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THE EFFECT OF WHOLE-BODY VIBRATION (WBV) DURING THE INTER-SET REST PERIOD ON RATE OF MUSCLE ACTIVATION DURING STRENGTH TRAINING EXERCISE

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AZRENA ZACHARY ZAIREEN BINTI AHMAD ZAHUDI

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THESIS SUBMITTED IN FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF SPORTS SCIENCE
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ABSTRACT

The main aim of this study is to investigate neural effect of using whole-body vibration (WBV) modality, as a non-fatiguing training stimulus (active recovery), metabolic performance (blood lactate) and heart rate responses during the inter-set rest period of hypertrophy based loading. Second to this, comparisons were also made between WBV effects versus traditionally use passive recovery method. Eight recreationally trained men were recruited for this study. Subjects randomly attended to testing sessions, where WBV modality was used during the inter-set rest period in one session and passive standing recovery was used in another session. In both sessions, subjects performed three sets of 10 repetition of squat exercise at 70% 1RM with 2 minutes inter-set rest period. Quadriceps and hamstring in-vivo muscle activation were assessed during the squat performance. The result of this study indicated that no significant differences were found between WBV active recoveries versus non-WBV passive recoveries in term of rate of muscle activation, blood lactate collection and heart rate responses. Thus, while WBV has been commercially promoted as an effective training tools, its effectiveness as an inter-set strength training active recovery tools was equivocal questionable. WBV application during the inter-set rest period did not promote muscle neural drive and it was similar with passive recovery in terms of muscle activation as it did not provide any additional stimulus that was expected. However, WBV as an inter-set recovery modality can be used as an alternative to passive recovery modality.

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THE EFFECT OF WHOLE-BODY VIBRATION (WBV) DURING THE INTER-SET REST PERIOD ON RATE OF MUSCLE ACTIVATION DURING STRENGTH TRAINING EXERCISE

ABSTRAK

Tujuan utama kajian ini adalah untuk mengkaji kesan neural penggunaan modaliti latihan getaran seluruh badan (WBV) sebagai rangsangan pemulihan aktif, yang tidak melemahkan prestasi metabolik (darah laktik) dan tindak balas kadar denyutan jantung, semasa tempoh rehat antara set berasaskan parameter bebanan hipertropi. Perbandingan juga dibuat antara kesan WBV berbanding kaedah pemulihan pasif. Lapan orang lelaki separa terlatih telah direkrut secara sukarela untuk kajian ini. Subjek secara rawak menghadiri dua sesi ujian, dimana modaliti WBV telah digunakan semasa tempoh rehat antara set dalam satu sesi, dan pemulihan kedudukan pasif telah digunakan pada sesi yang lain. Dalam kedua-dua sesi, subjek melakukan senaman mencangkung sebanyak 3 set dengan 10 ulangan pada 70% 1RM, dengan 2 minit tempoh rehat antara set. Kadar pengaktifan otot peha dinilai semasa lakuan senaman mencangkung. Hasil kajian ini menunjukkan tiada perbezaan yang signifikan didapati antara penggunaan pemulihan aktif WBV berbanding pemulihan pasif bukan WBV dari segi kadar pengaktifan otot, penghasilan darah laktik dan tindak balas kadar jantung. Oleh itu, walaupun WBV secara komersilnya digalakkan sebagai alat latihan yang berkesan, penggunaannya sebagai modaliti rehat aktif antara set dalam latihan kekuatan boleh diragui. Penggunaan WBV semasa tempoh rehat antara set tidak menggalakkan rangsangan otot menunjukkan bahawa ia tidak memberi apa-apa rangsangan tambahan untuk dipraktikkan. WBV sebagai modaliti pemulihan aktif antara set boleh digunakan sebagai alternatif kepada pemulihan pasif, tetapi mungkin manfaat tambahan dalam rangsangan latihan masih boleh dipersoalkan.

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CHAPTER 1

INTRODUCTION

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1.1 Background of Study

Whole body vibration or also known as WBV has gain a lot of attention for strength development within the sports and exercise science fraternity over the past few years. Studies have been conducted on the effectiveness of using WBV as a strength training tools in many different set-up such as sports performance (Cochrane, Legg & Hooker, 2004; Torvinen et al., 2002), rehabilitation (Bruyere et al., 2005), and general fitness for untrained population (Roelants, Delecluse, Goris & Verschueren S., 2004).

In term of performance, whole body vibration has been found to be effective in developing strength and power (Cormie et al., 2006) improving agility and quickness (Cochrane, Legg & Hooker, 2004) improving balance (Torvinen et al.,

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2002) and increased leg muscle activity (Roelants et al., 2006). However, none of these studies have used whole body vibration as recovery modalities.

Studies on active recovery using other modalities or exercises during strength training session has indicated that active recovery is useful in a manner that it will improves blood lactate clearance rate or lactate metabolism (Bangsbo et al., 1994; Corder et al., 2010 and Martin et al., 1998), improves power output (Bogdanis et al., 1996 and Connolly, Brennan & Lauzon, 2003) and increased amount of work performed (Spierer et al. 2004).

Previous study has found that metabolic power in whole body vibration can be parametrically controlled by frequency and amplitude, and by application of additional load; with muscle activities might directly be influenced by these (Rittweger et al., 2002). While many studies have investigated appropriate frequency and amplitude of WBV application for work period exercise performance (Adams et al., 2009; Cardinale & Lim 2003; Gerodimos et al. 2010; Turner et al., 2011), as far as the researcherôs knowledge, none has ever investigated and published appropriate frequency and amplitude for inter-set rest and recovery during strength training session. However, Armstrong et al., did performed a study looking into the possibilities of using WBV as a warm-up tools, in which they concluded that WBV have only a small window of effectiveness as a warm-up tools (Armstrong et al., 2010).

Results of previous studies has also indicated that not all physical training aiming for peak performance will gain benefits that have a significance results

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compared to conventional strength training (Jones et al., 2011) . Due to this, questions arise whether the WBV for peak performance might be more suitable to be used in combination with conventional strength training program, such as by implementing it during the inter-set rest period.

Electromyography (EMG) assessment typically use in determining muscle recruitment pattern, and in assessing overall muscle activity during certain strength training exercise and session (Isear et al., 1997). EMG signal amplitude and rate of EMG rise also indicate rate of neural drive involvement in muscle contraction during strength training exercises (Aagaard et al., 2002). It is a common knowledge that strength improvement during the earlier phase of strength training program is due to the improvement in neural adaptation, rather than changes in cross-sectional area of muscle fibers (Bandy et al., 1990; Behm 1995; Bradenburg & Docherty 2002).

As a conclusion, it had been the main aim of this study to investigate the possibilities of retaining muscle activities during each sets of squat exercise in a strength training session, by using WBV during the inter-set rest period as the active-recovery tools.

1.2 Significance of Study

The use of whole body vibration as training modalities during exercise is common nowadays. However, the possibility of using WBV as another alternative mode of

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active recovery is still unexplored, and thus this study is significance due to this reason.

1.3 Problem Statement

The rationale behind this is that a component of training period consists of work and rest period. If the work period performance can be maintained or improved, overall adaptations longitudinally might be increased. At present, most of the studies are focusing on vibration as training tools, thus provide more findings for the work period, in which studies on the rest period during training seems to be neglected. More research during the rest period is needed in order to give balance to the overall body of knowledge regarding a good quality of training period.

There are many factors involved that indicate the work period exercise performance during strength training. One of it is the rate of activities produces by each muscle group. By monitoring muscle activity level, one can accurately see whether the in-between set recovery is actually contributing or not, in ensuring optimal performance for each sets performed, during the strength training exercise (in example squat exercise).

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As a conclusion, this study provided the foundational basis for other further studies in future for the use of WBV as a recovery tool, instead of it current usage limited to training and rehabilitation of injury.

1.4 Purpose of Study

The purpose of this research was to investigate the effect of having whole body vibration as an active recovery modality as opposed to typically used passive recovery during the inter-set rest period on squat exercise in neural performance (muscle activity), metabolic performance (blood lactate) and heart rate responses.

1.5 Hypotheses of Study

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This study was addressed to these hypotheses:

a) HO: There is no significant difference in squat exercise in-vivo rectus femoris and biceps femoris muscle activation rate on WBV exposure during inter-set rest period.

   HI: There is significant difference in squat exercise in-vivo rectus femoris and biceps femoris muscle activation rate on WBV exposure during inter-set rest period.

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b) HO: There is no significant difference in squat exercise in-vivo rectus femoris and biceps femoris muscle activation rate on non-WBV exposure during inter-set rest period.

HI: There is significant difference in squat exercise in-vivo rectus femoris and biceps femoris muscle activation rate on non-WBV exposure during inter-set rest period.

c) HO: There is no significant difference in squat exercise in-vivo rectus femoris and biceps femoris muscle activation rate on WBV exposure and non-WBV exposure during inter-set rest period.

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HI: There is significant difference in squat exercise in-vivo rectus femoris and biceps femoris muscle activation rate on WBV exposure and non-WBV exposure during inter-set rest period.

d) HO: There is no significant difference in squat exercise in-vivo metabolic performance in WBV exposure and non-WBV exposure.

HI: There is significant difference in squat exercise in-vivo metabolic performance in WBV exposure and non-WBV exposure.

e) HO: There is no significant difference in squat exercise in-vivo heart rate on WBV exposure and non-WBV exposure.

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HI: There is significant difference in squat exercise in-vivo heart rate on WBV exposure and non-WBV exposure.

1.6 Limitations and Delimitations of The Study

a) Limitations

Subjects asked to have similar dietary intake on all testing and training days. However subjectsô typical daily nutritional intakes were not controlled. It was also beyond the researcherôs capabilities to control subjectôs daily physical activities, as some activities may unduly influence the training of the involved muscle groups of interest.

b) Delimitations

The findings of this study was delimited to males, aged between 23 to 33 years old, with no lower limb and spine injury record for the past 2 years, have no implant or foreign bodies and have a strength training background of at least 6 months. Thus, the results of this research were not being applicable to other groups of people with different characteristics.

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CHAPTER 2

LITERATURE REVIEW

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2.1 Background

Whole body vibration or also known as WBV is not a new equipment nowadays. The uses of WBV are increase from time to time due to high demands by users within the health and fitness industry whether in medical needs or as training tools. The whole body vibration can be defined as a mechanical machine and stimulated by oscillatory motion that delivered to the entire of the body from a platform itself (Albasini & Rembitzki, 2010).

Gustaz Zander who developed machines and pulley systems introduced the world for therapeutic exercises that based on vibration technology. Based on that,

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world getting innovated by Dr. John Harvey (Arnold, 1912). He utilized and invented vibration technology for health and wellness. In the beginning of the phenomenon, many machines are purposed for medical uses to cure constipation, headaches and back pain along with a standing platform with similar function (Arnold, 1912).

2.2 Principles of WBV

Mechanical vibration or known as whole body vibration are being used as a performance training tool long time ago. The platforms controlled by amplitude and frequencies despite the difference of type. However, lots of study has been exposed with variety of exposures such as level frequencies, amplitudes and kind of exercises (Bazett-Jones, Finch & Dugan, 2008).

One study had been found in comparing frequencies while exercising. In 2006 Da Silva et al had done different frequencies (20Hz, 30Hz and 40Hz) among 31 subjects and assessment of muscular performance was done. Subjects did squat jump, counter movement jump and muscle power test after vibration exposures. The tests showed increased in 20Hz and 30Hz for squat jump and counter movement jump but no significant different in power values. Whilst in 40Hz, all parameters seen decreased in values. Study also suggested that 30Hz frequency is an ideal frequency for neuromuscular eliciting enhancement with whole body vibration training.

Some other studies had used different parameters sets of exercise and time of exposures on whole body vibration (Cardinale & Lim, 2003; Da Silva et al., 2006;

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Cormie et al., 2006; Abercromby et al., 2007; Cochrane et al., 2010; Roelants et al., 2006; Humphries et al., 2004; Delecluse, Roelants & Verschueren, 2003; Bosco et al., 1998 and Melynk et al., 2008). Studies had also been manipulated in exercises regarding the stance of standing whilst on whole body vibration. Roelants et al., 2006 had set the stance into 3 parameters of standing on the whole body vibration machine. They were high squat, low squat and one legged squat with 20 seconds of vibration exposed. Time exposure was also found obviously high that lasted 5 minutes of exposure (Cochrane et al., 2010). Abercomby et al. 2007 had done 10 sets of whole body vibration among 16 healthy adults with 30 seconds of vibration exposure but none has been found in an active recovery during inter rest period.

In the previous study (Eklund & Hagbrath, 1966) stated that whole body vibrations was functioned by the mechanical vibrations that applied to the muscle belly or tendons and able to stimulate sensory receptors. Muscle contracted by the activation of the alpha-motoneurons. Therefore, the ótonic vibration reflexô occurs (Eklund & Hagbrath, 1966). The vibration is also not only perceived by neuromuscular spindles but also by the skin, the joints and secondary nerve endings (Ribot-Ciscar et al., 1989). In contrast to single muscle stimulation, the use of whole body vibration involves applications to the entire body. The stimulation, which comes from distally from the platform, has a long way to go before it arrives at the sensors (Krause & Albasini, 2010).

There are a lot of differences of whole body vibration machines but the purpose of using it has been recognized as two-fold which are for training purpose or rehabilitation purpose (Marin & Rhea b, 2010). *Avant Wellness* is a site that presented

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the full text of differences among whole body vibration platforms (www.avantwelness.com/technology/wbv-types). Below would be a table that identifies the differences between whole body vibration machines.

Table 2.2

Type of whole body vibration based on platforms

	Vertical	Oscillating	Elliptical
Motion	The platform moves straight up and down	The platform is tilting or alternating	The platform moves more horizontal with less vertical
Frequency	2Hz to 100Hz	30Hz to 40Hz	20Hz to 50Hz
Example Models	Turbosonic and Theravibe	Noblerex K-1 and Vibratrim, HyperVibe	Powerplate
Previous Study	Bosco et al., 1998; Krol et al., 2011; John B. Cronin, Melody Oliver and Peter J. McNair, 2004; M. E. Da Silva et al., 2006; Marco Cadinale and Jon Lim, 2003; Christophe Delecluse, Machteld Roelants and Sabine Verschueren, 2003; Cormie et al., 2006; Bazett Jones, W. Finch and L. Duncan, 2008; Giorgos Paradisis and Elias Zacharogianis, 2007; Abbasi et al., 2011; Bosco et al., 2000; Bosco et al., 1999; Erskine et al., 2007; Kaushige Goto and Kaoru Takamatsu, 2005	Marco Cardinale and Jon Lim, 2003; Darryl J. Cochrane, Stephen J. Legg and Michael J. Hooker, 2004; Kawanabe et al., 2007; Cheung et al., 2007; Hoyo Lora et al., 2010; Brad Roberts et al., 2009; Ruiter et al., 2003; Jorn Rittweger, Marcus Mutschelknauss and Dieter Felsenberg, 2003; Cochrane et al., 2010; Hazell et al., 2008	

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Few studies had been found with uncategorized of platforms in vibration exposures (Cardinale & Lim, 2003; Sperlich et al., 2009; Rittweger, Beller and Felsenberg, 2000; Reveron et al., 2012 & Roelants et al., 2006). Some other studies have been found created vibration stimulation to due purposes (Cochrane et al., 2008; Issurin, Liebermann and Tenenbaum, 1994; Issurin and Tenenbaum, 1999; Ronnestad, 2004 and Humphries et al., 2004).

2.3 WBV as training tool in muscular performance

Currently what most trainers know is to use of whole body vibration (WBV) as a training tools. Due to high demand of WBV as training tools, many researches has been focusing on this, as to verify what has been claimed by practitioners, with most studies were conducted on geriatric population (Roelants, Delecluse, Goris, & Verschueren, 2004; Roelants, Delecluse, & Verschueren, 2004). However, similar to other method of training (i.e., stretching) started to be used as an active recovery; it might also possible to use WBV as an active recovery tool, especially during inter-set rest period. Some of the benefits that has been identified in using WBV as a training tools such as improvement in muscle activity, muscle flexibility, jump height, contractile element, balance, muscle strength and speed of movement (Cheung et al., 2007; Dolny & Reyes, 2008; Jackson, Merriman, Vanderburgh & Brahler, 2008; Roelants, et al., 2004 & Ruiter, Raak, Schilperoort, Hollander & Haan, 2003). WBV machine use with loading parameters for improving physical performance had also been shown not significantly alter muscle stiffness in untrained individuals (Cronin, Oliver & McNair, 2004). But none of the reviews has been found using the whole

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vibration technology as an active recovery during inter-set of rest periods. This is significant due aim of the study to investigate the muscle activity as whole body vibration as an active recovery during inter-set of rest period.

Muscle activity was measured either in static or dynamic movement. Muscle contraction leads to muscle activity. Therefore, electromyography is needed in converting muscle activity in figures and numbers. Electromyography (EMG) is an experimental technique concerned with the development, recording and analysis of myoelectric signals. Myoelectric signals were formed by physiological variations in the state of muscle fiber membranes. While in biomechanical methods, EMG is unlike the other areas. A researcher decided on biomechanical method suits the processes related hypotheses as cited in Peter Konrad, 2005. Hence, EMG is functioned to measure muscle activity and this was significant due this study.

Basically EMG consist hardware and software due to measure and converts muscle activity into figures and numbers. The surface EMG signals were recorded by electrodes and reference electrodes were attached to muscles that researcher wanted to look. Depending on exercises or activities that a subjectôs performing, it will then give a result as the outcome. A software converted the amplified of EMG raw signal to an average root-mean-square signal vial its built ï in hardware circuit network and defined as a function of the time by millivolts or microvolts (Cardinale & Lim, 2003; Roelants et. al, 2006). The effect of vibration is to elicit short fast changes in the length of the muscle-tendon complex. This input is detected as a ótype of sensory stiffnessô through which reflex muscular activity will try to dampen vibratory waves (Krause & Albasini, 2010). Analytical questions are the basis of proper sensor

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selection within the methods (Konrad, 2005). The frequencies and amplitudes used were the main effect of whole body vibration towards muscle activities.

Depending on level of question, the analysis was complexes to one extent. EMG findings very demanding and requires fundamental understanding of the sensi-motor system and a muscle alone can never answered a ñwhyò (Konrad, 2005). Below is the table that shown the level of question based on Peter Konrad, 2005.

Table 2.3

Categories of analysis assessment

	Level Of Question	Type Of Answer	Type Of Scaling
1	Is the muscle active?	Yes / No and On / Off	Nominal
2	Is the muscle more or less active?	Ranking between tests in qualitative terms	Ordinal
3	When is the muscle on or off?	Onset / Offset calculations, firing orders	Metric
4	How much is the muscle active?	Expressed in e.g. % MVC	Metric
5	Does the muscle fatigue?	Slope calculation of EMG parameters	Metric

Some studies had shown the effect of WBV on muscle activation. WBV is believed, stimulates the muscle spindles (sensory receptors) that came from the mechanical vibrations that applied to muscle or joints (Eklund & Hagbrath, 1966 & Lance et al., 1973).

Many studies have been found that whole body vibration increased lower limb muscles activation. The whole body vibration had become as intervention in training

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tool between initial and post-test but none of the study using the whole body vibration as a recovery tool in inter-set during exercises. It also applied to electromyography device.

Cardinale and Lim, 2003 stated that there were significant differences between 30Hz and 50Hz frequencies ($p<0.05$), 40Hz and 50Hz frequencies ($p<0.05$). Different frequencies were applied in this study to find the activity of vastus lateralis muscle during WBV. Subjects underwent 4 sets of vibration, 60s lasting on vibration exposure and 60s rest in between set with subject stood on vibration platform with knee angle 100°. Electromyography was measured the activity with bipolar surface placed on vastus lateralis of the dominant leg.

It is also been found which WBV resulted in a significantly higher ($p<0.05$) in all muscles group (rectus femoris, vastus lateralis and vastus medialis) during whole body vibration with applying different squat exercises (Roelants et al., 2006). Subjects performed unloaded isometric exercises with 3 types of exercise; high squat, low squat and one legged squat. Subjects were also done 4 sets of vibration exposure with 20s of vibration exposure and 60s rest in between set (sat down on a chair) with frequency 35Hz. Muscle activity was found significantly higher in one legged squat ($p<0.05$) compared in high and low squat.

Similar study had been done with results statistically significant in all trials both for vastus medials and vastus lateralis; $p<0.001$ (Krrol et al., 2011). Subjects performed 6 sets of vibration exposure with 30s duration of vibration exposure with 2 minutes rest in between set. 3 frequencies were used in this study (20Hz, 40Hz and

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60Hz). Assessment underwent with three trials with first trial was to record the background EMG activity in relaxed position, second trial subjects were standing on the vibration platform and third until eight trial, vibration exposure had occurred. Results also shown that there were statistically significant in vastus lateralis in comparing vibration and non-vibration effects ($p<0.001$).

As the whole body vibration as training tools, many interventions as variables has been set up (Abercromby et al., 2007). Rotational and vertical vibration with 30Hz frequency was used in this study while as the measure outcome; subjects are needed to perform static and dynamic unloaded squats. Electromyography has recorded based vastus lateralis, biceps femoris, gastrocnemius and tibialis anterior muscles activity. These four muscles has found significantly increased ($p<0.05$) in both rotational and vertical vibration. This has found that neuromuscular responses were affected by knee angles. The knee angle was set in between 10°-15°, 16°-20°, 21°-25°, 26°-30° and 31°-35°. Results also shown that small angle has the greatest responses.

Meanwhile in 2004, Humphries et al found that there was no significant difference between vibration and no vibration condition for peak normalized on the isometric leg extension ($p<0.05$). Subjects were done 2 testing protocols separated by 2 hours rest (vibration and no vibration treatment) with positioned in dynamometer chair with straps anchored across the chest and waist. The frequency was used 50Hz and rectus femoris was recorded to evaluate the muscle activity on dominant limb.

Along with that, a study also been found that pre and post of vibration exposure for the treatment and control limbs was not significantly different; $p=0.118$

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with vibration used was 26Hz with 5 sets of vibration exposure, 60s lasting on vibration platform and 60s rest in between set. Only one leg (plantar flexor muscles) was assigned to the vibration treatment (Cronin, Oliver & McNair, 2004).

No significant difference were also found in all sessions of EMG (vastus lateralis, vastus medialis and biceps femoris) to see the acute effects of WBV on muscle activity, strength and power (Cormie et al., 2006). Assessment needed subjects to perform counter movement jump and static squat after vibration exposure (30Hz) and without vibration exposure. Tests were measured again on 5, 15 and 30 minutes after the vibration or sham stimulus.

Many studies were focusing on vibration training as training tools with the effects after. One study has been found to observed the stability of knee while doing static squat in 30° flexed (intervention group) on whole body vibration that lasted 60 seconds in two trials while the control group were asked to do their normal daily activities without participating in whole body vibration training (Melynk et al., 2008). Lateral hamstring, medial hamstring and tibial were involved in order to see muscle activity. Results shown that there was significantly increased after the whole body vibration exposure $p=0.039$ for lateral hamstring and $p=0.043$ for medial hamstring in short latency responses. But there was no significant different on hamstring in medium latency response ($p>0.05$) while tibial was significantly decreased after the exposure ($p=0.0310$).

Bosco et al 2000 found reduced (EMG^{rms}) in leg extensor muscles compared to pre-treatment ($p=0.008$). It also stated that ration in EMG^{rms} were decreased ($p<0.001$). Muscles recorded were vastus lateralis and rectus femoris during the leg

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press measurement. Subjects underwent 10 sets of vibration exposure, 60s lasting on vibration platform and 60s rest in between set (a rest period lasting 6 minutes was allowed after 5 vibration sets).

Based on all of the studies reviewed, none of them had used electromyography as recording tools for only exercise that does not involve vibration while exercising. Hence, electromyography recording should be done during exercising as the whole body vibration becomes a recovery in interest in rest period during exercise.

2.4 WBV Effect on Muscle Force, Power and Velocity of Movement

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One of the earliest studies which combined weight training and vibration training was performed by Issurin et al 1994 showed 46% improvement was found after weight training with vibration. Many studies have mentioned to use the whole body vibration as a treatment between exercises. However the treatment differs by frequencies, rest intervals and time session of treatment using whole body vibration. Usually, the test of measurement as a outcome were done in jumping test and gender; counter movement jump, jump height and squat jump (Da Silva et al., 2006; Cardinale & Lim, 2003; Delecluse, Roelants & Verschueren, 2006; Bazett-Jones, Finch & Dugan, 2008; Cochrane, Legg & Hooker, 2004; Hoyo Lora et al., 2010; Cormie et al., 2006 & Ruiter et al., 2003) or a sprint and agility test (Cochrane, Legg & Hooker, 2004; Paradisis and Zacharogiannis, 2007 & Roberts et al., 2009)

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According to previous study (Cardinale & Lim, 2003), low frequency (20Hz) WBV stimulation was shown significantly increase hamstringsô flexibility and squat jump by 10.1% ($p<0.001$) and 4 %($p<0.05$). This is due to acute enhancement in neuromuscular performance. Meanwhile, the high frequency (40Hz) showed a significant decrease in squat jump by -3.8% ($p<0.05$) and counter movement jump by 3.6% ($p<0.001$) as the whole body vibration was set 5 bouts, lasting 60s for each bout and 60s rest in between bouts. The study performed sit and reach test, squat jump and counter movement jump for outcome measures.

A study also been found that there were significant enhancement of highest rise of center gravity and performance best jumping in counter movement jump $p<0.05$ (Bosco et al., 1998). It also stated that there was no significant difference in average power during 5s on continuous jump. The study was done with 26Hz of vibration frequency, 5 sets of vibration exposure, 90s lasting on vibration platform and 40s rest in between set. Subjects were treated with WBV treatment for 10 days.

In other study, a significant reduction has been found $p<0.01$ and $p<0.005$ in the mechanical power output of the leg extensor muscle and the average height during 5s continuous jump (Bosco et al., 2000). The frequency of the whole body vibration as treatment was set at 26Hz with seven times for a duration 60s lasting on the whole body vibration machine and 60s of rest between each set. Jumping exercises; counter movement jump and 5s of continuous jump were measures as outcome.

One study has been found that similar with other review as jumping become the outcome measures. Frequency of whole body vibration was set at 26Hz with five

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times of exposed with duration 90s and 40s of rest between of set. Significant has been found $p<0.05$ in height jump and maximal mechanical power (counter movement) in experimental group. There was no improvement in control group which failed to show any changes (Bosco et al., 2000). It has also been found as whole body vibration exposed to be a treatment between counter movement jump (Bazett-Jones, Finch & Dugan, 2008). The treatments were set with 0Hz, 30Hz, 35Hz, 40Hz and 50Hz with 45s of exposures and jumping were performed within 10-15s. The interactions of acceleration-gender and time-gender has found significant to another; $p=0.033$ and $p=0.05$. Women has found significant better $p=0.0064$ and 0.0125 comparing men that has no improvement between variables.

Muscular performance has been measured by two different vertical jumps as whole body vibration being a treatment in between pre and posttest. Squat jump, counter movement jump and strength-power were recorded as outcome measures. 6 exposures of whole body vibration with 60s lasting standing on machine, consisted frequencies 20Hz, 30Hz and 40Hz and 2 minutes of rest between the intervals set. It shows significant increases for the frequencies of 20Hz ($p<0.05$) and 30Hz ($p<0.001$). While the 40Hz found significant decrease $p<0.05$ (Da Silva et al., 2006).

Vibration exercise resulted not only in an increased the maximal strength but also in increased in flexibility much greater than in conventional training procedures (Issurin, Liebermann & Tenenbaum, 1994). Similar with this study (Delecluse, Roelants & Verschueren, 2006), results shown that there were increased significantly in isometric knee extensors torque ($p<0.001$) and counter movement jump showed a significant interaction effect ($p<0.001$) and jumping height increased significantly

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over 12 weeks in WBV group. The 12 weeks WBV program consisted with frequency of WBV 35Hz-40Hz and training intensity increased over the 12 weeks training period by shortening the rest periods, amplitude or the frequency.

Meanwhile in 2006, Cormie et al stated that there were significant difference between counter movement jump from baseline immediately post-treatment ($p<0.05$). The study had used 30Hz as the frequency with 30 seconds of vibration exposure. A study showed no significant differences were found between any acceleration for men and no significant difference were found within each gender (Bazett-Jones, Finch and Dugan, 2008). Vibration exposures were used in 5 different frequencies (0Hz, 30Hz, 40Hz, 35Hz and 50Hz) with 45 seconds timing. But results shown there was a significant difference in two-way interaction for Time X Gender ($p<0.05$) and for Acceleration X Gender ($p<0.033$). Significant increase was also found in frequency of 40Hz and 50Hz ($p<0.0064$ and $p<0.0125$).

Cochrane, Legg and Hooker, 2004 found that there were no significant differences between the performance variables (vertical jump, sprint and agility performance) for pre-training and post-training on vibration scores. The study also stated that there were no significant differences in pre-training and post-training performances score for men and women but there was a significant difference in day 1 versus following 8 days ($p<0.05$) but no differences in between group. Subjects were exposed with 26Hz for vibration and underwent for 9 days with 5 days consecutive days separated by 2 days recovery and another 4 days of treatment. The tests were only tested after 2 days after the last WBV treatment.

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One study had done with 5 weeks training period with different squats workout (week 1, 3, and 5 with 3 workouts and week 2 and 4 with 2 workouts). On the first week, subjects were performed 3 sets of 10RM, second week 4 sets of 8RM and last 2 weeks 4 sets with 6RM. The vibration of exposure was 40Hz and later subject performed 4 trials of counter movement jump. Effecting from that, results shown that WBV group significantly improved their jump height ($p<0.01$) (Ronnestad, 2004).

Meanwhile in 2007, Kawanabe et al. had conducted a training period for 2 months with vibration frequency 12Hz-20Hz, 4 minutes of vibration exposure, once and a week and exercise group. The study compared with exercise group alone that consisted with balance, muscle, strength training and walking exercise (30 minutes and twice a week). The results shown no significant difference in any of the baseline between the WBV exercises plus routine exercise group and the routine exercises group.

Similar study had been found (Paradisis and Zacharogiannis, 2007) in done with 6 weeks of program, 3 times a week, a day rest between sessions and 6 X 30m progressive sprint comparing control group (did not participate in any training). The study was used 30Hz as the frequency, 3 sets with 8 repetitions (2 repetitions of each exercise) of 40s and rest 60s in between 2 repetitions. Those exercises were squatting 90° knee angle, standing in a position slightly flexed knees 120° and standing on one leg (120° knee angle). This study consisted tests (pre and post) which were sprint running 60m sprint and explosive strength (counter movement jump in 30s). Results

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shown that there were significant main effect for WBV group in time for 60m sprint in every 10m ($p<0.05$) and in explosive strength improved significantly ($p<0.05$).

Another similar study was found (Cheung et al., 2007) stated that there was a significant improvement in movement velocity ($p<0.01$) and maximum point ($p<0.01$). The study was used 20Hz with 3 minutes a day, 3 days in a week for 3 months program and stability test assessed on a basic balance master system. Meanwhile, Abbasi et al 2011 stated that there were significant interaction between time and groups ($p=0.05$) and effect time in WBV group ($p=0.05$) in 8 weeks program with 3 sessions in a week with duration of 30 minutes.

A study had shown that there were a tendency ($p=0.07$) for a faster stimulated maximal rate of force rise in WBV group at week 7 and 13 and during the last week of 14 (Ruiter et al., 2003). The difference between groups reached the level of significance ($p=0.02$). There was a tendency ($p=0.07$) for jump height to increase but this tendency was present to an equal extent ($p=0.71$) in both groups, indicating that application of WBV during training did not improve jump height. Amazingly, the study was on 11 weeks of program with 30Hz of vibration frequency with 3 training in a week, 5 sets of vibration and 60s of vibration exposure with 60s rest in between set. On the week 5, 6 and 13, there was no training and testing prior to that stated week 24 hours to 48 hours following the last preceding training session. The tests were jump height and contractile properties assessments.

In 1999, Issurin and Tenenbaum created a vibratory simulation device with vibration exposure was 44Hz and subjects underwent bilateral biceps curl exercises in a sitting position on a ñSchnellò dynamic bilateral biceps machine. Subjects were only

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performed 2 separate series of 3 sets of exercises in random order with 3 repetitions for each set. Results shown no significant difference between the two series was found for the elite or amateur group but results in mode exercise had shown there was a significant effect for mean power (with versus non-WBV) $p<0.001$ and for maximal power $p<0.001$ and also in group factor (elite versus amateur) $p<0.04$.

In previous study, results shown no significant differences at all were found in both jump tests (Hoyo Lora et al., 2010). The assessment was performed just after the vibration and after 30 minutes in order to determine residual effect with vibration 30Hz, 5 sets of vibration exposure, 60s of vibration exposure and 60s rest between sets. Subjects then underwent tests (3 counter movement jump and squat jump with rest time was 30s between consecutive jumps). Similar study had been found that there was no significant difference in 30m sprint time in short term effect of WBV training on sprint star performance in collegiate athletes (Roberts et al., 2009). Frequency of vibration was used 26Hz with 3 trials were performed.

There was also a study in sharing benefits and training in WBV (Dolny and Reyes, 2008). The study suggested that exercises using WBV platforms may increase muscle activity and subsequently enhance muscle performance in both acute and chronic conditions. Produce ranging of vibrations were also suggested from 15Hz to 60Hz. But none of the study stated WBV as a recovery tool in between sets. Due to this, this is significant to have a whole body vibration as an active recovery in interval set of rest period should be done.

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2.5 WBV effect on hormonal responses

Hormonal response had been one of the variables to see the effect of whole body vibration on human. Cortisol, testosterone and growth hormone had determined the effect of the vibrations (Bosco et al., 1999; Bosco et al., 2000; Goto and Takamatsu, 2005 and Erskine et al., 2007).

Bosco et al 1999 had done hormonal responses among 8 men with vibration frequency was used 26hz, 7 sets of vibration exposure and 60s of vibration exposure and 60s rest in between set. Jumping exercises were included; counter movement jump and 5s of continuous jump and results shown statistical significant decrease of both serum; testosterone ($p<0.01$) and cortisol ($p<0.005$). In 2000, Bosco et al had found significant decrease in testosterone ($p=0.026$) and growth hormone ($p=0.0014$) in hormonal response to WBV in men. Cortisol had found significantly ($p=0.03$) and there were significant enhancement in jumping performance ($p<0.001$). The study was using 26Hz of vibration exposure with 10 sets of vibration, 60s of vibration exposure and 60s rest in between set. The counter movement jump tests were done in 3 times.

Similar with the study, results had shown that there were no significant differences in salivary testosterone concentration ($p>0.05$) and salivary cortisol concentration ($p>0.05$) (Erskine et al., 2007). But somehow, statistical analysis found that salivary concentration of cortisol was increased over time ($p=0.052$) among vibration treatment. The study was exposed with 10 sets of vibration, 60s of vibration exposure and 60s rest in between set. The frequency was used 30Hz and performed in an isometric squat on the vibration platform.

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In 2005, Goto and Takamatsu found that plasma epinephrine (EPI) and norepinehrine (NE) significant increases with a significant difference in NE between trials ($p<0.05$) in WBV treatment. There was no significant difference in fatty free acid (FFA) concentration ($p<0.01$) and serum glycerol concentration ($p=0.185$) in WBV treatment. It also found that there was no significant difference in between trials for serum lipase concentration ($p<0.274$). The study had used 10 sets of vibration exposure with duration of 60s of vibration exposure each and 60s rest in between set with frequency of 26Hz.

2.6 WBV on blood lactate accumulation

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The other variable to see the WBV effect was physiological effect (blood lactate accumulation). There was a study from Rittweger et al 2003 stated that dynamic squat exercise with an additional load (35-40% body mass) to volitional fatigue increased blood pressure. Therefore, there were some studies pertaining this variable.

Sperlich et al 2009 had done the physiological responses of adding vibration to cycling. The instruments were invented (vibration device) and subjects were consisted cycling at 70RPM for 5 minutes, workload 100w and incremental 50w increases every 5 minutes until volitional exhaustion reached. The vibration frequency was used 20Hz and it was applied vertically through the crank into the pedals. A blood sample of 20µL from the right ear lobe was collected at the end of 5 minutes intervals into a

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capillary tube. As results, there were no statistically significant changes in lactate concentration and all lactate values remained unaffected in vibration exposure.

In 2003, Rittweger, Mutschelknauss and Felsenberg found that blood lactate increased after an exercise but there was no treatment effect. It also found that significant correlation between vibration and without vibration in value of exercise time ($p<0.001$) but not in blood lactate. The study was used 26Hz as frequency, subjects performed squat exercise with additional load 40% of the body mass. Blood lactate was measure before and 2 minutes after exercise sets from capillary finger.

Acute physiological effects of exhaustive WBV exercise in man was conducted and the results shown there was no significant difference for the mean concentration before, second and third visit on the blood lactate SD 0.50 (Rittweger, Beller & Felsenberg, 2000). Blood lactate was collected from the capillary finger. The study started with exercise until exhaustion assessment and vibration exposure only exposed on the second and third visit with 26Hz of frequency for 30s of vibration exposure duration. Continued with load fixed around waist (40% in male and 25% in female of body mass), done squatting with 6s cycle with 3s down and 3s up smoothly. Later, jump height in 3 trials with 5s intervals, cutaneous laser Dopper flow over the calf and over the foot and 10s maximal voluntary contraction of the knee extensors on the dominant side were assessed.

2.7 WBV effect on heart rate responses

In 2012, Reveron et al stated that there was a significant vibration ($p=0.02$) and load ($p=0.008$) as main effects for heart rate. Results shown that heart rate during vibration

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was greater (97.0 ± 20.3 beats per min) than no vibration (86.8 ± 25.7 beats per min). During loaded, heart rate also resulted greater with 101.3 ± 20.8 beats per min conditions compared to unloaded 90.8 ± 12.6 beats per min. The study was assessed with 10 sets of vibration exposure with 60s of vibration exposure and 60s rest in between set with isometric squat (45° knee flexion). During isometric squat, subjects underwent four conditions; unloaded, unloaded vibration, loaded and loaded vibration with loaded barbell of 30% body weight across subjectsô shoulder. Heart rate was obtained using polar heart rate and strap on subjectsô chest.

Meanwhile, there was no interaction between condition and time for heart rate ($p=0.3430$ in cardiovascular stress static semi-squat exercise assessment (Hazell et al., 2008). It also stated that there was no significant differences in between WBV versus non-WBV ($p<0.05$). This study was used 45Hz with two conditions (seated as passive and unloaded and a semi squat with static and loaded) with both were done in semi-squat position. The assessments were done with 15 repetitions of 1 minute and 1 minute of seated rest followed by 10 minutes of recovery. Heart rate was collected at baseline, minute 8, 16, 24, and 30 of whole body vibration exposure with 1 minute on and 1 minute off and right after minutes 2, 5 and 10 recover.

In 2008, Cochrane et al found that during WBV and load produced significant increase in heart rate ($p<0.001$) with and interaction between load and group ($p<0.05$). Subjects underwent 9 conditions experimental with 4 minutes of vibration exposure each and 30s rest in between set. A heart rate strap was attached to subjectsô chest and telemetrically interfaces with the K4b^2 system and analyzed during 2 to 4 minutes interval. The frequency of 30Hz was used for this assessment. This result implying

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the young group exhibits a greater increase in heart rate response to load compared with the older group.

But in 2010, Cochrane et al had found that there were no significant differences in heart rate (p=0.43) between the intervention in comparing muscle temperature during static and dynamic squatting with and without WBV. Subjects underwent 4 interventions in a randomized order with 48 hours separating each testing session; dynamic squat with WBV, dynamic squat without WBV, static squat with WBV and static squat without WBV. 26Hz had been used as the frequency of the vibration. Heart rate was recorded from a telemetric belt every 5 minutes during the rest phase and the final 2 minutes of each intervention. Results also shown that time versus WBV interaction effect was higher at 10 minutes with WBV compared to without WBV. Similar study had been found which heart rate increased significantly less in vibration exercise than in bicycle ergometry (Rittweger, Beller & Felsenberg, 1999). Results were also found unaffected by the application of vibration as compared to without vibration (Sperlich et al., 2009).

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CHAPTER 3

METHOD

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3.1 Process flow of The Study

This study determined whole body vibration will be an effective active recovery tools. Therefore, purposive sampling was chose to get the precise subjects. This research entitled in pre experimental design as one group would be conducted to have pretest and post test to measure the effect of whole body vibration in selected variables; neural performance (muscle activity), metabolic performance (blood lactate) and heart rate responses.

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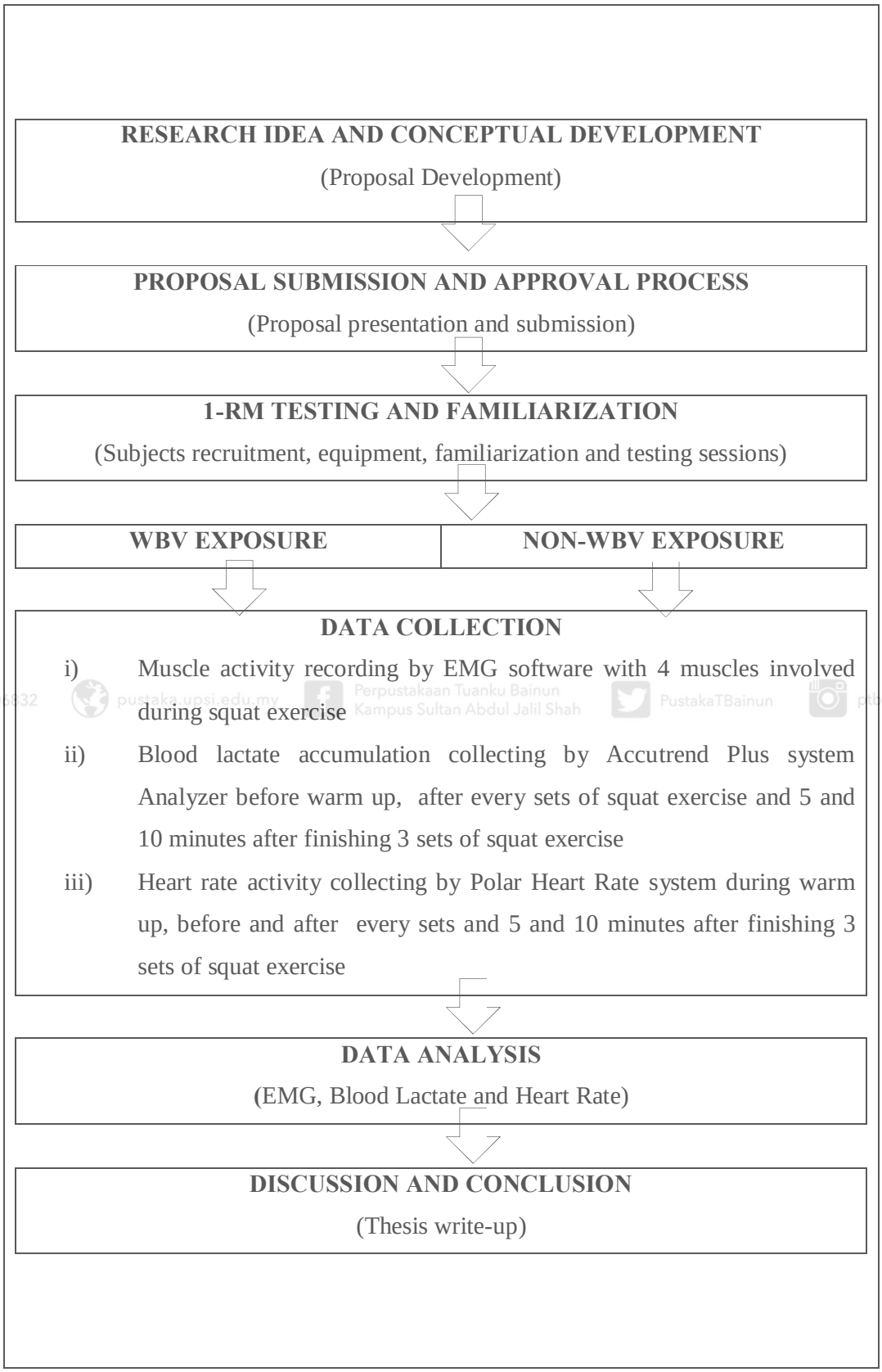


Figure 3.1. Process flow of the study

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3.2 Subjects

Eight recreationally active men in National Sports Institute of Malaysia aged 22-33 years old were recruited for this study with no implant or foreign bodies. The subjectsô mean age, height, body weight, body mass index and 1RM were 26.63 ± 3.96 years old, 1.71 ± 0.02 meter, 72.01 ± 8.76 kg, 24.54 ± 2.78kg and 135.63kg ± 24.84kg/m2 respectively. Subjects were recreational athletes with at least six months weight training experience. The subjects were fully informed of any risks and discomforts with these experiments before giving their oral consent to participate.

3.3 Equipment

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Squat exercises were performed by selected apparatus to record and save all the activities by hardware and software system. Therefore, squat exercises was performed on a force plate inside the power cage (FT700 Isotronic Power System, Fitness Technology, Australia) with 20kg Olympic barbell (Olympic bar, Uesaka, USA) on the back of each participant. Lifting load for each participants were adjusted by adjusting the iron cast weight plates (Metal Plates, Uesaka, USA) used with the Olympic bar. Whole body vibration machine were used during active recovery inter-set rest period with 40Hz as the frequency and vertical sinusoidal as the type of the vibration platform (Powerplate Pro5, USA). Muscle activation was assessed using an electromyography (EMG) machine (Noraxon, USA) as a measurement method in biomechanical analysis. Four electrode channels were placed on muscles (selected areas) to record muscles activity during squat exercises. A wireless transmitter then

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will transfer the recording into the software. Blood lactate of the participant were collected during selected time using a blood lactate analyzer (Accutrend Plus System, La Roche Ltd). Heart rate was taken using polar heart rate chestõs strap and telemetry with a watch (Polar, USA).

3.4 Procedures

Participant has gone few stages before done the real test. Therefore, familiarization and 1-RM testing were done and measured to get the baseline measurement. Familiarization was selected to get participants familiarized with the test flow and 1-RM testing were chose and done according to 1-RM testing protocol (Baechle and Earle 2000).

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3.4.1 Baseline measures

a) Familiarization

Prior to the testing in week 1, subjects were involved in one familiarization and 1-RM testing occasions. The familiarization session begun with a briefing from the researcher on exercise program and testing procedures involved. Briefings included exercise technique, exercise demonstration and explanation on 1-RM testing session that followed suit within the next 72-hours. Subjects read the participation consent letter and voluntarily signed. All doubt and questions arisen has been answered by the researcher. Subjects noticed that they are allowed to quit the study at any time during

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any phase of the study without the need to give a reason for it. Subjects were guided into a warm-up session and performed a trial for all exercises that used in the session. A warm up was performed by a cycle with ergometer bicycle in the gym with rpm in between 70 to 80 for 5 minutes. A polar heart rate was worn by subject to detect the heart rate. Subjects stopped warm up when heart rate reached 130 to 140 based on Haskel chart for the activity. Subjects were also done 5 minutes an active stretching before a demonstration proper squat technique according to Brown and Weir (2001) showed. Subjects had ten trials to familiarize themselves with the squat exercises. The squat performed to a parallel depth that had been standardized between testing occasions by using a band, which their buttocks had touched for each repetition. Correction had been made wherever necessary by the researcher in order to ensure proper exercise technique execution is performed. The familiarization session ended with a cooling down session and stretching.

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b) 1-RM Testing Occasions

The 1-RM session was done at least 72-hours from the familiarization session. The 1-RM test session had begun with a standardized warm-up for 10 minutes involving 5 minutes of ergometer cycling and 5 minutes of active stretching prior to the first 1-RM test. The squat 1RM on had been assessed according to the procedures described by Baechle & Earle, 2000 (Baechle & Earle 2000). Subjects were performed a proper cooling down after the 1-RM was determined and given a rest period of 1-week before the first testing session starts. Hypertrophy loading parameters had been used for squat exercise performance. The loading had been done in three sets of 10 repetitions of squat exercise at 70% 1RM with self-selected tempo.

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3.4.2 Testing Procedures

Subjects were required to attend two testing occasions which had been done sessions with passive recovery (standing still on top of whole body vibration machine with switched off) and another one was sessions with active recovery (standing still on top of whole body vibration machine with switched on) that applied during the inter-set rest period. During both testing sessions, subjects were performed a standardized warm-up similar to what have been done during the familiarization session. Subjects then were performing the squat exercise at the power rack station according to the loading patterns prescribed. For the passive and active recovery sessions, subjects completed the inter-set rest period by standing passively on the whole body vibration machine.

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3.4.3 Electromyography (EMG)

EMG is functioning to record and measure the activity of muscles during the squat exercise. The muscles that involves were quadriceps rectus femoris and hamstring biceps femoris for both left and right leg. The exercise had been assessed using a 4-channel portable surface electromyography (EMG). As lower limb muscles were involved, subjects needed to wear a light short that later not interrupt the process of placing electrodes on subjectsô skin. Prior assessment, all involved muscles area had been shaved before it is placed on. The electrode had two wires for each channel for each muscle. One of the electrodes was a reference. For right leg, odd numbers were placed on the rectus femoris and biceps femoris while even numbers were placed on the left leg. These numbers were references from the EMG portable that connected the

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wire to the electrodes that placed on the muscles area. Therefore, the muscles activities were recorded from the portable via wireless into the software and recognized on the model as chosen on the laptop.

The portable EMG suited on subjectsô waist and switched on. The portable EMG had used the wireless as for data transferred. Muscle activities were only recorded when subjects had performed a squat exercise by standing on the power plate in power cage area. Recording the muscle activity is controlled by a laptop. The recording stopped when a subject done by leaving the power cage area. All recorded data were saved on each subjectôs profile. Collecting data muscle activities was performed by selecting 5 second before a subject started and 5 seconds after a subject done with squat exercise. Cropping data from the activity has been done to despise unneeded data. All the crops data was highlighted from initial and the ending waves from the graphs. Eventually, the exact time frame of activity that be needed. All the data were also rectified to exclude noise that may involve while muscles activities were recording. Rectifying for all set for all muscles had been standardized by using the same protocols from selecting mode in the system. EMG cables and wires had been secured with an appropriate setup from any uneasy circumstances on subjectsô bodies. Subjects were performed a standardized cooling down and stretching after the completion of the last set on the active and passive sessions.

3.4.4 Heart Rate and Blood Lactate

The purpose of collecting data of heart rate and blood lactate was to monitor and to determine if there was any significant between variables. Therefore, heart rate data

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were collected before the subject was done warm up, before and every sets of squat activity until the end of the whole session either in neither WBV nor non-WBV and the minutes of 5 and 10. Subjects will strapped with a polar heart rate on their chest, telemetry with a watch and data appeared to be collected on selective time.

Whilst in blood lactate, data were collected before subjects done warm up, before and every sets of squat activity until the end of the whole session either in neither WBV nor non-WBV, inclusive the minutes of 5 and 10 right after subjects done their squat activity. Blood lactates were collected from the finger of the capillary (none specific).

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Figure 3.4.5: Framework of Data Recording Protocol

BASELINE MEASURES

1-RM Testing and Familiarization

(at least 72 hours after done familiarization)

TESTING PROCEDURES

i) Portable EMG had been set up on subjectsô body for muscle activity recording and measuring before session started
ii) Started a session with warmed up for 10 minutes
iii) Heart rate and blood lactate were collected before warm up, before and after squat exercise and 5 and 10 minutes done squat exercise
iv) 5 minutes of cycled ergometer (Haskel Chart based) and 5 minutes of stretching
v) Performed squat exercise with 10 repetitions and 3 sets
vi) WBV and non-WBV exposures during rest period of squat exercise with frequency of 40Hz that lasting for 60 seconds
vii) Performed a proper cooling down after sessions ended

Figure 3.4.5. Framework of Data Recording Protocol

3.5 Data Analysis

Raw data for each testing was transferred into a Microsoft Excel. Every subject had designed into their own profile that been created. The raw data from blood lactate collection were analyzed by a blood lactate analyzer. The results were recorded into a Microsoft Excel sheet. It was also applied to EMG after the analyzed mode of EMG had been chosen in this study. The basic amplitude parameters (mean and peak

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muscle activity) analysis had been done during the exercise performance. The EMG data that collected were raw signals and signals were processed by full wave rectification and smoothing. The raw EMG was sampled at 1000Hz frequency and raw signal calculated to an average root-mean-square (rms) signal. Myoresearch XP Master Edition software had been used to convert the amplified EMG raw signal into a standard EMG analysis report.

3.6 Statistical Analysis

All raw data were collected during the experiment and transferred into a Microsoft Excel then had analyzed using SPSS version 16. Mean and standard deviations had been used as measures of centrality and spread of data. Repeated measure Annova was used to analyze within subjects contrast while paired sample T-Test to analyze comparison between the chosen pairs and significant differences between pre and post scores of data had been calculated. An alpha level of 0.05 was used for statistical significance.

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CHAPTER 4

RESULTS

4.1 Anthropometry of the subjects

Eight recreationally men with no implant or foreign bodies participated this study. The subjectsô mean age, height, body weight, body mass index and 1RM were 26.63 ± 3.96 years old, 1.71 ± 0.02 meter, 72.01 ± 8.76 kg, 24.54 ± 2.78kg and 135.63 ± 24.84kg/m2 respectively. The subjects were fully informed of any risks and discomforts with these experiments before giving their oral consent to participate. Table 4.1 represents the mean and standard deviation of anthropometry among the subjects.

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Table 4.1. Anthropometry of Subjects

Variables	Mean ± SD
Age	26.63 ± 3.96 years old
Height	1.71 ± 0.02 meter
Weight	72.01 ± 8.76 kg
BMI	24.54 ± 2.78 kg/m2
1-RM	135.63 ± 24.84 kg

4.2 Muscular Performance with Whole Body Vibration (WBV) Treatment

The data were collected for each participant of WBV during inter-set rest period on rate muscle activation during squat training exercise. Four muscles involved and to see their muscle activity during the squat exercise using EMG. The results were analyzed with repeated measures ANOVA.

Table 4.2 shown that the mean and standard deviation for each muscle during the squat exercise using EMG and the muscles were; right rectus femoris, left rectus femoris, right biceps femoris and left biceps femoris.

The results shown for all the muscles that p value is greater than 0.05. The hypotheses are rejected as the results are not significant between the variables within sets as right rectus femoris, left rectus femoris, right biceps femoris and left biceps femoris were stated the p value 0.328, 0.709, 0.825 and 0.688.

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Table 4.2. Muscular performance during squat training exercise with whole body vibration (WBV) treatment

	Mean ± SD			
Muscle	**Set 1**	**Set 2**	**Set 3**	**p Value**
Right Rectus Femoris	322.73 ± 90.02	351.29 ± 94.17	392.66 ± 152.53	0.328
Left Rectus Femoris	289.17 ± 96.71	324.40 ± 86.11	314.17 ± 143.20	0.709
Right Bicep Femoris	153.18 ± 108.68	144.72 ± 64.24	165.37 ± 71.36	0.825
Left Bicep Femoris	175.69 ± 140.01	149.46 ± 101.49	156.73 ± 51.93	0.688

4.3 Muscular Performance with Non-Whole Body Vibration (NWBV) Treatment

The data were collected for each participant of NWBV during inter-set rest period on rate muscle activation during squat training exercise. Four muscles involved and to see their muscle activity during the squat exercise using EMG. The results were analyzed with repeated measures ANOVA.

Table 4.3 shown that the mean and standard deviation for each muscle during the squat exercise using EMG and the muscles were; right rectus femoris, left rectus femoris, right biceps femoris and left biceps femoris.

The results shown for all the muscles that p value is greater than 0.05. The hypotheses are rejected as the results are not significant between the variables within sets as right rectus femoris, left rectus femoris, right biceps femoris and left biceps femoris stated the p value were 0.214, 0.548, 0.785 and 0.402.

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Table 4.3. Muscular performance with non-whole body vibration (NWBV) treatment

Muscle		Mean ± SD			
		Set 1	**Set 2**	**Set 3**	**Set 4**
Right Femoris	Rectus	384.96 ± 75.5	399.55 ± 71.5	316.51 ± 128.2	316.51 ± 128.3
Left Femoris	Rectus	339.47 ± 96.08	299.54 ± 90.18	303.11 ± 155.10	303.11 ± 155.11
Right Femoris	Bicep	145.30 ± 32.95	194.02 ± 157.45	141.45 ± 53.95	141.45 ± 53.96
Left Femoris	Bicep	123.26 ± 36.69	118.81 ± 17.90	112.55 ± 47.33	112.55 ± 47.34

4.4 Muscular Performance with Whole Body Vibration (WBV) Treatment versus Non Whole Body Vibration (NWBV) Treatment

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The data were collected for each participant of WBV and NWBV during inter-set rest period on rate muscle activation during squat training exercise. Four muscles involved and to see their muscle activity during the squat exercise using EMG. The results were analyzed with paired-samples T-Test.

Table 4.4 shown that the mean and standard deviation for each muscle during the squat exercise using EMG between WBV and NWBV. The muscles were; right rectus femoris, left rectus femoris, right biceps femoris and left biceps femoris.

The results shown for all the muscles that p value is greater than 0.05. Although muscle activation rate were seen higher in session non-WBV usage (except for left biceps femoris), statistical comparisons made indicates that there were no

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significant differences exist in rate of muscle activation between session that used WBV versus session done without WBV assistance (Table 4.4). However, higher percentage of differences between the WBV versus without WBV session in right rectus femoris and left biceps femoris muscleôs rate of muscle activation can be clearly seen in Table 4.4.

Table 4.4. Comparisons in rate of muscle activation (mV) between session with WBV versus session non-WBV (NWBV) on rectus femoris and bicep femoris

Muscle	Mean ± SD		% Difference	p Value
	WBV	NWBV		0
Right Rectus Femoris	355.56 ± 35.16	484 ± 158.51	30.6	0.81
Left Rectus Femoris	309.25 ± 18.12	314 ± 22.10	1.52	0.783
Right Bicep Femoris	154.42 ± 10.38	160 ± 29.30	3.55	0.832
Left Bicep Femoris	160.63 ± 13.54	118 ± 5.38	30.6	0.259

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4.5 Metabolic Performance

Based on Table 4.5, blood lactate accumulation or clearance rate seems have not been influence much by WBV modality during the inter-set recovery. There are no significant differences in between WBV and NWBV in all variables ($p<0.05$).

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Table 4.5. Blood lactate level (mmol/L) between sessions with WBV versus session non-WBV (NWBV) for each sets performed

	Mean ± SD		% Difference	p Value 0
	WBV	**NWBV**		
PRE SET	6.23 ± 1.73	5.28 ± 1.43	16.49	0.176
POST SET 1	7.31 ± 2.11	6.30 ± 1.33	14.85	0.279
POST SET 2	7.68 ± 3.34	8.31 ± 2.61	8.08	0.628
POST SET 3	8.53 ± 2.23	7.28 ± 1.55	15.82	0.269
POST 5 MINS	8.44 ± 1.09	7.50 ± 2.72	11.79	0.363
POST 10 MINS	7.33 ± 2.28	7.08 ± 2.13	3.47	0.861

4.6 Heart Rate Responses

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Table 4.6 shown results were not significant to all variables ($p<0.05$) except on the minutes of 10, value stated $p=0.042$. Statistic shown higher in p Value over the warm up $p=0.939$. Variables were shown statistically increased in p Value in Rest ($p=1.00$) after Set 1 and decreased over the Set 2 ($p=0.255$). Continuous on Rest after the Set 2, p Value increased ($p=0.356$) until the Set 3 ($p=0.809$). However, right after the Set 3, the Rest variable shown decreased statistically ($p=0.307$) and increased back on Minutes 5 ($p=1.00$) before significant result on Minutes 10 ($p=0.042$).

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Table 4.6. Heart rate response in whole body vibration and non-whole body vibration exposure

	Mean ± SD		% Difference	p Value 0
Variables	**WBV**	**NWBV**		
Warm up	106.63 ± 8.99	106.71 ± 14.95	0.075	0.939
Set 1	141.75 ± 8.50	141.29 ± 9.39	0.5	0.24
Rest	109.38 ± 4.60	109.29 ± 8.50	0.15	1
Set 2	147.38 ± 8.43	152.00 ± 13.91	4.63	0.255
Rest	110.00 ± 5.63	113.43 ± 4.55	5.6	0.356
Set 3	151.38 ± 7.21	156.57 ± 18.27	5	0.809
Rest	109.25 ± 2.82	117.86 ± 14.95	7.58	0.307
Minutes 5	101.00 ± 5.21	104.29 ± 11.36	3.2	1
Minutes 10	90.88 ± 2.85	99.00 ± 8.85	8.55	0.042

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CHAPTER 5

DISCUSSION

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5.1 Introduction

Over the past years, WBV is known to help human in increasing health by using the vibration device as a training tool (Albasini & Rembitzki, 2010). This research study is to investigate the effect of having whole body vibration as an active recovery modality as opposed to typically used passive recovery during the inter-set rest period on squat exercise in kinematic, kinetic and muscle activity. To my knowledge, this was the first finding regarding using whole body vibration as active recovery mobility during the inter-set rest period. Therefore, some variables were selected to see the effect of whole body vibration as an active recovery method.

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5.2 Muscular Performance Output

An earlier assumption was that with WBV active recovery, overall strength capabilities during the squat exercise regime will be increased. Strength capabilities or force output can be influenced by metabolic factors such as blood lactate accumulation which decrease muscle contractile performance (i.e., weak force generation) (Tesch & Wright, 1983). Loading parameters and squat exercise which have been used in this study has been associated with high rate of energy utilization through phosphagen breakdown and activation of glycogenolysis which have excess lactate accumulation (Mohamad et al., 2012; Tesch, Colliander, & Kaiser, 1986).

The results shown that there is no significant difference between whole body vibration and non-whole body vibration as a recovery modality in inter-set rest period. This is aligning with Humphries et al., 2004 that indicate no significant in normalized peak of EMG in between whole body vibration and non-whole body vibration. The study was found that to use the same method of applying whole body vibration exposure and recording muscle activity on same muscles but not with a same amount of subject. Unfortunately, the results came significant with a knee flexed 90° and frequency was set 26Hz for vibration exposure with a same amount of sample size but different kinematic standing on whole body vibration (Bosco et al., 1998). Therefore, some characteristic and factor has been found that might influence this insignificant outcome.

There are few factors that may lead the insignificant results. Kinematic factor such as lower limb position on whole body vibration during exposure vibration could

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lead one of the insignificant reasons (Abercromby et al., 2007). Kinematics and kinetics output were also dependable on neuronal factors such as motor unit activations by stimulus provided (i.e. external load). This is due to high thresholds unit maybe recruited by the nervous system in an effort to maintain force production and resist muscle fatigue, such as recruitment of a more powerful fast twitch muscle fibers (McDonagh & Davies, 1984). Either way (recruitment of fast or slow twitch), both actions can be seen via EMG amplitude assessed, with typically involvement of fast twitch will yields higher amplitude responses (Yao, Fuglevand & Enoka, 2000). However, no significant differences found in the present study for all variables of interest brings in the possibility that previous assumptions and its popularity might be due to one of it, psychological factor.

For this study, subjects were done in standing with a quarter angle squat (less than 45°) on whole body vibration for exposure. They are studies regarding squat position during whole body vibration exposures as an active recovery alone (Roelants et al., 2006; Cardinale & Lim, 2003; Cormie et al., 2006; Bosco et al., 2000; Abercromby et al., 2007 & Cochrane & Stannard, 2009) but most of the studies has been found that whole body vibration has been done as a training tool.

Meanwhile there is a study that found the smaller angle given the greatest neuromuscular responses (Abercromby et al., 2007). Results shown there is a significant difference in neuromuscular responses among three muscles that involved at small knee flexion; gastrocnemius, vastus lateralis and tibialis anterior. Knee angle was set up in 10°-15°, 16°-20°, 21°-25°, 26°-30° and 31-35°) with frequency of vibration was 30Hz but time of exposure were not identified . Amazingly, few studies

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has been found were significant with huge difference in kinematic factor (squat angle) with little amount of subjects (Bosco et al., 2005 & Cochrane & Stannard, 2009). Both were stated with same frequency 26Hz, 90° and 40° and 60 seconds (7 bouts) and 5 minutes (single active vibration) last of vibration exposures.

Generally, whole body vibration applications are purposed for entire body that comes from distally platform and later stimulate the sensors. As far as researcher concerned, none of the study has elaborated why squatting in any angle during whole body vibration exposure is important. But it has explained that standing still while having vibration exposure could give effects in muscles, tendons and even joints. This may lead in enhancing proproception depending on the muscles itself that been vibration exposed. (Krause & Albasini, 2010). Further investigation regarding kinematic factor (knee angle flexion) should be done in future aligning with a selected frequency to be compared later.

There was a suggestion in other previous study that positive effect of whole-body vibration on increased in power output observed during training and conflicting results reported might be due to psychological factor rather than due to mechanical effect of the modality (Poston, Holcomb, Guadagnoli, & Linn, 2007). Another possible reason of insignificant differences found between WBV and the non-WBV protocol might be due to the WBV frequency (Hz) used. However, a current study which also used squat exercise and EMG measurement on similar muscles, has indicated that WBV effects were not frequency dependent (either 20Hz, 40Hz or 60Hz) (Raphael, Wesley, Daniel & Olivier, 2012).

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Comparison with other studies with similar conceptual framework is difficult due to no other similar study has been done or widely published. However the use of WBV as post-session recovery modality had been investigated in many previous studies. WBV implemented as post-session recovery modality following 3 km time trial and high-intensity interval training (8 x 400m) found insignificant differences between WBV recovery versus non-WBV control group (Edge et al., 2009). Another study which compared combinations of WBV and 1 minutes treadmill run recovery; versus active recovery using 15 minutes treadmill low intensity jogging had also shown no significant differences between the two active recovery method (Shakerian, Korandi & Habibi, 2012). One study that examined the effect of low-frequency handgrip vibration (not whole body vibration) performed for 9 seconds during the inter-set recovery during rock climbing found no effect of recovery strategy on any measure. In fact the study had suggested that rock climbers and their coaches focus on optimizing body position rather than compromising body position to allow for shaking out during the climb (Green & Stannard, 2010). Low frequency vibration strategy applied during 15 minutes after short and intense exercise did not seem to be effective on blood lactate removal, muscle contractile properties, and on time to exhaustion during cycling maximal oxygen uptake power output (Carrasco, Sanudo, De Hoyo, Pradas & Silva, 2011).

Interestingly, in one study six sets of WBV used for 60 seconds in each sets as a training modality with 30-Hz frequency and a 4-mm peak-to-peak displacement produces improved muscle performance measured by squat jump, counter movement jump, and power output (Da Silva-Grigoletto, De Hoyo, Sanudo, Carrasco, & Garcia-Manso, 2011). Based on this finding (Da Silva-Grigoletto et al., 2011) it may be

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speculated that this study found no significant differences in all variables might be due insufficient WBV stimulus (less total volume) treated on all subjects (only 3 sets of WBV) although the frequency was higher (40 Hz).

5.3 Metabolic and Heart Rate Responses

On the other hand regarding blood lactate (whole body vibration exposure comparing non whole body vibration exposure), the results were insignificant during the squat exercise activity. Interestingly, results shown fluctuation for each selective time until the last variable.

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Similar results were found in a study conducted by Sperlich et al 2009 revealed that there is no difference in blood lactate before, during and after the squat exercise with loads. It also found in 2000, Rittweger, Beller and Felsenberg stated that there was no significant difference for the mean of blood lactate concentration for baseline, second and third visit (SD 0.50). A study also found one study had found that blood lactate were increased after the exercise but there was no treatment related (Rittweger, Mutschelknauss & Felsenberg, 2003). A significant correlation between vibration and without vibration in values of exercise time ($r=0.67$, $p<0.001$) but not in blood lactate.

Non whole body vibration exposure were found decreased as similar to Bangsbo et al 1994 stated that lactate production reduced when intense exercise was repeated obviously in the last two set. While in whole body vibration exposure results

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were increasing comparing non whole body vibration. It can be say that the used of whole body vibration in inter-set rest period can be a modality in active recovery as blood lactate is increased. It is expecting that after an exercise there would be a fatigue with reduction of blood lactate results but it was not. Even though blood lactate canôt be determined of fatigue (Bangsbo et al, 1994) and it was repetitive exercise, using whole body vibration as modality during inter-set of rest period can leads to another. This may explained why comparing with non-whole body vibration exposure.

Whilst in heart rate responses, study shown that results were insignificant to all variables ($p>0.05$) except in minutes for 10 ($p=0.042$). Along with that, two study had found supporting the results, shown no significant difference in heart rate ($p=0.43$) between the intervention (Cochrane et al., 2010) and heart rate at all levels was unaffected by the application of vibration compared to without vibration (Sperlich et al., 2009).

There is lack of study regarding whole body vibration in integrated heart rate and blood lactate responses. Therefore, future research need to be conducted to investigate heart rate and blood lactate responses during squat exercise as whole body vibration device as an active recovery tool.

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5.4 Conclusion

In accordance with principal of training which emphasize of variety in training, WBV modality can be used inter-changeably with other modalities. Psychologically, it might provide better motivation to the athletes or clients during a strength training session, and thus maintain overall training performance during the session.

Even whole body vibration is known as a training tool and studies shown improvement in gaining muscle performance, similar with comparable traditional resistance exercise training programs among sedentary nor elderly, it is still unclear in using whole body vibration as an active recovery since in the current study; participants were active men which small population in National Sports Institute of Malaysia and may have its limitations. Therefore, enlarging participation in further research can be considered especially in finding hormonal responses and kinetic involvement.

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REFERENCES

Aagaard, P., Simonsen, E. B., Andersen, J. L., Magnusson, P., & Dyhre-Poulsen, P. (2002). Increased rate of force development and neural drive of human skeletal muscle following resistance training. *Journal of Applied Physiology, 93*(4), 1318-1326.

Abbasi A., Sadeghi H., Tabrizi H. B., Bagheri K., Ghasemiza A. & Asl A. K. (2011). *World Applied Sciences Journal*, 15 (1), 84-91.

Abercromby AF, Amonette WE, Layne CS, McFarlin BK, Hinman MR, Paloski WH (2007b) Vibration exposure and biodynamic responses during whole-body vibration training. *Medicine Science Sports Exercise*, 39, 1794ï 1800.

Adams, J. B., Edwards, D., Serviette, D., Bedient, A. M., Huntsman, E., Jacobs, K. A., et al. (2009). Optimal frequency, displacement, duration, and recovery patterns to maximize power output following acute whole-body vibration. *The Journal of Strength & Conditioning Research, 23*(1), 237-245.

Albasini A. & Rembitzki I. (2010). *Using Whole Body Vibration in Physical Therapy and Sport.* Edinburgh: Churchill Livingstone.

Armstrong W. J., Grinnell D. C. & Warren G. S. (2010). The acute effect of whole body vibration on the vertical jump height. *Journal of Strength and Conditioning Research, 24* (10), 2835ï 2839.

Arnold Snow (1912). Mechanical Vibration. *www.mcmillinmedia.co/eamt/files/snow/mvcont.htm*

Baechle, T. R., & Earle, R. W. (2008). *Essentials of strength training and conditioning / National Strength and Conditioning Association* (3 ed.). Champaign, IL: Human Kinetics.

Bandy W. D., Lovelace-Chandler V. & McKitrick-Bandy B.(1990). Adaptation of skeletal muscle to resistance training. *Journal of Orthopaedic and Sports Physical Therapy*, 12 (6), 248-255.

Bangsbo J, Graham, T., Johansen, L., & Saltin, B. (1994). Muscle lactate metabolism in recovery from intense exhaustive exercise: Impact of light exercise. *Journal of Applied Physiology, 77*(4), 1890-1895.

Bazett-Jones D. M., Finch H. W. & Dugan E. L. (2008). Comparing the effects of various whole-body vibration accelerations on counter-movement jump performance. *Journal of Sports Science and Medicine*, 7, 144-150.

Behm D. G. (1995). Neuromuscular implications and applications of resistance training. *Journal Strength and Conditioning Research*, 9, 264-274.

Bogdanis, G., Nevill, M., Lakomy, H. A., Graham, C., & Louis, G. (1996). Effects of active recovery on power output during repeated maximal sprint cycling. *European Journal of Applied Physiology and Occupational Physiology, 74*(5), 461-469.

Bosco, C., Colli, R., Cardinale, M., Tsarpela, O., & Bonifazi, M. (1998). The effect of whole body vibration on mechanical behaviour of skeletal muscle and hormonal profile. *In: Musculo–Skeletal Interactions, 2*, 67-76.

Bosco C., Cardinale M., Colli R., Tihanyi R., Von Duvillard S. P. & Viru A. (1998). The influence of whole body vibration on the mechanical behaviou of skeletal muscle. *Biology of Sport*, 15 (3), 1-8.

Bosco C., Iacovelli M., Tsarpela O., Cardinale M., Bonifazi M., Tihanyi J., Viru M., De Lorenzo A. & Viru A. (2000). Hormonal responses to whole-body vibration in men. *European Journal of Applied Physiology*, 81, 449-454.

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

Brandenburg, J. E., & Docherty, D. (2002). The effects of accentuated eccentric loading on strength, muscle hypertrophy, and neural adaptations in trained individuals. *The Journal of Strength & Conditioning Research, 16*(1), 25-32.

Brown L. E & Weir J. P. (2001). ASEP procedures recommendation I: Accurate assessment of muscular strength and power. *JEP Online*, 4 (3), 1-21.

Bruyere, O., Wuidart, M.-A., Di Palma, E., Gourlay, M., Ethgen, O., Richy, F., et al. (2005). Controlled whole body vibration to decrease fall risk and improve health-related quality of life of nursing home residents. *Archives of Physical Medicine and Rehabilitation, 86*(2), 303-307.

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

Cardinale J. & Lim J. (2003). The acute effects of two different whole body vibration frequencies on vertical jump performance. *Med Sport,* 56, 287-92

Carrasco, L., Sanudo, B., Hoyo, M. d., Pradas, F., & Silva, M. E. D. (2011). Effectiveness of low-frequency vibration recovery method on blood lactate removal, muscle contractile properties and on time to exhaustion during cycling at VO2max power output. *European Journal of Applied Physiology, 111*(9), 2271-2279.

Cheung W. H., Mok H. W., Qin L., Sze P. C., Lee K. M. & Leung K. S. (2007). High-frequency whole-body vibration improves balancing ability in elderly women. *ArchPhys Med Rehabili*, 88, 852-7.

Cochrane, D. J., Legg, S. J., & Hooker, M. J. (2004). The short-term effect of whole-body vibration training on vertical jump, sprint, and agility performance. *Journal of Strength and Conditioning Research, 18*(4), 828-832.

Cochrane D. J. & Stannard S. R. (2005). Acute whole body vibration training increases vertical jump and flexibility performance in elite female field hockey players. *Journal Sports Medicine*, 39, 860-865.

Cochrane, D. J., Sartor Francesco, Winwood Keith, Stannard R. S., Narici V. M. & Rittweger J. A. (2008). Comparison of the physiologic effects of acute whole-body vibration exercise in young and older people. *Archives of Physical Medicine and Rehabilitation*, 89, 815-21.

Cochrane, D. J., Stanndard S. R., Firth E. C. & Rittweger J. (2010). Comparing muscle temperature during static and dynamic squatting with and without whole-body vibration. *Scandinavian Society of Clinical Physiology and Nuclear Medicine*, 30 (4), 223-229.

Connolly, D. A. J., Brennan, K. M., & Lauzon, C. D. (2003). Effect of active versus passive recovery on power output during repeated bouts of short term, high intensity exercise. *Journal of Sports Science and Medicine, 2*, 47-51.

Corder, K. P., Potteiger, J. A., Nau, K. L., Figoni, S. E., & Hershberger, S. L. (2000). Effects of active and passive recovery conditions on blood lactate, rating of perceived exertion, and performance during resistance exercise. *The Journal of Strength & Conditioning Research, 14*(2), 151-156.

Cormie, P., Deane, R. S., Triplett, N. T., & McBride, J. M. (2006). Acute effects of whole-body vibration on muscle activity, strength, and power. *Journal of Strength and Conditioning Research, 20*(2), 257-261.

Cronin J. B., Oliver M. & McNair P. J. (2004). Muscle stiffness and injury effects of whole body vibration. *Physical Therapy in Sport 5*, 68-74.

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

Da Silva M. E., Nunez V. M., Vaamonde D., Fernandez J. M., Poblador M. S., Garcia-Manso J. M & Lancho J. L. (2006). *Biology of Sport*, 23 (3).

Da Silva-Grigoletto, M. E., De Hoyo, M., Sanudo, B., Carrasco, L., & Garcia-Manso, J. M. (2011). Determining the optimal whole-body vibration dose-response relationship for muscle performance. *The Journal of Strength & Conditioning Research, 25*(12), 3326-3333.

Delecluse C., Roelants M. & Verschueren S. (2003). Strength increase after whole-body vibration compared with resistance training. *Medicine & Science in Sports & Science*, 35 (6), 1033-1041.

Dolny D. G. & Reyes F. C. (2008). Whole body vibration exercise: Training and benefits. *Current Sports Medicine Reports*, 7 (3), 152-157.

Edge, J., Mundel, T., Weir, K., & Cochrane, D. J. (2009). The effects of acute whole body vibration as a recovery modality following high-intensity interval training in well-trained, middle-aged runners. *European Journal of Applied Physiology, 105*(3), 421-428.

Erskine J., Smillie I., Leiper J., Ball D. & Cardinale M. (2007) Neuromuscular and hormonal response to a single session of whole body vibration exercise in healthy young man. *Clinical Physiology and Functional Imaging*, 27 (4), 242-248.

Eklund G. & Hagbrath K. E. (1966) Normal variability of tonic vibration reflex. *Experimental Neurology* 16**,** 80-92.

Green, J. G., & Stannard, S. R. (2010). Active recovery strategies and handgrip performance in trained vs. untrained climbers. *The Journal of Strength & Conditioning Research, 24*(2), 494-501.

Goto K. & Takamatsu K. (2005). Hormone and lipolytic responses to whole body vibration in young men. *Japanese Journal of Physiology*, 55 (5), 279-284.

Hazell T. J., Thomas G. W. R., DeGuire J. R. & Lemon P. W. R. (2008). Vertical whole-body vibration does not increase cardiovascular stress to static semi squat exercise. *Europe Journal of Applied Physiology*, 104, 903-908

Hoyo Lora M., Granados S. R., Corrales B. S. & Paez L. C. (2010). Whole body vibration: Acute and residual effect on the explosive strength. *Journal of Human Sport & Exercise*, 5 (2), 188-195.

Humphries B., Warman G., Purton J., Doyle T. L. A. & Dugan E. (2004). The influence of vibration on muscle activation and rate of force development during maximal isometric contractions. *Journal of Sports Science and Medicine*, 3, 16-22.

Isear, Erickson J. C. & Worrell T. W. (1997). EMG analysis of lower extremity muscle recruitment patterns during an unloaded squat. *Medicine Science Sport Exercise,* 29, 532ï 9.

Issurin V. B & Tenenbaum G. (1999). Acute and residual effects of vibratory stimulation on explosive strength in elite and amateur athletes. *Journal of Sports Sciences*, 17, 177-182.

Issurin V. B., Liebermann D. G. & Tenenbaum G. (1994). Effect of vibratory stimulation training on maximal force and flexibility. *Journal of Sports Sciences*, 12, 561-566.

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

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

Jones M. T., Parker B. M. and Cortes N. (2011). The effect of whole body vibration training and conventional strength training on performance measures in female athletes. *Journal of Strength and Conditioning Research*, 25 (9), 2434-2441.

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

Krause M. & Rembitzki I. (2010) *Using Whole Body Vibration in Physical Therapy and Sport.* Edinburgh: Churchill Livingstone.

Krol P., Piecha M., Slomka K., Sobota G., Polak A. & Juras G. (2011). The effect of whole-body vibration frequency and amplitude on the myoelectric activity of vastus medialis and vastus lateralis. *Journal of Sports Science and Medicine*, 10, 169-174.

Lance J. W., Burke D. & Andrews C. J. (1973). The reflex effects of muscle vibration. Studies of the tendon jerk irradiation, phasic reflex inhibition and the tonic vibration refex. *New Developments in EMG and Clinical Neurophysiology,* 444ï 462.

Marin, P. J., & Rhea, M. R. (2010b). Effects of vibration training on muscle strength: A meta-analysis. *The Journal of Strength & Conditioning Research, 24*(2), 548-556.

McDonagh, M. J. N., & Davies, C. T. M. (1984). Adaptive response of mammalian skeletal muscle to exercise with high loads. *European Journal of Applied Physiology and Occupational Physiology, 52*(2), 139-155.

Melynk M., Kofler B., Faist M., Hodapp M. and Gollhofer A. (2008). Effect of a whole-body vibration session on knee stability. *International Journal Sports Medicine*, 29 (10), 839-844.

Mohamad, N. I., Cronin, J. B., & Nosaka, K. K. (2012). The effect of aerobic exercise during the interset rest periods on kinematics, kinetics, and lactate clearance of two resistance loading schemes. *The Journal of Strength & Conditioning Research, 26*(1), 73-79.

Paradisis G. & Zacharogiannis E. (2007). Effects of whole-body vibration training on sprint running kinematics and explosive strength performance. *Journal of Sports Science and Medicine*, 6, 44-49.

Peter Konrad (2005). The ABC of *EMG*: A Practical Introduction to Kinesiological Electromyography. *Peter Konrad*. Version 1.4 March 2006. Noraxon INC. USA.

Poston, B., Holcomb, W. R., Guadagnoli, M. A., & Linn, L. L. (2007). The acute effects of mechanical vibration on power output in the bench press. *The Journal of Strength & Conditioning Research, 21*(1), 199-203.

Raphael, Z., Wesley, A., Daniel, K., & Olivier, S. (2012). Occurrence of fatigue induced by a whole body vibration session is not frequency dependent. *The Journal of Strength & Conditioning Research, Publish Ahead of Print*, 10.1519/JSC.1510b1013e31827fd31730.

Reveron J. A., Goodson C., Dupler T. L., Stroud L. C., & Amonette W. E. (2012). Exercising metabolic, ventilator and cardiovascular responses to isometric whole body vibration exercise. *International Journal of Exercise Science*

Ribot-Ciscar E, Vedel JP, Roll JP (1989) Vibration sensitivity of slowly and rapidly adapting cutaneous mechanoreceptors in the human foot and leg. *Neuroscience Letters,* 104-130

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

Rittweger J., Beller G. & Felsenberg D. (1999). Acute physiological effects of exhaustive whole-body vibration exercise in man. *Clinical Physiology,* 20 (2), 134-142.

Rittweger J., Mutschelknauss M., & Felsenberg D. (2003). Acute changes in neuromuscular excitability after exhaustive whole body vibration exercise as compared to exhaustion by squatting exercise. *Clinical Physiology and Functional Imaging,* 23 (2), 81-86.

Rittweger, J., Ehrig J., Just K., Mutschelknauss M., Kirsch K. A & Felsenberg D. (2002). Oxygen uptake in whole body vibration exercise: Influence of vibration frequency, amplitude, and external load. *International Journal of Sports Medicine, 23* (6), 428ï 432.

Roberts B., Hunter I., Hopkins TY. & Feland B. (2009). The short-term effect of whole body vibration training on sprint start performance in collegiate athletes. *International Journal of Exercise Science*, 2 (4), 264-268.

Roelants, M., Delecluse, C., Goris, M., & Verschueren, S. (2004). Effects of 24 weeks of whole body vibration training on body composition and muscle strength in untrained females. *International Journal of Sports Medicine, 25*(1), 1-5.

Roelants, M., Verschueren, S. M. P., Delecluse, C., Levin, O., & Stijnen, V. (2006). Whole-body-vibration-induced increase leg muscle activity during different squat exercises. *Journal of Strength and Conditioning Research, 20*(1), 124-129.

Ronnestad B. R. (2004). Comparing the performance-enhancing effects of squats on a vibration platform with conventional squats in recreationally resistance-trained men. *Journal of Strength and Conditioning Research*, 18 (4), 839-845.

Ruiter C. J., Raak S. M., Schilperoort J. V., Hollander A. P. & Haan A. (2003). *Europe Journal Applied Physiology*, 90, 595-600.

Shakerian, S., Korandi, H., & Habibi, A. (2012). Comparison of active recovery and whole body vibration combined with active recovery effects on blood lactate after exhaustive activity. *Annals of Biological Research, 3*(8), 3945-3948.

Sperlich Billy, Kleinoeder Heinz, De Marees Markus, Quarz Dieter, Linville John, Haegele Matthias & Mester Joachim. (2009) Physiological and perceptual responses of adding vibration to cycling. *Journal of Exercise Physiology*, 12 (2).

Tesch, P., Colliander, E., & Kaiser, P. (1986). Muscle metabolism during intense, heavy-resistance exercise. *European Journal of Applied Physiology and Occupational Physiology, 55*(4), 362-366.

Tesch, P., & Wright, J. (1983). Recovery from short term intense exercise: Its relation to capillary supply and blood lactate concentration. *European Journal of Applied Physiology and Occupational Physiology, 52*(1), 98-103.

Turner A. P., Sanderson M. F. & Attwood L. A. (2011). The acute effect of different frequencies of whole body vibration on countermovement jump performance. *Journal of Strength and Conditioning Research, 25* (6), 1592ï 1597.

Torvinen, S., Kannus, P., Sievanan, H., Jarvinen, T. A., Pasanen, M., Kontulainen, S., et al. (2002). Effect of four-month vertical whole body vibration on performance and balance. *Medicine and Science in Sports and Exercise, 34*(9), 1523-1528.

Vibration type. In www.avantwelness.com/technology/wbv-types. Retrieved 2008 from http:// www.avantwelness.com/technology/wbv-types.

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

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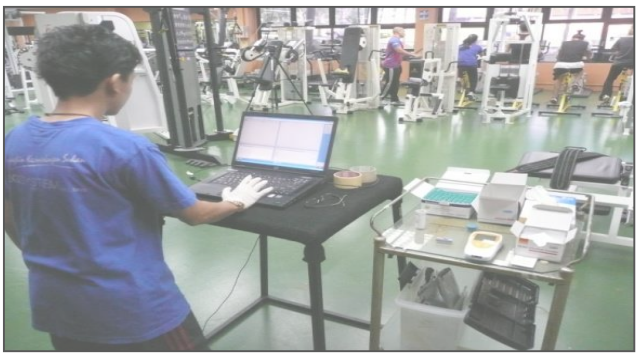
Yao, W., Fuglevand, R. J., & Enoka, R. M. (2000). Motor-Unit synchronization increases EMG amplitude and decreases force steadiness of simulated contractions. *Journal of Neurophysiology, 83*(1), 441-452.

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APPENDICES



Zaireen with the blood troly, BMS and EMG output computer monitoring



Blood lactate sample being analyze on-site by Zaireen





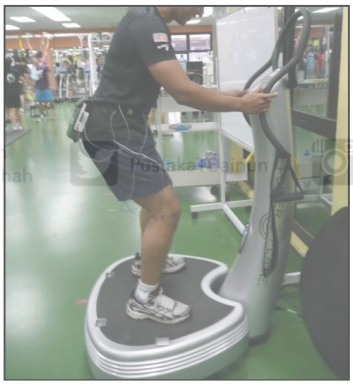


Photo shows subject was performing the WBV active recovery.



Power Cage Station



Polar Heart Rate

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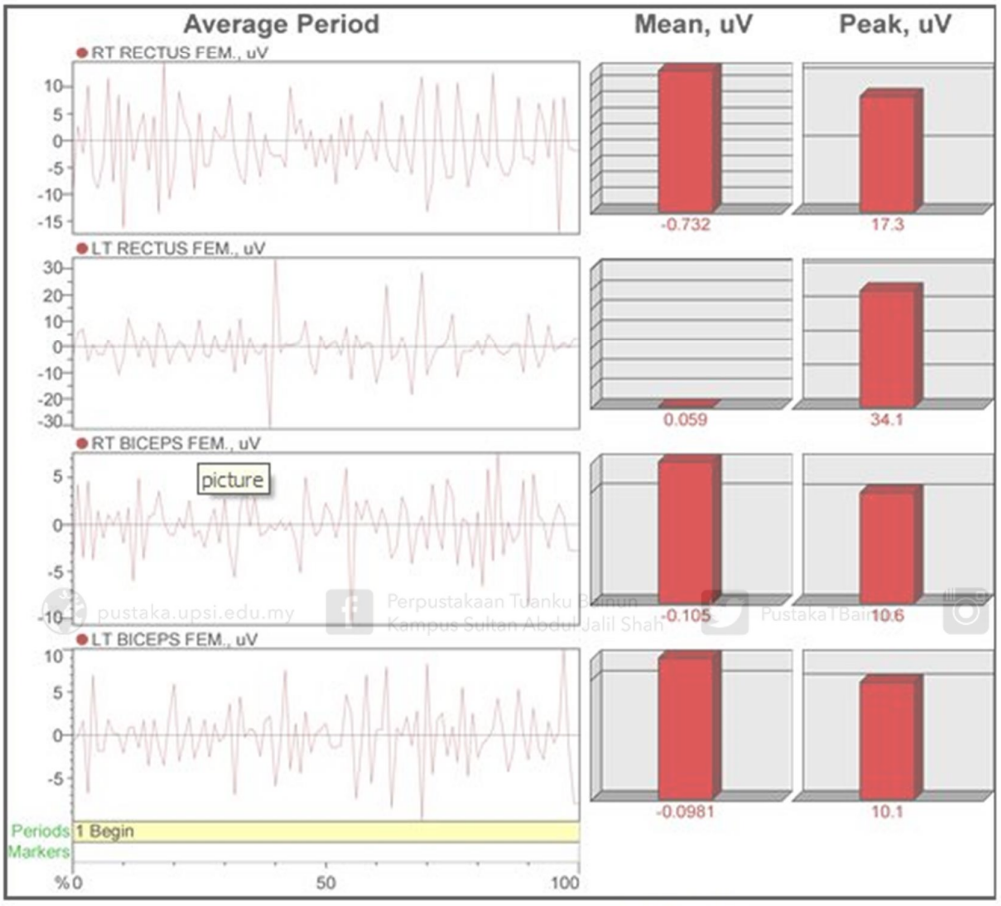
Noraxon Average Activation Pattern Report

Subject

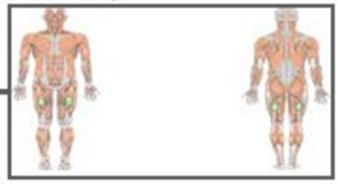
First Name	Post Test
Last Name	Ali
Sex	Male

Record

Name	ali post test
Record type	Mvc
Date Measured	5/30/2012 3:24 PM



Muscle Setup



Subject Comments

Record Comments

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