants were required to complete either the whole-body vibration or the conventional land-based resistance training program, three times a week. Duration of the programme was approximately 40 minutes and consisted of three sections including a warm-up, specific upper leg strength training exercises and a cool down. The warm-up protocol consisted of a five-minute cycle on a stationary Monarch 2000 cycle ergometer followed by a series of stretches, as a means of providing an effective warm-up for the muscles before the commencement of the strength training exercises. The cool down protocol consisted of flexibility exercises which were replicated for the WBV training group and the comparison group, respectively.

3.8.1. The Whole Body Vibration training program

The WBV training group was required to perform five exercises on the power plate. The following exercises were used in the programme. A semi squat, deep squat, wide stance squat, lunges and calf raises. All the exercises were performed in a dynamic nature to simulate the exercises that were performed by the resistance training (RT) group. The warm-up was performed prior to completing the WBV training programme. The initial setting on the power plate was 30 seconds at 30 Hz on low intensity. The program progression was adhered to by increasing the frequency every week and after four weeks the amplitude was changed from a low to a high intensity setting and the same frequency progression was repeated on the higher amplitude.

This program was designed by the researcher using strength training principles of intensity, volume, frequency, rest periods, overload and progression as guidelines. The programme was designed so that both the WBV and the

conventional land-based RT group performed exactly the same movements during the exercise intervention. The difference would be that the WBV training group was exposed to the vibrations on the vibration platform and the RT group was exposed to land-based resistance training. There was no set duration, but the time exposed to the vibrations was determined by how long it took the participant to complete a set of exercises. Each set consisted of six repetitions and three sets had to be completed for every exercise. Appendix E contains a detailed explanation and visual replication of the exercises performed in the WBV training program.

3.8.2 The resistance training program

The RT-group had to perform a one-repetition maximum (1RM) for each of the exercises that were to be performed during the intervention period. Thus, the 1RM for semi squat, deep squat, wide stance squat, lunges and calf raises were assessed prior to commencement of the training program. From the results 80% of the 1RM was calculated according to the method proposed by Earle and Baechle (2004). These values were used as the starting weight for the dynamic resistance training exercises. The RT-group performed the same warm-up and stretching protocol as the WBV training group. The participants were asked to perform three sets of six repetitions of the prescribed exercises.

According to Earle and Baechle (2004) the prescribed repetitions and sets were the most effective load and resistance for increasing muscular strength. Progression was measured by adhering to the 2-for-2 rule. This meant that if the participant could complete two repetitions more than the prescribed six repetitions on the suggested weight, the load had to be increased for the next session.

Isotonic resistance training programs were used for one specific goal, namely the development of muscular strength. Isotonic contractions are dynamic in nature indicating that there is joint movement involved and consists of two stages, known as concentric contraction and eccentric contraction (Powers and Howley, 2001). Concentric contraction is a result of the muscle shortening and eccentric contraction occurs when a muscle is activated and force produced while the muscle lengthened. For example; when the participant performed a squat as one of the prescribed intervention exercises, the downwards movement from the anatomical zero position comprised the eccentric contraction of the quadriceps muscle component, while the upward movement returning to the anatomical zero position, consisted of the concentric contraction of the quadriceps muscle component, (Earle and Baechle, 2004). Both phases of concentric and eccentric contraction involved the completed performance of a dynamic isotonic movement. The same movement pattern was used for both the experimental and comparison intervention groups. The WBV training group, however used amplitude, frequency and intensity of the vibration as a predetermined work load instead of 80% of 1RM as in the case of the land-based resistance training group. Appendix F contains a full explanation and visual replica of the exercises performed in the land-based RT programme.

3.9 Ethical considerations

According to De Vos *et al*., (2002), ethics are defined as a set of widely accepted moral principles that offer rules for and behavioural expectations of the most correct conduct towards experimental subjects and respondents. To ensure that the study followed adequate ethical and moral guidelines, permission for the proposed research was sought from and granted by The Human Ethics Committee of the Nelson Mandela Metropolitan University.

A covering letter which described the rationale for the study (Appendix A) and a formal document of informed consent (Appendix C) was given to each participant

prior to the commencement of the study. The nature, procedure and outcome of the research, as well as the rights of the participants, were explained within the documentation. The participants were required to complete a consent form in full before the testing commenced. A statement of and declaration from the researcher was explained to each participant and a signed copy was presented to the participants (Appendix D). The participants received a medical history questionnaire (Appendix B) to ensure screening was done prior to inclusion in the study and to ensure that no contra-indications existed that could place the participant at risk during the performance of either of the training programs.

To ensure that the research was conducted in an ethical manner the researcher verbalised to the participant that participation was voluntary and that he/she may withdraw from the study at any stage without any fear of being discriminated against in any manner. Confidentiality with regards to each participant's identity with reference to their test results was upheld. All information was treated as highly confidential and only a general conclusion was made public.

On completion of the eight week power-plate® and conventional resistance training program, the comparison group was offered the opportunity to participate in the eight week WBV training programme, as participation in the power-plate® program could possibly have been the initial reason for voluntary participation in the study. On completion of the study, both the comparison and experimental groups received a brief summary of the study outcome in an attempt to provide the participants with the results of the study as well as to encourage further participation in physical activity.

3.10 Data analysis

Analysis of data was performed utilizing descriptive and inferential statistics through the help of a qualified statistician. According to Gravetter and Willnua

(1995) descriptive statistical analysis is a technique that uses raw data, in the form of standard deviations, means or pie charts, to produce more logical, understandable and manageable information.

According to Hair, Babin, Money and Samouel (2003) ANCOVA stands for analysis of variance and tests whether the means of two or more groups are statistically different on more than one dependent variable. Analysis of co-variance (ANCOVA) as described by De Vos *et al.,* (2002) is a commonly used statistical technique that allows differences existing between the pre- and post-test experimental-, comparison- and control groups for each of the variables being studied to be determined. The significance of the results was reported within the 95% interval utilizing Scheffé's test ($p < 0.05$). Post hoc analysis was done to determine and compare if differences between the exercise, comparison and the control group existed for the selected variables (Christensen, 1997). Partial eta^2 was applied to determine the practical significance ($p > 0.1$) of the results.

3.11 Summary

A descriptive, exploratory research design with a quasi-experimental approach was incorporated into the study to determine underlying differences between the experimental, comparison and control groups with regard to upper leg strength differences in peak torque flexion and extension variables, following the completion of an eight week intervention programme. Accidental and snowball sampling techniques were utilized to obtain a base of volunteers and subsequently a non-randomised technique for participant selection was selected. In accordance with this, exclusion criteria were set prior to the initial assessments of the participants and a physical assessment to ensure their safety during the performance of the intervention programs. Healthy volunteers between the ages of 18 and 25, were matched paired into a three group pre- and post-test design

incorporating an experimental, comparison and control group following completion of the initial assessment.

A medical history questionnaire was completed as a screening test to assess the health risk of the participants. The pre- and post-test assessment consisted of recording height, weight and gender. These variables were used to calibrate the measurement equipment to ensure adjustment of the equipment during all assessments, accordingly. ANCOVA and post hoc analysis was used to determine statistical differences existing between the pre- and post-test experimental, comparison and control groups for the dependent variables being studied.

Chapter 4 – RESULTS: PRESENTATION AND DISCUSSION

4.1 Introduction

The data was gathered for the 43 healthy participants in a pre-test isokinetic assessment of leg strength for the dependent variables of the peak torque, work per repetition produced, and the average power per repetition for flexion and extension at the knee joint for both legs. Following an eight week intervention program of either WBV training or resistance training, the participants were re-tested at the post-test phase using the same protocol that was used in the pre-test. The raw data was subsequently processed to describe and compare the effect of two methods of strength training on leg strength for the experimental (WBV) -, comparison (RT) -, and control group. Thus, inter group differences and the significance of the differences for aforementioned three dependent variables, were established at a 95% level of probability ($p<0.05$) as suggested by Thomas and Nelson (1990).

Descriptive statistics pertaining to means and standard deviation were tabulated. Inferential statistics consisted of post hoc analysis utilizing Scheffé's test, and ANCOVA was applied as a combination of regression and analysis of variance, to determine the significance of results. ANCOVA is a technique used to adjust the dependent variable for a covariate variable by correlation and then the analysis of variance is calculated on the adjusted dependent variable (Thomas and Nelson, 1990). Practical significance was calculated by means of the partial eta^2.

The objectives of the study were strongly supported by the data gathered for analysis. Statistically and practically, the experimental and comparative group showed significant improvements in the selected dependent variables after the eight week intervention period. These results indicated that WBV was an effective mode of resistance training; however, the conventional land-based

resistance training method was significantly superior when compared to the WBV training to increase leg strength.

4.2 Peak torque leg flexion at the knee joint

There was a significant increase in peak torque leg flexion strength in both the WBV- and the resistance training group. The WBV group obtained a pre-test mean of 100.47 Nm and a post-test mean of 108.60Nm indicating a strength increase difference of 8.13 Nm (8.09%). In comparison, data indicated that the resistance training group had a greater significant effect with a pre-test mean of 99.63 Nm increasing to a post-test mean of 112.21 Nm, indicating a strength increase of 12.58 Nm (12.63%). The control group decreased by 0.78 Nm from a mean value of 95.72 Nm in leg strength from the pre-test to a mean post-test score of 94.94 Nm.

Results indicated that both WBV as well as conventional resistance training had a strengthening effect in the posterior muscle compartment of the thigh as these are the prime agonists to produce peak torque leg flexion at the knee joint. Descriptive data is exhibited in tabular format in Table 1.

Table 1: Descriptive data for peak torque flexion

	Control			Resistance (RT)			WBV		
	Pre-test	Post-test	Diff	Pre-test	Post-test	Diff	Pre-test	Post-test	Diff
N	16	16	16	12	12	12	15	15	15
Mean	95.72	94.94	-0.78	99.63	112.21	12.58*	100.47	108.60	8.13*
SD	34.20	35.85	14.72	38.91	45.75	23.49	44.47	41.66	9.19
Minimum	58.50	44.00	-28.00	56.00	57.50	-7.50	53.00	61.00	-8.50
Quartile 1	67.63	72.25	-9.63	71.13	73.88	-0.75	63.75	71.00	4.00
Median	84.50	84.25	-1.75	96.75	108.75	2.75	72.00	86.00	8.50
Quartile 3	118.38	117.63	10.25	110.38	140.88	13.00	135.25	145.25	13.00
Maximum	164.50	183.50	21.00	193.50	190.50	67.50	185.00	176.50	27.5

* $p < 0.05$

The results are presented in a histogram in Figure 1.

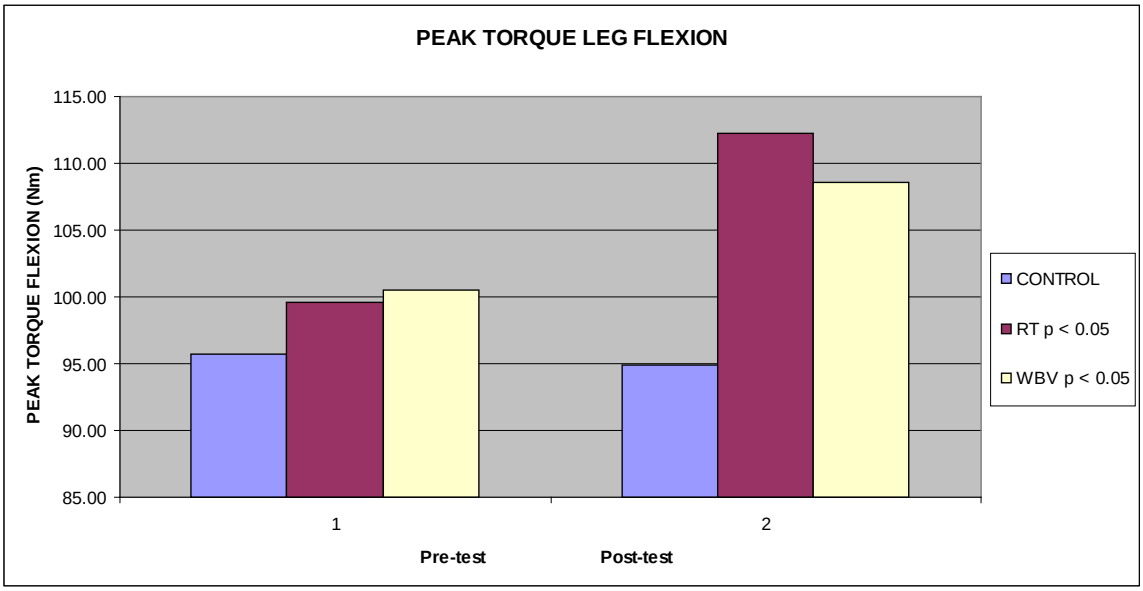

Figure.1 Histogram of the peak torque for flexion

As revealed in Table 2, ANCOVA revealed that there was a statistically significant difference among the three groups p=0.048 (p < 0.05). The post hoc analysis using Scheffé's test revealed statistical significance between both the WBV- and the resistance training group, as indicated by p=0.023 (p < 0.05), and between the resistance training group and the control group for p=0.006 (p < 0.05). Practical significance by means of the partial eta^2 was indicated for both WBV- and resistance training groups at a level of p= 0.16 (p > 0.1).

Table 2: ANCOVA for peak torque leg flexion

	Means				ANCOVA			Scheffé	Partial eta^2
Groups	1. Control	2. RT	3. WBV	Overall Mean	F	Df	P		
Peak torque flexion pre-test	95.72	99.63	100.47	98.47	14.88	1	.000		0.30
Group					3.33	2	.048*	1:2 (.006) 2:3 (.023)	0.16**

* p < 0.05

** p > 0.1

4.3 Work per repetition for flexion of the leg at the knee joint

There was a significant increase in work output per repetition for flexion strength in both the WBV and the resistance training groups. The WBV group obtained a pre-test mean of 121.8 Nm and a post-test mean of 138.3 Nm, indicating an increase of 16.53 Nm (13.57%). Data indicated that the resistance training group had a pre-test mean of 119.2 Nm and increased to a post-test mean of 141.1 Nm, indicating a difference of 21.83 Nm (18.31%). The work output per repetition for flexion strength in the control group increased by 5.03 Nm from a mean value of 115.88 Nm in the pre-test to a mean post-test score of 120.9 Nm. These descriptive results are displayed in Table 3 and indicate that both WBV and resistance training had a strengthening effect in the posterior compartment

of the thigh as the work output per repetition for leg flexion at the knee joint increased.

Table 3: Descriptive data for work per repetition for flexion

	Control			Resistance			WBV		
	Pre-test	Post-test	Diff	Pre-test	Post-test	Diff	Pre-test	Post-test	Diff
N	16	16	16	12	12	12	15	15	15
Mean	115.88	120.91	5.03	119.29	141.13	21.83*	121.83	138.37	16.53*
SD	47.64	50.99	17.80	46.31	53.51	27.93	57.94	56.78	14.34
Minimum	53.50	63.50	-30.00	66.50	75.50	-10.50	57.50	68.00	-2.50
Quartile 1	80.63	86.75	0.13	89.75	103.88	8.38	77.75	91.75	7.50
Median	99.00	110.00	3.00	114.00	131.50	12.75	89.50	106.50	14.00
Quartile 3	143.25	140.63	13.63	132.13	168.38	21.75	159.00	184.25	22.25
Maximum	220.00	258.50	38.50	231.50	235.50	90.50	250.00	247.50	46.50

* $p < 0.05$

The results are presented in a histogram in Figure 2.

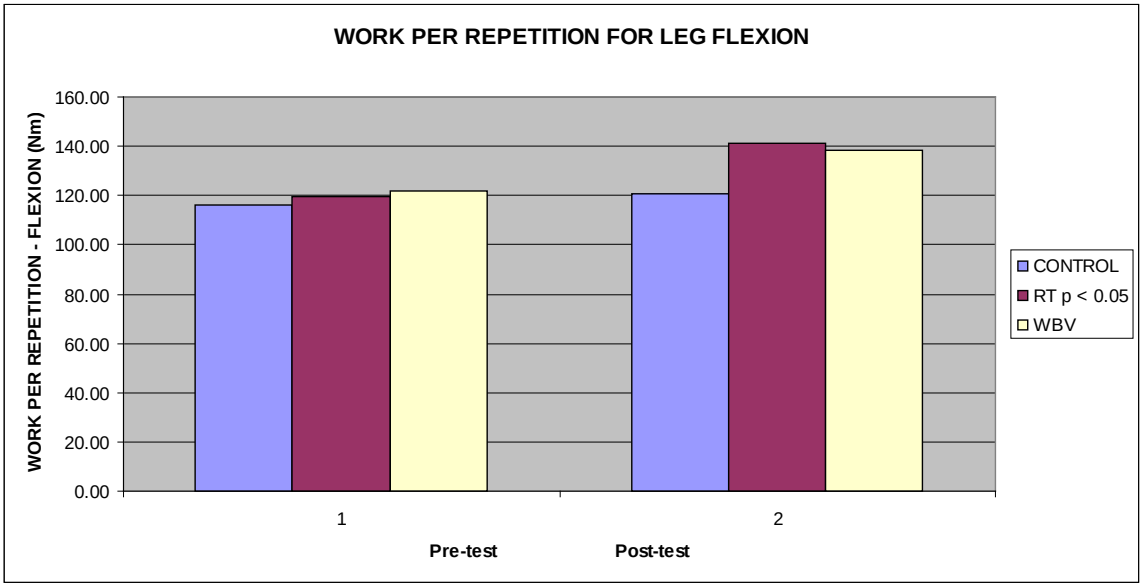

Figure.2 Histogram of the work per repetition for flexion

As revealed in Table 4 ANCOVA indicated that there was no statistical significance among the three groups p=0.092 ($p < 0.05$). As there was no statistical significance by means of ANCOVA, the Scheffé's test could not be performed, thus indicating no practical significance by means of the partial eta^2.

Table 4: ANCOVA for work per repetition for flexion

	Means				ANCOVA			Scheffé	Partial eta^2
Groups	1. Control	2. RT	3. WBV	Overall Mean	F	Df	p	n/a	
Peak torque flexion pre-test (Nm)	115.88	119.29	121.83	118.91	32.78	1	.000		0.49
Group					2.56	2	.092*	n/a	n/a.

* $p < 0.05$

** $p > 0.1$

n/a: not applicable

4.4 Average power per repetition for leg flexion at the knee joint

Table 5 indicated a significant increase in average power per repetition for leg flexion strength in both the WBV- and the resistance training groups. Data indicated that the resistance training group had a greater significant effect with a pre-test mean of 69.21 W increasing to a post-test mean of 78.75 W, resulting in an increase of 9.54 W (13.78%). In comparison, the WBV group obtained a pre-test mean of 70.40 W and a post-test mean of 76.40 W indicating a difference of 6.00 W (8.52%).

The dependent variable decreased by a score of 0.19 W from a mean value of 66.84 W in the pre-test to a mean value of 66.66 W in the post-test for the control group. Results indicated that WBV had a strengthening effect in the posterior

compartment of the thigh as the average power per repetition for leg flexion had increased.

Table 5: Descriptive data for average power per repetition for flexion

	Control			Resistance			WBV		
	Pre-test	Post-test	Diff	Pre-test	Post-test	Diff	Pre-test	Post-test	Diff
N	16	16	16	12	12	12	15	15	15
Mean	66.84	66.66	-0.19	69.21	78.75	9.54*	70.40	76.40	6.00*
SD	25.95	25.68	10.38	26.60	30.99	15.03	33.28	31.46	6.57
Minimum	36.00	34.00	-24.50	37.00	41.00	-3.00	35.50	39.50	-4.50
Quartile 1	46.50	51.63	-3.50	52.13	55.88	2.75	44.25	50.25	0.75
Median	58.50	58.25	0.00	67.75	75.50	4.00	53.00	57.50	4.50
Quartile 3	82.63	78.50	5.75	77.88	99.88	6.88	93.00	103.25	9.25
Maximum	119.50	133.00	17.50	131.50	131.00	46.50	140.50	136.00	18.00

* $p < 0.05$

The results are presented in a histogram in Figure 3.

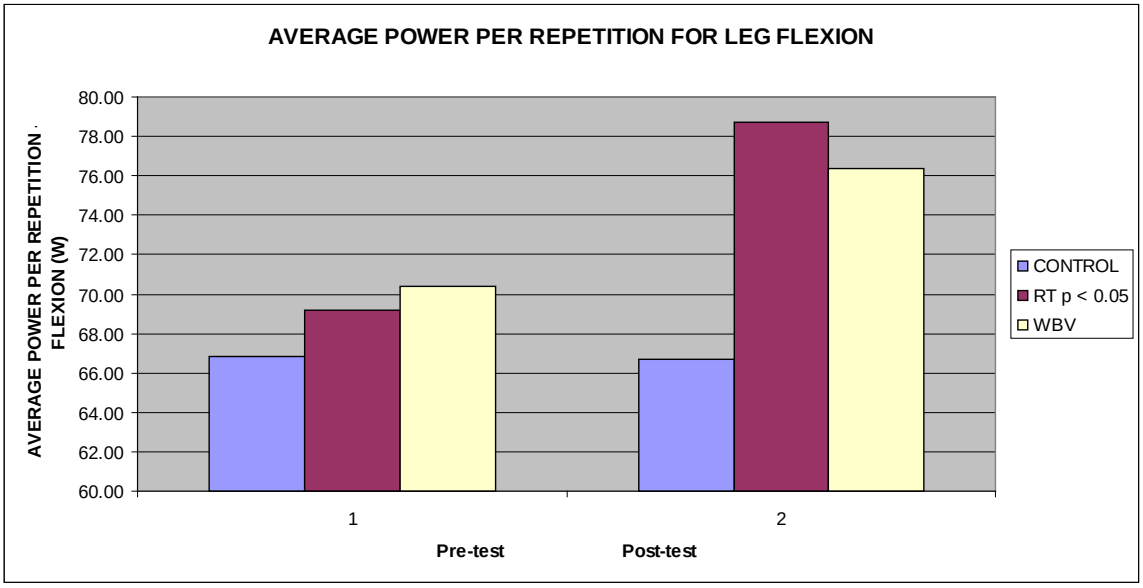

Figure.3 Histogram of the average power per repetition for flexion

The ANCOVA as revealed in Table 6 indicated no statistically significant differences among the three groups p=0.058 ($p < 0.05$). Thus, there existed no statistical significance between any groups, also resulting in no practical significance to be reported.

Table 6: ANCOVA for average power per repetition for flexion

	Means				ANCOVA			Scheffé	Partial eta^2
Groups	1. Control	2. RT	3. WBV	Overall Mean	F	Df	P		
Peak torque flexion pre-test (Nm)	66.84	69.21	70.40	68.74	27.35	1	.000		0.45
Group					3.10	2	.058*	n/a	n/a.

* $p < 0.05$

** $p > 0.1$

n/a: not applicable

4.5 Peak torque leg extension at knee joint

The WBV training group showed no significant difference from the pre-test result of 178.67 Nm to the post-test result of 178.27 Nm after the eight weeks of WBV intervention. However, results for the resistance training group indicated a significant increase in leg extension strength, obtaining a pre-test mean of 182.29 Nm and a post-test mean of 190.25 Nm, resulting in an increase of 7.96 Nm (4.37%). Thus, an increase in the strength of the agonists situated in the anterior muscle compartment of the thigh was indicated. In comparing mean peak torque extension values, the control group decreased with a mean difference of 5.47 Nm, whereas the WBV training group only decreased with 0.40Nm. The latter finding could be attributed to the vibration therapy's effect on the maintenance of peak torque leg extension strength, while the control group lost muscle strength

as a result of detraining. Descriptive data is exhibited in tabular format in Table 7.

Table 7: Descriptive data for peak torque extension

	Control			Resistance			WBV		
	Pre-test	Post-test	Diff	Pre-test	Post-test	Diff	Pre-test	Post-test	Diff
N	16	16	16	12	12	12	15	15	15
Mean	174.94	169.74	-5.47	182.29	190.25	7.96*	178.67	178.27	-0.40*
SD	58.09	48.13	17.95	62.95	72.12	18.32	59.18	57.30	14.89
Minimum	107.00	107.50	-34.00	101.50	101.00	-30.50	99.00	98.50	-22.50
Quartile 1	128.38	129.25	-12.38	122.75	128.25	-0.50	123.25	135.75	-9.00
Median	160.00	163.50	-6.25	176.00	181.75	5.25	164.00	159.00	-0.50
Quartile 3	208.50	194.63	4.50	227.63	234.50	17.50	233.25	225.00	5.75
Maximum	312.00	278.00	31.50	282.00	311.50	41.50	269.00	267.00	31.50

* $p < 0.05$

The results are presented in a histogram in Figure 4.

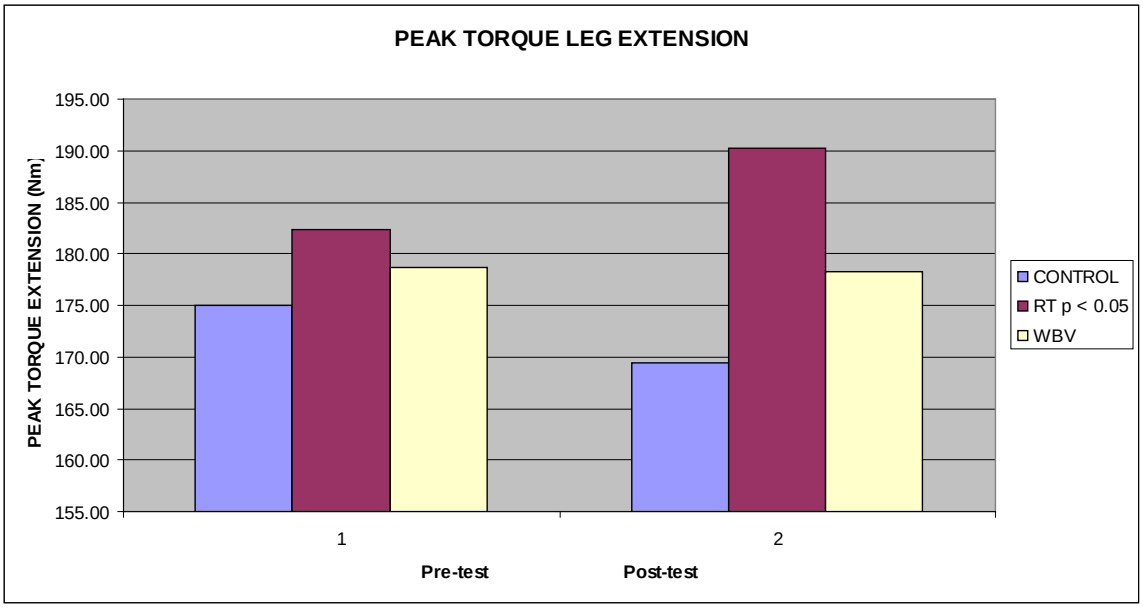

Figure.4 Histogram of the peak torque for extension

ANCOVA reflected in Table 8, revealed that there was a statistically significant difference among the three groups p=0.017 ($p < 0.05$). Post hoc analysis using Scheffé's test indicated a statistically significant difference between the control and resistance training group p=0.03 ($p < 0.05$). Furthermore, the partial eta^2 of the results for peak torque leg extension indicated practical significance, p= 0.21 ($p > 0.1$) for leg strength in the resistance training group.

Table 8: ANCOVA for peak torque extension

	Means				ANCOVA			Scheffé	Partial eta^2
Groups	1. Control	2. RT	3. WBV	Overall Mean	F	Df	p		
Peak torque extension pre-test (Nm)	174.94	182.29	178.67	178.29	34.40	1	.000		0.50
Group					4.60	2	.017*	1:2 (.003)	0.21**

* $p < 0.05$

** $p > 0.1$

4.6 Work per repetition for leg extension at the knee joint

The WBV training group showed increases in work output per repetition for extension from the pre-test result of 212.17 Nm to a post-test result of 228.17 Nm, resulting in an increase of 16Nm (7.54%) after the eight weeks of WBV training. Results indicated a significant increase in work output per repetition for extension strength in the resistance training group, with a pre-test mean of 219.58 Nm and post-test mean of 236.46 Nm, resulting in an increase of 16.88 Nm (7.69%). In comparing mean work per repetition for extension, the control group also increased with a mean difference of 6.97 Nm. The latter finding indicates that all participants regardless of inactivity or intervention achieved a better result during the post-test. This effect could possibly be attributed to the better understanding of the test protocol, resulting in enhanced test results in the control group. Descriptive data is exhibited in tabular format in Table 9.

Table 9: Descriptive data for work per repetition for extension

	Control			Resistance			WBV		
	Pre-test	Post-test	Diff	Pre-test	Post-test	Diff	Pre-test	Post-test	Diff
N	16	16	16	12	12	12	15	15	15
Mean	210.06	217.03	6.97	219.58	236.46	16.88*	212.17	228.17	16.00
SD	62.72	59.33	18.54	72.50	77.80	19.71	73.06	68.76	18.85
Min	128.00	139.00	-20.00	132.00	134.50	-23.00	114.00	128.50	-18.00
Quartile 1	158.00	173.38	-6.63	161.25	183.13	9.63	154.25	177.25	3.75
Median	194.50	210.50	7.00	206.50	212.50	18.25	187.50	212.50	14.50
Quartile 3	247.75	242.38	13.13	269.50	282.13	26.38	266.50	291.75	28.25
Maximum	314.50	342.00	49.50	330.50	379.50	59.00	325.50	329.50	54.50

* $p < 0.05$

The results are presented in a histogram in Figure 5.

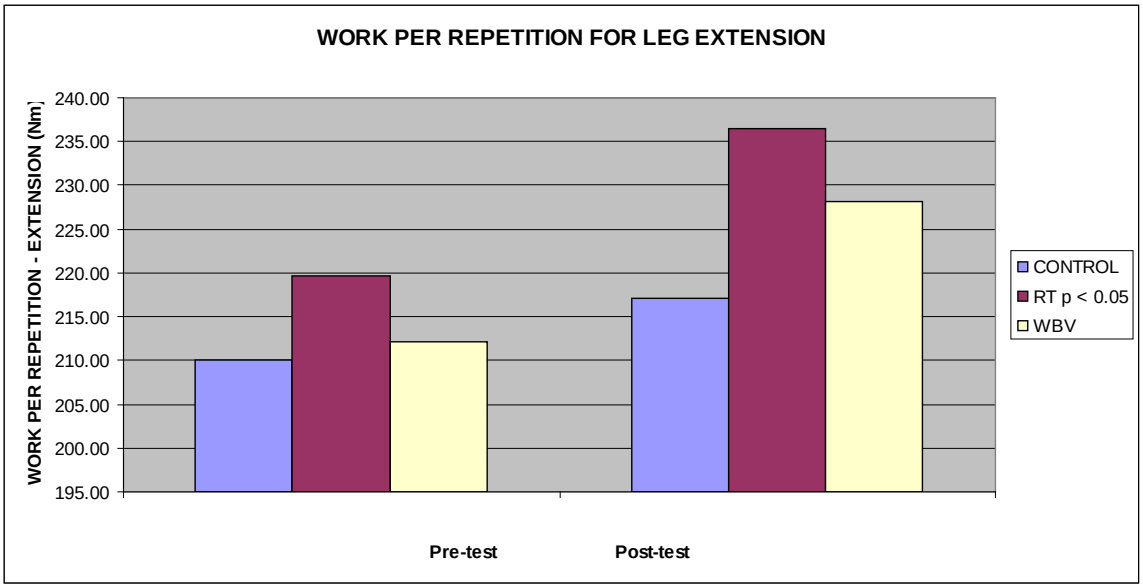

Figure.5 Histogram of the work per repetition for extension

As revealed in Table 10, the ANCOVA revealed that there was a statistically significant difference among the three groups p=0.043 ($p < 0.05$). Post hoc analysis using Scheffé's test revealed statistical significance between the control and the resistance training group, as indicated by p=0.011 ($p < 0.05$). Practical significance by means of the partial eta^2 was indicated for the resistance training groups at a level of p= 0.17 ($p > 0.1$).

Table 10: ANCOVA for work per repetition for leg extension at knee joint

	Means				ANCOVA			Scheffé	Partial eta^2
Groups	1. Control	2. RT	3. WBV	Overall Mean	F	Df	p		
Peak torque extension pre-test (Nm)	210.06	219.58	212.17	213.45	39.74	1	.000		0.54
Group					3.47	2	.043*	1:2 (.011)	0.17**

* $p < 0.05$

** $p > 0.1$

4.7 Average power per repetition for leg extension at the knee joint

The WBV training group showed a significant increase in the average power per repetition output from the pre-test result of 119.47 W to the post-test result of 123.60 W after the eight week WBV training. Similarly, the resistance training group obtained a significant increase in average power per repetition for extension strength with a pre-test mean of 123.63 W and a post-test mean of 129.88 W, resulting in an increase of 6.26 W (5.06%). In comparison, the mean average power per repetition for thigh extension decreased with a mean difference of 0.59 W in the control group. These findings indicated that both WBV and resistance training were responsible for increased average power per repetition for thigh extension strength in the anterior muscle compartment of the leg. The control group, however, lost muscle strength measured as average power per repetition and could potentially be ascribed to a detraining effect. Descriptive data is exhibited in tabular format in Table 11.

Table 11: Descriptive data for average power per repetition for extension

	Control			Resistance			WBV		
	Pre-test	Post-test	Diff	Pre-test	Post-test	Diff	Pre-test	Post-test	Diff
N	16	16	16	12	12	12	15	15	15
Mean	118.72	118.13	-0.59	123.63	129.88	6.25*	119.47	123.60	4.13
SD	35.87	33.02	10.60	41.78	45.72	10.32	42.63	39.02	11.00
Minimum	74.50	75.50	-21.00	73.00	73.50	-10.00	68.00	72.00	-14.00
Quartile 1	92.25	90.38	-7.00	88.88	92.00	1.25	85.50	95.25	-2.00
Median	112.50	116.50	-0.50	112.75	124.75	2.75	98.00	112.50	3.50
Quartile 3	141.38	133.63	2.25	151.13	152.63	10.38	154.75	154.00	12.25
Maximum	191.00	190.50	26.50	187.50	218.50	31.00	188.50	189.00	23.50

* $p < 0.05$

The results are presented in a histogram in Figure 6.

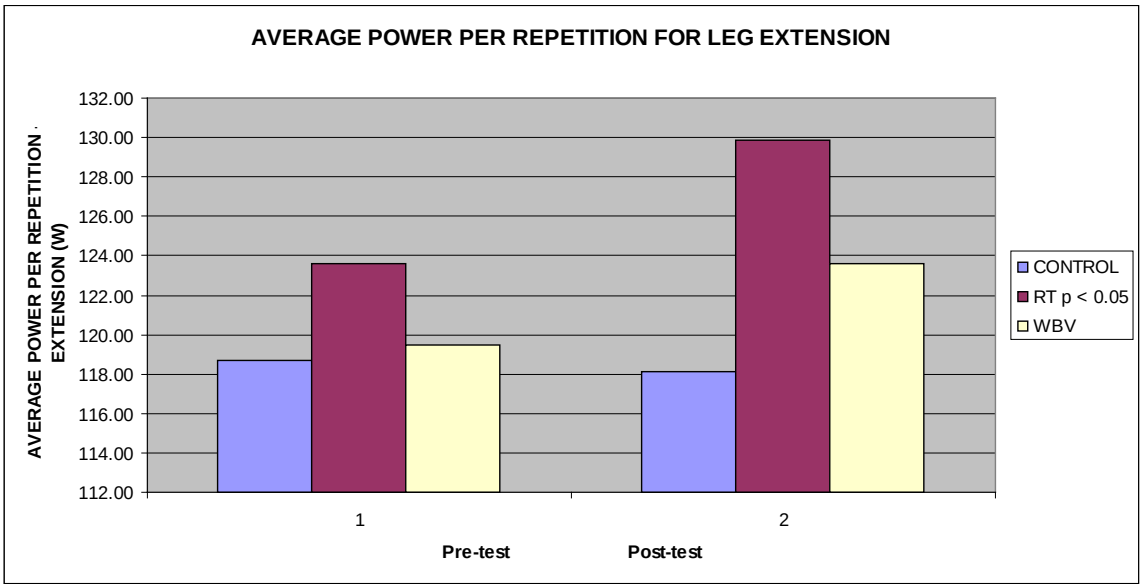

Figure.6 Histogram of the average power per repetition for extension

ANCOVA revealed statistical significance among the three groups p=0.042 ($p < 0.05$). Post hoc analysis using Scheffé's test indicated statistically significant differences between the control and resistance training group p=0.08 ($p < 0.05$). Furthermore, the partial eta^2 of the results for the dependent variable, average power per repetition for leg extension, indicated practical significance, p= 0.17 ($p > 0.1$) in the resistance training group.

Table 12: ANCOVA for average power per repetition for extension

	Means				ANCOVA			Scheffé	Partial eta^2
Groups	1. Control	2. RT	3. WBV	Overall Mean	F	Df	P		
Peak torque extension pre-test (Nm)	118.72	123.63	119.47	120.35	46.64	1	.000		0.58
Group					3.50	2	.042*	1:2 (.008)	0.17**

* $p < 0.05$

** $p > 0.1$

4.8 Conclusions

Data analysis of the dependant variables, peak torque leg flexion, work per repetition for both extension and flexion and average power per repetition, both the resistance training and WBV training groups revealed significant strength gains in the posterior and anterior compartment of the thigh respectively. However, for all the aforementioned dependent variables the resistance training group indicated superior increases in leg strength.

The dependant variable peak torque leg extension, indicated significant improvement in the resistance training group only. Although the WBV group maintained the strength output of the anterior muscle group situated mostly in the quadratus femoris muscle group, the control group who remained sedentary revealed a detraining effect after the eight week intervention period.

Chapter 5 – DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The aim of this study was to explore, describe and compare the effect on leg strength by measuring the concentric force produced in isokinetic testing by the anterior and posterior compartments of the upper leg musculature using whole body vibration training and conventional resistance training as modes of resistance exercise. The forces were produced during a dynamic movement and there were limited literature on vibration training as a strength enhancing mode to provide baseline levels of comparison for this study. It is here where the challenge of this research lay in attempting to bridge the gap in existing documented evidence using the whole body vibration as a mode for strength enhancement.

Within the limitations of the study design as mentioned in chapter three, results indicated that resistance training over an eight week intervention period, led to leg strength gains and more specifically in the dependent variable of leg flexion strength at the knee joint. In addition, results indicated that the conventional mode of gymnasium-based resistance training without vibration led to superior results when compared to the alternative mode of WBV training, although both modes of resistance training yielded strength increases in the upper leg. Caution should be taken when generalising these results to samples of the general population at large as a major limitation of this study design was the selection of volunteers that comprised a relative small non-randomised sample size.

Results were discussed according to the dependent variables selected for this study, namely; peak torque, work per repetition and average power per repetition for flexion and extension for both legs at the knee joint.

5.2 Discussion of results for the variables effecting leg flexion at the knee joint.

Based on the literature of researchers like Earle and Baechle (2004), resistance training is responsible for effective increases in muscle strength. Corbin *et al.,* (2000) and Goldspink (1992) reiterated principles of physiological adaptations by the human body to the physiological demands due to resistance training causing an increase in muscular strength. Researchers such as Hunter *et al*., (2004) and Kraeme (2004) supported the existing body of evidence that resistance training was a primary and reliable mode of exercise to improve muscular strength.

In support of aforementioned evidence results for peak torque leg flexion at the knee joint indicated that both WBV and conventional resistance training were responsible for increases in leg strength. Although the increase in peak torque flexion at the knee joint was significantly greater in the conventional resistance training group. Both variables, work per repetition and average power per repetition for leg flexion at the knee joint produced similar increases in leg flexion strength. Studies done on WBV and resistance training concluded that both WBV and resistance training led to significant increases in dynamic strength (Delecluse *et al*., 2003). Bosco *et al*., (1999) contributed to the field of research by disseminating results indicating that WBV increased leg power output. Whilst Rittweger *et al*., (2003) produced literature that showed that WBV was responsible for improving isometric torque and tendon reflex amplitude.

When reviewing the aim and objectives of this study, the focus was to determine whether WBV could produce similar or comparable results to conventional resistance training. Although aforementioned studies did not differentiate in the superiority of any one of the modes of resistance training, the current research indicated that an increase in strength could be obtained by using both these modes of resistance exercise; specifically in producing muscle strength of the posterior compartment of the upper leg, namely in the hamstring muscle group, causing flexion of the leg at the knee joint.

5.3 Discussion of results for the variables effecting leg extension at the knee joint.

Results for the increase of peak torque extension, work per repetition and average power per repetition for leg extension at the knee joint showed significant increases in the resistance training group only. The dependent variables for leg extention strength in the WBV group were maintained. The question begs to be answered whether a longer duration of the intervention program could have yielded significant results for this variable.

Addressing the gap in literature pertaining to the effect of WBV on physiological adaptations the following findings in literature were made. One of the studies that contributed the closest comparable results was the study conducted by Delecluse, Roelants and Verschueren (2003), which found that both WBV and resistance training significantly increased isometric torque at the knee joint after a12-week intervention period. Similar studies showed that WBV training could be responsible for physiological enhancements that led to an increase in leg strength.

However, none of these studies had effectively compared the resistance training to WBV. Most of the studies mentioned above and in chapter two implemented different modes of interventions to bring about the results and there were no comparative experimental groups in many of these studies. The study designs were not randomised and the measuring instrument varied highlighting the need for more accurate research pertaining to the problem at hand.

5.4 Conclusion

Documented evidence showed that both conventional resistance training as well as whole body vibration, could lead to significant strength enhancement in the Hamstring muscle group situated in the posterior compartment of the thigh causing leg flexion at the knee joint. Conventional resistance training used with the correct principles in terms of intensity, volume, frequency, rest periods and progressions, successfully improved both leg extensor as well as flexor strength of the posterior situated hamstring muscle group of the upper thigh. There is an urgent need for the design and program prescription guidelines for resistance training on the whole body vibration device utilising, frequency, duration, intensity and amplitude to generate resistance training principles of equivalent stature.

In summary results revealed that conventional resistance training was the only mode of exercise that significantly increased leg extension strength in the anterior compartment of the thigh as measured in terms of average power. The insignificant results obtained in the WBV training group for this variable might have been partially ascribed to the relatively short intervention period used in the current study. The author therefore strongly recommends that a similar study be replicated using a 12 week intervention period to challenge the reliability of results obtained for leg extension strength gained.

Based on the fact that the WBV device is a compound machine that can be used in conjunction with other modes of exercise, WBV training could prove to be a valuable alternative to conventional modes of resistance training. WBV as a mode of training could broaden and supplement the repertoire of modes of training relevant for selection in exercise program prescription of the practising biokineticist, exercise scientist and health professional.

5.5 Recommendations

Future research could focus on extending the intervention period to at least a12 week duration so that the effect of prolonged exposure to both resistance training and WBV training could be monitored. Studies with this prolonged intervention period could then furthermore study the adherence effect to the intervention program.

Further research is required in respect of gender differences and strength increases as the hormonal response to WBV could impact upon results.
In addition, an educational perspective needs to address misconceptions created among the general population that WBV training could improve strength within ten minutes and that results obtained would be comparable to conventional resistance training.

Study designs that use randomised sampling and larger sample groups could strengthen the generalisation of results to the population at large within the South African context. .

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7. Appendices

7.1 Appendix A

Preamble

Dear participant

You are being asked to participate in a research study. Information regarding the study will be presented to you by the researcher. The researcher will also be available for any further questions regarding the study, should you require additional information.

Prior to inclusion in the research project you will be asked to sign an informed consent form which will indicate your understanding and agreement to the conditions. Should an emergency or problem during the course of the research period arise, a contact number will be made available for consultation with the researcher. You are welcome to contact the researcher if you have any questions or concerns about the study.

You have the right to ask questions pertaining to the study at any time. Immediately report any new problems that might occur to the researcher.

This study has been approved by the Human Ethics Committee. They are a committee consisting of a group of independent experts. It is their responsibility to ensure that the rights and welfare of participants in research are protected. Should you wish to contact this committee for more information about your rights as a participant you may contact the following individual:

Name:…… Telephone no:……

If after consultation with the researcher or the Human Ethics Committee the information provided is not satisfactory, you may write to the South African Medical Research Council, PO Box 19070, Tygerberg, 7505

Participation in the research is voluntary. Should you wish to discontinue participation in the research study, please contact and inform the researcher. A final discussion will then be scheduled so that the research may be terminated in an orderly manner.

The researcher may choose to discontinue your participation without regard to your consent if you fail to follow instructions, or if your medical condition changes in such a way that the researcher believes it is not in your best interest to continue in this study.

Your identity will remain confidential. Results from this study may be presented in scientific publications or conferences, but your participation will remain anonymous.

This informed consent statement has been prepared in compliance with current Medical Research Council guidelines.

Yours sincerely

Nadus Nieuwoudt
Tel no. 0829002318
Nadz24@gmail.com

7.2 Appendix B

Medical history questionnaire

Medical history questionnaire

Participant's name ……..

You are kindly requested to indicate (if any) of the following contra-indications apply to you, and to provide further details where applicable:

- Pregnancy
- Acute thrombosis
- Serious cardiovascular disease
- Pacemaker
- Recent wounds from an operation or surgery
- Hip and knee implants
- Acute hernia, discopathy, spondylolysis
- Severe diabetes
- Epilepsy
- Recent infections
- Severe migraine
- Tumours
- Recently placed metal pins, or plates

Brief history of your condition

……

……

……

……

……

Other conditions that may influence your ability to participate in this research project

……
……
……
……
……

I hereby confirm that the information provided is accurate to the best of my knowledge

…….. ……..
……

Participant’s signature date place

7.3 Appendix C

Informed consent form

Title of research project: A comparison of whole body vibration versus conventional training on leg strength

Reference number:

…….

Principal investigator: Nadus Nieuwoudt

Address: 10 Lidia Court, 10th avenue Summerstrand, PE 6001

Contact telephone no.: 041-5831102

DECLARATION BY PARTICIPANT: I, THE UNDERSIGNED, ……. (name) [I.D. No:……] the patient/participant in my capacity as ……of the patient/participant [I.D. No: …….] of ……... ……. (address) A. HEREBY CONFIRM AS FOLLOWS: 1. I/The patient/participant was invited to participate in the abovementioned research project which is being undertaken by Nadus Nieuwoudt of the Department of Human Movement Science in the Faculty of Health Sciences Nelson Mandela Metropolitan University	Initial
2. The following aspects have been explained to me/ the patient/ participant: 2.1 Aim: The investigator is studying the effect of resistance training and whole body vibration training on leg strength The information will be used for research purposes and future exercise prescription in the field of biokinetics	Initial
2.2 Procedures: I understand that a pre- test will be performed. I will be divided into either the control group or one of the experimental	Initial

groups. I will undergo eight weeks of intervention training if I form part of one of the intervention groups. All participants will be re-tested after eight weeks of intervention have passed.	
2.3 Risks: There is no health risks involved in the study, provided that the participant has completed the medical history questionnaire and no contra-indications have been found.	Initial
Possible benefits: As a result of my participation in this study the information that will be disseminated may be used for future studies or exercise prescriptions.	Initial
Confidentiality: My identity will not be revealed in any discussion, description or scientific publication by the investigator.	Initial
Access to findings: Any new information / or benefit that develop during the course of the study will be shared with me.	Initial
Voluntary participation / refusal / discontinuation: My participation is voluntary. My decision whether or not to participate will in no way affect my present of future medical care / employment / lifestyle	Initial
3. The information above was explained to me / the participant by ……(name of relevant person) in English and I am in command of this language I was given the opportunity to ask questions and all these questions were answered satisfactorily.	Initial
4. No pressure was exerted on me to consent to participation and I understand that I may withdraw at any stage without penalization	Initial
5. Participation in this study will not result in any additional cost to myself	Initial
B. I HEREBY CONSENT VOLUNTARILY TO PARTICIPATE IN THE ABOVEMENTIONED PROJECT.	Initial

Signed / confirmed at …….. On ……. 20…..	
(place) (date)	
…….. ……..	
Signature of participant Signature of witness	

7.4 Appendix D

STATEMENT BY OR ON BEHALF OF INVESTIGATOR(S):

I……Nadus Nieuwoudt…… , declare that

- I have explained the information given in this document to …… (name of patient/participant) and or representative ……..(name of representative)
- He/she was encouraged and given ample time to ask me any questions;
- This conversation was conducted in English and no translator was used

Signed at…….. On …… 2006……

(date) (place)

…… ……..

Signature of investigator / representative Signature of witness

7.5 Appendix E

Warm-up

Cycle 5min

Stretches – hold all stretches for 30sec

Calf stretch – wall lean

Achilles stretch – wall lean bent leg

Quadriceps stretch – stork stand

Hamstring stretch – sit and reach

Gluteus stretch – figure four stretch

Strength program – 3 sets of 6 repetitions for each exercise

Semi squat

Deep squat

Wide stance squat


Lunges

Calf raises


Eight week training progression schedule

Exercise	Week 1		Week 2		Week 3		Week 4	
	F	A	F	A	F	A	F	A
Semi squat	30Hz	low	35hz	low	40hz	low	50hz	low
Deep squat	30Hz	low	35hz	low	40hz	low	50hz	low
Wide stance squat	30Hz	low	35hz	low	40hz	low	50hz	low
Lunges	30Hz	low	35hz	low	40hz	low	50hz	low
Calf raises	30Hz	low	35hz	low	40hz	low	50hz	low

Exercise	Week 5		Week 6		Week 7		Week 8	
	F	A	F	A	F	A	F	A
Semi squat	30hz	high	35hz	high	40hz	high	50hz	high
Deep squat	30hz	high	35hz	high	40hz	high	50hz	high
Wide stance squat	30hz	high	35hz	high	40hz	high	50hz	high
Lunges	30hz	high	35hz	high	40hz	high	50hz	high
Calf raises	30hz	high	35hz	high	40hz	high	50hz	high

F= frequency
A= amplitude

7.6 Appendix F

Warm-up

Cycle 5min

Stretches – hold all stretches for 30sec

Calf stretch – wall lean

Achilles stretch – wall lean bent leg

Quadriceps stretch – stork stand

Hamstring stretch – sit and reach

Gluteus stretch – figure four stretch

Strength program

Semi squat

Deep squat

Wide stance squat

Lunges




Calf raises


Exercise	Sets	Reps	Weight
Semi squat	3	6	80% of 1RM
Deep squat	3	6	80% of 1RM
Wide stance squat	3	6	80% of 1RM
Lunges	3	6	80% of 1RM
Calf raises	3	6	80% of 1RM

7.7 Appendix G

Application to NMMU Human Ethics Committee

Title of proposed project:	
Details of the investigator	
Name	Nadus Nieuwoudt
Qualifications	2003 – B.Hms degree 2004 – Honors Biokinetics [BA(HMS)HB]
Position	Biokinetics intern
Departmental address	Department of Human Movement Science
Functions in the proposed research	Principle investigator
Name of the principle investigator	Nadus Nieuwoudt
Experience of principle investigator in the field of research concerned	Honours research in lower limb rehabilitation and internship that primarily involves strength training
Place where research is to be undertaken: Nelson Mandela Metropolitan University Sport Science and Biokinetics Unit	
Objective of the research: The aim of this study is to determine and compare the effect of an eight-week training period of WBV to conventional resistance exercises on leg strength of 18-25 year old students. The following objectives will be addressed in the pre- and post test assessments for both the experimental groups as well as the control group, in order to achieve the aim: - To explore and describe the peak torque flexion and extension at the knee joint for both legs.	

- To explore and describe inter group differences for the peak force variables of both legs at the knee joint - To explore and describe the significance of the differences obtained for the variable peak torque knee flexion and extension
Scientific background: Previous researchers have proven that Whole Body Vibration (WBV) training is indeed responsible for an increase in muscular strength. The exercises that were prescribed for the studies were however not similar for experimental groups and leaves the question of whether the research can conclusively prove that the vibration intervention was responsible for the strength increase.
Design of the study: The experimental and control groups will undergo pre-test and then post-test measurements and the scores will then be compared to determine if significant differences exist. The study follows a Quasi-experimental design with multiple comparison pretest-posttest design. The comparison pretest-posttest design comprises of the experimental and comparison groups. The study is descriptive and explorative in nature.
Type of subjects: The participants will be recruited from the NMMU student population who are in a healthy physical condition. A total of 60 participants aged between 18 and 25 of both genders will be conveniently sampled on the basis of interest and having a medical history that is clear of any recent illnesses, injuries or disease symptomatology.
Substances to be given: Not applicable
Samples to be obtained: Not applicable
Other procedures: Pre- and post test isokinetic peak torque of flexors and extensor muscles of the knee joint
Potential risks and inconvenience to the subjects: Adequate fluid intake before and during exercise.
Benefits of research to research subject and/or community: Improve in muscular strength and fitness level for both experimental groups.

Manner in which the subject's consent will be obtained: Consent will be obtained through a written document. See appendix C.
State whether the subject's personal doctor is to be informed of recruitment of the subject before the study begins, and whether the subject's consent to such information being passed on is a condition of participation: Subjects have to complete a medical history questionnaire before participation in the research study will be granted. Should the researcher have any doubt about conditions not covered in the questionnaire, a medical doctor will be consulted.
Regulatory status under the relevant legislation of any drug or appliance to be used or tested: Not applicable
Investigators' interests: The interest is both personal and professional relating to the study. WBV training is a growing interest in the field of exercise science, biokinetics and the fitness industry and a lack of research pertaining to whole body vibration and its effects on various health related and fitness parameters, prevailed.