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THE EFFECT OF WHOLE BODY VIBRATION INDUCED POST- ACTIVATION POTENTIATION UPON INDICES OF ISOMETRIC AND DYNAMIC FORCE/POWER PRODUCTION DURING, AND FOLLOWING A SIX WEEK PERIODISED SMITH MACHINE BACK SQUAT PROTOCOL

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A DISSERTATION APPROVED FOR THE

DEPARTMENT OF HEALTH AND EXERCISE SCIENCE

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ABSTRACT

PURPOSE: The purpose of this study was to examine the chronic and acute effects of a 6 wk, periodized Squat training program, with (G2) or without (G3) low frequency vibration upon select force characteristics, as well as to changes in body composition. **METHODS**: Participants (G1 n = 6; G2 n = 13; G3 n = 11; ranged in age from 18 to 30 years) were randomized into either a 6 wk periodized Squat training regimen, with or without whole body low frequency vibration or a control group. Measures of dynamic and isometric strength (1RM Squats and Isometric Quarter Squats), dynamic power (Depth Jumps and Squat jumps with a 20 Kg load) and body composition (DXA) were assessed. **RESULTS:** Both training groups increased significantly for the Squat 1RM from baseline to week 7 compared to the controls. There were significant group differences for Rate of Force Development at 250 ms, initial peak in force, and Peak RFD. There were also significant group differences for Force at 250ms, Force at initial peak, and MVC. There were significant differences in Peak jump power between G2 and G3 from weeks 1 to 3 under both jumping conditions. Both training groups had significant increases in total lean tissue, lean trunk tissue, and lean leg tissue (g), and significant decreases in percent leg fat. **CONCLUSIONS**: Whole body vibration did not improve maximal force generating capability beyond resistance training alone and actually lead to a decreased performance.

CHAPTER I
INTRODUCTION

Post activation potentiation (PAP) has previously been reported to increase low frequency force, as well as rates of force production during both dynamic and isometric muscle actions. (Abbate *et al* ., 2000; Vanderboom *et al*., 1997; Güllich *et al.*, 1996; Sale *et al*., 2002 and 2004; French *et al*., 2003; Aagaard, 2003; Aagaard *et al.*, 2002). This particular method of attempting to increase force/ velocity characteristics has been studied quite extensively in animal models, but has only received attention with regards to enhanced sports performance in humans over the last 10 years. It has been widely used anecdotally within sporting settings as a form of neuromuscular warm up and performed in addition to the more traditional, temperature related warm up routines. More conventional warm up regimens have aimed at increasing localized muscle blood flow, intra muscular temperature, and nerve conduction velocity (Bishop *et al*., 2003; Gossen *et al.,* 2001 and 2002). The concept of active warm up has become very popular in recent years, which attempts to prepare the target musculature for peak sports specific performance. Such warm up regimens can last between 5 and 30 minutes in duration (Gray *et al*., 2002; Stewart *et al*., 2003). However, such warm up routines may be too taxing and cause both metabolic and muscular fatigue related disruptions to subsequent high-powered performance. Creating a balance between priming prospective strength/power performance, while at the same time minimizing fatigue is the main performance objective of PAP directed protocols.

Previous research has suggested that neuromuscular potentiation can affect rates of force development, increase force produced during high velocity ballistic actions, and help off set fatigue during endurance activity (Güllich *et al*., 1996; Vanderboom *et al*., 1997., Hamada *et al*., 2000 and 2002; Sale *et al*., 2002 and 2004; Aagaard *et al.,* 2002 and Aagaard, 2003; Fowles *et al*., 2003). Increased hydrogen ion concentration within the Sarcoplasmic Recticulum has been linked to the disruption of actively bound cross bridges (Edwards *et al*., 1981). In this process the myosin head is actively displaced from the actin binding site by hydrogen ions, resulting in decreased force production. Potentiation appears to have an opposing action, which may off set such a disruption to the contractile machinery. Specifically, potentiation leads to an increase in low frequency force production following an acute near maximal contractile stimulus.

Sale *et al*. (2002) reported that there was no appreciable increase in high frequency force generation seen after a maximal voluntary contraction (MVC). Having said this, an increase has been observed in force generation produced at the lower motor unit firing frequencies (Fowles *et al*., 2003). Further to these findings dynamic rates of force development have also been seen to increase following MVC's of differing durations up to 10 seconds (Abbate *et al*., 2002; Gullich *et al*., 1996; Vandervoot *et al*., 1983; French *et al*., 2003).

A number of different modes of activity have been used in an attempt to elicit an acute state of post activation potentiation (PAP) (Abbate *et al*., 2001; Rassier *et al*., 2002; Behm *et al.,* 2002, 2004; Jensen *et al*., 2003; Baker *et al*., 2003, 2005; Lees *et al*., 2003; Gullich *et al*., 1996; Bosco *et al*., 1999; Cardinale *et al*., 2003; Scott *et al*., 2004 Smilios *et al*., 2005). Commonly used methods include electrical stimulation to induce tetanic contractions (PAP), Maximal voluntary isometric actions, near maximal dynamic actions, and more recently whole body, low frequency vibration. (Jensen *et al*., 2003; Baker *et al*., 2003, 2005; Lees *et al*., 2003; Gullich *et al*., 1996; Bosco *et al*., 1999; Cardinale *et al*., 2003; Smilios *et al*., 2005).

Specific maximal voluntary contractions (MVC) and near maximal concentric contractions are often used in an attempt to elicit a state of post activation potentiation (Vandervoot *et al.,* 1983; Gullich *et al*.,1996; Ebben *et al.,* 1998; Hysomallis *et al*., 2001; Baker *et al*., 2003; Chiu *et al*., 2004; Baudry *et al.,* 2004 and 2005). The use of MVC's may be more effective than isotonic actions in bringing about a state of PAP due to the heavier loads utilized, as well as the motor unit recruitment patterns seen (Sale *et al*., 2002 and 2004; French *et al*., 2003; Gullich *et al*., 1996). MVC's performed emphasizing a step rise in force development, at the biomechanical angle where peak force generation is seen, may help maximize both motor unit recruitment and firing frequency. Such an intense conditioning stimulus may bring about acute changes in both central and peripheral sites while minimizing fatigue due to the restricted movement and overall metabolic costs of such actions (Hortobadgyi *et al*., 1996; Clarkson *et al*., 2001; Gullich *et al.,* 1996). Isotonic actions performed over a predetermined range of motion may cause greater low frequency fatigue due to higher metabolic cost. This may become increasingly evident if a number of repetitions and sets are used as a PAP stimulus. Bosco *et al*., (1998) showed a 12% increase in mean vertical jump height during a consecutive 5-jump counter movement vertical jump test following low frequency vibration exposure at a frequency of 27 Hz, amplitude 10mm. These authors suggested that low frequency vibration initiated the "tonic vibration reflex" which leads to stretch reflex potentiation via increased 1a afferent volley following the removal of the vibration stimulus.

Using a combination of resistance training methods and low frequency vibration a in an attempt to maximize post activation while minimizing fatigue may be helpful and has received research attention over the last 6 years. Most studies have applied vibration during resistance training (Ronnestad *et al*., 2004; Rittweger *et al*., 2003; Delucuse *et al*., 2002) or as an acute intervention prior to jump performance in an attempt to bring about a state of post activation potentiation (Bosco *et al*., 1998 and 2000). Using whole body vibration in between sets of exercise of a period of weeks is a novel idea which remains to be thoroughly researched.

PURPOSE

The purposes of this study were: 1) To examine the effect of a 6 week, periodized squat training program, with or without concurrent low frequency vibration PAP methods applied upon select force velocity characteristics; 2) to examine whether whole body low frequency vibration in conjunction with resistance training would lead to a greater acute PAP response due to chronic neuromuscular adaptation for the squat plus vibration group; and 3) to examine whether the addition of whole body vibration to resistance training would effect changes in body composition beyond that afforded by resistance training alone.

SIGNIFICANCE OF THE STUDY

Specific resistance training loading patterns have previously been shown to be effective at increasing indices of force and velocity over short term training periods (≤8 weeks). The use of heavy loads (80 – 95% of 1RM) to increase maximal strength and lighter loads (30 – 70% 1RM) to increase power and dynamic rates of force development within a periodized resistance training is commonly seen during "peaking" microcycles (Harris *et al*., 2000; Baker *et al*., 2002; Aaggard *et al*., 2002). Recently a few studies have added whole body low frequency during resistance training in an attempt to maximize the training effect of the resistance training (Roestand *et al*., 2004; McBride *et al.,* 2004) Results have been varied with some studies showing additional enhancement in force and power generating capability following training with others reporting no additional benefit. The use of vibration in between sets of resistance training with the intention to potentiate subsequent sets of exercise has rarely been researched over periods longer than 14 days. Increased research within this area using training studies of longer duration (6 weeks and greater) could be of great practical significance strength training professions as well as to rehabilitative science.

RESEARCH QUESTIONS

1. What effect does 6 weeks of periodized squat training, either with or without low frequency (50Hz) whole body vibration have upon measures of lower body strength and power?
2. What are the acute effects of low frequency (50Hz) whole body vibration on indices of jump performance?
3. What effect does 6 weeks of periodized squat training, either with or without low frequency (50Hz) whole body vibration have on measures of body composition.

HYPOTHESES

1. It was hypothesized that 6 weeks of periodized squat training with low frequency (50Hz) whole body vibration would increase measures of lower body strength and power to a greater degree than squat training alone (Roestand *et al*., 2004).

2a. It was hypothesized that acute application of low frequency (50Hz) whole body vibration would result in a state of post activation potentiation (PAP) leading to enhanced jump performance (Bosco *et al*., 1998; Issurin *et al*., 1994 and 1999).

2b. It was also hypothesized that exposure to chronic low frequency (505Hz) whole body vibration along with squat training would augment to acute effects of vibration resulting in a greater PAP state that could lead to better jump performance (Roestand *et al*., 2004).

3a. It was hypothesized that 6 weeks of periodized squat training with low frequency (50Hz) whole body vibration would enhance lower body muscle hypertrophy when compared to squat training alone. (Bosco *et al*., 1999).

3b. It was further hypothesized that the group receiving the 6 weeks of low frequency (50Hz) whole body vibration would significantly lose body fat. (De Ruiter *et al*., 2003).

ASSUMPTIONS

1. All subjects exerted a true maximal effort during both maximal isometric tasks (MVC Quarter Squat) and dynamic tasks (30 cm depth jumps, Smith Machine back squats, Squat Jumps).

2. All subjects were healthy and had no history of orthopedic dysfunction and had a least 1-year's experience weight training experience.

3. All subjects performed only the Smith Machine exercise protocol focusing upon the lower body musculature during the 6 week training and testing period and did not perform any additional resistance training targeting the lower body.
4. All subjects did not consume caffeinated beverages or tablets four hours prior to both testing and training sessions.

DELIMITATIONS

1. Measures of peak power were calculated indirectly by way of predictive mathematic equation apposed to using a force plate which would have allowed more specific ground reaction force /velocity/time data collection.
2. Only males were used as subjects preventing gender comparisons.
3. The inclusion of the age range 18 – 30 years for young healthy males.
4. The exclusion of subjects with existing neurological disease preventing them from “tolerating” both the intensive resistance training and whole body vibration programs.
5. The exclusion of subjects with a history cardiovascular disease such as a heart attack or stroke.
6. The exclusion of subjects with hypertensive blood pressure.

LIMITATIONS

1. The training and experimental protocols called for maximal isometric, dynamic, and ballistic actions of the lower body musculature. The possibility exists that not all subjects gave maximal efforts for all testing and training exercises. Maximal isometric squats may have been effected to the greatest extent due to the

perceived danger of performing maximal voluntary contractions with high rates of force development using a large muscle mass.

2. As the subject selection criteria calls for individuals to all ready be somewhat experienced with heavy squat exercise, this homogeneous sub group was not representative of the general population of age matched males.

3. Direct measures of dynamic rates of force development, peak velocity, peak power, and concentric impulse could not be recorded during jump tests as a force plate was not available.

OPERATIONAL DEFINITIONS

1. **Maximal voluntary contraction (MVC) (Quarter Squat Exercise).**

   The greatest amount of force that can be produced during a voluntary isometric action by the lower body during an isometric squat performed at a knee angle equal to 135 degrees. Maximal force value corresponds to peak, stabilized value obtained via load cell assessment (kg). Force time characteristics where also assessed with isometric rates of force development expressed as Newton/sec. Time integrals taken form force / time curves produced included the rate of force development (ISORFD) 0 – 30 ms, 0-50 ms, 0 – 100 ms, force at 100 ms, 100-200 ms. 200 – 250 ms. Such time integrals where selected as they have been found to correlate with differing aspects of isometric force generation.

2. **Power Plate Next Generation Vibration platform.**

   A free standing platform which allows subjects to sit or stand while receiving low frequency, whole body vibration (WBV) at varying frequencies (Hz) amplitudes (mm) and time exposures (sec). Subjects will be required to stand on the vibration platform with their knees bent to correspond to a knee angle of 135 degrees and then hold that fixed, static position through out the duration of vibration exposure.

3. **Smith Machine Squat.**

   A free standing scaffold which houses a steel bar which can be rested across the shoulder and upper back of subjects allowing them to perform the back squat exercise. Movement is restricted to the vertical plane. The successful completion of a repetition requires the subject to descend to a level where the upper thighs are parallel with the floor before ascending back to an upright starting position.

4. **1RM.**

   The performance of a maximal dynamic action over a predetermined full range of motion. A measure of maximal concentric strength (Kg). Such a test is used to assess subject's maximal dynamic strength throughout a predetermined range of motion.

5. **30 cm Depth Jump.**

   A two legged jump performed be dropping from a height of 30 cm onto a switch mat culminating in an intense stretch loaded shortening cycle resulting in the generation of high concentric impulse during the subsequent propulsive concentric phase. Such a jump test is used as it requires subjects to perform a very fast stretch shortening cycle relying upon high reflex excitation of alpha motor neurons via type 1A afferents.

6. **Squat Jump.**

A two legged jump performed by resting a 20kg bar across the shoulders , descending to a position so that the upper thighs are at a knee angle of 90 degrees then holding such a position for a count of three seconds. Such a count of three was used so as to negate any possible contribution of the series elastic component and reflex contraction afforded by a prior counter movement (Stretch Shortening Cycle). Following this time period subjects will be verbally prompted to jump upwards in an explosive manner with the intent to jump as high as possible. Such a jump was used to provide an indication of concentric only power during a motion similar to that used during the Smith Machine Squat training program.

7. **Maximal movement intent.**

The ability to apply maximal volitional effort against a mass (weight bar) with the intent to accelerate that mass as forcefully as possible over the pre determined range of movement for a selected exercise. The exercise can be either isometric, isoinertial, or ballistic in nature, and was used in an attempt to maximize isometric, dynamic, or ballistic rates of force development. Commonly referred to as compensatory acceleration.

8. **Post activation-potentiation.**

The increase in dynamic rates of force development and low frequency force following a pre-conditioning stimulus of varying nature (MVC, electrical stimulation, heavy load dynamic actions, supramaximal eccentric actions, whole body vibration (WBV)).

9. Periodization.

The logical phasic method of manipulating training frequency, volume and intensity in order to increase the potential for achieving specific performance goals.

CHAPTER II

LITERATURE REVIEW

The purpose of this study was to investigate the effect of a 6 week, periodized Smith machine back squat training program, with or without concurrent low frequency vibration PAP methods applied upon select force velocity characteristics. Measures recorded included tests of isometric (MVC Back squat) and dynamic strength (1RM Back Squat, 30 cm depth jump, 20kg Squat Jump). The 6 week back squat training regimen was periodised so as to focus initially upon maximal force production (weeks 1 – 3), and then upon maximal rates of force production and power development (weeks 4 – 6). Whole body vibration was applied prior to, and in-between sets of back squat exercise in an attempt to positively impact force/velocity characteristics during subsequent sets of Smith Machine back squats. A secondary purpose of this study was to see if using PAP techniques in conjunction with resistance training would lead to a greater acute PAP response.

POST ACTIVATION POTENTIATION – UNDERLYING MECHANISMS

Post activation potentiation acutely affects twitch magnitude or whole muscle force/velocity characteristics by way of facilitating neural and peripheral mechanisms following a brief, intense stimulus. Such a stimulus can take the form of a maximal voluntary contraction (MVC), an electrically evoked fused tetanus, a series of near maximal dynamic actions, or more recently whole body low frequency vibration. The most commonly reported benefit reported of PAP in the literature is an enhancement in the rate of force development at high activation frequencies (Raisser *et al*., 2000; Abbate *et al*., 2002; Sale *et al*., 2002, and 2004; Aggard *et al*., 2002). This appears to extend to both isometric and high power ballistic actions, with the later benefiting the most from enhanced rates of force development (RFD) at high activation frequencies (Sale *et al.,* 2002 and 2004). The ability to bring about such acute changes in the musculatures explosive qualities has wide ranging implications for strength and power performance.

It appears as though acute neural adaptation is one mechanism behind RFD potentiation during high velocity ballistic actions (Fleck *et al*., 1986; Güllich *et al*., 1996; Ebben *et al*., 1998; Sale *et al*., 1995*,* 2002 and 2004). Explanations cited include increased motor unit synchronization, desensitization of alpha motor neuron input, and decreased reciprocal inhibition to antagonists as potential key mechanisms (Fleck *et al*., 1986; Güllich *et al*., 1996; Baker *et al*., 2001; Baker., 2005; Bove *et al*., 2003; Sale *et al*., 2002 and 2004). In addition, changes in neurotransmitter release during action potential propagation at the neuromuscular junction may lead to protein kinase C dependent utilization of acetylcholine from the reserve pool (Bear *et al*., 2001). An increase in the total amount of quanta containing Acetylcholine released per action potential could be the result. Such an acute adaptation may lead to increased action potential firing frequency leading to a preferential activation of higher threshold motor units. There maybe varying contributions from all three aspects but supporting evidence is equivocal. The rational behind such claims suggests that the performance of a very heavy load dynamic or isometric action would preferentially activate a large number of high threshold motor units, which could be more readily “accessed” during subsequent high power ballistic actions. Such an adaptation however would rely upon a recruitment pattern that is contradictory to the Hennman’s size principle (Hennman *et al*., 1986) which suggests that motor units are recruited in accordance with their size (smallest to largest) and activation frequency going form the lowest the highest. Behm *et al*., (1993) and Zehr *et al*., (1994) speculated that Hennman's size principle might be bypassed during high power ballistic actions. A refractory period prior to agonist activity may allow for greater synchronization of high threshold motor units due to a pre movement silent period within the utilized motor unit pool. The net result would be increased RFD at the initiation of the movement as well as an increase in average power generation seen during ballistic movements. This would ad credence to the complex pairing method of a heavy load, high force isotonic, or isometric action followed by a high power ballistic action.

Recent post activation potentiation theories have focused upon a peripheral locus at the site of the muscle fibers (Sweeny *et al*., 1993; Vanderboom *et al*., 1993, 1995 and 1996; Davis *et al*., 2001 and 2002; Machintosh *et al*., 2002) in opposition to the more centrally based theories citing acute CNS plasticity (Fleck *et al*., 1986; Güllich *et al*., 1996; Baker *et al*., 2001; Baker., 2005; Bove *et al*., 2003; Behm *et al*., 1993). Such theories suggest that PAP may be due to the up regulation of myosin light chain phosphorylation. This up regulation in phosphorylation appears to increase calcium sensitivity during cross bridge cycling, and may have its greatest effects when levels of the ion are low within the myoplasm (Sweeny *et al*., 1993; Rassier *et al*., 2000, and 2002; Sale *et al*., 2002 and 2004; Hamada *et al*., 2000 and 2003). This may have some performance implication during fatigue produced as a result of force generated at lower activation frequencies, but may have little, or no effect, upon peak force production at higher activation frequencies when myoplasmic calcium concentration is near saturation (Sweeny *et al.,* 1993; Sale *et al*., 2002 and 2004; Rassier *et al*., 2000 and 2002; Abbate *et al*., 2002; Hamada *et al*., 2000; McIntosh *et al.,* 2002). Such a factor may be very important if the performance out come is an attempt to increase absolute force production at higher frequencies. If peak force facilitation is the primary performance objective then PAP protocols may not be an effective "warm up" strategy. More conventional temperature dependent warm ups coupled with a gradual increase in load over a period of sets until a repetition maximum is found may still be the most efficient method of maximizing force production. This would appear to be especially evident during maximal isotonic actions.

THE ROLE OF MYOSIN LIGHT CHAIN PHOSPHORYLATION IN POST ACTIVATION POTENTIATION

The regulatory myosin light chains (RLC) found within both skeletal and smooth muscle have previously been shown to increase rates of force development (Sweeny *et al*., 1993; Metzger *et al*., 1989; Raissier *et al*., 2002). Regulatory light chains add structural integrity to the myosin heavy chain alpha helix, forming a junction between the shaft of the myosin filament and the essential light chain (Davis *et al*., 2002).Activation of regulatory light chains is dependent upon phosphorylation of serine residues by a calcium/calmodulin dependent myosin light chain kinase (MLCK). Inactivation of regulatory light chain phosphorylation is bought about by a type I m phosphatase.

The Phosphorylation of myosin light chains appears to bring about increases in dynamic rates of force development, independently of temperature and muscle length. As increasing intramuscular temperature alone has previously been reported to increase rates of force development (Sale *et al*., 2002; Raissier *et al*., 2002; Davis *et al*., 2001) such a temperature independent enhancement may be additive. Such an increase in phosphorylation rates has been implicated as the primary underlying mechanism responsible for inducing a state of potentiation by up regulating cross bridge cycling rates. (Sweeny *et al*., 1993; Vanderboom *et al*., 1993, 1995, and 1996; Davis *et al*., 2001 and 2002; Machintosh *et al*., 2002).

Regulatory light chains in skeletal muscle when phosphorylated appear to increase the sensitivity of actin and myosin to calcium. Such an increase in sensitivity appears to have is greatest performance enhancing effect when myoplasmic levels of calcium are already somewhat depleted. Alternatively, at maximal saturation, RLC's seem not to confer any performance enhancing benefits (Davis *et al*., 2001 and 2002; Machintosh *et al.,* 2002). This is in agreement with Sale et al., (2002 and 2004) who suggest that an increase in sensitivity to calcium, when calcium concentration is low, increases both low frequency force and rates of force development at higher activation frequencies.

Sweeny *et al*., (1993) suggested a mechanism of action for myosin light chain related force enhancement. These authors suggested that when the light chains are phosphorylated, cross bridges swing out and away from the myosin back- bone, which brings the actin-binding site closer to the actin filaments. The net result of this action would be a greater amount of crossbridge's formed leading to greater force generation during a twitch. This in part explains why under none acidic conditions potentiation is length dependent, because at longer muscle lengths the individual myofilaments may be too close to one another for myosin light chains to add structural integrity to the cross bridge. Adhikari *et al*., (1999) showed via probe analysis that regulatory light chains are somewhat mobile prior to phosphorylation, but increase their mobility two fold upon phosphorylation.

Davis *et al*., (2002) suggested that regulatory myosin light chain phosphorylation up regulates the flux of weakly attached cross bridge's by way of increasing the actin-catalyzed phosphate from myosin, independent of the conventional interaction seen between calcium and troponin. Such an interaction would have implications when calcium concentration is low, such as during fatigue induced by long-term sub maximal contractions or endurance activity. This again adds support for PAP induced RLC phosphorylation up regulation as the primary strategy to increase low frequency force and rates of force development.

Macintosh *et al*., (2002) tried to enhance maximal shortening velocity by imposing electrically stimulated, un-fused tetanic contractions of the Medial Gastronomies of the rat. Three pulses per second at a frequency of 80 Hz resulted in an increased maximal shortening velocity from 60.5 to 91.8 mm/s. Additionally, myosin regulatory light chain phosphorylation increased from 11.1% at rest to 32.9 % after 4 seconds of intermittent electrical stimulation at 80 Hz. Light chain phosphorylation was also increased following an additional seven second intermittent pulse interval. When peak-shortening velocity was assessed at optimal length after the 7-second potentiating stimulus, isometric force was shown to be five times as great compared to as the isotonic condition. Of interest, these researchers found that although the rate of light chain phosphorylation was sustained from 4 to 7 seconds, the rate of shortening development decreased. The authors suggested that there might be a slower change in the rate of shortening velocity because maximal velocity is being approached. Such a statement is intuitively appealing, but more research is needed within this area to elucidate what is happening to the muscle architecture when maximal shortening velocities are approached. This mechanism may work independently of phosphorylation of Myosin Light Chains and may be affected more by neurological factors.

The effects of training upon myosin light chain function were studied by Bozzo *et al.,* (2003). Rats were used to study the effects of imposed hypertrophy, atrophy, and a combination of both treatments. The atrophy protocol involved placing the rat's hind limbs in a suspended position for a 14-day period to mimic a reduced gravity environment. The hypertrophy group were administered the Beta A agonist Clenbuterol for a similar period, with the combined group undertaking both conditions simultaneously. Histological analysis of the soleus muscle revealed that there was an increase seen in the Myosin Light Chain sub type MLC2f content (Clenbuterol 30.9% increase, Hind limb induced atrophy, 23% increase, Combined treatment increased 25.3%) for all conditions when compared to a control soleus muscle. There was also seen an up regulation in phosphorylation rates of within the same MLC subtype. This would suggest that the soleus, a muscle comprised primarily of type I slow twitch fibers, can transition towards exhibiting contraction type characteristics normally seen in Type II muscle fibers. The authors also suggested that this occurred independently of induced hypertrophy or atrophy. This could have wide-ranging implications if such findings could be duplicated in human subjects. This could, in part explain why resistance training status seems to effect responsiveness to PAP with more experienced trainers responding more favorably. It could also explain why some athletes who participate primarily in endurance sports, and are shown to have a high proportion of Type I fibers but also resistance train, still respond favorably to PAP protocols. More research is needed within this area using human subjects to see if such results can be duplicated.

EFFECTS OF FIBER TYPE UPON PAP

Potentiation appears to be more specific to Type II muscle fiber types when compared to Type I (Abbate *et al*., 2001; Chiu *et al*., 2003 and 2004; Hamada *et al*., 2000 and 2003). This has important sport specific implications for resistance-trained individuals since the greater amounts of the "fast" Myosin isoform within Type II fibers may lead to greater rates of myosin light chain phosphorylation (Sale *et al*., 2002). Although greater potentiation of RFD is seen in Type II fibers, enhanced force production at low frequencies has been demonstrated in Type 1 fibers (Sale *et al*., 2002; Hamada *et al.,* 2000 and 2003).

A study carried out by Hamada *et al*., (2000) looked at fiber type and twitch contraction potentiation. Twenty young males' subjects performed a 10 second MVC during a knee extension exercise in an attempt to illicit twitch potentiation. Maximally evoked twitch characteristics were assessed prior to, and following the MVC. The investigators found that there was a negative relationship seen between PAP and the baseline measure of twitch time to peak torque ($r = -0.73$ $p < 0.001$). The moderate to strong correlation accounts for roughly 50% (coefficient of determination RSq = 49%) of the common variance seen between these two factors. The researches then subdivided the experimental groups into the four subjects with the highest potentiation and four subjects with the lowest potentiation responses and took needle biopsies of the Vastus lateralis muscle. Comparative group analysis revealed that the group that exhibited the greatest PAP response had a greater percentage of Type II (72 ± 9% vs 39 ± 7%) compared to the group that showed the least potentiation. Further to this, it was found that the group exhibiting the greatest PAP response also showed the quickest twitch time to peak torque values (61 ± 12 ms vs 86 ± 7 ms $p < 0.05$). These data would suggest that subjects who have a greater percentage of type II fibers are better able to produce a state of PAP following a 10-second conditioning MVC.

Hamada *et al*., (2000) further investigated the effects of training status and type of athlete. The authors looked at post activation potentiation in endurance trained male athletes. Subjects included triathletes, distance runners, active controls, and sedentary controls in order to explore the effects of postactivation potentiation in endurance athletes of differing training status. Both the elbow extensors and the plantar flexor muscles were subjected to a 10-second maximal isometric contraction (MVC) for all subjects. Maximal twitch contractions were evoked via electrical stimulation prior to, and during a five-minute period following the MVC. Results indicated that potentiation was enhanced in both muscle groups. This was in contrast to the distance runners who only showed enhanced potentiation in the plantar flexors. It would appear from the results that prior resistance training had an impact on the specific muscles ability to produce a state of PAP, since only the plantar flexors were affected for the runners, while both muscle groups were able to achieve PAP for the other groups. Previous resistance training my have increased the size of existing Type II fibers as well as up regulating enzymatic activity (myosin ATPase Type II) enhancing Type II fiber contraction characteristics.

A further investigation by Hamada *et al.,* (2003), examined fatigue and PAP within the knee extensors of 8 males ho where deemed to have predominantly type I or type II fibers within this targeted musculature. A total of sixteen MVC's were performed each lasting five seconds in duration with a three second rest interval between each one. Maximal twitches were evoked using electrical stimulation of the vastus lateralis muscle of the right leg prior to the first MVC. Twitches were further evoked during the three second rest period between each of the subsequent MVC'S, and within a five minute period following performance of the last MVC. Results indicated that the group containing the subjects with a greater percentage of Type II fibers produced the greatest decline in MVC force. This finding would agree with previous work, which showed a greater decline in force with subjects who had a predominance of Type II fibers (Linnamo *et al*., 1998 and 2000). The greatest PAP seen in twitch force was apparent early on in the group with the highest proportion of Type II fibers. This initial PAP in twitch force for the mentioned group was only evident early on and eventually was replaced with post tetanic depression in twitch force. Increased low frequency fatigue appeared to affect predominantly Type II fibers rather than Type I as evidenced by the percentage depression in twitch force at the end of the protocol (33.7% Type II vs 17.4% Type 1). Similarly time to peak twitch and half relaxation time were shown to be reduced initially but then increased as the protocol progressed. This suggests that PAP has positive impact upon twitch force, time to peak torque, and half relaxation time as well as M-wave intensity. This would argue in favor of using a limited amount of MVC's in an attempt to bring about a predominance of PAP over low frequency fatigue.

These three studies carried out by Hamada provide evidence in favor of PAP of force time characteristics within subjects with a higher percentage of Type II muscle fibers and, or a greater size of Type II fibers due to resistance training induced hypertrophy.

TRAINING STATUS

Resistance trained individuals may benefit more from potentiation than non-resistance trained individuals. The greater size of their Type II fibers, as well as their greater ability to tolerate high loads close to their maximum without exhibiting high levels of fatigue may be responsible for the greater benefits from potentiation. Other research has also indicated that there is a benefit to endurance performance, specifically that potentiation within Type I fibers helps off set low frequency fatigue. As mentioned elsewhere potentiation increases force, but only at the lower end of the motor unit activation spectrum (Sale *et al*., 2002).

Increases in dynamic rates of force development appear to be the most beneficial acute adaptations with regards force /velocity characteristics. Chiu *et al*., (2003) carried out a study looking at comparing response to post activation potentiation in athletic and recreationally trained subjects. Subjects carried out a heavy load warm up which consisted of performing 5 sets of 1 repetition during a back squat exercise utilizing loads equal to 90% of the subjects pre determined 1 repetition maximal lift (1RM). Jump squats were then performed utilizing loads equal to 30%, 50%, and 70% of back squat 1RM. Jump squats were performed on a force plate so force velocity data could be collected at time points 5 minutes and 18.5 minutes following the heavy load warm up. When the two groups were compared, percentage potentiation (100% indicating no potentiation, greater than 100% indicating potentiation, less than 100% indicating post activation depression) was assessed. The subject's classified as being athletic showed a higher percentage of potentiation than their recreationally trained counter parts. This was attributed to a higher percentage of Type II muscle fibers as well as the greater experience with high intensity training methods evident in the athletic group.

A further study by Chui *et al*., (2004) looked at the effect of performing two different types of workouts within a single day .High velocity squats were performed during both protocols. Loading strategies differed slightly as a fixed load, expressed relative to the subjects pre determined one repetition maximum lift (1RM) equal to 70% was used for the initial session. The second session differed in that if bar velocity dropped below 90% of that produced during the first action the loading was reduced so that bar velocity could be maintained. A total of 10 sets, with 5 repetitions per set were performed for both sessions. Muscle biopsies were taken from the superficial aspect of the vastus lateralis so that myosin heavy chain composition could be assessed. Measures of neuromuscular performance were assessed by way of isometric leg extensions at an angle of 90 degrees. Results indicated that there was high frequency fatigue present following workouts 1 and 2 resulting in maximal force decrements (16.9% and 19.9% respectively). There was however, a trend towards a state of post activation potentiation in subjects who showed a higher number of Type II a muscle fibers. This in agreement with Hammada *et al.,* (2000) who reported similar fiber type dependent responses to post activation potentiation.

THE EFFECTS OF PH ON POTENTIATION

The metabolic environment within which the target musculature resides may affect the magnitude of the potentiated response. A change in the local acidotic environment, bought about by high intensity anaerobic exercise appears to affect not only the magnitude of the potentiated response, but also the optimal muscle length at which PAP is seen.

Rassier *et al.*, (2002) examined the effects of changing pH upon length dependent potentiation in skeletal muscle. The study aimed to test the hypothesis that when pH decreased, there is a loss of length dependent calcium sensitivity, which in turn abolishes the length dependence of stair case potentiation. Mouse extensor digitorum muscle fibers were subjected to staircase potentiating electrical trains of differing frequencies at five different muscle fiber lengths. Measurements were taken at extra cellular pH levels equal to 6.6, 7.4, and 7.8. As pH was increased to 7.4 and 7.8, a linear decrease was observed in potentiation with increased muscle fiber bundle length. When pH was lowered to 6.6, the length dependence of potentiation was abolished; this suggests that length dependence of potentiation is highly dependent upon extra cellular pH. Decreasing pH appears to affect the charge potential of the muscle filaments, and. ultimately, and calcium sensitivity.

This could have practical implications when attempting to manipulate post tetanic potentiation states. During intense anaerobic exercise, fatigue can be bought about by localized lactic acid accumulation disrupting cross bridge cycling dynamics. This increased acidity, coupled with decreasing intramuscular pH, may help off set this reduction in force output by negating the normal length dependence seen with potentiation. On the other hand, an increased sensitivity to calcium uptake, when calcium concentration is low within the myoplasm, could have a positive effect upon high frequency tetanic contractions. More research is need in this area to using human subjects, exposing them to differing metabolic stresses before attempting PAP interventions. As most sporting activities require athletes to generate high power outputs over extended periods while battling against fatigue, greater knowledge of how acidotic conditions affect PAP responses could be of great practical importance.

POST ACTIVATION POTENTIATION AND LOW FREQUENCY FATIGUE

Sale *et al*., (2002) reported that if the potentiating stimulus was too great, high frequency force could be disrupted. A maximal voluntary contraction (MVC), 5-10 seconds in length appears to be optimal duration with a longer contraction eliciting a greater amount of low frequency fatigue than actual potentiation (Güllich *et al*., 1996). This may differ if more than one MVC is used in series with a lower MVC duration producing more favorable results. (French *et al*., 2003). If conventional isotonic methods are used to elicit a state of potentiation, the total number of repetitions and sets performed can dictate whether potentiation or increased low frequency fatigue predominates.

THE LENGTH OF THE POTENTIATING STIMULUS

Much of the research dealing with the use of dynamic actions have utilized loads expressed relative to 1RM. Loads ranging between 65 and 95% of dynamic 1RM have been used previously (Gossen *et al*., 2001; Chui *et al*., 2003 and 2004; Baker *et al*., 2003 and 2005; Duthie *et al*., 2002; Jones *et al*., 2003; Smilios *et al*., 2005). With isometric actions (MVCS), maximal angular specific force has been used. When looking at dynamic actions repetitions have ranged between 1-5 reps, for 1 to 10 sets (Chiu *et al*., 2003; Duthie *et al*., 2002; Baker *et al*., 2003; Ebben *et al*., 1998). For isometric contractions a single MVC and a series of MVCS lasting between 3-10 seconds has been used in an attempt to elicit a state of potentiation (Gurllich *et al*., 1996; Schimdbleicher *et al*., 1993; Gossen *et al.,* 2001; Vanderboom *et al*., 1997; French *et al*., 2003).

French *et al.,* (2003) used maximal isometric knee extensions (MVC) as a potentiating stimulus for subsequent power related tests. Fourteen track and field athletes were used as subjects who were either exposed to potentiating stimuli or not. Two MVC protocols were used during testing. Three MVC's lasting 3, or 5 seconds in duration, where utilized in an attempt to induce a state of post activation potentiation. A significant increase in depth jump height (cm) ($p < 0.05$), maximal force production (N), acceleration impulse (m/s/s) and knee extensor torque were seen while using the 3 x 3 protocol. No significant changes were noted for CMVJ or 5-second sprint cycle parameters. No significant changes were seen for the 3 x 5 protocol p (>0.05)

A more favorable environment leading to minimal low frequency fatigue while optimizing a state of post activation potentiation appears to have been produced with the 3 x 3 protocol. It is interesting to note that no potentiation seen during the CMVJ, or the 5-second sprint protocols. The authors suggested that because these activities have contraction times above 250 milliseconds that RFD is less of a factor with peak force generation being more of a factor. Haff *et al*., (1997) suggested a similar situation with actions that lasted less than 250 milliseconds being highly reliant upon peak RFD. Depth jumps typically produce greater stretch loads than CMVJ's and utilize faster stretch shortening movements (Murphy *et al*., 1996; Young *et al*., 1999). This may also be true of other protocols that do not see potentiation in counter movement vertical jumps. Further comparison using differing protocols comparing relative duration and frequency may provide results that are more specific.

TIME COURSE OF PAP DECAY

Research has indicated that initially after the heavy load stimulus there is an acute state of fatigue which can last from 30 seconds to a number of minutes depending upon the volume of the pre conditioning stimulus (amount of total work performed over sets). Force disruption because of low frequency fatigue however can last for a number of days (Sale *et al*., 2002; Ingalls *et al.,* 2001).

The potentiated state appears to last anywhere between 1 minute to an hour or more depending upon the mode used to elicit potentiation. As mentioned elsewhere the resultant effectiveness of the potentiating stimulus would appear to be dependent upon the balance between low frequency fatigue and post activation potentiation (Gullich *et al*., 1996; Gossen *et al*., 2001 and 2002; Vanderboom *et al*., 1997; Smilios *et al*., 2005; Baudry *et al*., 2004).

ELECTRICALLY EVOKED TWITCH POTENTIATION (POST TETANIC TWITCH POTENTIATION)

Theories put forward at the level of the neuromuscular junction for increases in twitch responses include an increased presynaptic influx of calcium leading to preferential mobilization of acetylcholine from the neurotransmitter readily releasable pool in the pre synaptic junction (Millar *et al*., 2005; Habets *et al*., 2005; Van Cutsem, *et al.,* 2005). Millar *et al*., (2005) also reported that when comparing phasic, to tonic synapses, a greater magnitude of quanta are released in response to a solitary action potential within phasic synapses. However, the author also reported that postsynaptic depression could arise quickly if a train of high frequency impulses were sent along the motor axon. The authors suggested that tonic synapses are not shown to be highly responsive to single action potentials, but do respond well to multiple presynaptic action potentials, thus increasing their capacity for facilitation and post tetanic potentiation. Such mechanisms seen at the two different types of synapse, May in part, explain why low frequency fatigue and post tetanic potentiation states can coexist. Over stimulation of the alpha motor neurons may lead to post synaptic depression at phasic synapses, which may in part be counteracted by post synaptic potential facilitation at tonic synapses. The net result may still be a prevalence of PAP over low frequency fatigue. Research within such an area is difficult to extend to large muscle masses used in many practical interventions aimed at bringing about a state of PAP. Due to the complexity and diversity of synaptic networks within large areas of muscle it would be very difficult to accurately test such a hypothesis making such a theory highly speculative.

Stair case summation can be induced by directly stimulating the motor axon. Staircase potentiation refers to the progressive increase in developed tension during low frequency stimulation (Rassier *et al*., 2002) During this phenomena presynaptic action potentials fire in specific time phase so that post synaptic potentials summate on one another leading to a potentiated neuromuscular response **(**Abbate *et al*., 2002**).** Summation with facilitation produces a greater post synaptic response than stair case summation alone. Continued increases in calcium concentration, as well as an increase in acetylcholine containing quanta release during presynaptic action potentials have been cited as the primary mechanisms responsible for potentiated post synaptic responses. Such a compound increase in calcium concentration has been referred to as the residual calcium hypothesis. **(**Edwards *et al*., 1981; Sweeny *et al*., 1993; Sale *et al*., 2002; Bear *et al*., 2001; Rassier *et al*., 2002; Abbate *et al*., 2002**).**

Abbate *et al.,* (2002) used high frequency triplets applied via electrical stimulation at a frequency of 150 Hz to single muscle fibers taken from the flexor brevis muscle of mice. The study was carried out to assess the role that free myoplasmic calcium concentration played in electrically induced potentiation. Tetanic stimulation was first applied for either 350 ms or 700 ms. Triplets were applied at the start of the 350ms tetanus or in the middle of the 700ms tetanus. It was shown that a significant increase in force production ($p < 0.05$) was brought about using both methods of application with greater variability seen when the triplet was applied during the middle of the 700ms tetanus. Free myoplasmic calcium concentrations were not altered during the potentiation stimulus; this suggests that the increase in force seen was due to factors other than changes in calcium concentration, such as contractile plasticity. There may be differences seen however, between single fiber and whole muscle calcium dynamics, which may prevent accurate practical cross application.

A very short term form of post synaptic potentiation involves stimulating the motor axon with two or three high frequency pulses very closely grouped together causing pre synaptic action potentials. The resultant postsynaptic potentials have to be very close to one another for facilitation to take place (of the order of 200 msec or less) (Bear *et al*., 2001; Abbate *et al.,* 2002; Baudry *et al.,* 2004). Post activation potentiation, in actuality, appears to be a combination of summation and facilitation, as well post tetanic enhancement. These mechanisms at the site of the motor axon and neuromuscular junction appear to be only a part of the story however, with other acute peripheral adaptations adding greatly to the resultant potentiated response within the targeted musculature.

MVC INDUCED POST –ACTIVATION POTENTIATION

Research utilizing MVC'S have revealed that the optimal time for holding contractions is between 3 and 10 seconds in order for maximal performance enhancement. (Gossen *et al*., 2000 and 2001; Güllich *et al*., 1996; French *et al*., 2003; Hamada et *al*., 2000 and 2003), However, if the contraction period is too short, (less than 3 seconds) no increase in PAP is reported . Conversely, if the contraction period is greater than 10 seconds, PAP may be masked by elevated low frequency fatigue as a result of disruptions to excitation contraction coupling (Chiu *et al*., 2002; Sale *et al*., 2002; Chiu *et al*., 2003 and 2004; Warren *et al*., 2001; Gullich *et al*., 1996).

Behm *et al*., (2004) carried out a study using both voluntary and evoked MVC'S as the primary potentiating stimulus. A range of 1-3 MVC'S were used in an attempt to bring about a state of post activation potentiation. Both twitch, tetanic, as well as submaximal (30%) and maximal (MVC) contractile properties were assessed. Such indices of contraction were assessed at time points corresponding to 1, 5, 10 and 15 minutes following the MVC stimulus. Three protocols were utilized using 1, 2 or 3 MVC's, ten seconds in duration, with 1 minutes rest between MVC's.

Results showed that following the MVC's there were significant increases in twitch force for all protocols ($p \leq 0.05$). The protocol utilizing 3, 10 second MVC'S produced the greatest amount of twitch potentiation at all time points, other than 1 minute post. This could suggest that a higher volume of MVC's are needed to elevate twitch force above baseline, becoming more apparent 5 minutes following the potentiating stimulus. The higher volume of MVC's used may have initially, at the 1-minute post time point, lead to a masking of the twitch potentiation by increased levels of low frequency fatigue.

Measures of peak force were significantly affected by the single, 10 second MVC condition ($p \leq 0.05$) leading to increased peak tetanic force following the MVC stimulus. As much of the previous literature has suggested, there is a decrease seen in high frequency force production these data are interesting. If potentiation of peak MVC force is the primary performance outcome, using such a reduced volume MVC protocol may be advantageous. The increased peak force seen with the one MVC protocol may have resulted from improved synaptic facilitation rather than a classical PAP response as high frequency force is normally not altered, or diminished following a tetanic contraction. (Gossen *et al*., 2001 and 2002; Güllich *et al*., 1996; French *et al*., 2003; Hamada *et al*., 2000; Sale *et al*., 2002 and 2004; Shlumberger *et al.*, 2001; Abbate *et al*., 2002).

Measures of twitch rate of force development (RFD) were significantly greater at the 1-minute post time point for the 2 MVC's condition when compared to the other two conditions. However, rate of force development (n\s) was significantly greater at time points 5 min, 10 min, and 15 min for the 3 MVC condition compared to the other two conditions. This would have practical implications if peak elevation of twitch RFD were the main performance objective after one minute following the potentiating stimulus with the use of 2 MVC's. If an elevated potential for RFD of a slightly lower magnitude is required, which remains for a longer time period (15 ≥ minutes), then 3 MVC's could be used. It would appear again in this instance that the three MVC's condition initially produces the greatest amount of low frequency fatigue, which dissipates greatly by the 5-minute post time point. A trend for increased muscle inactivation was seen during the 3

MVC conditions which approached significance. Such an inactivation could in part be facilitated by increased low frequency fatigue.

SUBMAXIMAL DYNAMIC CONCENTRIC ACTIONS

With regards to near maximal concentric contractions, studies have examined the effects of 1 to 10 repetitions and 1 to 10 sets of lifts on PAP (Jensen *et al*., 2003; Chiu *et al*., 2002; Sale *et al*., 2002; Scott *et al.,* 2004 ; Smilios *et al*., 2005). It appears that the potentiating effects of a prior, near maximal contraction are more readily carried over to concentric actions when compared to isometric actions (Sale *et al*., 2002; Baker *et al*., 2003; Jensen *et al*., 2003; Smilios *et al*., 2005). In addition, maximal force production is not altered, and in some cases even decreased by a prior potentiating stimulus (Shmidtbleicher *et al*., 1993; Güllich *et al.,* 1996; Abbate *et al.,* 2002; Sale., 2002 and 2004).

SUB MAXIMAL AND MAXIMAL ECCENTRIC ACTIONS

The use of near maximal eccentric actions is less commonly used as a potentiating stimulus. Greater forces have been reported during eccentric actions compared to both concentric and isometric actions (Dudley *et al*., 1991; Hortobadgyi *et al*., 1996; Clarkson *et al.,* 2002; Warren *et al*., 2001). Warren *et al*., (2001) reported that maximal and supra-maximal eccentric actions disrupt excitation contraction coupling and can lead to decrements in subsequent concentric force generation. Childers *et al*., (2004) reported that regulatory myosin light chain phosphorylation following high force producing eccentric actions can help produce supra maximal forces which can lead to subsequent force deficits in other action types. A disruption to the excitation-contraction coupling dynamics within the targeted musculature following high load eccentric actions may lead to extensive low frequency fatigue, decreasing power potential during subsequent ballistic actions. If using eccentric actions as a possible potentiating stimulus this needs to be taken into consideration. Different protocols may be needed, with a reduced volume of eccentric actions being employed when compared to near maximal and maximal concentric actions. In addition, as EMG activity has been shown to be less at the same force level when comparing eccentric to concentric actions (Hortobadgyi *et al.,* 1996) the level of CNS activation may be less effective than that produced during maximal isotonic or isometric actions. More research looking at heavy load eccentric actions as a possible potentiating stimulus is needed to assess the efficacy of using such actions.

COMPLEX TRAINING

Practical methods such as complex training have been used in athletic settings in an attempt to improve force and rate of force development during subsequent high velocity ballistic actions (Jensen *et al*., 2003; Hrysomalis *et al*., 2001; Duthie *et al*., 2002; Abbate *et al*., 2001; Chui *et al*., 2003 and 2004; Baker *et al*., 2003 and 2005; Smilios *et al*., 2005). Research in this area has produced varied results. Some studies have reported a positive impact by performing heavy load MVC or concentric actions upon force and rate of force development at high velocities during subsequent high power ballistic actions (Gullich *et al.,* 1996; Abbate *et al*., 2001). While other studies have reported no benefit afforded by maximal or near maximal isometric and concentric action s with regards to increased power during subsequent high velocity actions (Hrysomallis *et al*., 2001; Jensen *et al.,* 2003). Baudry *et al*., (2004) suggested that there was no difference between the PAP responses when dynamic concentric; MVC’s, and eccentric actions were used. Such complex pairings performed in a gym setting may fail to provide performance enhancing results due to the high power exercise being performed in to close a proximity to the potentiating stimulus.

SHORT TERM POST-ACTIVATION POTENTIATION TRAINING STUDIES

Scott *et al.,* (2004) used a heavy load back squat protocol with the intent to bring about a state of neuromuscular potentiation leading to improved performance in both counter movement (CMVJ) and horizontal vertical jumps (HJ) (n = 19 previously resistance trained men). A secondary purpose was to see whether the subjects would favorably adapt to the potentiating protocol over a period of training. Subjects participated in 4 practice sessions as well as 4 training sessions. Four practice sessions were included so that technique could be fine-tuned during the CMVJ and HJ conditions. The four testing sessions were used to assess whether subjects adapted to the repeated exposure to the potentiation protocol. Practice sessions included a 10 minute warm up which consisted of 5 minutes cycling on a cycle ergometer, as well as self selected stretching exercises. A total of 4 sets of 4 repetitions were performed for both the CMVJ and HJ prior to, and following (2 sets prior to, and 2 sets after the completion of the 5RM back squat) a 5RM back squat evaluation. Results indicated that there was an increase seen in both CMVJ and HJ distance over the practice sessions (2% for both jump conditions). A considerable increase was seen however, for the 5RM back squat over the 4 practice sessions (162.4 ± 25.1 kg – 196.9 ± 23.0 kg) suggesting that there was a considerable learning effect for the back squat exercise. The testing sessions consisted of 1 set of both the CMVJ and HJ (order of execution was randomly assigned) followed by a 5-minute rest before a 5RM back squat was performed. A further 5-minute rest was taken between the completion of the 5RM back squat protocol and a further set of jumps. This was carried out in an attempt to minimize low frequency fatigue and to maximize post activation potentiation. No significant differences were seen for maximal and averaged distances following the 5RM back squat protocol ($p \geq 0.05$). It is possible that the performance of five repetitions with a 5RM loading over the back squat range of motion may have caused more low frequency fatigue than potentiation, which was still evident at the 5-minute post mark. The same protocol using quarter range of motion squats within the biomechanical range were force is maximized may have been more effective due to a heavy load and a reduced total work commitment.

LOW FREQUENCY VIBRATION

The use of low frequency vibration as a modality to bring about a state of PAP has been the focus of a number research papers over the last seven years (Bosco *et al*., 1998; Issurin and Tenenbaum, 1999; Cardinale. *et al*., 2003; Ruiter *et al*., 2003). The activation of the "tonic vibration reflex" during imposed whole frequency vibration, and the subsequent potentiation of the stretch reflex has been cited as the primary neuromuscular mechanism responsible for vibration induced post activation potentiation. The activation of localized sensory receptors during vibration exposure has been termed the Tonic Vibration Reflex. Activation of intrafusal fibers contained within muscle fibers, leads to the activation of the stretch-reflex loop. Reflex activation of the Alpha motor neuron leads to an increase in neuronal excitation leading to a decreased sensitivity of the Alpha motor neuron. Increased neuromuscular activity as assessed by way of EMG has previously been reported to take place (Bosco *et al*., 1999, 2000, Cardinale *et al*., 2003). When a muscle is stretched, the muscle spindle contained within it is also stretched. Within the stretched region of the intrafusal fiber there is a central sensory region, which relays information concerning changes in length and tension. They are also referred to as nuclear chain fibers and are innervated by type 1A afferent nerve endings. Such nerve endings have been shown to be the fastest conducting nerves within the human body (Bove *et al*., 2003). Theses type 1A afferent nerve fibers also interact with the Alpha motor neuron leading to an increased or decrease excitability. An increase in reflex excitability within the Alpha motor neuron leads to increased motor unit recruitment and firing frequency. The resultant reflexive contraction is referred to as the stretch reflex, specifically a Myotatic stretch reflex, (Bove *et al*., 2003).

Other sensory receptors are reportedly affected during vibration exposure. The Golgi Tendon apparatus found within the musculotendinous junction is also sensitive to vibration. Too high a frequency, at the site of the Golgi Tendon Organ could potentially lead to inhibition of force production due to an increase in sensitivity of the Alpha motor neuron. As mentioned elsewhere an up regulation of the stretch reflex appears to occur in response to vibration application. Another acute physiological change seen is a reduction in reciprocal inhibition (Torvinen *et al*., 2002). The result of this is an acute increase in flexibility of antagonistic muscle groups. Standing on a vibration plate may have a similar effect as performing proprioceptive neuromuscular facilitation (PNF) stretching upon the upper leg. An increase in proprioceptive discharge has previously been reported during vibration application (Bove *et al*., 2003). Reciprocal inhibition allows the antagonists to apply a regulatory braking effect towards the end of the range of movement within the quadriceps muscle group. A reduction in such a braking phenomena could also lead to a greater power generation during ballistic tasks such as jumping and throwing (Sale *et al*., 1995).

Vibration amplitude and frequency manipulation appears to be an important factor whether you are using whole body vibration as a training stimulus in its self, or in an attempt to potentiate subsequent power performance during power specific tasks. A key site that may be affected by excessive exposure to low frequency vibration could be the neuromuscular junction (Warren *et al*., 2001). Depletion in the localized concentration of the neurotransmitter Acetylcholine could lead to a decreased force production. As Acetylcholine is needed for muscular contraction to take place, reduced concentrations of the neurotransmitter could lead to both a decrease in maximal force generation as well as a decrease in fatigue resistance (Warren *et al*., 2001). Acetylcholine may also be inhibited pre synaptically, thus reducing the release from the pre synaptic membrane into the synapse. Post tetanic depression could then arise in response to further vibration stimulation. Optimal stimulus duration may lead to neuromuscular potentiation resulting in an increase force production at low frequencies as well as an increase in rate of force development (Gullich *et al*., 1996; Sale *et al*., 2002; Cardinale *et al*., 2003). Positive enhancement of vertical jump height has been seen following 4 minutes of low frequency vibration exposure (1 minutes vibration flowed by 1 minutes rest for 4 total sets) resulting in a 2.5% improvement (Torvinen *et al*., 2002). A study carried out by Cunnington *et al*., (2002) reported a 3.8% increase in vertical jump height following 10 sets of 1-minute low frequency vibration. Bosco *et al.,* (1998) reported a 12% increase in a repetitive counter movement jump test following 10 days of whole body vibration using a frequency of 26 Hz and amplitude of 10 mm. It is possible that the repetitive nature of the jump test (5 consecutive counter movement vertical jumps) lead to a greater contribution from reflexive contraction than single counter movement vertical jumps with a slower amortization phase. As low frequency vibration has been previously shown to potentiate the stretch reflex following removal, an acute increase in reflexive capability as during CMVJ's with short ground contact times is to be expected (Bove *et al.,* 2003).

Research concerning the time course of the potentiating effects of low frequency vibration is divided. Low frequency vibration stimulates short-range reflex contraction of the targeted musculature by stimulating the tonic vibration reflex. This causes localized increases in the force of gravity up to 15g. Gullich and Schmidtbliecher *et al*., (1996) suggested that positive enhancement in force velocity characteristics can be seen up to an hour post vibration. It appears that the length of the application of the vibration stimulus has a strong determining effect upon force/velocity potentiation and its time course of decay. Too long a duration of vibration exposure may lead to a low frequency fatigue because of a disruption in Excitation Contraction coupling. Also the excessive duration may affect sensory feedback from the Golgi Tendon Organ (via type 1b afferents) (GTO) leading to inhibitory inputs being sent via interneurons to alpha motor neurons. The net result would be a further reduction in force generating capability (Rittweger *et al*., 2000; Torvinen *et al*., 2002).

Some research suggests that low frequency vibration may preferentially affect the CNS leading to both acute and chronic adaptations. As mentioned elsewhere, acutely there, may be an increase in neuromuscular potentiation bought about following exposure to low frequency vibration. Following chronic exposure over a number of week's increases in the hormones Human Growth hormone and Testosterone has been seen (Bosco *et al*., 2000). A reduction in the catabolic hormone Cortisol has also been reported which may indirectly increase the anabolic action of testosterone and Human Growth hormone. Because of these chronic adaptations, the effect of low frequency vibration exposure has been likened to moderate load resistance training (Bosco et al. 1999; Rittweger *et al*., 2003) and may have similar effects with regards changes in strength, power and body composition.

A study carried out by Rittweger *et al*., (2003) looked at the effects of a 4-minute half squat to exhaustion protocol, with and without superimposed vibration. A total of 19 men and women were used as subjects. Pre and post-tests included a maximal jump endurance test lasting 30 seconds, EMG recorded at 70% of maximal isometric knee extensor torque, and patella tendon reflex analysis. Following the completion of the exhaustive squatting exercise it was found that time to exhaustion was significantly shorter in the group, which performed the half squats with superimposed vibration. Measures of RPE and power post, exhaustive exercise, were not statistically different between groups. EMG analysis revealed that mean power frequency within the Vastus Lateralis was higher during an isometric contraction in the vibration group. Patella tendon reflex amplitude was significantly greater within the vibration group. It appears that half-squat exercise to exhaustion is affected by superimposed vibration as a reduction in time to exhaustion is seen. Motor unit recruitment patterns, as reflected by mean power frequency elevation during vibration exposure suggest an enhanced neuromuscular excitability. As power and force output was not measured during the half-squat exercise it is not clear whether the superimposed vibration affects such variables during the performance of the exhaustive exercise. It is possible that the early onset of fatigue within the vibration group could be due to low frequency fatigue, and/or extended synchronization of motor units resulting from chronic vibration exposure. However as power measures were not different post vibration this could be indicative that higher threshold motor unit activation was not compromised and that fatigue during squatting exercise came about as a result of low threshold motor unit depression.

Training studies using vibration as the primary stimulus as well as in conjunction with resistance training have produced varying results. De Ruiter *et al*., (2003) carried out an 11-week training study using ten untrained subjects. The study specifically looked at the effects of vibration upon max jump height as well as contractile properties of the knee extensors. Subjects were exposed to vibration three times per week on none consecutive days. Subjects stood on a vibration platform at a knee angle equal to 110 degrees. Vibrations were applied at a frequency equal to 30 Hz with amplitude of 8 mm. The training consisted of 5-8 sets of 1-minute vibration exposure with a 1-minute rest period in-between. Testing procedures pre and post included quadriceps femoris MVC (isometric knee extension, as well as voluntary activation and rate of force development. No significant differences were seen between vibration training and control groups during MVC, voluntary activation, and voluntary rate of force development. However, when similar tests were performed but using electrically invoked muscle activation there was a significant increase in rate of force development seen ($p \leq .050$). This would suggest that a certain amount of neural inhibition took place during voluntary activation, which was not present during electrically invoked activation. Counter movement jump height was found to be no different from control measures. The results from this study would suggest that 11 weeks of vibration training does not increase indices of voluntary muscle activation, but that there is a training adaptation with regards RFD highlighted by electrical stimulation techniques.

Schlummberger and Schmidtbleicher, (2001) carried out an investigation utilizing both conventional resistance training methods, and a combination of resistance training with concurrent vibration exposure. A total of 10, previously untrained men were resistance trained over a period of 6 weeks, totaling three training sessions per week. One-legged squats were utilized as the primary exercise targeting the lower body musculature. Each individual training session consisted of performing 4 sets of 8-12 repetitions. Pre and post training force velocity testing consisted of assessing maximal rate of force development (RFD) (n/s), and 1RM lifts. One-repetition maximal efforts in a seated unilateral leg press were recorded at pre, and post training points. Results indicated that at the end of the 6-week period there were no statistical differences in leg extensor force between the two legs with both conditions statistically increasing strength. Also no significant differences were seen in rate of force development although there was a trend toward significance in the leg exposed to vibration. It would appear that the application of vibration during the current study conveyed no performance benefits with regards to improved force, or rate of force production within the knee extensors. In addition, the concept of cross education could have lead to training adaptations within the leg not receiving direct vibration. This phenomenon could mask any potential performance enhancing effects of the vibration treatment. Also the application of vibration during the squatting exercise may have bought about fatigue unduly when compared to conventional squatting. Vibration if used in conjunction with resistance training methods may provide more of a performance enhancing effect if used prior too, and then in between sets in an attempt to potentiate force/velocity properties during subsequent sets. Also, vibration could be applied during specific “sticking points” of a particular exercise in an attempt to briefly increase motor unit synchronization and firing frequency thus allowing the resistance being lifted to pass through that sticking point could be of interest. This could be an interesting research path for future high performance based research interventions.

Most studies looking at using low frequency vibration to bring about a state of PAP have used exposure times between 30 – 60 seconds, for multiple exposures (2 – 10), with 1-minute rest between treatments. The frequency and amplitudes used ranged from 20 – 50 Hz, at displacements ranging from 3 – 10 mm. Maximal muscle activation within the Vastus Lateralis has been shown to be achieved using a frequency of 30hz (Cardinale *et al*., 2003) When higher frequencies were used, a drop off in muscular activation within the same musculature was seen (Cardinale *et al*., 2003). Even though there is seen a reduction in EMG while whole body vibration is applied there may be seen potentiation of the stretch flex once the stimulus has been removed and a short period of inactivity is allowed to pass (120 – 300 seconds) (Ribo Circat *et al.,* 1979, Archangel *et al*., 1979). Higher frequencies up to 50 Hz may elicit a state of PAP even though the initial exposure may not produce the same amount of muscle activation as 30 Hz. The higher vibration frequency however may lead to an enhancement of RFD during subsequent high power actions such as counter movement vertical jumps as a result of increased motor unit synchronization and increased type Ia afferent discharge (Bosco *et al*., 1998 and 1999; Sclumberger *et al.,* 2001). A reduction in the duration of the vibration exposure may be needed however as the likelihood of postsynaptic depression may be increased with increasing vibration frequency (Mester *et al.,* 2005, Cardinale *et al.,* 2002 and 2003). Preliminary data from a study carried out within our laboratory suggests that using 50 Hz for three exposures of ten seconds, with a minutes rest in between exposures has a greater potentiating effect upon counter movement vertical jump (CMVJ) performance than a similar protocol using vibration exposure at 30 Hz. More research is needed within this area to find optimum frequencies and durations of exposure required to bring about the greatest state of PAP.

Studies looking at resistance training and vibration used concurrently are scarce. Ronnestad *et al.,* (2004) performed a study looking at the effects of a 5-week, periodised Smith Machine back squat training regimen, with or without imposed whole body vibration. Pre and post measures included 1RM Smith Machine back squat assessment as well as counter movement vertical jumps for maximal height. A total of 14 subjects took part in the study; two groups were created of equal size (n = 7) by way of random assignment. Subjects then undertook a 5 week periodised Smith Machine back squat training regimen, which required them to squat three times per week on weeks 1, 3 and 5, and twice per week on weeks 2 and 4. Loads utilized ranged from 75% to 88% of the subjects pre determined 1RM Smith Machine back squat. Whole body vibration was applied to the squat + vibration group for the duration of each set at a frequency of 40 Hz. Three sets of 8-10 repetitions were performed on weeks one and four, and four sets of 6 - 10 repetitions were preformed on weeks 2, 3, and 5. Rest periods in between sets where not specified which could impact the subjects ability to recover in readiness for the subsequent set. Results indicated that both groups significantly increased in 1RM Smith Machine back squat strength from pre to post test ($p \leq 0.05$). There was found no significant differences between groups for percent increases in strength following completion of the 5-week program ($p > 0.05$). A trend was seen whoever in favor of the group receiving vibration when percent increases in 1RM Smith Machine back squat were compared (Squat + vibration = 32.4± 9.0% vs Squat only = 24.2± 3.9%). The greater standard deviation seen for the Squat + Vibration group indicates there was a greater amount of variability with the group receiving vibration, ultimately negating any potential significant differences between the two groups.

When indices of counter vertical jump height where assessed only the group who received vibration significantly improved their jump height ($p \leq 0.01$) post training, however, no significant difference was seen when relative jump height changes (% increase from baseline) where compared between groups ($p = 0.088$). This would suggest the application of the vibration stimulus during the resistance training protocol lead to additional neuromuscular stimulus, which was evidenced during a ballistic jump utilizing a stretch shortening cycle. The 9.1 ±5.5 % increase seen in vertical jump following the completion of the 5 week squat + vibration protocol was more than double that recorded by the squat only group (4.2 ± 4.2) although not found to significant ($p > 0.05$). The small number of subjects per group ($n = 7$) coupled with lager variability within the vibration group may have contributed to the non significant differences between the two groups. The use of greater sample sizes ($n = 12$ +) could increase the statistical power and effect size of such an intervention.

This study does suggest however that there is some advantage to applying vibration to more conventional resistance training methods in an attempt to maximize training adaptations in strength, and especially power. The authors cited that increased neural drive as a result of alpha motor neuron reflex excitation bought about by the tonic vibration reflex could help synchronize motor unit recruitment during heavy load resistance training. This could help maintain force/velocity characteristics during heavy load back squats as long as repetitions were low (≤ 6). Completing more repetitions may result in decreased force generating capability due to prolonged synchronization of motor units inducing neuromuscular fatigue. The use of whole body vibration in-between sets of resistance training may be an alternative to vibration applied during resistance training in an attempt to synchronize, and possible preferentially recruit (via a reduction in activation threshold) high threshold motor units in readiness for the high load resistance exercise. More research is need within this area as well as looking at combined methods utilizing vibration applied during, in between, and in conjunction with more conventional resistance modalities aimed at inducing a state of PAP.

CONCLUSIONS

It was the objective of this review to analyze the applicable literature relating to the concept of post-activation potentiation paying attention to the different modalities used. Several conclusions can be drawn for the previous review which included: 1) Post activation potentiation appears to bring about acute adaptations within the central nervous system and the peripheral musculature; 2) increased motor unit synchronization, firing frequency, calcium utilization, and increased phosphorylation of myosin light chains appear to be the primary mechanisms involved in PAP; 3) using maximal voluntary contractions appears to be more effective than using near maximal dynamic actions due to greater force generation and lower metabolic cost of such actions; 4) training status affects responsiveness to all modalities used to elicit a state of PAP, with more highly resistance trained individuals responding more favorably; 5) whole body vibration induces the tonic vibration reflex which leads to increased excitation of the alpha motor neuron via group 1a afferents; 6) whole body vibration can bring about a temporary state of post activation potentiation primarily by way of increasing stretch reflex potentiation following withdrawal of the tonic vibration reflex; and 7) the incorporation of whole body vibration into a conventional resistance training program with the aim to potentiate force/velocity characteristics during resistance exercise performance appears to be a viable, and practical modality worthy of more research.

CHAPTER III

METHODOLOGY

SUBJECTS

Thirty-six men (n = 36) between the ages of 20 – 30 years volunteered to participate in this study. Subjects were recruited from the University of Oklahoma and surrounding areas by way of informational fliers, class announcements and e-mail announcements. Each subject signed written informed consent form, which had previously been approved by the University of Oklahoma's Institutional Review Board. Subjects were semi-randomly, assigned to two training groups (G2, n = 14 and G3, n = 14) and a non-training control group (G1, n = 8). Such a number of subjects per group was found to be adequate to attain a statistical power of .80 or more (Cohen, 1988). Effect size (ES = Post measurement mean – pre measurement mean / pooled standard deviation) was calculated from a previous study of a similar kind which performed 5 weeks of Smith Machine back squat training, with (n = 7) or with out (n = 7) imposed low frequency vibration (Roennstad, 2004). Group 1 acted as an active control group that did not participate in the 6 week Smith machine squat protocol (G1: n = 8) and only participated in testing sessions. Group 2 performed Smith machine back squat training but also received low frequency whole body vibration (50Hz), prior to, and then in between sets of Smith Machine squats (G2: n = 14). The third group performed 6 weeks of Smith Machine squats without vibration application (G3: n = 14). Medical history and current physical activity levels were assessed via completion of the University of Oklahoma's Bone Density Laboratory Health Status Questionnaire. Also subjects were provided with a questionnaire, which allowed them to self-report Frequency, intensity, and duration of resistance training sessions they were currently engaged in.

A total of 6 (G1: n = 6) subjects completed the study within group 1 (Control) due to two subjects dropping out due to conflicting time commitments. One subject failed to complete the training protocol within group 2 (Squat + Vibration) (G2: n = 13) and 3 (Squat Only) (G3: n = 11) subjects failed to complete the full 6-week training intervention. The total amount of subjects who completed all components of the study equaled thirty (n = 30).

EXPERIMENTAL DESIGN

This study utilized a longitudinal design where subjects were assigned to two training groups which where of equal size at the start of the study (n = 14 per group) or a non-training control (n = 8). All subjects had a least 1-year's weight training experience having been working out no more than three times per week with free weights and resistance training machines. Chronological age of the subject was defined as the age in years at the date of their first visit to the Neuromuscular physiology laboratory at the University of Oklahoma, Norman, Oklahoma. Subjects were required to attend two familiarization sessions during which Smith Machine back squats, MVC quarter squats, and 30 cm depth jumps, 20kg Squat jumps and whole body vibration exercises were performed. Over the 6-week training period subjects were required to complete 12 Smith Machine squat workouts with variable loads (55% - 90% 1RM) and sets (3 – 5). Testing sessions were carried out during weeks 1, 3, and 7, over a nonconsecutive two-day period, and consisted of height (cm), weight (Kg) IRM Smith Machine Squat, MVC quarter squat, 30 cm Depth Jump, and a squat jump. 1RM smith machine squat, MVC quarter squat and body composition were assessed on day 1 with jump tests performed on day two. Testing days were 72 hours apart in an attempt to minimize fatigue. The Sayers mathematical peak power estimation was used to estimate depth jump and 20kg squat jump peak power using the height measure attained while jumping off a switch mat. Pre mid and post strength and power measures were analyzed along with percent potentiation during depth jumps at the three testing phases.

PHYSICAL CHARACTERISTICS

The measurement obtained during this study included chronological age, height, weight, 1RM Smith Machine squat, MVC Quarter Squat force/time variables, 30 CM Depth Jump and 20kg Squat Jump. Both jump tests were assessed at weeks 1, 3, and 6 prior to, then following acute whole body vibration application.

Chronological age

Chronological age was defined as the subject’s age in years at the time of their first visit to the neuromuscular physiology research laboratory at the University of Oklahoma. The age ranges of subjects participating in the study were 20 – 30 years.

Standing Height

Standing height was assessed by way of a wall-mounted stadiometer. Subjects were required to remove their shoes and then stand with their backs against the wall against the stadiometer. The heels were placed together and the hands were positioned upon the hips just above the iliac crest. The head was positioned so that the nose was facing directly forward with the top of the head level and stable in readiness for measurement. Following a deep inhalation and a momentary holding of the breath a straight edged measuring device was lowered to the top of the subjects head. Once a measure had been secured subject were instructed to step away from the stadiometer.

Height in centimeters was then read of off the stadiometer and recorded to an accuracy of 0.25 cm.

Body Weight

Body weight was assessed using a Detecto physician's beam scale (Webb City, MO). Each subject had to measurements taken, one with and the other without exercise foot wear. Body weight was recorded in pounds and then converted to kilograms to the nearest kilogram. A second measure weighing the subjects with their exercise footwear on was recorded as jump testing using a switch mat and Fitdrodyne device used total body weight in there respective calculations of jump power.

Training Status

Subjects training status was assessed by way of a combination of questionnaire, self reported training experience and Smith Machine 1RM ability.

SPECIFIC RESEARCH PROTOCOLS

Prior to engaging in 1RM assessment subject under took a 5-minute, low intensity warm upon a Monarch 864 cycle ergometer with no resistance applied at a rate of 60-70 rpm.

1RM Smith Machine Squat

The IRM Smith Machine back squat was performed during the first workout day on week one. Such assessment was worked in with the periodised routine on weeks 1, 3, and six during the first workout of the week. The Cybex free standing Smith Machine apparatus was used to obtain measures of maximal dynamic strength during a Smith machine back squat exercise. Subjects were instructed to approach the bar within the Smith Machine apparatus form behind, ducking their head and shoulder underneath the bar in readiness to get into the starting position. The starting position required subjects to position their heels on a taped off line at a set distance forward of the line of the bar. Such a foot position was selected so that all subjects could descend down to a bottom position during the squat exercise so that their upper leg was parallel with the lifting platform. Feet where placed shoulder width apart with the bar resting across the top of the trapezius and shoulders. The arms were positioned so that hands gripped the bar at equidistant positions from the mid line of the torso to add stability and symmetry to the lift. Subjects were then instructed to take in a deep breath and hold during the descent phase. The bottom of the decent phase was set a level where the upper thighs were parallel with the lifting platform. Subjects were instructed to move forcefully upwards with "maximal movement intent" once they had attained a sufficient bottom position. Such an instruction was verbally given in an attempt to get subjects to maximize acceleration through out the lift. The subject's 1RM were searched for using the methods of Fry and Kraemer (1995). The subject's 1RM were deemed to be the last successfully completed attempt in accordance with guidelines with the heaviest load. Following warm up sets, 5 attempts were allowed to find the subject's 1RM. Three minutes rest was given in between the maximal attempts in an attempt to minimize residual fatigue over multiple trials.

MVC Quarter Squat

The MVC quarter squat was performed on the first day of the week, 10 minutes prior to the start of the 1RM assessment. The MVC quarter squat was performed within a freestanding scaffold, which allowed for a bar to be moved to accommodate specific knee joint angles for each subject. The angle used for each subject was 135 ± 5 degrees as peak force has previously been shown to be maximized during an isometric quarter squat at this angle (Stone *et al.,* 2001). Subjects positioned them selves underneath the bar as if to perform a Smith Machine back squat. The bar height was then adjusted so that knee angle could be set to 135 degrees by way of hand held goniometer assessment. Foot spacing was the same as that used during the Smith Machine back squat so as to assess force/time characteristics but the heels were positioned directly underneath the bar to allow for maximal force transmission upwards against the bar. Once situated under the bar subjects were given verbal instructions to "push fast and as hard as possible "up against the fixed bar for a duration of 3 seconds. The tester counted down from 3 to 1 with the subject pushing upon a final "go" prompt from the tester. A total of four trials were performed with 90 seconds rest in-between attempts. The 90 second rest period was used to allow adequate recover between multiple, maximal trials. Force time data was recorded by way of two load cells placed at opposite ends of the bar providing an integrated signal relayed back to a computer interface. Lab view was used to compute and then analysis force/time data.

Force (N) and rates of force development (N/s) where assessed from force time curves produced within the Lab View program. Time integrals taken form force / time curves produced included the peak isometric rate of force development (PISORFD), time of onset of PISORFD, as well as ISORFD for between time integrals 0 – 30 ms, 0-250 ms and the rate of force at initial force peak (ISOINIp) and average RFD over the whole MVC period (RFDMVC). Measures of force analyzed (n) included MVC (N), time to MVC (ms) force at 30 ms (N), and 250 ms (N), force at initial peak (N) and time at initial peak (ms) will be recorded. Such time integrals where selected as they have been found to correlate with differing aspects of isometric force generation (Mirkov *et al.,* 2003; Aaggard *et al.,* 2002 and 2003).

30 cm Depth Jump

The depth jump from a height of 30 cm was performed on day three of weeks 1, 3, and 7 randomly interspaced with 20Kg Squat Jumps. The depth jump was performed by dropping from two aerobic exercise boxes onto a switch mat (Just jump, Alabama) with a two-foot landing. The just jump switch mat estimates height jumped (inch) from flight time (ms). Subjects rested a broom handle across their upper trapezius and shoulder so that a Fitrodyne linear accelerometer chord could be attached to one end of the broom. The chord was housed within a cylindrical housing, which was interfaced with a graphical computer display. The Fitrodyne provided data concerning mean power (W) and velocity (m/s) during the upward, concentric phase of the jumps and Smith Machine back squat exercises. The broom handle positioning also required the subjects to hold onto it as if performing a back squat exercise. This action negated any contribution to concentric propulsion afforded by a preparatory arm swing (Young *et al*., 1999). Prior to the performance of the depth jump the switch mat was set to the “step on the mate “setting. Subjects were then verbally instructed to rebound as quickly, and as forcefully as possible so as to minimize ground contact time while maximizing musculotendinous stiffness. Such a jump was included to record data concerning power and velocity during a quick stretch shortening cycle movement. A total of 2 trials were performed with 45 seconds rest in-between trials. The average of the two trials was used for data analysis. Such a jump type was used to give a representation of ballistic concentric lower body power while utilizing moderately intensive stretch shortening cycle (SSC).

20 kg Squat Jump

The squat jump was performed on day three randomly interspaced with the 30cm Depth Jump. The squat jump was performed using both the just jump mat and the Fitrodyne apparatus. Subjects were instructed to rest a broom handle across their shoulders as if to perform a back squat. Foot position during the squat jump was standardized to the position used during the Smith Machine back squat. The Fitrodyne apparatus was set in readiness for their squat jump attempt. They were than verbally prompted to step on the mat and to descend to a position were their upper thighs were parallel with the floor and hold that position for a count of three. The tester counted down from 3 to 1 and then prompted subjects to "jump" at estimated zero. Subjects then propelled themselves upwards by way concentric power of the lower body musculature, leaving the ground, being careful not to perform a preparatory dip leading to a stretch shortening cycle. If subjects did perform such a preparatory dip that particular trial was dropped and another performed following a rest period. Data recorded included mean power (W) and mean velocity (m/s) from the fitrodyne, and maximal height (in), flight time (ms) and peak power estimation (Sayers *et al.,* 1999) from the switch mat. A total of two were performed with 45 seconds rest in between trials. The average of the two trials was used for data analysis This type of jump was selected to give a representation of ballistic concentric lower body power while not utilizing a stretch shortening cycle (SSC).

TRAINING PROTOCOL DESIGN

Subjects were required to perform the Smith Machine back squat exercise with, or without low frequency vibration applied prior to, and then in-between sets. The program followed a periodised design focusing upon maximal strength gain during the first three weeks, then maximal power and rate of force generation over the final three weeks. Such a mixed design was used as previous work has supported the efficacy of such an extended microcycle (Stone *et al.,* 2003, Harris *et al.,* 2000). Subjects performed the Smith Machine Back squat twice per week with sessions 72 hours apart (training on a Monday and Thursday or a Tuesday and Friday). Such a recovery period was used so as to minimize residual fatigue from the previous workout sessions. Loading ranged from 55% to 90.0% of the subjects predetermined 1RM at weeks 1 and 3. Loads utilized during the final three weeks of the protocol ranged from 55% to 85% of Smith Machine back squat 1RM. During the second work out of the week the load was reduced by 15% to allow recuperation from the previous "heavy session" as well as to achieve greater mean bar velocity as assessed by the Fitrodyne. During the second session of the week from week four onwards subjects were instructed to perform "speed squats" by continuing the squat movement upwards, raising up onto their toes by way of a strong contraction of the Gastrocnemius muscles of the lower leg. Subjects were verbally encouraged to push as forcefully as possible throughout the full range of motion of the Smith Machine squat exercise. Rest periods in-between sets were set at 4 minutes so as to allow for recovery of force generating capabilities in readiness for the next set.

Weekly loading progression for Smith Machine Squats

	Sets		**Repetitions**	**% 1RM Load**	
Week 1	4	x	5	(85% - 70% of 1RM)	(2 x 5 first workout)
Week 2	3	x	4	(88% - 75% of 1RM)	
Week 3	3	x	3	(90% - 80% of 1RM)	(1 x 3 first workout)
Week 4	3	x	5	(85% - 70% of 1RM)	
Week 5	4	x	5	(75% - 60% of 1RM)	
Week 6	4	x	6	(65% - 55% of 1RM)	

- All sets were performed with maximal movement intent in an attempt to maximize acceleration with the load used during that particular workout.
- Reduced volume loads were used during the first workout of the week on weeks 1 and 3 as 1RM squat assessment was performed prior too performing sets with the newly acquired 1RM measure.
- All sets were performed as speed squats during the last three workouts in an attempt to maximize power generation.

Vibration PAP protocol

Whole body vibration was applied by way of a power plate, next generation vibrating platform. Subjects stood on the platform holding an isometric quarter squat position similar to the position attained during MVC Quarter squat assessment. Foot position was the same as that used during both the Smith Machine back squat and Squat Jumps. Subjects reached out and held onto handles in front and slightly to the sides of their body. The amplitude and frequency of vibration of the vibration stimulus was then set using a touch sensor computer display in directly in front of the subject.

The subjects who received low frequency vibration in conjunction with Smith Machine back squats did so firstly 210 seconds (3 minutes and 30 seconds) prior to the start of the first non-warm up set. Subjects were exposed to low frequency vibration at a frequency of 50hz for 30 seconds at a low amplitude (3 – 5 mm) Such a placement of vibration would allow 180 seconds (3 minutes) rest following vibration exposure in an attempt to allow for possible stretch reflex potentiation prior to the first set of Smith Machine squats. Vibration was then applied intermittently utilizing three exposures of 10 seconds at the same frequency but at high amplitude (6 – 8 mm) at time points corresponding to 60, 120, and 180 seconds into the 240-second rest period. Vibration was applied for 30 seconds (50Hz, 3-5mm) prior to the first work set in an attempt to potentiate force and power production during the first heavy work set. Vibration was then applied intermittently in-between sets following the completion of the initial set in an attempt to compensate for possible reductions in alpha motor excitability produced by multiple repetition heavy load resistance training by initiating type 1a afferent reflex volleys in response to vibration stimulation. A reduced time course of exposure (10 seconds) was used in an attempt to reduce potential for inducing post activation depression (PAD) rather than post activation potentiation (PAP) resulting from to long a time course of application at such a frequency (50 Hz). When subjects where not being exposed the vibration they were instructed to sit in a chair with the legs elevated against a wooden box. The training group not receiving whole body vibration sat down for the full 240-second rest period until it was ready to perform their next set of Smith Machine back squats.

Vibration treatment

(Rest period = 240 seconds) Total sets performed =   3 – 4.

```
                 (180s)
 - 210 secs /-------- /squat / 0----------------60---------------120-------------180-----------240s
           (sit)                        (sit)       V1     (sit)      V2    (sit)      V3    (sit)
  (50*30)                                      (50*10)          (50*10)          (50*10)
```

(30 seconds of accumulated vibration, high amplitude 6 – 8 mm)

Non Vibration treatment

(Rest period = 240 seconds) Total sets performed =   3 – 4.

```
            (210s)
-210 secs /---------/squat / 0------------------------------------------------------------------ 240
           (sit)                                          (sit)
   (no vibration)                                    (no vibration)
```

Both training groups performed 3 warms up sets prior to receiving either 50*30 seconds of vibration (low amplitude 3– 5 mm), or sat until the first “work set” of the squat protocol.

- Each warm up set became progressively heavier until a load equal to 90% of the load used during the first “work set” was reached.
- Subjects stood on a vibration platform in a quarter squat position with their knees bent at an angle of 135 degrees.
- Vibration was applied in between sets in three bouts of 10 seconds at a frequency of 50 Hz and high amplitude (6 – 8 mm).
- Control group performed testing only on weeks 0, 1, 3, and 7.

EXPERIMENTAL EXPLANATION

Groups: Gr 1 (n=6) Control group, no training.

Gr 2 (n=13) 6 weeks of squat training + whole body low frequency vibration.

Gr 3 (n=11) 6 weeks of squat training only.

Basic Design:

Pre-Test	Mid Test	Post-Test
(Week 1 of training)	(Week 3 of training)	(Week 7; 1 week after the intervention)

Testing Schedule:

Pre-Test	**Mid-Test**	**Post – Test**
1RM Squat Strength (kg)	**1RM Squat Strength (kg)**	**1RM Squat Strength (kg)**
Dj (pre and post V)	**Dj (pre and post V)**	**Dj (pre and post V)**
a. Height (cm)	a. Height (cm)	a. Height (cm)

b. Peak Power (W)	b. Peak Power (W)	b. Peak Power (W)
c. Peak Power/kg/BW	c. Peak Power/kg/BW	c. Peak Power/kg/BW
d. Mean Power (W)	d. Mean Power (W)	d. Mean Power (W)
SQj (pre and post V)	**SQj (pre and post V)**	**SQj (pre and post V)**
a. Height (cm)	a. Height (cm)	a. Height (cm)
b. Peak Power (W)	b. Peak Power (W)	b. Peak Power (W)
c. Peak Power/kg/BW	c. Peak Power/kg/BW	c. Peak Power/kg/BW
d. Mean Power (W)	d. Mean Power (W)	d. Mean Power (W)
Isometric Squat (RFD)		**Isometric Squat (RFD)**
a. RFD to 30ms (N/s)		a. RFD to 30ms (N/s)
b. RFD to 250ms (N/s)		b. RFD to 250ms (N/s)
c. RFD initial peak (N/s)		c. RFD initial peak (N/s)
d. Peak RFD (N/s)		d. Peak RFD (N/s)
e. Time Peak RFD (ms)		e. Time Peak RFD (ms)
f. RFD for MVC (N/s)		f. RFD for MVC (N/s)
g. Force at 0 ms (N)		g. Force at 0 ms (N)
h. Force at 30 ms (N)		h. Force at 30 ms (N)
i. Force at 250ms (N)		i. Force at 250ms (N)
j. Force initial Peak (N)		j. Force initial Peak (N)
k. Time to initial Peak (ms)		k. Time to initial Peak (ms)
l. MVC force (N)		l. MVC force (N)
m. Time at MVC (ms)		m. Time at MVC (ms)

Body Composition	**Body Composition**
a. Total body fat (%)	a. Total body fat (%)
b. Leg % fat (%)	b. Leg % fat (%)
c. Trunk % fat (%)	c. Trunk % fat (%)
d. BF-FFLBM	d. BF-FFLBM

EXPLANATION OF EACH PARAMETER OF INTEREST

1RM Smith Machine back squat: Test used to assess maximal isoinertial strength over a predetermined range of motion (kg).

30 CM Depth Jump (Dj) (Pre and Post vibration): A jump test used to assess reactive explosive strength utilizing a stretch shortening cycle (SSC).

a. Dj jump height (cm): Maximal vertical height attained estimated from flight time (ms) from a just jump switch mat.

b. Dj Peak Power (W): Maximal power calculated using the Sayers nomogram using data collected for subject’s body mass (kg) and maximal height jumped (cm).

c. Dj Peak Power per kilogram of body mass (W/kg): Maximal power calculated using the Sayers nomogram divided by the subjects body mass (kg).

d. Dj mean power (Fitrodyne): The average power calculated throughout the entire concentric phase of the Depth Jump via a linear line force transducer (W).

20kg Squat Jump (Pre and Post vibration): A jump test performed with a 20 kg Olympic size barbell placed across the shoulders over a just jump switch mat. The starting position required subjects to descend to a position where the upper thighs were parallel, or as close to parallel to the switch mat without elevating onto the toes.

This position was then held for a 3 second count in an attempt to negate any potential contribution from the series elastic component during a stretch shortening cycle (SSC) as seen during the Depth Jump. Subjects were instructed to jump vertically as high as possible.

a. 20kg Squat Jump height (cm): Maximal vertical height attained estimated from flight time (ms) from a just jump switch mat.
b. 20kg Squat Jump Peak Power (W): Maximal power calculated using the Sayers nomogram using data collected for subjects body mass (kg) and maximal height jumped (cm).
c. 20kg Squat Jump Peak Power per kilogram Body Mass (W/kg): Maximal power calculated using the Sayers nomogram divided by the subjects body mass (kg).
e. 20kg Squat Jump mean power (Fitrodyne): The average power calculated throughout the entire concentric phase of the Depth Jump via a linear line force transducer (W).

Isometric Squat: A squat performed within a Smith Machine apparatus, fixed in position (135 ± 5 degrees) by two equidistant apart chains attached to two Iomega 1000 load cells. Subjects applied force against the fixed bar (as fast and as hard as possible for 3 seconds) which produced tension within the chains attached to the Iomega load cells. The two load cell signals were integrated into one and converted from mill volts to Newton's for data analysis by a Lab View software analysis package.

a. Rate of force development from 0 – 30 ms (RFD30ms) from the onset of contraction taken from a Force/Time curve produced by Lab View software during a 3 second maximal voluntary contraction (MVC) (N/s). The initial rate of force development recorded during the first 30 milliseconds following the onset of contraction (N/s). Often referred to as “starting strength” and correlated highly with the ability to accelerate a un weighted limb quickly (example, boxers jab) (Siff *et al*., 2000, Haff *et al*., 1997).

b. Rate of force development from 0 – 250 ms from the onset of contraction taken from a Force/Time curve produced by Lab View software during a 3 second maximal voluntary contraction (MVC) (N/s) (RFD250ms). The rate of force development during the first 250 milliseconds following the onset of contraction. Cited as being the ceiling time frame for explosive force generating capability (Shmitbleicher *et al.,* 1993, Haff *et al.,* 1997).
c. Rate of force development at first initial peak in force (N/s) (RFDinitial). The rate of force development taken from 0 to the first initial peak in force from a Force/Time curve produced by Lab View software during a 3 second maximal voluntary contraction (MVC). Such a value is representative of “explosive strength” or the ability to accelerate weighted objects quickly (example throwing a shot put). (Siff *et al.,* 2000, Haff *et al.,* 1997, Stone *et al.,* 2002).
d. Peak rate of force development (N/s) (PRFD). The peak rate of force development taken from a 50 data point sample from the Force/Time curve produced by Lab View software during a 3 second maximal voluntary contraction (MVC). Such a value has been shown to correlate strongly with both jump and sprint performance (Stone *et al.,* 2002, Carlock *et al.,* 2004, Young *et al.,* 1999).
e. Time of onset of peak rate of force development (ms) (TPRFD). The time of onset of the 50 data point sample taken from the force/time curve produced by Lab

View software during a 3 second maximal voluntary contraction (MVC). Such a value provides information concerning the time frame over which subjects take to reach peak rate of force generating capability. The shorter the time frame taken to reach peak rate of force development the more “explosive” the action (Haff *et al.,* 1997 and 2004).

f. Average Rate of force development during a 3 second maximal voluntary contraction (MVC) (N/s). MVC was taken as a 0.5 second average of peak data points to provide a stable measure of maximal isometric force generating capability (Haff *et al.,* 1997 and 2004) (RFDMVC). Such a value provides an indication of subject’s ability to accelerate from the onset of contraction to MVC over a 3 second time frame.

g. Force at 0 milliseconds (F0ms). A data point selected from a force/time curve indicating the onset of contraction manually selected by the tester using Lab View software from a 3 second maximal voluntary contraction (MVC) force/time graph. Such a value is commonly referred to as rest tension and can affect the resultant rate of force development (Van Cutsem *et al.,* 2005).

h. Force at 30 milliseconds following the onset of contraction (F30ms). A data point selected from a force/time curve indicating the force level at 30ms following the onset of contraction.

i. Force at 250 milliseconds following the onset of contraction (F250ms) (N). A data point selected from a force/time curve indicating the force level at 250ms following the onset of contraction.

j. Force at initial peak in force production (N). A data point selected from a force/time curve indicating the force level the first initial peak in force following the onset of contraction during a 3 second MVC. Initial peak was defined as the highest single data point reached following the onset of contraction which was at least ten Newtons greater than the following data point force reading (Aaggard *et al.,* 2002).

k. Time to initial peak in force (ms). The time taken from the onset of contraction to reach the first initial peak in force production during a 3 second MVC. The combination of force at (N), and time at (ms) initial peak provides an index of concentric impulse during the early stages of contraction (Aaggard *et al.,* 2002).

l. Maximal Voluntary Contraction Force (MVC) (N). The maximal isometric force generated during a Quarter Squat recoded over a 0.5 second time window taken from a Force/Time curve produced by Lab View software. Such a value provides a measure of a subject's maximal force generating capability during an Isometric Quarter Squat within a 3 second time window.

m. Time at MVC (ms). The time taken to go from FO to maximal voluntary force within a 3 second window. Such a value provides an indirect measure near maximal motor recruitment (Enoka *et al.,* 1996).

DATA ANALYSES

Statistic analyses were performed using SPSS for Windows (V.12.0). Descriptive statistics were used to describe the physical attributes and each parameter of interest expressed as means ± standard errors. Each parameter that had multiple trials was subject to a one-way repeated measures ANOVA in order to produce the most stable representation for that parameter. Bonferroni pair-wise comparisons were used as a post hoc analysis if significant differences were found ($p \leq 0.05$). The initial analysis included a one-way ANOVA to explore baseline (pre-test) values for each parameter of interest. Once again if there was a significant group effect then a Bonferroni pair-wise comparison was utilized as a post hoc analysis. 3. For the parameters that were tested during weeks 1, 3, and 7 (1RM Squat, Dj, SQj) a 2 way repeated measures ANOVA (group [3] * Trial [3] was used with Bonferroni post hoc comparisons. Since the Dj and SQj parameters (height. Peak power, Peak power/kg, mean power) were also assessed pre and post acute vibration at each time period (week 1, 3, 7) a 3 way repeated measures ANOVA (Group [3], Trial [3], Time [2]) was used with Bonferroni post hoc comparisons and to re-analyze significant interactions, the data was split by group. For the rest of the parameters of interest a 2 way repeated measures ANOVA (Group [3] * Trial [2]) was used and again Bonferroni post hoc analysis as well as split data files by group were utilized. 1 way ANOVA were used to compare groups percent change in variables between weeks 1 and 3 and 3 and 7 and 1 and 7. Percent change was calculated as {Post value – pre value / pre value x 100}. Significance level was set at $p \leq 0.05$.

CHAPTER IV

RESULTS AND DISCUSSION

This study was conducted to investigate the effects of a 6 week, periodized Smith Machine Squat training regimen, with or with out imposed Whole Body Low Frequency Vibration prior to and then in between sets of exercise upon indices of neuromuscular function. College aged males were used as the targeted subject population for the study. The results of this study are presented first as baseline characteristics for; Physical characteristics for each subject Group at baseline, then; baseline data 1RM Smith Machine Squats, 30 cm Depth Jumps and 20Kg Squat Jumps; baseline data for rate of force development parameters of interest; baseline data for Force/time parameters of interest and baseline data for Body composition parameters of interest. Next, one-way ANOVA analyses are presented for the same performance parameters motioned above showing potential statistical differences between groups at baseline. Third, two-way repeated measures ANOVA data are discussed and plotted highlighting any significant Group*Trial interactions for all parameters of interest, then measures of Depth Jump and Squat performance, both prior to, and fter receiving whole body low frequency vibration are discussed. The final section of the results presents data for percent change (%) from weeks 1 and 7 for all the parameters of interest.

SUBJECT CHARACTERISTICS

The subjects in this study were all college aged males recruited from the University of Oklahoma, Norman Campus. A total of 36 individuals were initially recruited for the study. A total of 30 subjects completed the entire 6 week training and all testing sessions (n = 30). A total of 6 subjects did not complete the study due to conflicting time commitments, illness, or not completing the desired amount of workouts leading to their exclusion form data analyses. Subjects were allocated to one of three groups in a semi randomized manner resulting in 6 subjects in a control group (G1), 13 subjects in a Squat + Vibration Group (G2), and 11 subjects in a Squat Only Group (G3)

Table 1 displays the physical characteristics for each group at baseline. A one-way ANOVA revealed no significant differences between subjects age, height, or percent body fat, although a significant difference was seen between group for weight ($p \leq 0.05$), however, post hoc pair-wise comparisons revealed no significant differences between groups ($p \geq 0.05$).

Table 1. Physical Characteristics for each Group at baseline

	Group 1 (Control n = 6)	Group 2 (Squat + Vibration n = 13)	Group 3 (Squat Only n = 11)
Age (yrs)	22.8 ± 0.90	24.1 ± 0.87	23.2 ± 0.86
Height (cm)	177.67 ± 3.53	181.89 ± 1.89	179.27 ± 2.02
Weight (kg)	87.15 ± 5.81	83.83 ± 3.44	73.86 ± 2.27
% Fat	15.15 ± 3.53	15.10 ± 1.41	15.65 ± 1.58

Values are Means ± SE
Control – Performed just testing
Squat + Vibration – Performed testing, 6 weeks of training with added whole low frequency vibration.
Squat Only – performed testing and 6 weeks of training

BASE LINE MEASURES FOR 1RM SQUAT, 30 CM DEPTH JUMP, AND 20 KG SQUAT JUMP

Table 2 outlines base line measures for 1RM Squat (kg), as well as Jump height (cm), peak power (W), peak power per kilogram of body mass (Peak power/kg) , and mean power as assessed via Fitrodyne © for both the 30 cm Depth Jump and the 20 kg Squat Jump.

Table 2. Baseline Data for 1RM Squat, 30 cm Depth Jump, and 20kg Squat Jump

	Group 1 Control (n=6)	Group 2 Squat + Vibration (n=13)	Group 3 Squat Only (n=11)
1 RM Squat (kg)	139.29 ± 14.79	120.22 ± 7.41	91.36 ± 5.68
Depth Jump	a. 48.79 ± 2.90 b. 4877.80 ± 162.35 c. 56.30 ± 2.44 d. 1505.00 ± 80.08	a. 49.82 ± 2.81 b. 4753.55 ± 239.15 c. 57.00 ± 2.22 d. 1485.15 ± 66.85	a. 43.26 ± 1.76 b. 3960.20 ± 146.74 c. 53.09 ± 1.58 d. 1205.91 ± 57.55
Squat Jump	a. 35.07 ± 2.39 b. 4951.24 ± 204.43 c. 57.01 ± 2.18 d. 1402 ± 73.95	a. 35.53 ± 2.29 b. 4792.01 ± 241.43 c. 57.30 ± 1.73 d. 1360.92 ± 61.00	a. 28.86 ± 1.19 b. 3992.29 ± 140.17 c. 53.41 ± 0.98 d. 1064.64 ± 80.78

Values are Means ± SE
1RM Squat – One repetition maximum Smith Machine Squat value.
Dj – 30 cm Depth Jump
a. Maximal jump height (cm)
b. Peak jump power (W)
c. Peak jump power per kilogram of body mass (Peak power/kg)
d. Mean jump power assessed via Fitrodyne ®.

BASE LINE MEASURES FOR RATE OF FORCE DEVELOPMENT PARAMETERS OF INTEREST

Table 3 outlines rate of force development parameters of interest which include rate of force development at 30 ms following the onset of contraction (N/s) (RFD 30ms), RFD at 250 ms (N/s), RFD at initial peak in force (N/s), Peak RFD (N/s), Time of onset of Peak RFD (ms), and the average rate of force development over the whole MVC (RFD MVC).

Table 3. Baseline measures for Rate of force development parameters of interest.

RFD Variables (N/s)	Group 1 (Control n = 6)	Group 2 (Squat +Vibration Group) (n = 13)	Group 3 (Squat Only Group) (n = 11)
RFD 30 N/s	2410.59 ± 642.87	1292.40 ± 380.30	1270.82 ± 421.99
RFD 250 N/s	6821.43 ± 1206.44	4525.87 ± 310.65	3186.21 ± 467.44
RFD ini P N/s	9253.70 ± 660.75	5835.85 ± 693.60	4254.48 ± 744.38
Peak RFD N/s	17373.43 ± 1835.57	10461.40 ± 1008.79	8172.45 ± 1080.64
Time PRFD ms	99.67 ± 10.63	144.83 ± 19.51	156.05 ± 33.60
RFD MVC N/s	1178.50 ± 195.07	1197.70 ± 252.49	807.98 ± 122.58

Values are Means ± SE

BASE LINE MEASURES FOR FORCE/TIME PARAMETERS OF INTEREST

Table 4 outlines baseline measures for all Force/Time parameters of interest which included Force at 30 ms from the onset of contraction (F 30ms) (N), F250 ms (N), force at first initial peak in force (F initial peak) (N), time at initial peak (T initial peak) ms), MVC peak force (N), and time at peak MVC (ms).

Table 4. Baseline measures for Force/Time parameters of interest.

Force variables (N)	Group 1 Control (n = 6)	Group 2 Squat + Vibration (n = 13)	Group 3 Squat Only (n = 11)
Force 30ms (N)	76.48 ± 19.65	41.39 ± 12.08	39.79 ± 12.97
Force 250 ms (N)	1484.68 ± 198.84	1008.78 ± 71.46	717.26 ± 85.43
Force initial P (N)	1623.56 ± 217.12	1386.43 ± 86.06	979.71 ± 68.65
Time initial P (ms)	204.67 ± 17.01	352.35 ± 39.17	342.45 ± 57.67
MVC Force (N)	2497.44 ± 291.43	2121.65 ± 181.18	1435.07 ± 86.37
Time MVC (ms)	2537.22 ± 184.19	2574.35 ± 199.55	2376.37 ± 195.33

Values are Means ± SE
Force 30ms – Force value at 30 ms from the onset of contraction (N).
Force 250ms – Force value at 250 ms from the onset of contraction (N).
Force initial P – Force value at first peak in force following the onset of contraction (N).
Time initial P – Time at first peak in force following the onset of contraction (ms).

MVC Force – Maximal voluntary contraction force attained over a 0.5 sec average (N).
Time MVC (ms) – Time at which maximal voluntary contraction force is attained.

BASE LINE MEASURES FOR BODY COMPOSITION

Table 5 outlines baseline body composition measures of interest which include Total percent body Fat (%), Total lean tissue (g), Trunk percent body Fat (%), Lean Trunk Tissue (g), Leg percent body Fat (%), and Leg lean Tissue (g).

Table 5. Baseline measures for Body Composition.

Body composition variables	Group 1 Control (n = 6)	Group 2 Squat + Vibration (n = 13)	Group 3 Squat Only (n = 11)
% Fat total	15.15 ± 3.53	15.10 ± 1.41	15.65 ± 1.58
Lean Tissue T	69897.17 ± 1521.49	67086.15 ± 2410.39	58810.91 ± 1901.64
% Fat trunk	17.33 ± 3.59	17.08 ± 1.70	17.28 ± 1.76
Lean Tissue Tr	34767.17 ± 1003.60	32167.92 ± 1266.06	28489.46 ± 990.84
% Fat Leg	14.77 ± 3.76	15.79 ± 1.57	16.85 ± 1.74
Lean Tissue L	21257.50 ± 570.47	21602.08 ± 770.54	18779.00 ± 780.05

Values are Means ± SE
% Fat total - Total body fat percentage (%)
Lean Tissue T - Total body lean tissue (g)
% Fat trunk - Trunk fat percentage (%)
Lean Tissue Tr – Trunk lean tissue (g)
% Fat Leg - Leg fat percentage (%)
Lean Tissue L – Leg lean tissue (g)

ONE -WAY ANOVA ANALYSES COMPARING BASE LINE DATA

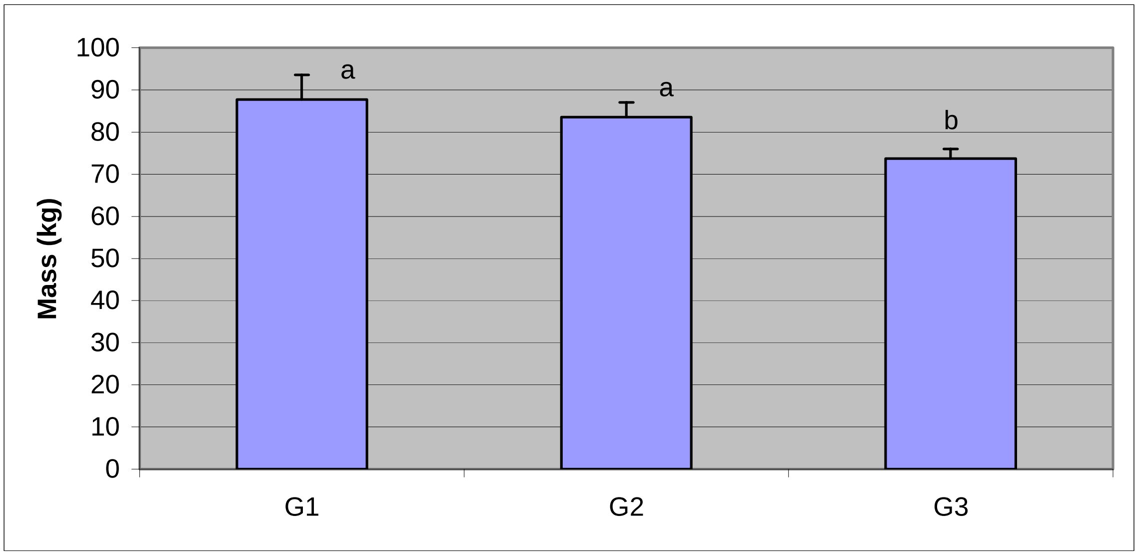
One-way ANOVA'S were used to compare the means for each group at baseline for all the performance measures outlined. A significant difference was seen between groups at baseline for measures of body mass (kg) ($p = 0.044$), although post hoc pair wise comparisons revealed no significant group differences ($p > 0.05$). Figure 1. graphically display group differences.

Table 6. One-way ANOVA to compare the means for each group Physical characteristics at Baseline.

Variable	F – ratio	Probability level	
Age (Yrs)	.460	0.636	ns
Ht (cm)	.827	0.448	ns
Wt (kg)	3.513	0.044 *	
% Fat	.028	.973	ns

* Significant at $p \leq 0.05$; ns denotes none significance ($p > 0.05$).

Figure 1. Weight for each subject at baseline.



[a] denotes that groups G1 and G2 were found to be statistically similar by Bonferroni Post Hoc analysis ($p > 0.05$) but significantly different from G3 ($p \leq 0.05$).

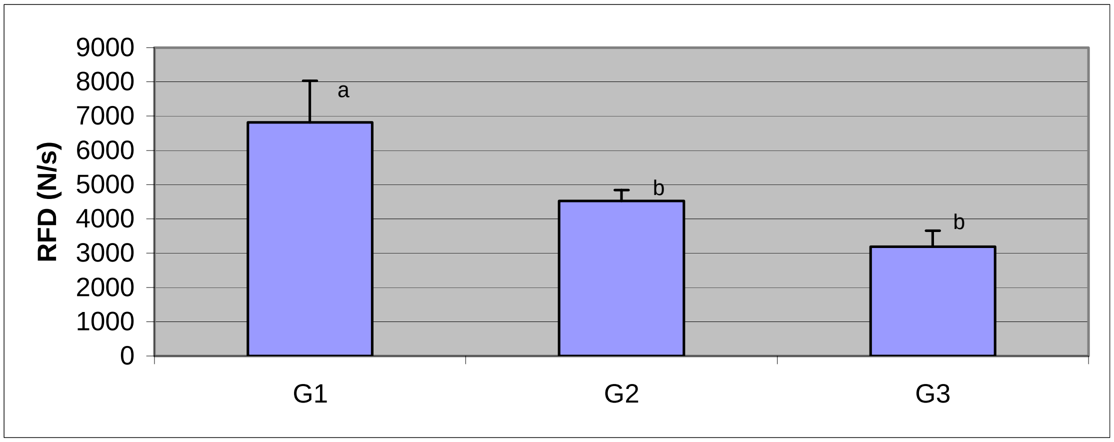
Table 7. One-way ANOVA to compare the means for each group RFD parameters of interest at Baseline.

Variable	F – ratio	Probability level	
RFD 30 N/s	1.512	0.238	ns
RFD 250 N/s	8.373	0.001**	
Peak RFD N/s	11.663	0.000**	
Time PRFD ms	.931	.406	ns
RFD MVC N/s	1.088	.351	ns

** Significant at $p \leq 0.001$; ns denotes none significance ($p > 0.05$).

Significant differences between groups at baseline are seen for RFD 250 (N/s) ($p = 0.001$), RFD initial Peak (N/s) ($p = 0.001$) and Peak RFD (N/s) ($p = 0.000$). Significant differences were found between groups at baseline with the Control Group (G1) significantly greater than the Squat + Vibration Group (G2), and the Squat Only Group (G3) ($p \leq 0.05$). G2 and G3 were found to be statistically similar to one another at baseline ($p > 0.05$).

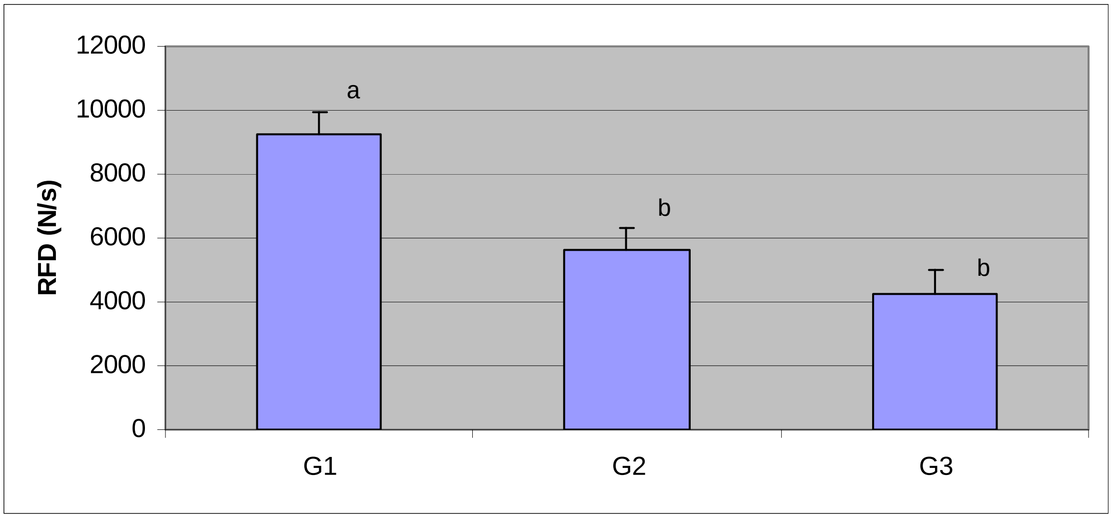
Figure 2. RFD250ms (N/s) for each group at baseline.



[a] denotes G1 significantly greater than G2 and G3 ($p \leq 0.05$).
[b] denotes G2 are G3 similar ($p > 0.05$).
Values expressed as Means ± SE

The Control Group (G1) was found at baseline to be statistically greater than both the Squat + Vibration Group (G2) and the Squat Only Group (G3) Groups with regards to RFD at 250 milliseconds ($p \leq 0.05$). G2 and G3 were found to be statistically similar to one another.

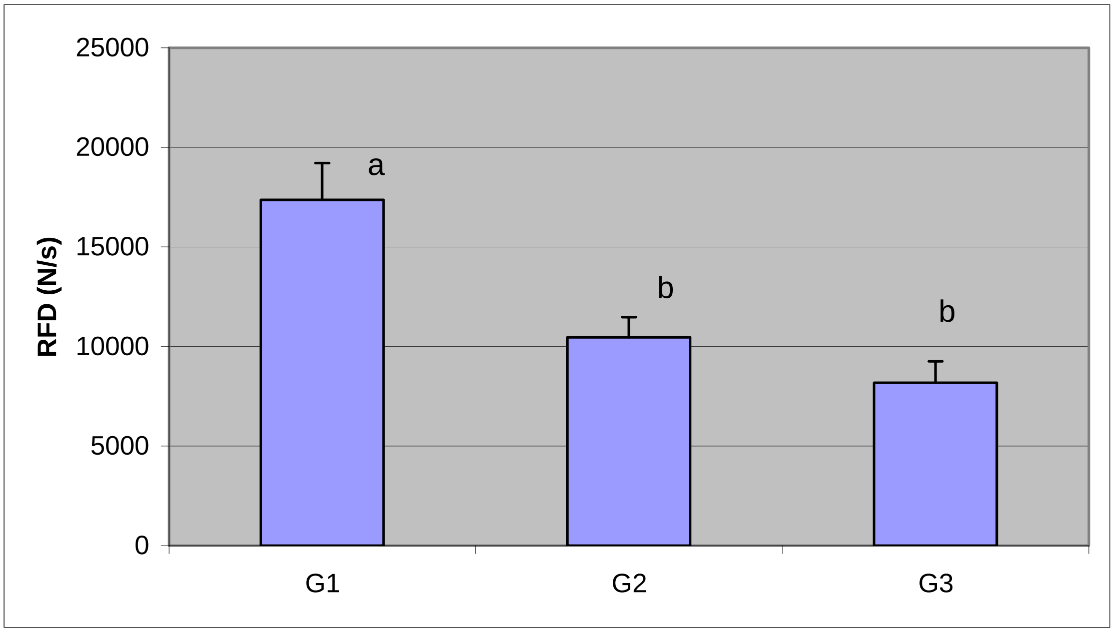
Figure 3. RFD from 0 to initial peak in force (N/s) for each group at baseline.



[a] denotes G1 significantly greater than G2 and G3 ($p \leq 0.001$).
[b] denotes G2 and G3 statistically similar ($p > 0.05$).
Values expressed as Means ± SE

Significant differences were seen at baseline between Groups with G1 significantly greater than G2 and G3 ($p \leq 0.05$). Both G2 and G3 were found to be statistically similar to one another ($p > 0.05$).

Figure 4. Peak RFD (N/s) for each group at baseline.



Values are Means ± SE
^{a} denotes G1 significantly greater than G2 and G3 ($p \leq 0.05$).
^{b} denotes G2 and G3 statistically similar ($p > 0.05$).

Statistically significant differences were seen between Groups at baseline with G1 greater than both G2 and G3 ($p \leq 0.05$). G2 and G3 were found to statistically similar to one another ($p > 0.05$).

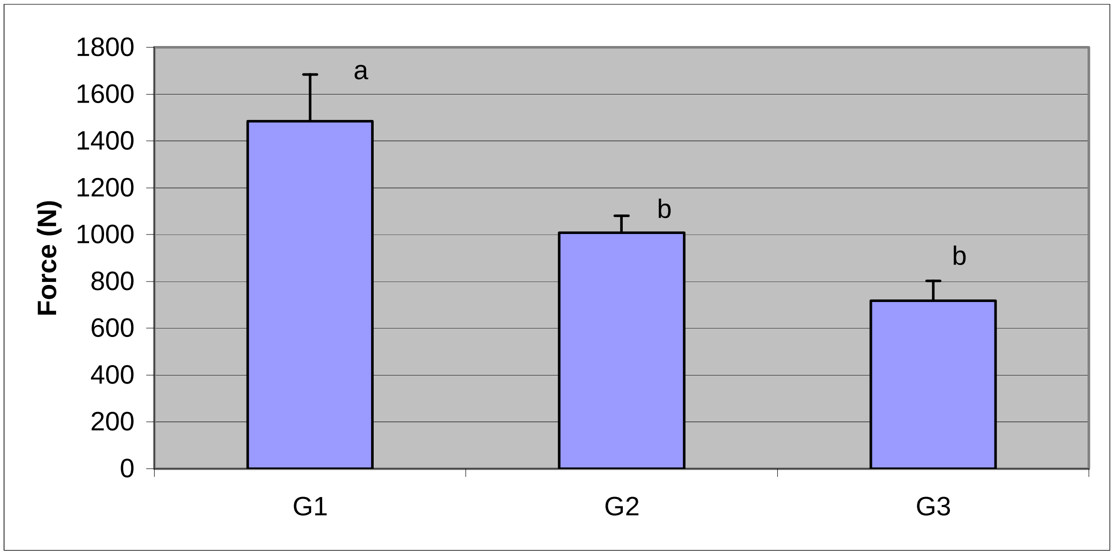
Table 8. One-way ANOVA to compare the means for each group Force/Time parameters of interest at Baseline.

Variable	F – ratio	Probability level	
Force 30ms (N)	1.577	0.225	ns
Force 250 ms (N)	11.097	0.000**	
Force initial P (N)	8.074	0.002*	
Time initial P (ms)	2.176	0.133	ns
MVC Force (N)	8.105	0.002*	
Time MVC (ms)	.292	0.749	ns

Values expressed as Means ± SE
*Denote significance at $p \leq 0.05$; ns denotes none significance ($p > 0.05$).
** Denotes significant at $p \leq 0.001$.

Statistically significant differences were seen between groups at baseline for force at 250ms (p = 0.000), Force at initial peak (p = 0.002), and MVC Force (p = 0.002) ($p \leq 0.050$).

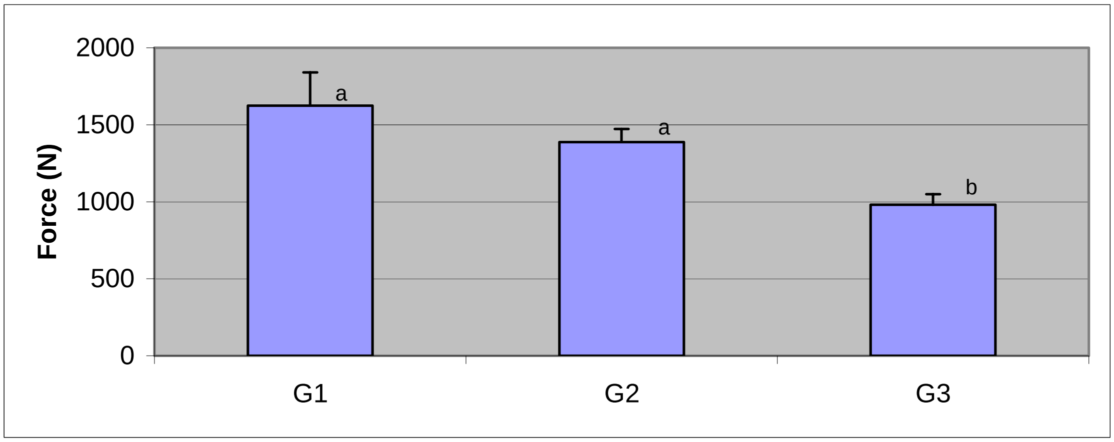
Figure 5. Force at 250ms for each group at baseline.



[a] denoted G1 significantly greater than G2 and G3 ($p \leq 0.05$).
[b] denotes G2 and G3 are statistically similar ($p > 0.05$).
Values expressed as Means ± SE

Statistically significant differences were seen between Groups at baseline with G1 significantly greater than both G2 and G3 ($p \leq 0.05$). G2 and G3 were found to statistically similar to one another ($p > 0.05$).

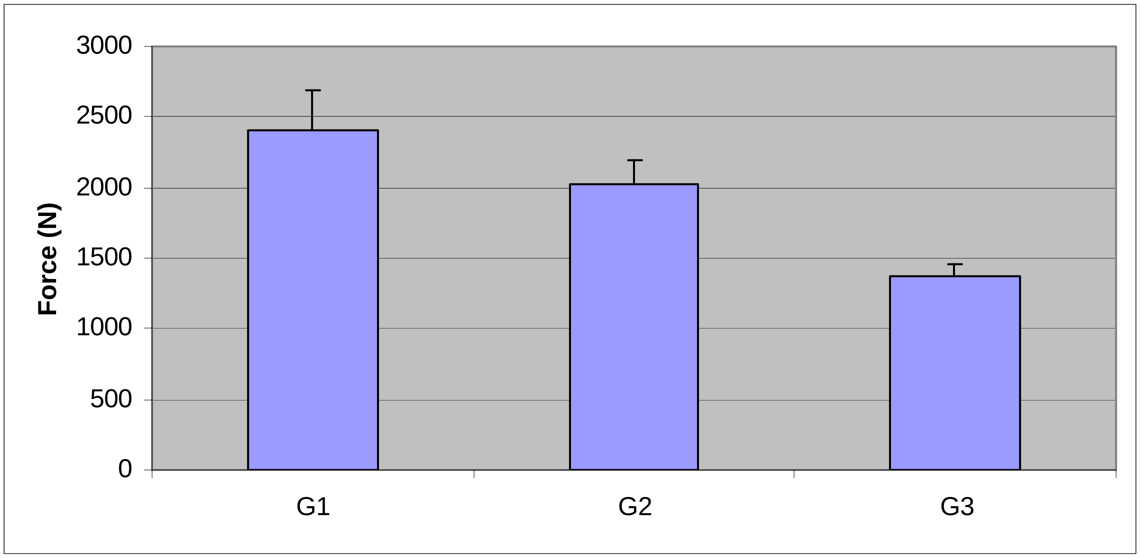
Figure 6. Force at initial Peak for each group at baseline.



[a] denotes G1 and G2 Statistically similar to one another ($p \leq 0.05$).
[b] denotes G3 statistically less than G1 and G2 ($p > 0.05$).

Statistically significant differences were seen between Groups at baseline with G1 and G2 significantly greater than G3 ($p \leq 0.05$). G1 and G2 were found to statistically similar to one another ($p > 0.05$).

Figure 7. MVC force for each group at base line.



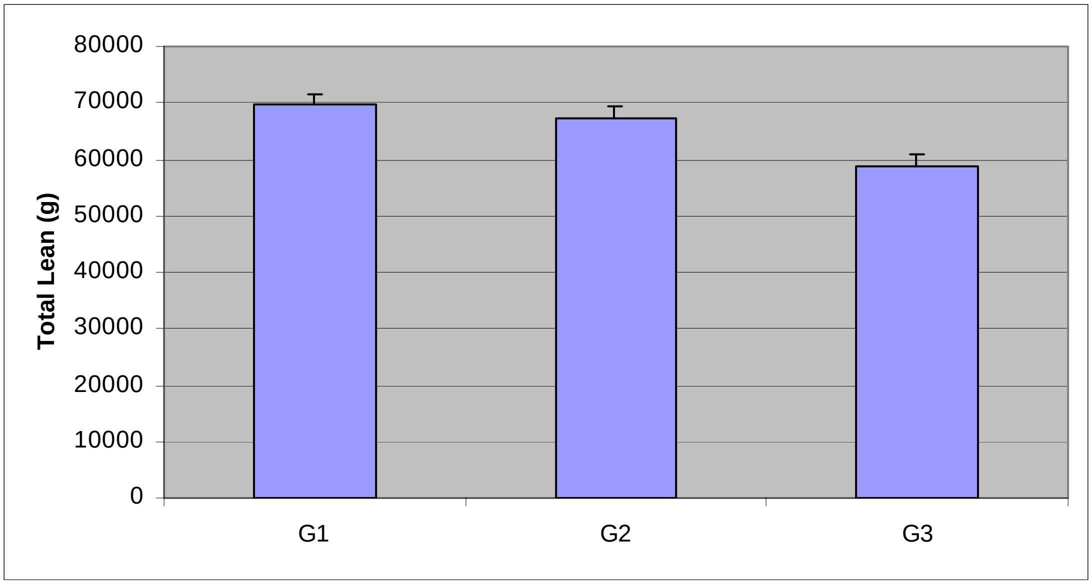
[a] denotes G1 and G2 statistically similar to one another ($p > 0.05$).
[b] denotes G3 statistically less than G1 and G2 ($p \leq 0.05$).

Statistically significant differences were seen between groups at base line with G1 and G2 significantly greater than G3 ($p \leq 0.05$). G1 and G2 were found to be statistically similar at baseline ($p > 0.05$).

Table 9. One-way ANOVA to compare the means for each group body composition parameters of interest at Baseline.

Variable	F – ratio	Probability level	
% Fat total	.028	0.973	ns
Lean Tissue T	6.068	0.007*	
% Fat trunk	.004	0.996	ns
Lean Tissue Tr	5.868	0.008*	
% Fat Leg	.208	.814	ns
Lean Tissue L	4.131	.027*	

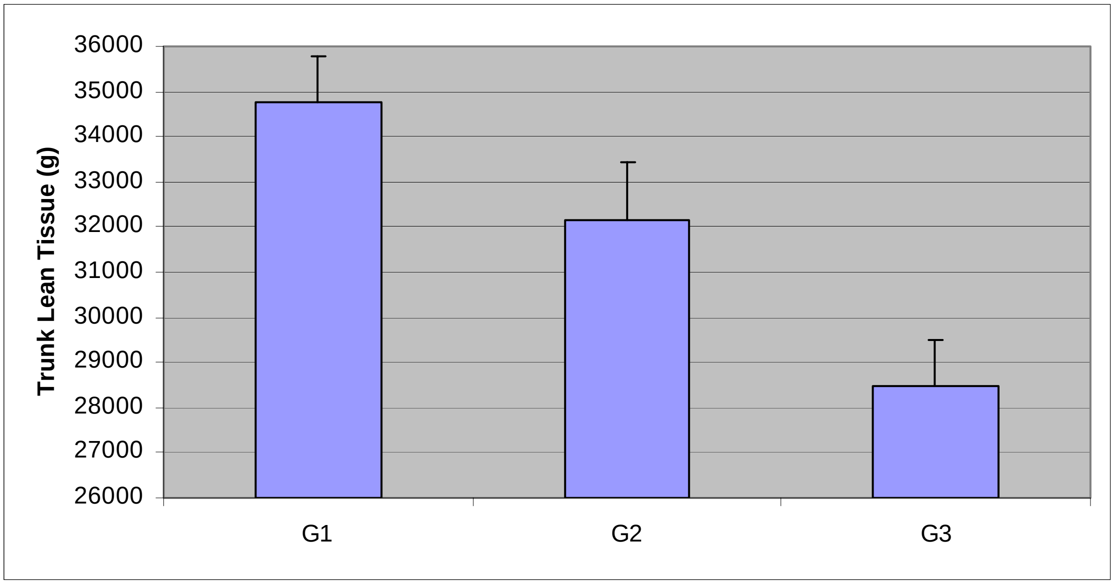
Figure 8. Total body lean tissue for all groups at baseline



^{a} denotes G1 and G2 significantly similar to one another ($p > 0.05$).
^{b} denotes G3 significant less than G1 and G2. ($p \leq 0.05$)
Values expressed as Means ± SE

Statistically significant differences were seen between groups at base line for Lean Tissue (g) ($p = 0.007$), Lean Trunk Tissue (g) ($p = 0.008$), and for Leg Lean Tissue (g) ($p = 0.027$) ($p \leq 0.05$).

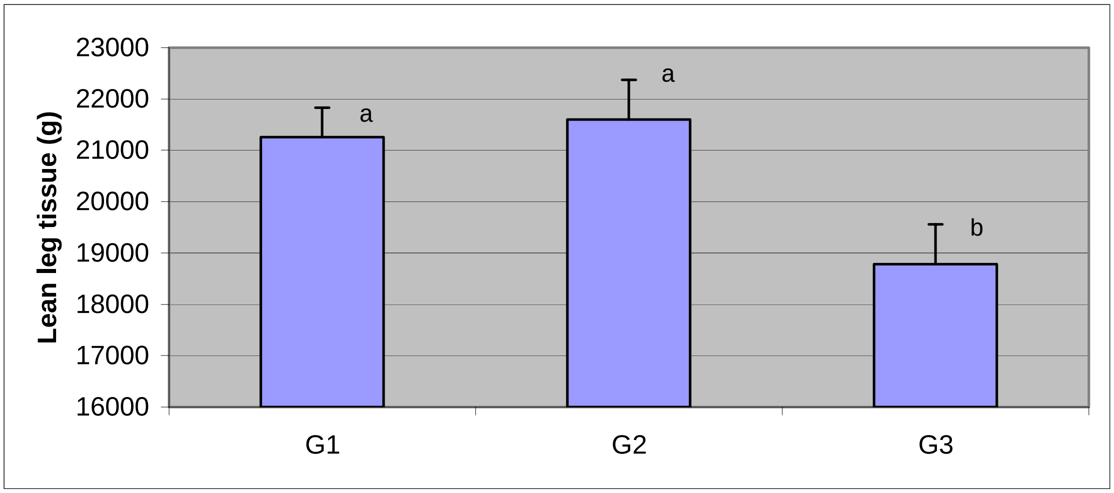
Figure 9. Trunk lean tissue for all Groups at baseline



[a] denotes G1 statistically similar to G2 ($p > 0.05$).
[ab] denotes G2 statistically similar to G1 and G3. ($p > 0.05$).
[b] denotes G3 significantly less than G1 ($p \leq 0.05$).
Values expressed as Means ± SE

Statistically significant differences were seen between groups at baseline with G1 significantly greater than G3 ($p \leq 0.05$). G1 and G2 were found to statistically similar as were G2 and G3 ($p > 0.05$).

Figure 10. Leg lean tissue for all groups at baseline.



[a] denotes G1 statistically similar to G2 ($p > 0.05$).
[b] denotes G3 statistically less than G1 and G2 ($p \leq 0.05$) .

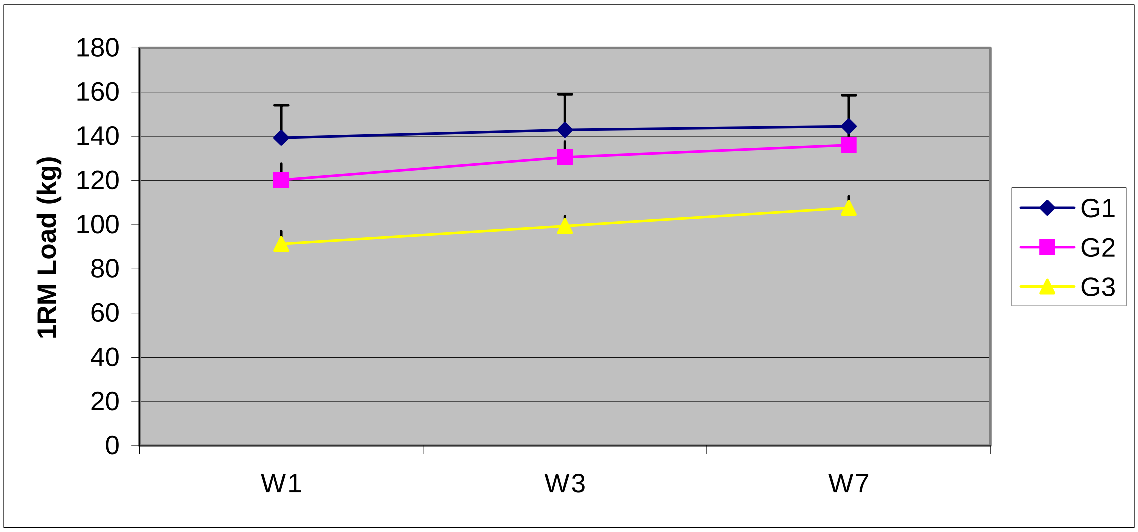
Statistically significant differences were seen between groups at baseline with G1 and G2 significantly greater than G3 ($p \leq 0.05$). G1 and G2 were found to be statistically similar to one another ($p > 0.05$).

Table 10. Two-way Repeated Measures (Group (3) * Trial (3) for lower body strength and jump performance.

	Variable	F- ratio	Probability level	
IRM Squat	Group	6.772	0.004*	
	Trial	40.233	0.000**	
	Gr*Tr	2.946	0.028*	
Dj pre Ht	Group	2.311	0.119	ns
	Trial	13.946	0.000**	
	Gr*Tr	2.675	0.041*	
Dj post Ht	Group	3.431	0.047*	
	Trial	4.956	0.011*	
	Gr*Tr	1.591	0.190	ns
DjPpower Pre	Group	5.525	0.010*	
	Trial	13.946	0.000**	

	Gr*Tr	3.952	0.007*	
DjPpower Post	Group	6.682	0.004*	
	Trial	6.910	0.002*	
	Gr*Tr	2.445	0.057	ns
DjPp/kg Pre	Group	1.274	0.296	ns
	Trial	12.131	0.000**	
	Gr*Tr	2.452	0.057	ns
DjPp/kg Post	Group	2.127	0.139	ns
	Trial	3.967	0.025*	
	Gr*Tr	1.455	0.229	ns
DjMp Pre	Group	5.284	0.012*	
	Trial	6.714	0.002*	
	Gr*Tr	2.672	0.042*	
DjMp Post	Group	6.223	0.006*	
	Trial	3.067	0.055	ns
	Gr*Tr	0.497	0.738	
SQj Ht Pre	Group	3.584	0.042*	
	Trial	26.300	0.000**	
	Gr*Tr	2.457	0.056	ns
SQj Ht Post	Group	4.400	0.022*	
	Trial	24.744	0.000**	
	Gr*Tr	2.746	0.038*	
SQj Power Pre	Group	5.318	0.008*	
	Trial	25.784	0.000**	
	Gr*Tr	2.825	0.034*	
SQjPp/kg Pre	Group	1.871	0.173	ns
	Trial	22.928	0.000**	
	Gr*Tr	2.693	0.040*	
SqjMpower Pre	Group	6.836	0.004*	
	Trial	6.705	0.003*	
	Gr*Tr	0.304	0.874	
SqMpower Post	Group	6.055	0.007*	
	Trial	6.939	0.002*	
	Gr*Tr	0.365	0.833	

Figure 11. Interaction Group*Trial for 1RM Squat (p = 0.028).

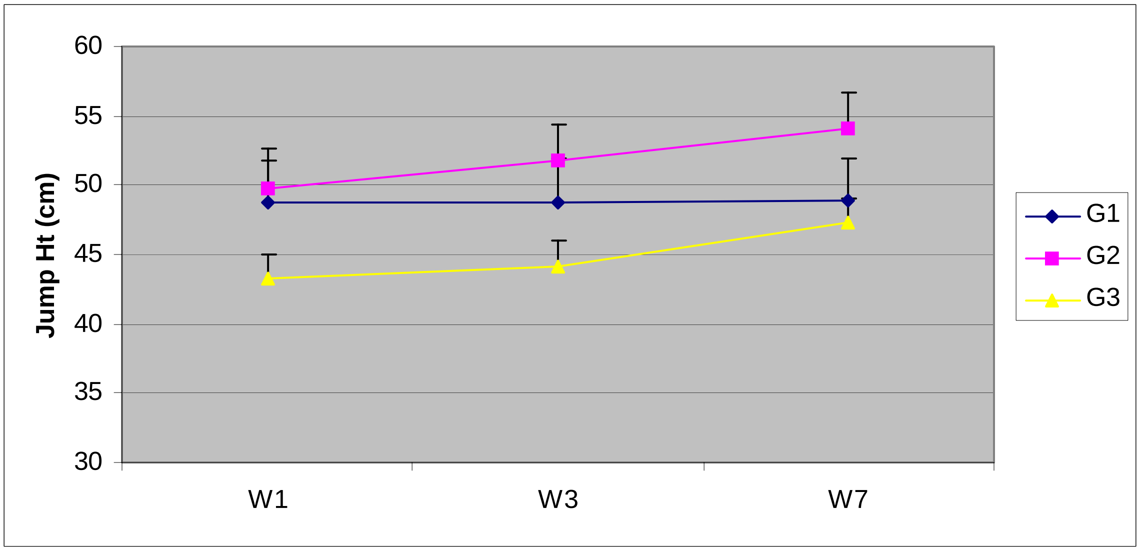


Values expressed as Means ± SE

A two-way repeated measures ANOVA found a statistically significant Group*Trial intercation for Smith Machine 1RM (p = 0.028). Statistically significant differences were seen for Smith Machine Squat 1RM for Group (p = 0.004), and Trial (p = 0.000) as well as Group*Trial interaction (p = 0.028). Post hoc analysis performed by group revealed that the control Group (G1) was significantly greater than the Squat Only Group (G3) (p = 0.007) but statistically similar to the Squat + Vibration Group (G2) (p = 0.884). G2 was found to be statistically greater than G3 (p = 0.025). Post hoc analysis performed on trial revealed that trial 3 was significantly greater than trial 1 (p = 0.000) and trial 2 (p = 0.001).

A one-way ANOVA with repeated measures (split file by Group) performed on 1RM trials (week 1, 3, and 7) revealed no significant difference between weeks 1, 3, and 7 for the Control Group (p = .279). A significant trial effect occurred for the Squat + Vibration Group (p = 0.000) with trial 3 (week 7) being significantly greater than trial 1(week 1) (p = 0.000) and trial 2 (week 3) (p = 0.027). Trial 2 (week 3) was significantly greater than trial 1 (week 1) (p = 0.000). A significant main effect for trial was seen for the Squat Only Group (p = 0.000), with trial 3 (week 7) significantly greater than trial 2 (week 3) (p = 0.002) and trial 1 (week 1) (p = 0.000). A one-way ANOVA performed on Group (3) revealed that at week 1 Group 1 and Group 2 were similar to one another (p > 0.050) and that they were both significantly greater than week 3 (p ≤ 0.050). At week 3, a similar relationship was seen between the three groups. At week 7, Group 1 was found to be statistically similar to both Groups 2 and Group 3 (p > 0.050), however Group 2 was found to be statistically greater than Group 3 (p ≤ 0.050).

Figure 12. Interaction Group*Trial for Depth Jump height (pre vibration)(cm) (p = 0.041).



Values expressed as Means ± SE

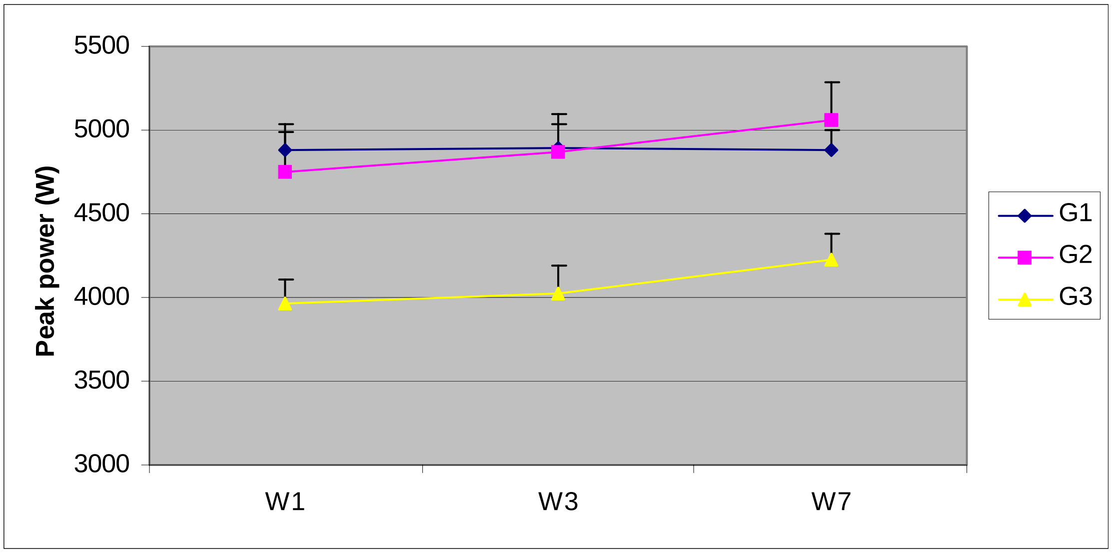
A two-way ANOVA (Group*Trial) with repeated measures performed on pre (week 1), mid (week 3) and post (week 7) measures for Depth Jump height (cm) revealed a significant Trial * Group Interaction (p = 0.040) as well as significant main effect for trial (p = .00). No significant main effects for group were seen (p = 0.119). Post hoc analysis revealed that trial 3 (week 7) was significantly greater than trial 2 (week 3) (p =

0.02) and trial 1 (week 1) (p = .00). Trials 1 (week 1) and trial 2 (week 3) were not found to be statistically different from one another (p = 0.254).

A one-way ANOVA with repeated measures (split by Group) revealed that there was no significant difference between trials for the Control condition (p = 0.952). A significant main effect for trial was found for the Squat + Vibration Group (p = 0.00) with trial 3 (week 7) significantly greater than trials 1 (week 1) (p = 0.007) and trials 2 (week 3) (p = 0.030). Trial 1 (week 1) and trials 2 (week 3) were not found to be statistically different from one another (p = 0.127). A significant main effect was seen for trial for the Squat Only Group (p = 0.00) with trial 3 (week 7) significantly greater than trials 1 (week 1) and trial 2 (week 3). Trials 1 (week 1) and Trial 2 (week 3) were not found to be statistically different from one another (p = 0.771).

A one-way ANOVA performed by Group revealed that Jump height was statistically similar between Groups at week 1, 3, and weeks 7 (p > 0.050).

Figure 13. Interaction Group*Trial for Depth Jump peak power (pre vib) (W) (p = 0.007).

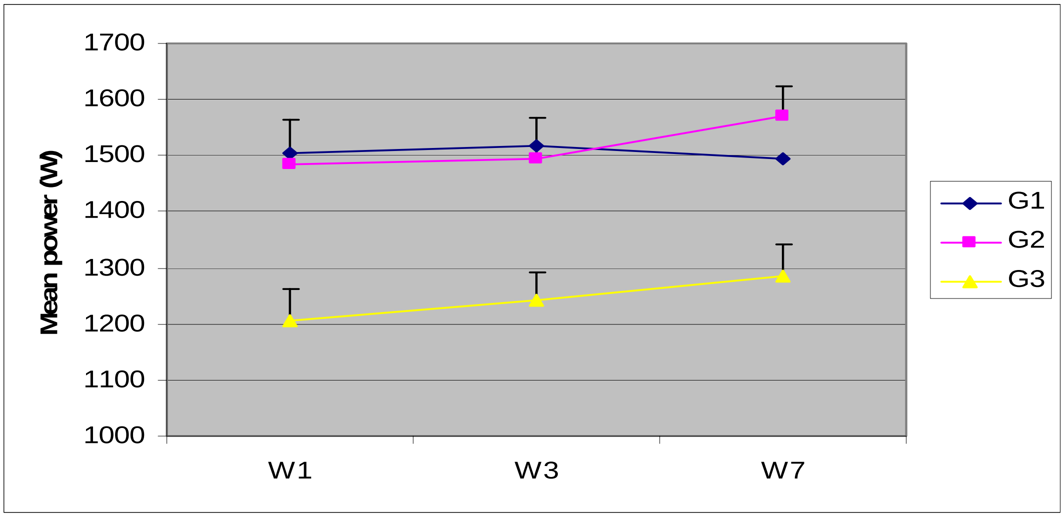


Values expressed as Means ± SE

A two-way ANOVA (Group*Trial) with repeated measures performed on pre (week 1), mid (week 3) and post (week 7) measures for Depth Jump Peak power (pre vibration) revealed a significant Group*Trial interaction ($p = 0.007$) as well as significant main effects for Group ($p = 0.01$) and Trial ($p = 0.00$). Post hoc analysis performed on Group revealed that The Squat + Vibration Group power was significantly greater than the Squat Only Group power ($p = 0.014$) but similar to the Control Group ($p = 1.000$). A one-way ANOVA with repeated measures (split by Group) revealed that there was no significant differences between Trials for the Control Group ($p = 0.969$) but a significant difference between Trials was seen for the Squat + Vibration Group ($p = 0.000$). Week seven trial measures were found to be significantly greater than week 3 and week 1 measures ($p \leq 0.050$). Measures recorded at week three were found to be statistically similar to those recorded at week 1. A significant Trial effect was also seen for the Squat Only Group ($p = 0.000$). A similar statistical relationship was seen between trails at weeks 1, 3, and week 7 for Group 3.

G1 and G2 were statistically similar at week 1 and week 3 ($p > 0.05$) but statistically greater than at week 7 ($p \leq 0.05$). G3 jump power was significantly less than G1 jump power at weeks 1, 3, and 7. ($p \leq 0.05$). Both G1 and G2 Depth Jump power was greater than G3 at weeks 1, 3, and 7 ($p \leq 0.05$).

Figure 14. Interaction Group*Trial for Depth Jump mean power (pre vib measures) (W)

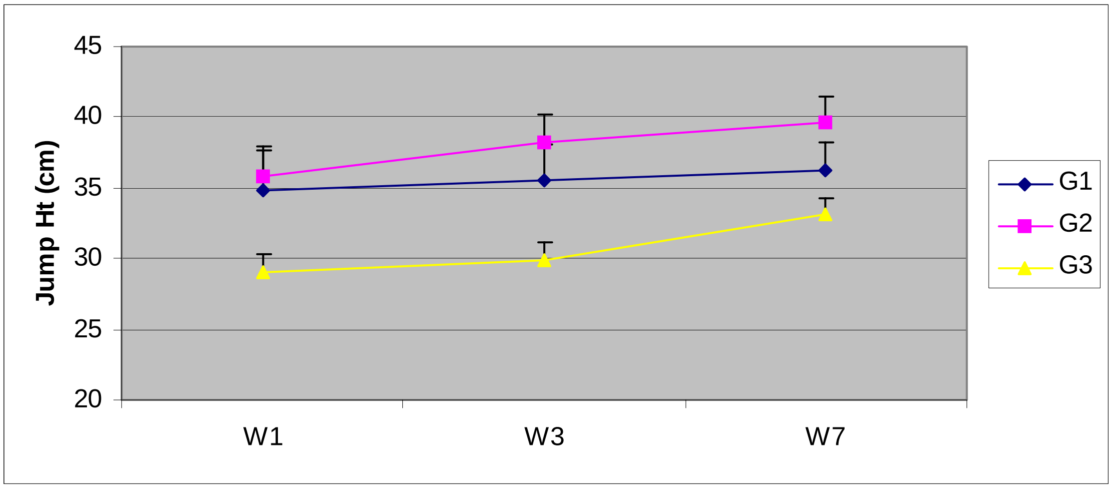


Values expressed as Means ± SE

A two-way ANOVA (Group*Trial) with repeated measures performed on pre (week 1), mid (week 3) and post (week 7) measures for Depth Jump mean power (pre vibration) revealed a significant Group*Trial interaction ($p = 0.042$) as well as significant main effects for Group ($p = 0.012$) and Trial ($p = 0.02$). Post hoc analysis performed on Group revealed that G2 mean power was significantly greater than G3 mean power ($p = 0.016$) but statistically similar to G1 ($p = 1.000$). G1 and G2 were statistically similar to one another at weeks 1, 3, and 7 ($p \geq 0.05$) G1 and G3 were found to be statistically similar on weeks 1, 3, 7 prior to vibration ($p = 0.077$).

A one-way ANOVA with repeated measures (split by Group) revealed that there was no significant differences between Trials for the Control Group ($p = 0.785$), but significant Trial effects were seen for G2 ($p = 0.000$) and G3 ($p = 0.001$). Group 2 measures of mean power were significantly greater on week 7 when compared to weeks 3 and week 1 ($p \leq 0.050$). Week 3 measures were found to be statistically similar to week 1 measures ($p > 0.050$). Group 3 measures of mean power were found to be significantly greater on week 7 when compared to week 1 measures ($p \leq 0.050$). Week 3 measures were not found to be significantly different from measures recorded at week 1 and weeks 7 ($p > 0.050$). A one-way ANOVA performed between Groups at a weeks 1, 3, and 7 revealed that at week 1, Group 1 was statistically similar to Group 2 ($p > 0.050$), both of which were statistically greater than Group 3 ($p \leq 0.050$). At week 3, Groups 2, and Group 3 were found to be statistically similar to Group 1 ($p > 0.050$). Group 2 was found to be statistically greater than Group 3 ($p \leq 0.050$).

Figure 15. Interaction Group*Trial for Squat Jump height (cm) (post vibration measures) ($p = 0.038$).



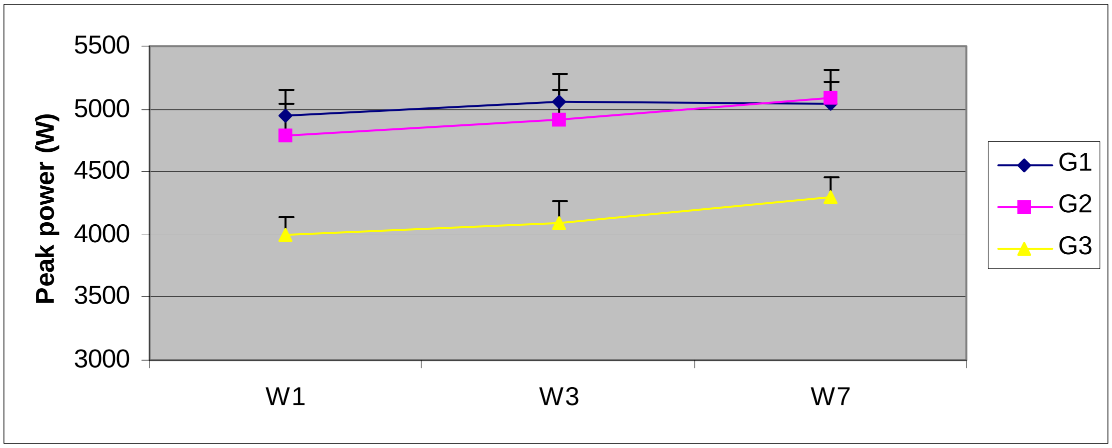
Values expressed as Means ± SE

A two-way ANOVA (Group*Trial) with repeated measures performed on pre (week 1), mid (week 3) and post (week 7) measures for Squat Jump height (cm) (post vibration measures) revealed a significant Group*Trial interaction ($p = 0.038$) as well as significant main effects for Group ($p = 0.022$) and Trial ($p = 0.000$). Post hoc analysis performed on Group revealed that G2 jump height was significantly greater than G3 jump height ($p = 0.020$) but statistically similar to G1 ($p = 1.000$).

A one-way ANOVA (split file by Group) with repeated measures revealed that there were no significant differences between the three trials (week 1, week 3, and week 7) for the control Group ($p > 0.050$). For Group 2, week 7 measures of mean power were found to be significant greater than measures recoded at week 1 ($p \leq 0.050$).

A one-way ANOVA was performed between groups looking at differences at weeks 1, 3, and 7. Group 1 and G2 were found to be statistically similar at weeks 1 and 3 ($p > 0.05$), but statistically different from one another at week 7 ($p \leq 0.05$). Both G1 and G2 were statistically greater than G3 at weeks 1, 3 ($p \leq 0.05$). G1 and G2 were statistically similar to one another at weeks 1, 3, and 7 ($p > 0.05$)

Figure 16. Interaction Group*Trial for Squat Jump Peak power (W) (pre vib) ($p = 0.019$).

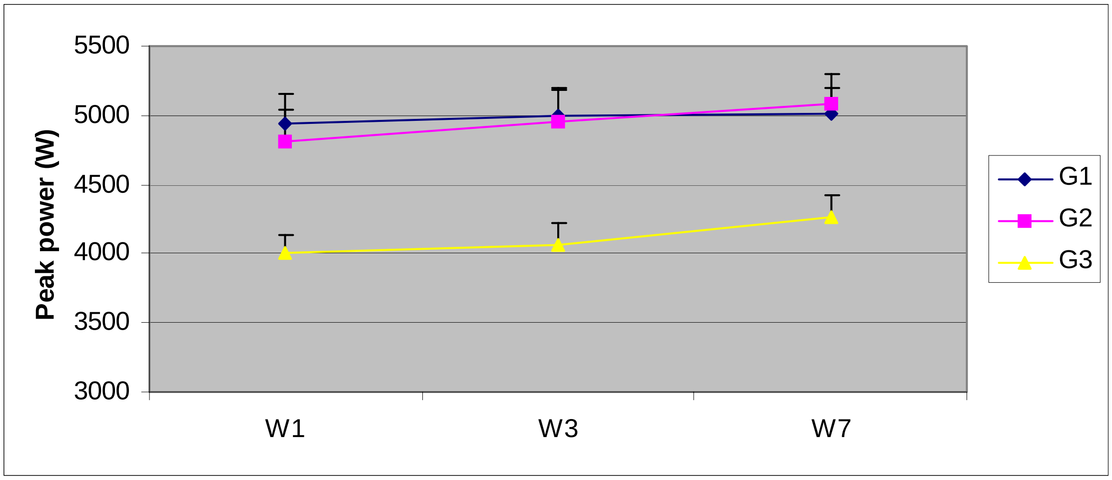


Values expressed as Means ± SE

A two-way ANOVA (Group*Trial) with repeated measures performed on pre (week 1), mid (week 3) and post (week 7) measures for Squat Peak power (W) (pre vibration) revealed a significant Group*Trial interaction ($p = 0.019$), as well as significant main effects for Group ($p = 0.001$), and Trial ($p = 0.000$). Post hoc analysis performed on Group revealed that G1 Squat Jump power (pre vibration) on weeks 1, 3, and 7 was significantly greater than G3 ($p = 0.046$) but statistically similar to G2 Squat power ($p = 1.000$) .G2 Squat Power was significantly greater than G3 ($p = 0.021$). A one-way ANOVA was performed on the same with the data split by group. The analysis revealed that G1 Squat Jump peak power pre vibration was statistically similar on weeks 1, 3, and 7 ($p > 0.050$). Group 2 analysis revealed that peak power was statistically greater at week 7 when compared to weeks 3 and 1. Jump Squat power at week 3 was found to be statistically greater than power produced at week 1 ($p \leq 0.050$). Measures at week 7 revealed that G1 was statistically similar to G2 and G3 ($p > 0.050$), G2 was found to be statistically greater than G3 ($p \leq 0.050$).

G1 and G2 jump power was found to be statistically similar at weeks 1, 3, and 7 ($p > 0.05$) and significantly greater than G3 at the same time points ($p \leq 0.05$).

Figure 17. Interaction Group*Trial for Squat Jump Peak power (W) (post vibration measures) ($p = 0.034$).



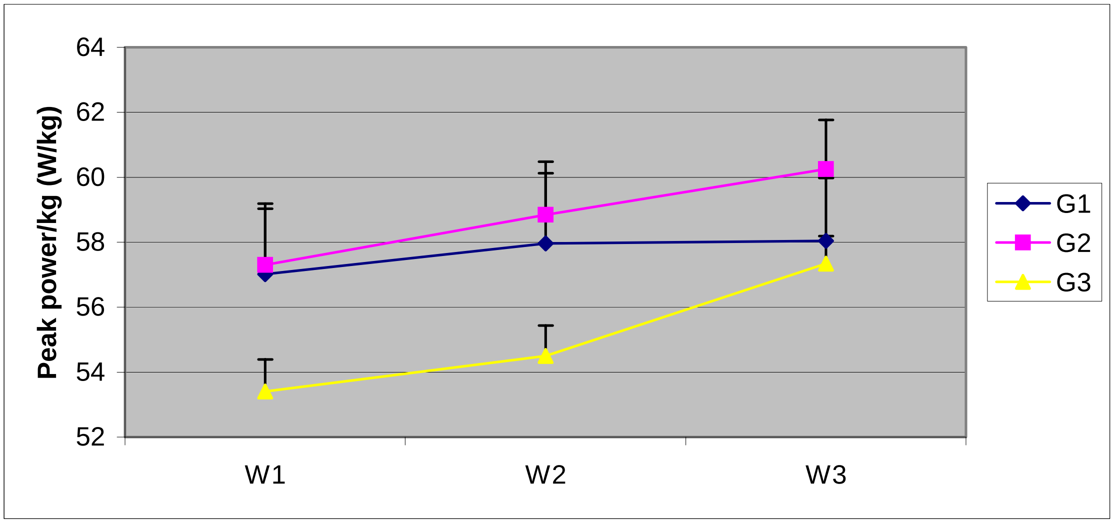
Values expressed as Means ± SE

A two-way ANOVA (Group*Trial) with repeated measures performed on pre (week 1), mid (week 3) and post (week 7) measures for Squat Peak power (W) (post vibration measures) revealed a significant Group*Trial interaction ($p = 0.034$), as well as significant main effects for Group ($p = 0.008$), and Trial ($p = 0.000$). Post hoc analysis performed on Group revealed that G1 Squat power (post vibration) on weeks 1, 3, and 7 was significantly greater than G3 ($p = 0.042$) but statistically similar to G2 Squat power ($p = 1.000$) . Post hoc analysis performed for Trial revealed that Trial 3 was significantly greater than both Trial 2 and Trial 1 ($p \leq 0.050$). Trial 2 was shown to be significantly greater than Trial 1 ($p \leq 0.050$).

A one-way ANOVA with repeated measures (Split file by Group) revealed that there was no significant difference between Trials for G1 ($p = 0.475$). For G2, measures taken at both weeks 3 and week 1 were significantly less than measures taken at week 7 ($p \leq 0.050$). Measures at week three were found to be significantly less than measures taken at week 1 ($p \leq 0.050$). For G3 week 7 measures were found to be statistically similar to measures taken at weeks 3 and week 1 ($p > 0.050$). Measures taken at week 3 were found to be statistically similar to measures taken at week 1 ($p > 0.050$).

G1 and G2 peak power were found to be statistically similar to one another ($p > 0.05$) at weeks 1, 3, and 7 but significantly greater than G3 at the same time points ($p \leq 0.05$).

Figure 18. Interaction Group*Trial for Squat Jump Peak power/ Kilogram of body mass (W/kg) (pre vibration measures) (p = 0.034).



Values expressed as Means ± SE.

A two-way ANOVA (Group*Trial) with repeated measures performed on pre (week 1), mid (week 3) and post (week 7) measures for Squat Peak power/ Kilogram of body mass (W) (post vibration measures) revealed a significant Group*Trial interaction (p = 0.040) as well as significant main effects for Trial (p = 0.000). No significant differences were seen between Groups (p = 0.102). A one-way ANOVA with repeated measures (Split file by Group) revealed that there was no significant difference between Trials for G1 (p = 0.190) on weeks 1, 3, and 7, but significant differences were seen for G2 and G3 ($p \leq 0.050$). Measures of Squat jump peak power/kg for G2 revealed week 7 measures were similar to week 3 ($p > 0.050$) measures but statistically greater than measures taken at week 1. Week 3 measures were found to statistically similar to those taken at week 1 ($p > 0.050$). For G3, week 7 measures were found to be significantly greater than measures taken at weeks 3 and week 1 (≤ 0.050).

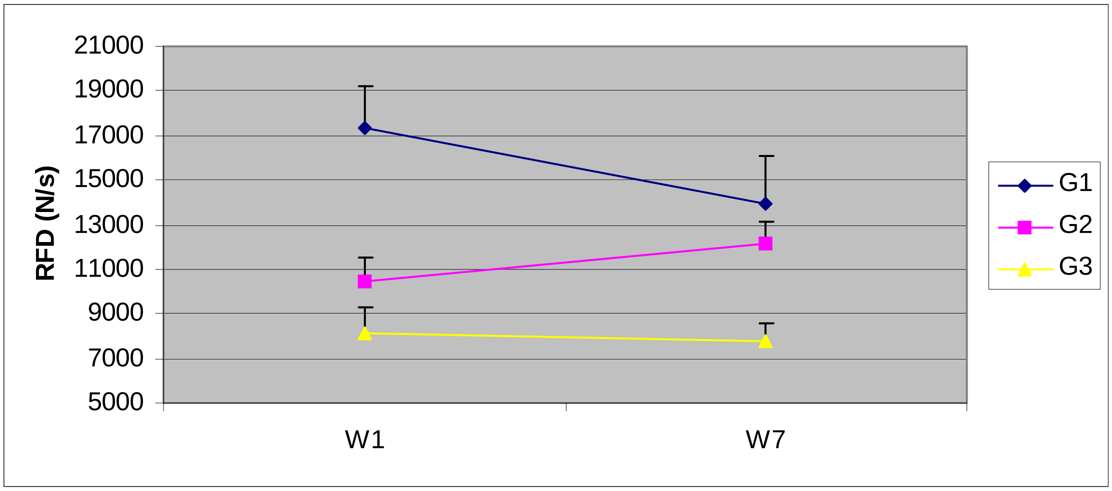
Table 11. Two-way repeated measures (Group*Trial) for RFD parameters of interest

	Variable	F-ratio	Probability level	
RFD 30 N/s	Group	2.241	0.126	ns
	Trial	2.282	0.142	ns
	Gr*Tr	0.507	0.608	ns
RFD 250 N/s	Group	8.764	0.001**	
	Trial	1.016	0.323	ns
	Gr*Tr	1.452	0.252	ns
RFD ini P N/s	Group	10.610	0.000**	
	Trial	3.178	0.086	ns
	Gr*Tr	2.785	0.079	ns
Peak RFD N/s	Group	11.061	0.000**	
	Trial	1.018	0.322	ns
	Gr*Tr	4.040	0.029*	
Time PRFD ms	Group	1.018	0.375	ns
	Trial	0.240	0.628	ns
	Gr*Tr	0.421	0.661	ns
RFD MVC N/s	Group	2.064	0.147	ns
	Trial	0.247	0.247	ns
	Gr*Tr	1.787	0.187	ns

Values expressed as Means ± SE

Table 11 displays the two-way repeated measures (Group*Trial) for RFD parameters of interest. Statistically significant main effects for Group and significant interaction for Group*Trial were seen for a select number of RFD parameters of interest ($p \leq 0.05$). A significant Group effect was seen for RFD 250 ms ($p = 0.001$). A significant Group effect was also seen for RFD at initial peak, ($p = 0.000$) and for Peak RFD ($p = 0.000$). A significant Group*Trial interaction was also seen for Peak RFD ($p = 0.029$). All other RFD parameters of interest were found to be none significant ($p > 0.05$).

Figure 19. Interaction Group*Trial for Peak isometric rate of force development from the onset of contraction (N/s) (p = 0.029).



Values expressed as Means ± SE

A two-way ANOVA (Group*Trial) with repeated measures performed on pre (week 1) and post (week 7) measures for peak isometric rates of force development revealed a significant Group*Trial interaction (p = 0.004), as well as significant main effects for Trial (p = 0.000), and for Group (p = 0.004). Post hoc analysis performed on Group revealed that G1 was significantly greater than both G2 and G3, and that G2 was significantly greater than G3 ($p \leq 0.050$). Post hoc analysis performed on Trial revealed that Trial 2 (week 7) was significantly greater than Trial 1 (week 1) ($p \leq 0.050$). A one-way ANOVA with repeated measures was performed with the data set split by Group revealed that control Group (G1) PRFD was significantly less at week 7 compared to week 1 values ($p \leq 0.05$). For Group 2, no significant differences were seen between weeks 1 and 7 ($p > 0.050$). For G3, no significant differences were seen between weeks 1 and 7 for PRFD (N/s) ($p > 0.050$). A one-way ANOVA performed on Group revealed that at week 1, G1 was statistically greater than Groups G2 and G3 ($p \leq 0.050$), G2 was found to be statistically similar to G3 ($p > 0.050$). At week 7, G1 was found to be statistically similar to G2 ($p > 0.050$) but greater than G3 ($p \leq 0.050$), G2 was found to be statistically greater than G3 ($p \leq 0.050$).

Table 12. Two-way repeated measures (Group*Trial) for Force/Time parameters of interest.

Variable		F-ratio	Probability level	
Force 30ms (N)	Group	2.332	0.116	ns
	Trial	2.183	0.151	ns
	Gr*Tr	0.514	0.604	ns
Force 250 ms (N)	Group	11.826	0.000**	
	Trial	0.330	0.571	ns
	Gr*Tr	1.091	0.350	ns
Force initial P (N)	Group	8.000	0.002*	
	Trial	0.139	0.712	ns
	Gr*Tr	0.305	0.740	ns
Time initial P (ms)	Group	2.212	0.129	ns
	Trial	1.613	0.215	ns
	Gr*Tr	2.004	0.154	ns
MVC Force (N)	Group	6.805	0.004*	
	Trial	8.935	0.006*	
	Gr*Tr	0.716	0.498	ns
Time MVC (ms)	Group	0.417	0.663	ns
	Trial	0.016	0.899	ns
	Gr*Tr	0.229	0.797	ns

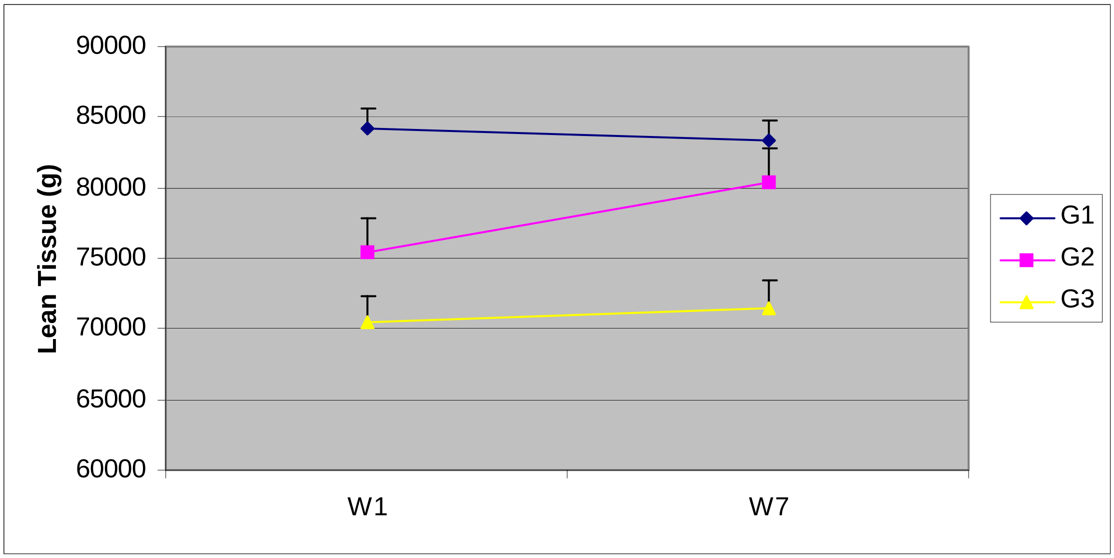
Statistically significant Group and Trial effects were seen for select Force/Time parameters of interest ($p \leq 0.05$). Significant Group effects were seen for Force at 250 ms ($p = 0.000$), force at initial peak ($p = 0.002$), and MVC force ($p = 0.004$). A significant Trial effect was also seen for MVC force ($p = 0.006$). All other force/time variables were found to be non significant ($p > 0.050$).

Table 13. Two-way repeated measures (Group*Trial) for Body composition parameters of interest.

	Variable	F-ratio	Probability level	
% Fat total	Group	0.051	0.950	ns
	Trial	1.255	0.273	ns
	Gr*Tr	0.255	0.777	ns
Lean Tissue T	Group	5.632	0.009*	
	Trial	3.523	0.071	ns
	Gr*Tr	4.792	0.017*	
% Fat trunk	Group	0.013	0.987	ns
	Trial	0.324	0.574	ns
	Gr*Tr	0.124	0.884	ns
Lean Tissue Tr	Group	5.595	0.009*	
	Trial	0.819	0.374	ns
	Gr*Tr	0.988	0.385	ns
% Fat Leg	Group	0.282	0.756	ns
	Trial	4.323	0.047*	
	Gr*Tr	0.471	0.630	ns
Lean Tissue L	Group	4.402	0.022*	
	Trial	1.923	0.177	ns
	Gr*Tr	2.050	0.148	ns

Statistically significant Group and Trial main effects were seen as well as significant Group*Trial effects ($p \leq 0.05$). A significant Group*Trial interaction was seen for total body lean tissue ($p = 0.017$) as well as a Group effect ($p = 0.009$). A significant Group effect was seen for Trunk Lean tissue ($p = 0.009$). A significant Trial effect was seen for Leg Fat percentage ($p = 0.047$) as well as significant Group effect for Leg Lean Tissue ($p = 0.022$). No significant differences were seen for all other body composition variables ($p > 0.05$).

Figure 20. Interaction Group*Trial for Total lean tissue mass (g) (p = 0.017).



Values expressed as Means ± SE

Statistically significant differences were seen between all groups at baseline ($p \leq 0.05$) with G1 significantly greater than G2 and G3. At week 7 there was no significant differences for total lean body mass between G1 and G2 ($p > 0.05$). G2 was significantly greater than G3 at weeks 1 and 7 ($p \leq 0.05$). Significant differences were seen between G1 and G3 at week 7 with G1 exhibiting significantly greater body mass than G3 ($p \leq 0.05$).

Percent change in Depth Jump and Squat Jump parameters on interest

Table 14. Depth Jump height (cm) and percent change following vibration at weeks 1, 3, and 7 for each Group.

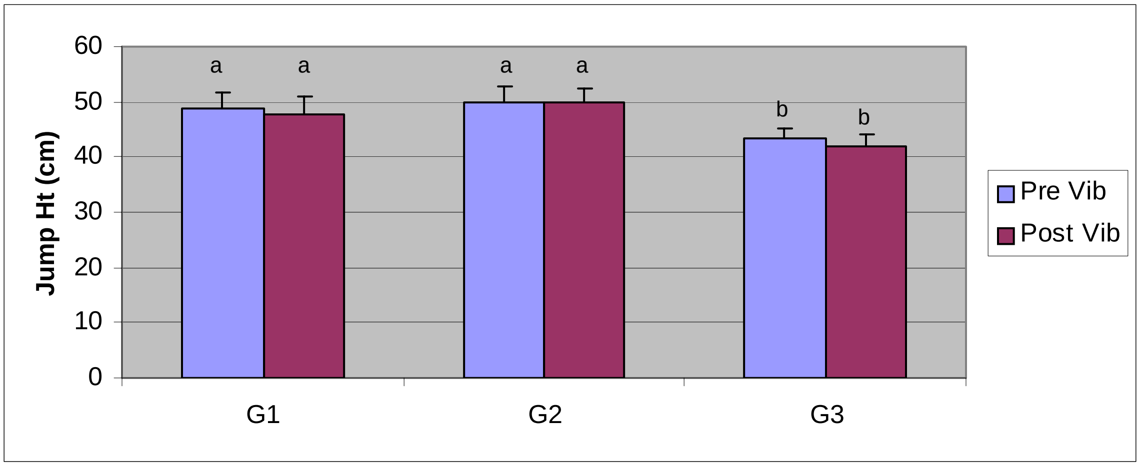
Week 1				% Change in	Relative change in
Group	N	Pre vibration Jump Ht (cm)	Post vibration Jump Ht (cm)	Jump Ht following Vibration	Jump Ht following Vibration
Control	6	48.79 ± 7.23	47.60 ± 3.42	- 2.74	- 1.19
Squat + V	13	49.82 ± 10.13	49.83 ± 2.50	+ 0.55	+ 0.01
Squat	11	43.26 ± 5.85	42.09 ± 2.01	- 2.89	- 1.15
Week 3					
Control	6	48.75 ± 3.23	47.88 ± 3.09	- 1.64	- 0.93
Squat + V	13	51.76 ± 2.62	51.18 ± 2.56	- 1.11	- 0.58
Squat	11	44.15 ± 1.82	42.33 ± 1.73	- 4.16	- 1.82
Week 7					
Control	6	48.96 ± 2.95	47.31 ± 2.91	- 3.24	- 1.65
Squat + V	13	54.05 ± 2.67	53.28 ± 2.72	- 1.44	- 0.77
Squat	11	47.35 ± 1.67	45.17 ± 1.56	- 4.54	- 2.18

Values expressed as Means ± SE

One-way analysis of variance was performed on measures of percent change (%) from pre to post vibration jump performance on weeks 1, 3, and 7. Significant differences were seen between groups for percent change in Depth Jump pre to post vibration exposure on week 3 ($p = 0.033$). Pair wise comparisons revealed that percent change for G2 was significantly greater than percent change for G3 ($p = 0.036$, mean difference 2.95 %). No significant differences were seen between Groups on weeks 1 or weeks 7 ($p \geq 0.05$).

Figure 21 presents the Depth Jump Height (cm) pre and post vibration for groups G1, G2, and G3 on week 1 (baseline). Depth jump was found to be statistically similar pre and post vibration for G1 and G2 ($p > 0.05$) while being significantly greater than G3 Jump height ($p \leq 0.05$) at week 1.

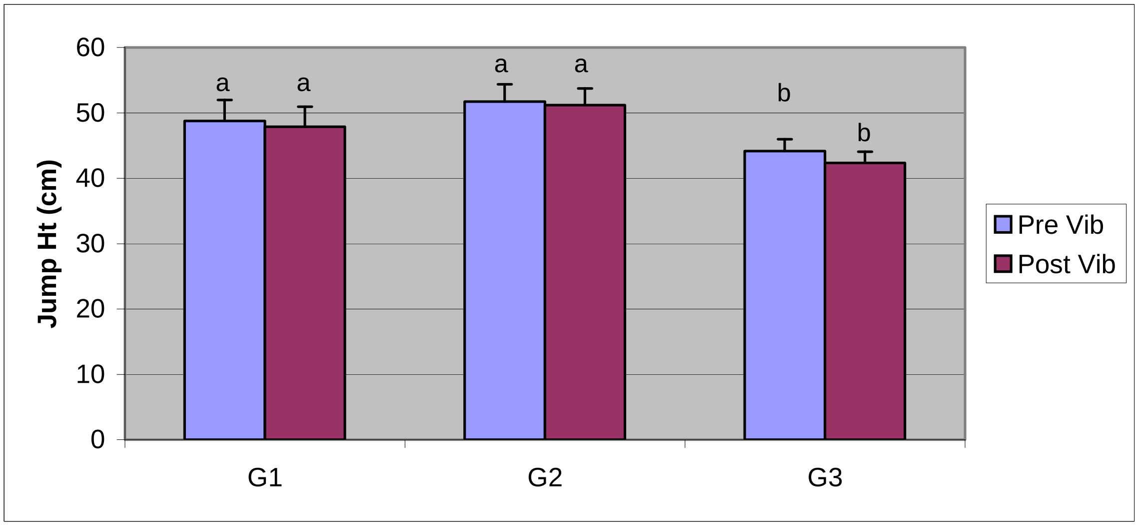
Figure 21. Depth Jump Height (cm) pre and post vibration for groups G1, G2, and G3 on week 1 (baseline).



Values expressed as Means ± SE

[a] denotes G1 trials pre and post vibration statistically similar to G2 pre and post vibration trials ($p > 0.05$) but statistically different from G3 pre and post vibration trials ($p \leq 0.05$).
[b] denotes G3 pre and post vibration trials statistically similar to one another ($p > 0.05$) but significantly less than G1 and G2 pre and post vibration ($p \leq 0.05$).

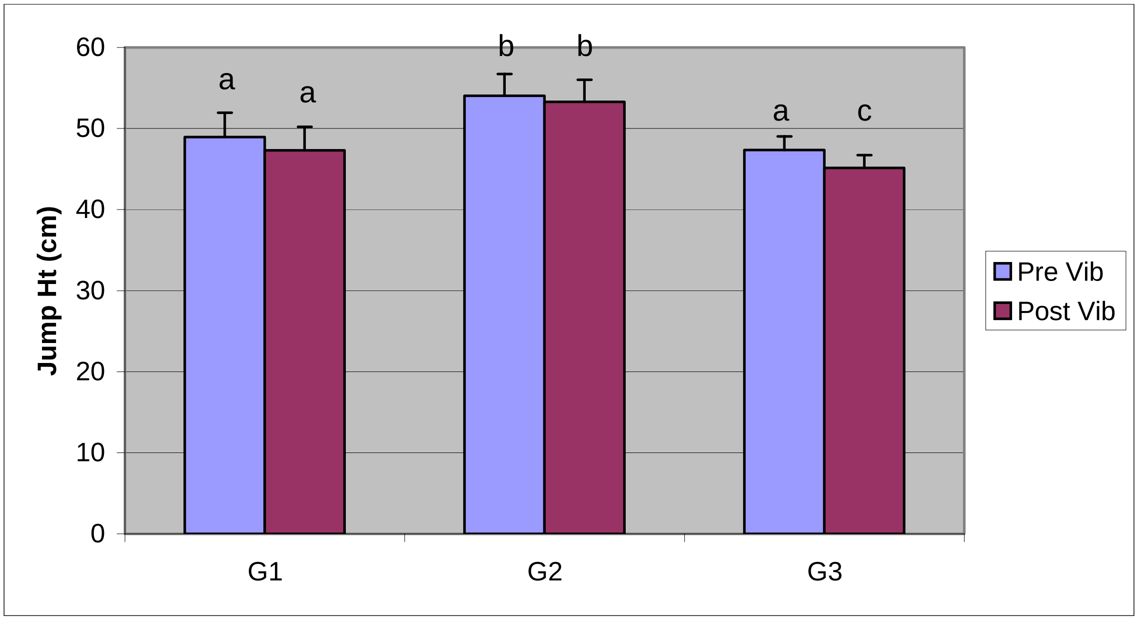
Figure 22. Depth Jump Height (cm) pre and post vibration for groups G1, G2, and G3 on week 3 (mid point in training).



[a] denotes G1 trials pre and post vibration statistically similar to G2 pre and post vibration trials ($p > 0.05$) but statistically different from G3 pre and post vibration trials ($p \leq 0.05$). [b] denotes G3 pre and post vibration trials statistically similar to one another ($p > 0.05$) but significantly less than G1 and G2 pre and post vibration ($p \leq 0.05$). Values expressed as Means ± SE

Depth Jump height was found to statistically similar pre and post vibration between G1 and G2 at week 3 ($p > 0.05$). G2 post vibration measures were found to be significantly greater than G3 post vibration measures at week 3 ($p \leq 0.05$).

Figure 23. Depth Jump Height (cm) pre and post vibration for groups G1, G2, and G3 on week 7.



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Values expressed as Means ± SE
[a] denotes G1 pre and post vibration statistically similar to G3 pre vibration)($p > 0.05$).
[b] denotes G2 pre and post vibration statistically similar ($p > 0.05$), statistically different from G1 and G3 pre and post vibration measures ($p \leq 0.05$).

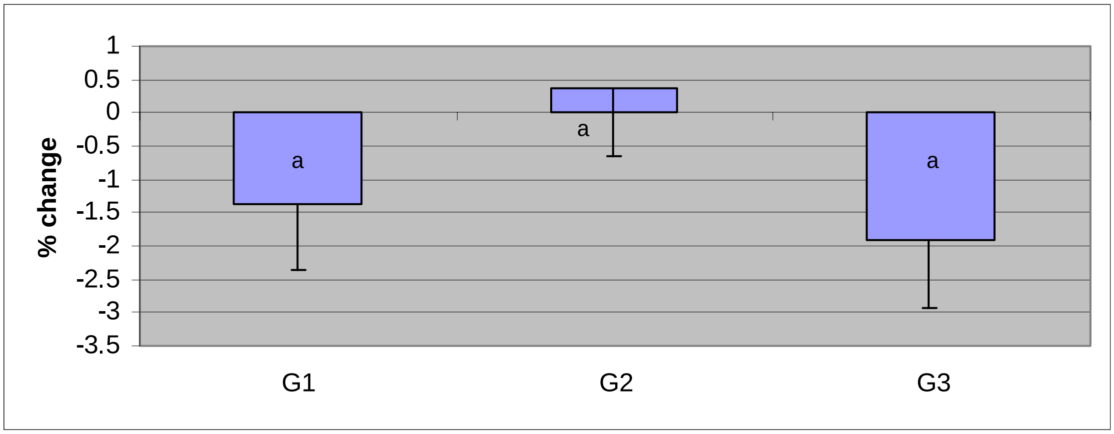
Depth Jump height at week 7 pre and post vibration was found to statistically similar between G1 and G2 ($p > 0.05$). Post vibration jump height at week 7 was found to be statistically different between G2 and G3 (G2 height greater than G3 height) ($p \leq 0.05$).

Table 15. Depth Jump Peak power (W) and percent change following vibration at weeks 1, 3, and 7 for each Group.

Week 1 Group	N	Pre vibration Jump Power (W)	Post vibration Jump Power (W)	% Change in Jump Power following Vibration	Relative change in Jump Power following Vibration
Control	6	4877.80 ± 162.35	4805.85 ± 138.58	- 1.39	- 72.05
Squat + V	13	4753.55 ± 239.15	4754.15 ± 220.11	+ 0.36	0.60
Squat	11	3960.20 ± 146.74	3889.41 ± 158.96	- 1.90	- 70.80
Week 3					
Control	6	4890.33 ± 144.48	4837.66 ± 164.33	- 1.13	- 52.44
Squat + V	13	4870.97 ± 228.61	4835.98 ± 229.82	- 0.80	- 34.99
Squat	11	4026.51 ± 159.65	3916.49 ± 148.29	- 2.66	- 110.03
Week 7					
Control	6	4880.53 ± 115.79	4780.32 ± 142.13	- 2.10	- 100.21
Squat + V	13	5055.62 ± 228.58	5008.77 ± 230.45	- 0.88	- 46.85
Squat	11	4220.64 ± 162.79	4088.18 ± 161.23	- 3.15	- 132.46

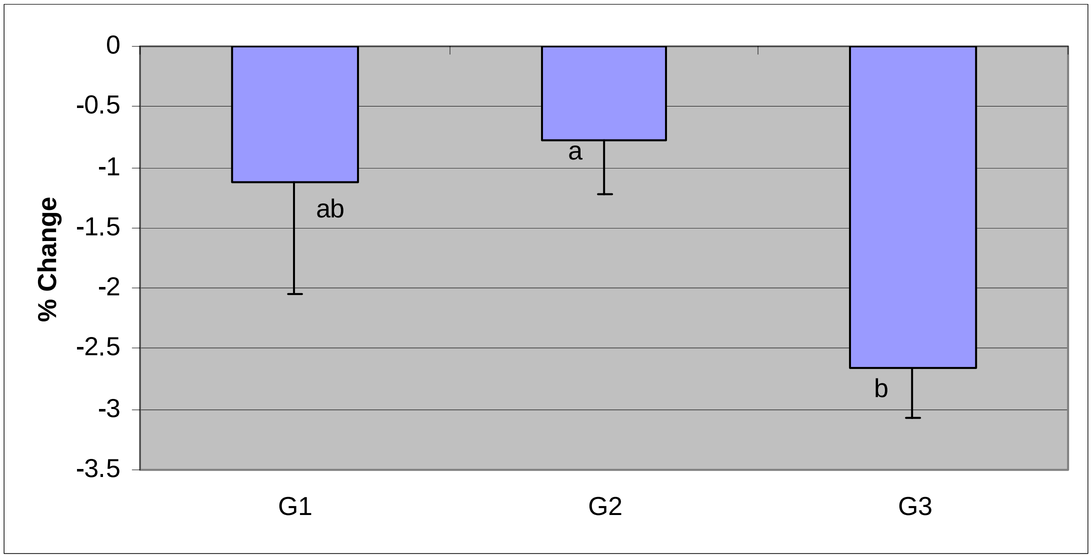
Values are Means ± SE

Figure 24. Percentage change (%) (pre to post vibration) in Depth jump peak power (W) following vibration application on week 1.



Only one Group (G2) increased Depth Jump power following vibration exposure on week one although not found to be significantly different from all other Groups ($p > 0.050$)

Figure 25. Percentage change (%) in Depth jump peak power (W) following vibration application on week 3.

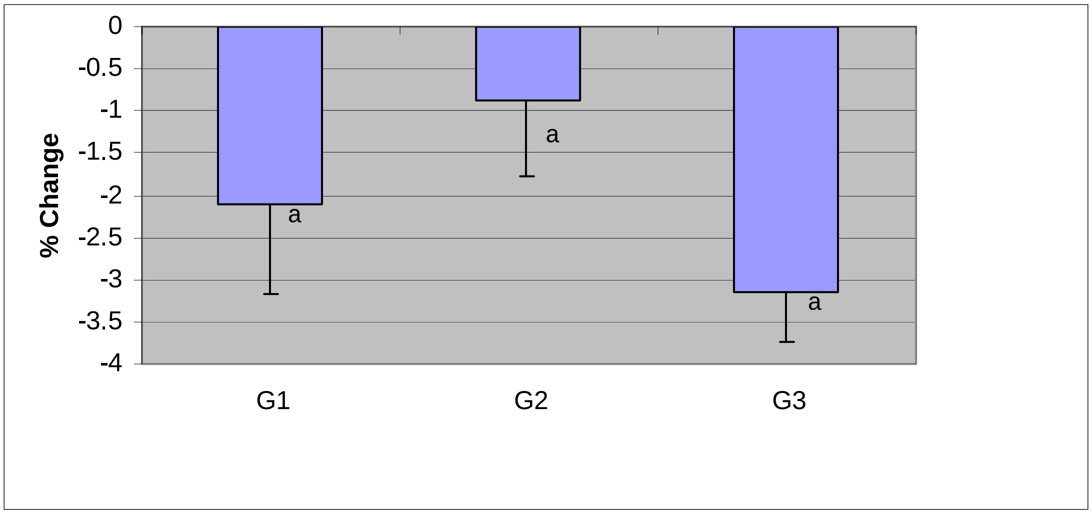


All values expressed as means ± SE.

[a] denotes percent change for G2 significantly less percent ($p \leq 0.05$) change than G3 but statistically similar to G1 ($p > 0.05$).

All groups exhibited post activation depression (PAD). Group's 3 percent change in Depth Jump peak power was significantly greater ($p \leq 0.05$) than G2 but statistically similar to Group 1. The percent change was a result of PAD leading to a 2.66 % reduction in Depth Jump peak power (- 110.03 W). Groups 1 and Group 2 were found to be statistically similar to one another with regards to percent change in Depth Jump peak power following vibration exposure on week 3 ($p > 0.05$).

Figure 26. Percentage change (%) in Depth jump peak power (W) following vibration application on week 7.



All values expressed as means ± SE
[a] denotes G1, G2, and G3 all statistically similar ($p > 0.05$).
All groups exhibited non-significant post activation depression (PAD).

Group 3 showed the largest percent decrease in Depth Jump Peak power (W) following vibration exposure on week 7 (- 3.15%, - 132.46 W) although not found to be significantly different from G1 and G2 ($p > 0.05$).

Table 16. Depth Peak power/kg (W/kg) and percent change following vibration at weeks 1, 3, and 7 for each Group.

Week 1				% Change in	Relative change in
Group	N	Pre vibration Jump Power/kg (W/kg)	Post vibration Jump Power/kg (W/kg)	Jump Power/kg following Vibration	Jump Power/kg following Vibration
Control	6	56.30 ± 2.44	55.58 ± 2.73	- 1.38	- 0.72
Squat + V	13	57.00 ± 2.22	57.08 ± 1.98	+ 0.36	+ 0.08
Squat	11	53.09 ± 1.58	52.13 ± 1.80	- 1.90	- 0.96
Week 3					
Control	6	56.34 ± 2.55	55.67 ± 2.46	- 1.13	- 0.67
Squat + V	13	58.54 ± 2.19	58.09 ± 2.08	- 0.77	- 0.45
Squat	11	53.73 ± 1.57	52.29 ± 1.51	- 2.76	- 1.44
Week 7					

Control	6	56.45 ± 2.34	55.24 ± 2.35	- 2.10	- 1.21
Squat + V	13	60.00 ± 2.09	59.46 ± 2.14	- 0.88	- 0.54
Squat	11	56.25 ± 1.33	54.44 ± 1.20	- 3.15	- 1.81

All Values expressed as Means ± SE

Table 17. Depth Jump mean power (W) and percent change following vibration at weeks 1, 3, and 7 for each Group.

Week 1				% Change in	Relative change in
Group	N	Pre vibration	Post vibration	Jump Mean P	Jump Mean P
		Jump Mean P	Jump Mean P	following	following
		(W)	(W)	Vibration	Vibration
Control	6	1505.00 ± 80.08	1497.75 ± 74.86	- 0.36	- 7.25
Squat + V	13	1485.15 ± 66.85	1477.81 ± 67.99	- 0.48	- 6.29
Squat	11	1205.91 ± 57.55	1208.23 ± 51.55	+ 0.49	- 2.32
Week 3					
Control	6	1518.75 ± 74.76	1497.17 ± 92.69	- 1.65	- 21.58
Squat + V	13	1494.08 ± 78.53	1504.81 ± 74.97	+ 1.03	+ 10.73
Squat	11	1242.27 ± 50.37	1213.68 ± 51.48	- 2.30	- 28.59
Week 7					
Control	6	1495.08 ± 53.47	1508.92 ± 66.81	+ 0.82	+ 13.84
Squat + V	13	1569.96 ± 76.60	1548.12 ± 72.08	- 1.19	- 21.84
Squat	11	1285.27 ± 55.68	1249.36 ± 53.20	- 2.71	- 35.91

Values expressed as Means ± SE

No significant changes were seen between Groups for percent change in mean power on weeks 1 (p = 0.360), 3 (p = 0.593), or week 7 (p = 0.505).

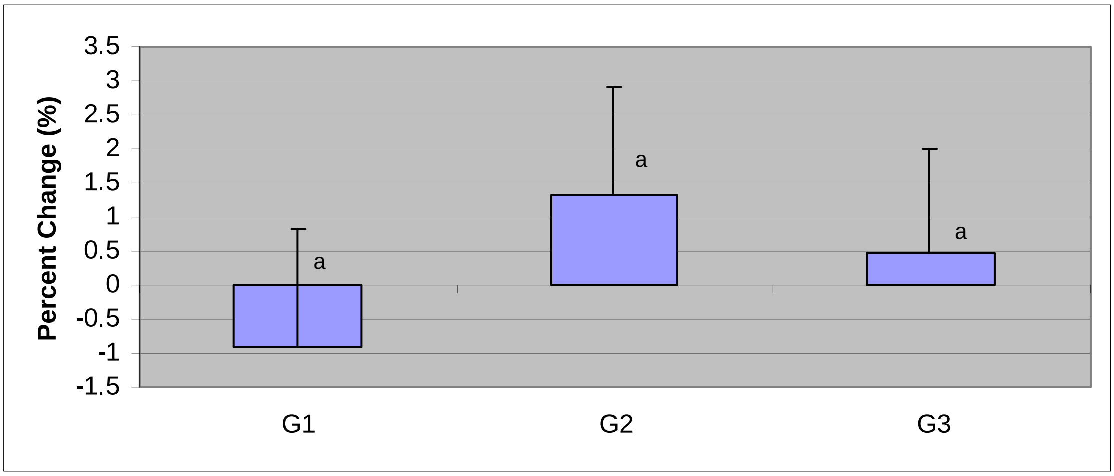
Table 18. Squat Jump height (cm) and percent change following vibration at weeks 1, 3, and 7 for each Group.

Week 1				% Change in	Relative change in
Group	N	Pre vibration Jump Ht (cm)	Post vibration Jump Ht (cm)	Jump Ht following Vibration	Jump Ht following Vibration
Control	6	35.07 ± 2.39	34.84 ± 2.75	- 0.92	- 0.23
Squat + V	13	35.53 ± 2.29	35.76 ± 2.13	+ 1.31	+ 0.26
Squat	11	28.86 ± 1.19	29.00 ± 1.25	+ 0.48	+ 0.14
Week 3					
Control	6	36.49 ± 2.38	35.54 ± 2.61	- 2.84	- 0.95
Squat + V	13	37.53 ± 2.16	38.17 ± 2.01	+ 2.08	+ 0.64
Squat	11	30.39 ± 1.31	29.82 ± 1.38	- 1.90	- 0.57
Week 7					
Control	6	36.55 ± 2.01	36.17 ± 2.10	- 1.08	- 0.35
Squat + V	13	39.66 ± 2.09	39.57 ± 1.94	- 0.07	- 0.09
Squat	11	33.81 ± 1.15	33.07 ± 1.22	- 2.24	- 0 .74

Values Means ± SE

No significant differences were found between Groups for % change in Squat Jump height on weeks 1, 3, or 7 (p > 0.05)

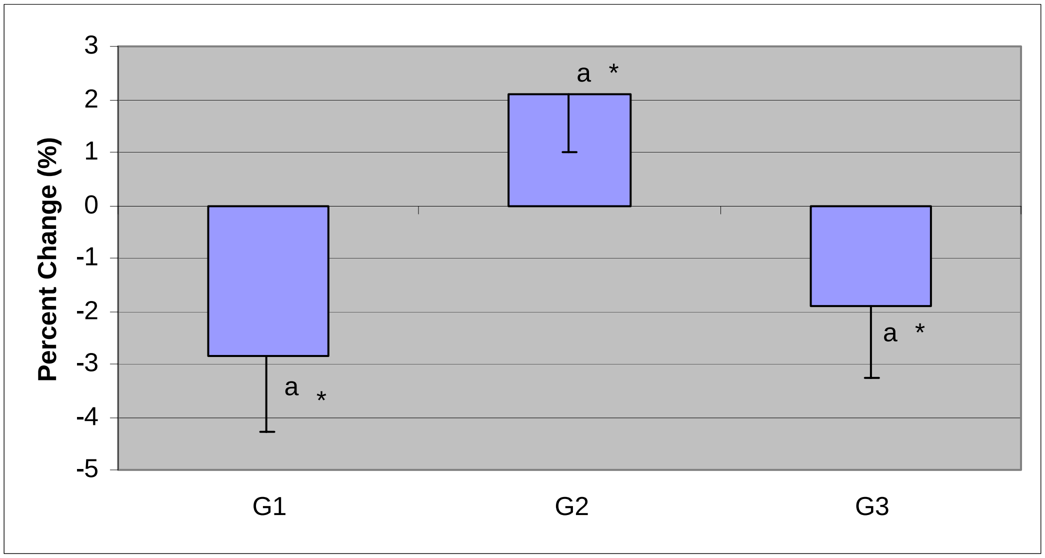
Figure 27. Percentage change (%) in Squat jump height (cm) following vibration application on week 1.



All values expressed as means ± SE.
[a] denotes G1, G2, and G3 statistically similar to one another (p > 0.05).

Greatest percent change was seen for G2 although not found to be statistically different from G1 and G3 ($p > 0.05$)

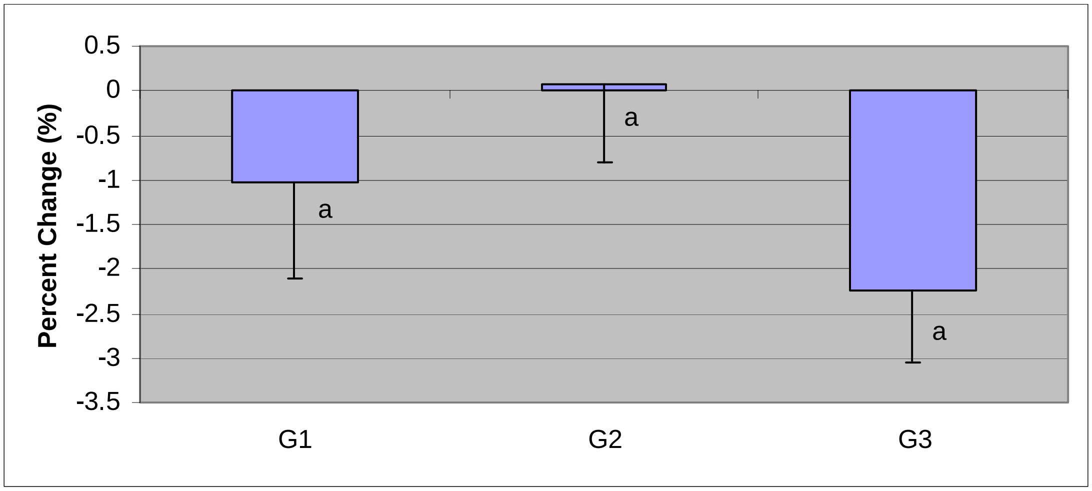
Figure 28. Percentage change (%) in Squat jump height (cm) following vibration application on week 3.



All values expressed as means ± SE.
[a]* denotes One way ANOVA revealed significant group differences ($p = 0.026$), however Bonferroni post hoc analysis revealed no significant differences between Groups ($p > 0.05$).

Although no significance was found between Groups at week three for percent change following vibration, only G2 improved Squat Jump height (cm) on week 3 indicating a non-significant potentiated state (PAP) compared to a non-significant depressed state (PAD) for G1 and G3.

Figure 29. Percentage change (%) in Squat jump height (cm) following vibration application on week 7.



All values expressed as means ± SE.
[a] denotes G1, G2, and G3 statistically similar to one another ($p > 0.05$).

Although no significant differences were found between groups for percent change in Squat Jump height (cm) following vibration on week 7, PAD was evident for G1 and G3 with a small non-significant PAP state evident for G2 ($p > 0.05$).

Table 19. Squat Jump Peak power (W) and percent change following vibration at weeks 1, 3, and 7 for each Group.

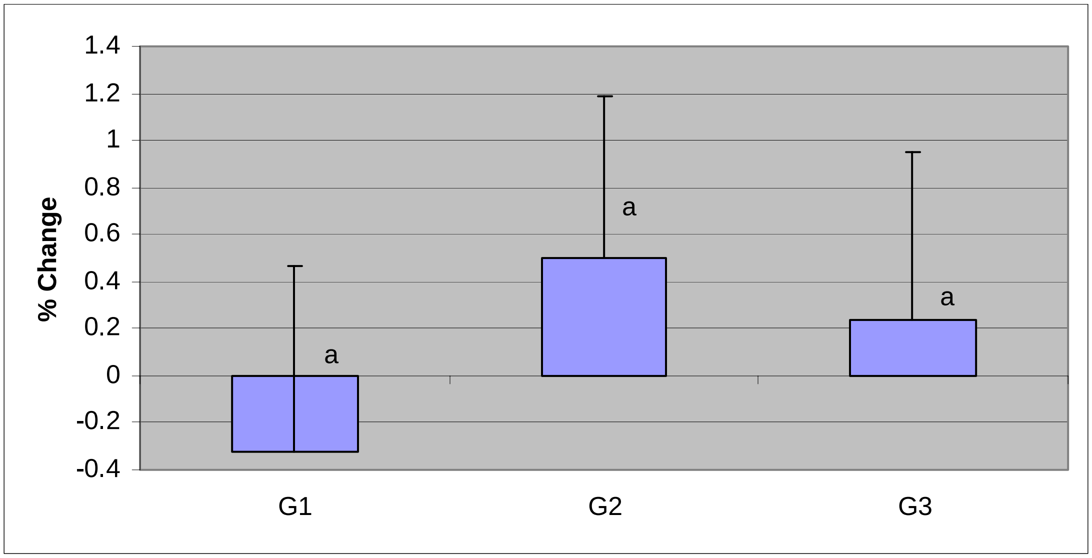
Week 1				% Change in	Relative change in
Group	N	Pre vibration Jump Power (W)	Post vibration Jump Power (W)	Jump Power following Vibration	Jump Power following Vibration
Control	6	4951.24 ± 204.43	4937.11 ± 214.87	- 0.32	- 14.13
Squat + V	13	4792.01 ± 241.43	4805.64 ± 230.35	+ 0.50	+ 13.63
Squat	11	3992.29 ± 140.17	4000.70 ± 141.00	+ 0.24	+ 8.41
Week 3					
Control	6	5052.42 ± 224.14	4994.61 ± 204.97	- 1.08	- 58.19
Squat + V	13	4913.45 ± 236.78	4952.11 ± 231.91	+ 0.91	38.66
Squat	11	4097.15 ± 165.44	4062.81 ± 162.47	- 0.80	- 34.68
Week 7					
Control	6	5033.63 ± 174.71	5010.50 ± 181.97	- 0.48	- 23.13

Squat + V	13	5088.14 ± 225.09	5082.80 ± 214.00	- 0.03	- 5.34
Squat	11	4304.59 ± 147.94	4259.74 ± 157.29	- 1.13	- 44.83

All values expressed as Means ± SE

No significant differences were seen for percent change in Squat Jump peak power (W) following vibration exposure (p > 0.05). The greatest non-significant percent increase (PAP) was seen for G2 on week 3 (+ 0.91%, 38.66 W). The greatest non-significant decrease seen was for G3 on week 7 (- 1.13%, - 44.83 W).

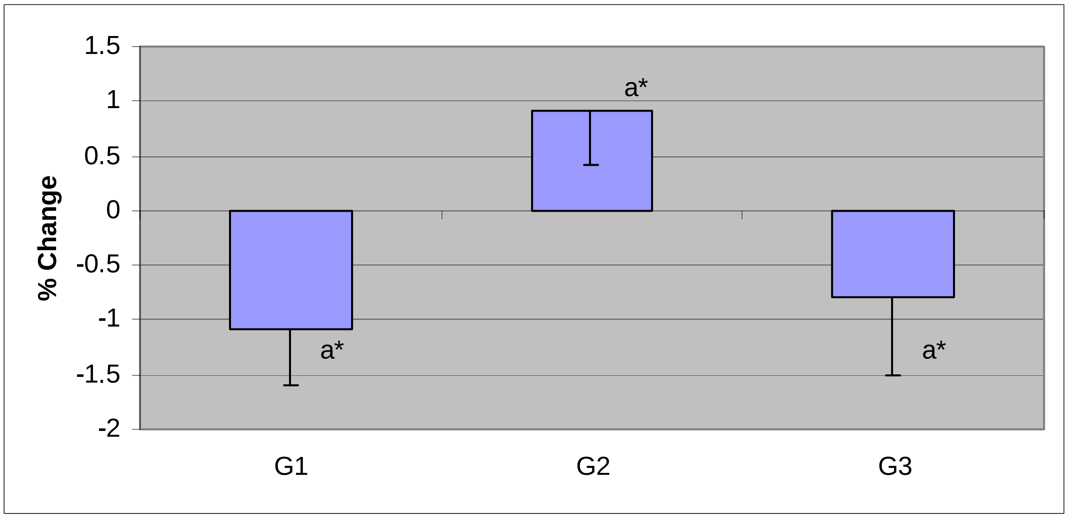
Figure 30. Percentage change (%) in Squat jump peak power (W) following vibration application on week 1.



All values expressed as Means ± SE,
^{a} denotes G1, G2, and G3 statistically similar to one another (p > 0.05).

No significant changes were seen between pre and post vibration measure of Squat Jump Peak power at week 1. Both Groups G2 and G3 exhibited non-significant PAP with G1 producing a non-significant state of PAD.

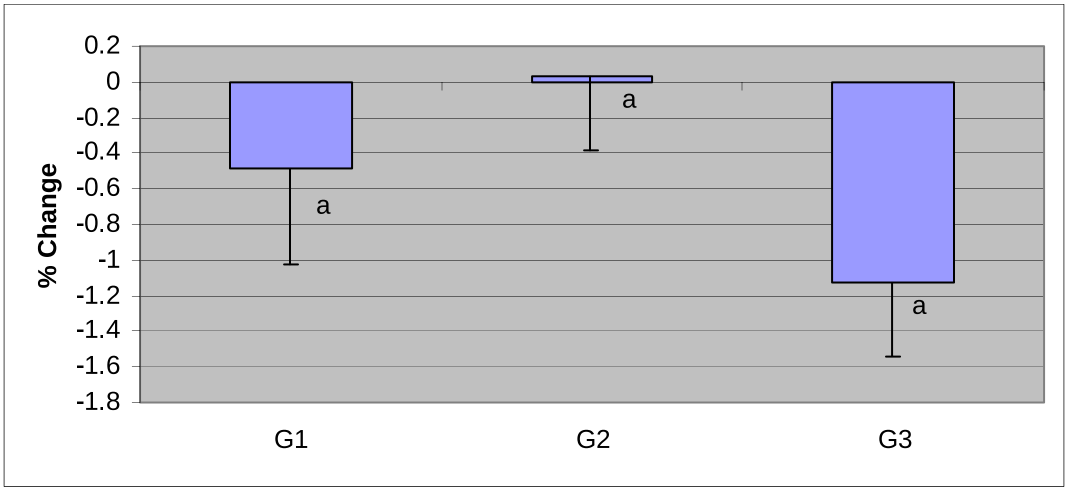
Figure 31. Percentage change (%) in Squat jump peak power (W) following vibration application on week 3.



All values expressed as Means ± SE.
[a]* denotes One –way ANOVA revealed significant group differences ($p = 0.043$), however Bonferroni post hoc analysis revealed no significant differences between Groups ($p > 0.05$).

The percent change in Squat Jump peak power on week 3 approached significance but was ultimately found non significant during post hoc pair-wise comparisons analysis ($p > 0.05$). Only G2 showed an increase in Squat Jump peak power (PAP) with G1 and G3 seeing reductions in Squat Jump power following vibration exposure (PAD) ($p > 0.05$).

Figure 32. Percentage change (%) in Squat jump peak power (W) following vibration application on week 7.



All values expressed as means ± SE.
[a] denotes G1, G2, and G3 statistically similar to one another ($p > 0.05$).

One –way ANOVA performed on percent change in Squat Jump peak power (W) following vibration on week 7 revealed no significant differences between Groups ($p > 0.050$). Group 2 was the only Group to see a non significant improvement in Squat Jump peak power following vibration (PAP) with all other Groups exhibiting non significant PAD ($p > 0.050$).

Table 20. Squat Jump Peak power/kg (W) and percent change following vibration at weeks 1, 3, and 7 for each Group.

Week 1					
Group	N	Pre vibration Jump P/kg (W)	Post vibration Jump P/kg (W)	% Change in Jump P/kg following Vibration	Relative change in Jump P/kg following Vibration
Control	6	57.01. ± 2.18	56.87± 2.43	- 0.32	- 0.14
Squat + V	13	57.30 ± 1.73	57.53 ± 1.61	+ 0.50	+ 0.23
Squat	11	53.41 ± 0.98	53.54 ± 1.08	+ 0.24	+ 0.13
Week 3					
Control	6	57.96 ± 2.18	57.36 ± 2.29	- 1.08	- 0.60

Squat + V	13	58.84 ± 1.64	59.33 ± 1.51	+ 0.91	+ 0.49
Squat	11	54.50 ± 0.93	54.08 ± 1.04	- 0.79	- 0.42
Week 7					
Control	6	58.04 ± 1.94	57.76 ± 2.00	- 0.48	- 0.28
Squat + V	13	60.25 ± 1.52	60.24 ± 1.45	- 0.03	- 0.01
Squat	11	57.34 ± 0.84	56.69 ± 0.83	- 1.13	- 0.65

All values expressed as Means ± SE

A one-way ANOVA performed on percent change in Squat Jump peak power/kg revealed significant differences between Groups at week 3 (≤ 0.050), however, post hoc pair wise comparisons revealed that there were no statistical differences between Groups (p > 0.050).

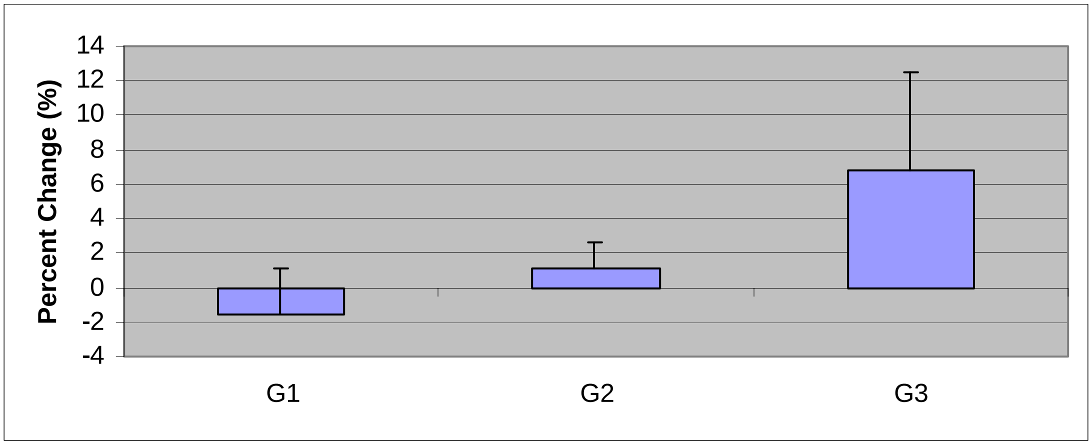
Table 21. Squat Jump Mean Power (W) and percent change following vibration at weeks 1, 3, and 7 for each Group.

Week 1					
Group	N	Pre vibration Jump M power (W)	Post vibration Jump M power (W)	% Change in M Jump power following Vibration	Relative change in M Jump power following Vibration
Control	6	1420.75 ± 73.95	1394.67 ± 63.28	- 1.66	- 26.80
Squat + V	13	1360.92 ± 61.00	1376.50 ± 66.90	+ 1.09	+ 16.42
Squat	11	1064.64 ± 80.78	1100.73 ± 54.78	+ 6.79	+ 36.09
Week 3					
Control	6	1489.67 ± 58.07	1459.17 ± 56.33	- 1.95	- 30.50
Squat + V	13	1414.73 ± 79.93	1428.65 ± 84.01	+ 1.28	+ 13.92
Squat	11	1142.18 ± 72.58	1116.23 ± 75.75	- 2.25	- 25.95
Week 7					
Control	6	1490.33 ± 71.41	1474.17 ± 51.27	- 0.73	- 16.16
Squat + V	13	1490.73 ± 79.93	1462.23 ± 68.01	- 1.93	- 47.50
Squat	11	1187.09 ± 72.88	1193.59 ± 73.56	+ 0.54	+ 6.50

All Values expressed as Means ± SE

No significant differences were seen between Groups at weeks 1, 3, or 7 for percent change in Squat Jump Mean power (W). The greatest actual percent increase seen following vibration was 6.79% for G3 (p > 0.05).

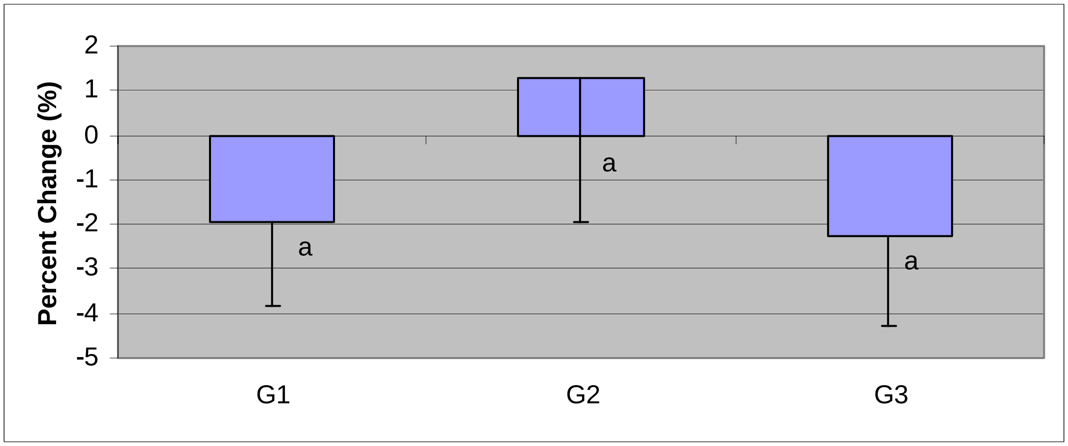
Figure 33. Percentage change (%) in Squat jump mean power (W) following vibration application on week 1.



Values expressed at means ± SE
[a] denotes G1, G2 and G3 statistically similar to one another ($p > 0.05$).

No significant differences were seen between Groups at week 1 for percent change in Squat Jump mean power ($p > 0.05$). G3 produced the greatest actual change in Squat Jump mean power (6.79%) although not statistically significant ($p > 0.05$).

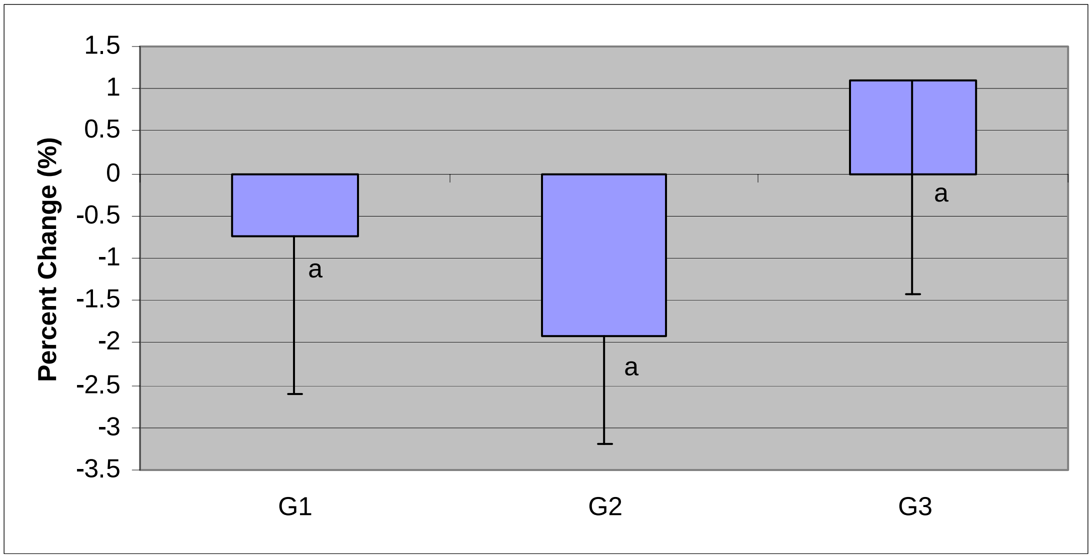
Figure 34. Percentage change (%) in Squat jump mean power (W) following vibration application on week 3.



Values expressed as means ± SE
[a] denotes G1, G2 and G3 statistically similar to one another ($p > 0.05$)

No significant differences were seen between Groups following vibration exposure at week 3 ($p > 0.05$). Only G3 produced a non-significant state of PAP following vibration exposure with G1 and G2 exhibiting PAD ($p > 0.05$).

Figure 35. Percentage change (%) in Squat jump mean power (W) following vibration application on week 7.



Values expressed as means ± SE
[a] denoted G1, G2, and G3 statistically similar to one another ($p > 0.05$).

No significant differences were seen between Groups following vibration exposure with regards to percent change in Squat Jump height (cm) at week 7. Group 3 was the only group to see an increase in Squat jump mean power following vibration on week 7 (1.09%) ($p > 0.050$).

Percent change in RFD parameters of interest.

Table 22. Rate of Force development between 0 – 30 ms (N/s) and percent change between weeks 1, and 7 for each Group.

Weeks 1 and 7				% Change in	Relative change in
Group	N	RFD 30ms (Week 1)	RFD 30ms (Week 7)	RFD 30 ms (Weeks 1 – 7)	RFD 30ms (Weeks 1 – 7)
Control	6	2410.59 ± 642.87	1677.47 ± 419.68	- 43.70	- 733.12
Squat + V	13	1292.40 ± 380.30	1230.82 ± 221.36	- 5.00	- 61.58
Squat	11	1270.82 ± 421.96	806.09 ± 292.49	- 42.35	- 464.73

Values expressed as Means ± SE

One-way ANOVA analysis of between Group differences for percent change revealed that G2 produced to least percent decline (non-significant, p > 0.050) in RFD at 30 ms (G2- 5.00 %, G1 -43.70%, G3 -42.35%).

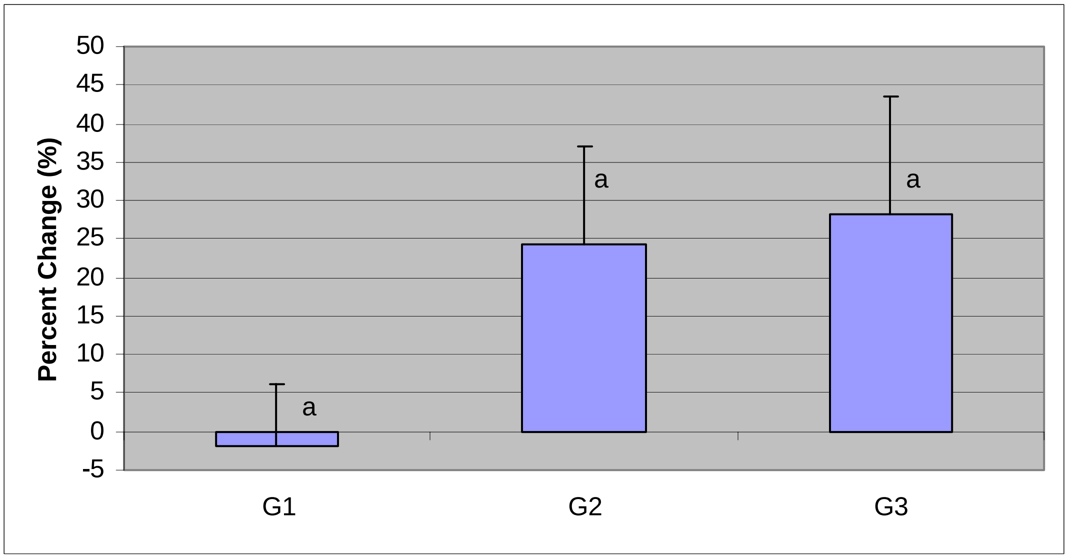
Table 23. Rate of Force development between 0 – 250 ms (N/s) for week 1 and week 7 and percent change between weeks 1, and 7 for each Group.

Weeks 1 and 7				% Change in	Relative change in
Group	N	RFD 250ms (Week 1)	RFD 250ms (Week 7)	RFD 250 ms (Weeks 1 – 7)	RFD 250ms (Weeks 1 – 7)
Control	6	6821.43 ± 1206.44	6424.52 ± 956.86	- 6.18	- 396.91
Squat + V	13	4525.87 ± 310.65	5399.10 ± 475.41	+ 16.17	+ 873.23
Squat	11	3186.21 ± 467.44	3592.15 ± 366.35	+ 11.30	+ 405.94

Values expressed as Means ± SE

One-way ANOVA analysis of between Group differences for percent change revealed that G2 improved the most compared with all other groups (G2 = 16.17%, G1 = -6.18%, G3 = 11.30%). No significant differences were seen between groups for percent change (p > 0.050).

Figure 36. Percentage change (%) in ISORFD 0 – 250ms from weeks 1 to week 7.



Values expressed as Means ± SE
[a] denotes G1, G2, and G3 percent change statistically similar (p > 0.050).

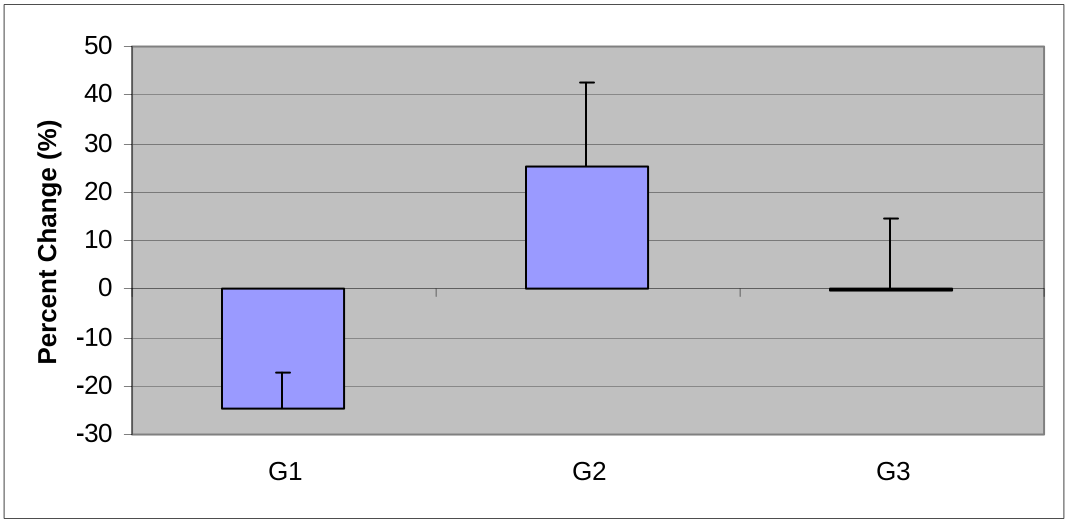
Percent change in isometric rate of force development between 0 and 250 milliseconds produced large, non significant increases for both G2 and G3 (p > 0.050) . G1 showed a non-significant reduction in rate of force development at 250 milliseconds (N/s) (p > 0.050). Large between subject variability may have contributed to the large, but non-significant changes seen (p > 0.050).

Table 24. Rate of Force development between 0 and initial peak in force (N/s) for week 1 and week 7 and percent change between weeks 1 and 7 for each Group.

Weeks 1 and 7				% Change in	Relative change in
Group	N	RFD ini P (Week 1)	RFD ini P (Week 7)	RFD ini P (Weeks 1 – 7)	RFD ini P (Weeks 1 – 7)
Control	6	9253.70 ± 660.75	7111.21 ± 1071.14	- 24.76	- 2142.49
Squat + V	13	5635.85 ± 693.60	6106.26 ± 533.51	+ 25.24	+ 470.41
Squat	11	4254.48 ± 744.38	3585.64 ± 475.77	- 0.25	- 668.84

Values expressed as means ± SE

Figure 37. Percentage change (%) in ISORFD 0 – initial peak in force (N/s) from weeks 1 to week 7.



Values expressed as Means ± SE

[a] denotes G1, G2, and G3 percent change statistically similar (p > 0.05).

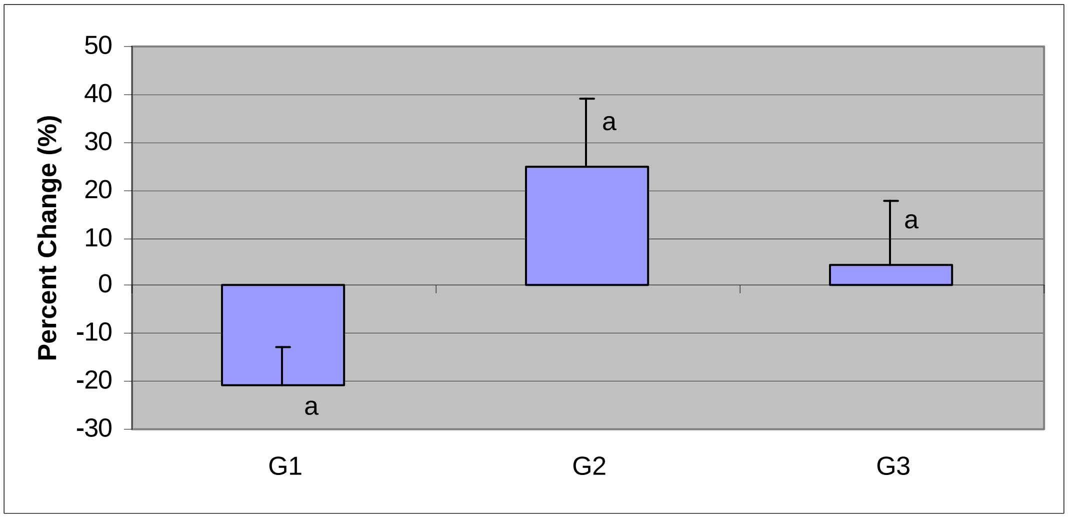
No significant differences were seen between Groups for rate of force development at initial peak in force (N/s) (p > 0.05). Large non-significant differences were seen, however, with only G2 improving from week 1 to week 7 (25.24%). G1 showed a 24.76% reduction at week 7 although not significant (p > 0.05). Large variability between subjects within Groups may in part explain the large non-significant differences seen (p > 0.050).

Table 25. Peak rate of force development at weeks 1 and week 7 (N/s) and percent change between weeks 1 and 7 for each Group.

Weeks 1 and 7				% Change in	Relative change in
Group	N	Peak RFD	Peak RFD	Peak RFD	Peak RFD
		(Week 1)	(Week 7)	(Weeks 1 – 7)	(Weeks 1 – 7)
Control	6	17373.43 ± 1835.57	13952.37 ± 2137.33	- 20.59	- 3421.06
Squat + V	13	10461.40 ± 1008.79	12164.89 ± 979.93	+ 25.02	+ 1703.49
Squat	11	8172.45 ± 1080.64	7739.53 ± 843.87	- 4.48	- 432.92

Values expressed as means ± SE

Figure 38. Percentage change (%) in Peak RFD (N/s) from weeks 1 to week 7.



Values expressed as means ± SE
[a] denotes G1, G2, and G3 percent change statistically similar ($p > 0.05$).

No significant differences were seen for percent change between Groups for Peak rate isometric rate of force development (N/s) ($p > 0.05$). The largest non-significant percent increase was 25.02% for G2. G1 showed a non-significant decrement (- 20.59%) in Peak RFD (N/s) from weeks 1 to 7 ($p > 0.05$). Large between subject variability may have contributed to the large, but non-significant differences seen for percent change between Groups ($p > 0.050$).

Table 26. Time of onset of Peak rate of force development at weeks 1 and week 7 (m/s) and percent change between weeks 1 and 7 for each Group.

Weeks 1 and 7				% Change in	Relative change in
Group	N	T Peak RFD (Week 1)	T Peak RFD (Week 7)	T Peak RFD (Weeks 1 – 7)	T Peak RFD (Weeks 1 – 7)
Control	6	99.67 ± 10.63	105.00 ± 14.07	+ 5.08	+ 5.33
Squat + V	13	144.83 ± 19.51	128.37 ± 13.88	- 12.82	- 16.46
Squat	11	156.05 ± 33.60	152.64 ± 28.79	- 2.23	- 3.41

Values expressed as Means ± SE

No significant differences were seen between Groups for percent change in the time of onset of Peak RFD (N/s) (p > 0.050). A trend was seen however for a reduction in the time of onset of peak RFD for the Squat + Vibration Group although not found to be significant (p > 0.050).

Table 27. Average RFD for MVC at weeks 1 and week 7 (N/s) and percent change between weeks 1 and 7 for each Group.

Weeks 1 and 7				% Change in	Relative change in
Group	N	RFD MVC (Week 1)	RFD MVC (Week 7)	RFD MVC (Weeks 1 – 7)	RFD MVC (Weeks 1 – 7)
Control	6	1178.50 ± 195.07	1531.07 ± 361.14	+23.03	+ 352.57
Squat + V	13	1197.70 ± 252.49	948.37 ± 65.10	- 26.29	- 249.33
Squat	11	807.98 ± 122.58	899.71 ± 128.74	+10.20	+ 91.73

Values expressed as Means ± SE

No significant differences were seen between Groups for percent change in Average RFD for the MVC although the Control Group increased by 23.03% and the Squat + Vibration Group decreased by 26.29% (p > 0.050).

Force/Time parameters of Interest percent change

Table 28. Force at 30ms at weeks 1 and week 7 (N) and percent change between weeks 1 and 7 for each Group.

Weeks 1 and 7				% Change in	Relative change in
Group	N	Force 30ms (Week 1)	Force 30ms (Week 7)	Force 30ms (Weeks 1 – 7)	Force 30ms (Weeks 1 – 7)
Control	6	76.48 ± 19.65	53.94 ± 13.08	- 41.79	- 22.54
Squat + V	13	41.39 ± 12.08	39.83 ± 7.07	- 3.92	- 1.56
Squat	11	39.79 ± 12.97	25.75 ± 9.30	- 45.48	14.04

Values expressed as Means ± SE

No significant differences were found between Groups although trends were seen for large non-significant reduction in force at 30ms for both the control Group (-41.79%) and the Squat Only Group (-45.48%) (p > 0.050). These large non significant percent changes may have in part been due to the higher resting tension seen prior to the initiation of contraction for both the Control Group and the Squat Only Group when compared to the Squat + Vibration Group.

Table 29. Force at 250ms at weeks 1 and week 7 (N) and percent change between weeks 1 and 7 for each Group.

Weeks 1 and 7				% Change in	Relative change in
Group	N	Force 250ms	Force 250ms	Force 250ms	Force 250ms
		(Week 1)	(Week 7)	(Weeks 1 – 7)	(Weeks 1 – 7)
Control	6	1484.68 ± 198.84	1401.13 ± 176.42	- 3.94	- 83.55
Squat + V	13	1008.78 ± 71.46	1131.28 ± 79.55	+ 16.73	+ 122.5
Squat	11	717.26 ± 85.43	772.19 ± 85.15	+ 14.95	- 54.93

Values expressed as Means ± SE

No significant differences were seen between Groups for percent change in force at 250 ms from weeks 1 to week 7, (p > 0.050) although the two experimental Groups had quite large non-significant increases in force at 250 ms (p > 0.050).

Table 30. Force at initial peak in force at weeks 1 and week 7 (N) and percent change between weeks 1 and 7 for each Group.

Weeks 1 and 7				% Change in	Relative change in
Group	N	Force ini P	Force ini P	Force ini P	Force ini P
		(Week 1)	(Week 7)	(Weeks 1 – 7)	(Weeks 1 – 7)
Control	6	1623.56 ± 217.12	1561.28 ± 211.71	- 3.35	- 62.28
Squat + V	13	1386.43 ± 86.06	1380.06 ± 91.68	+ 0.15	- 6.37
Squat	11	979.71 ± 68.65	1002.17 ± 61.80	+ 4.48	+ 22.46

Values expressed as Means ± SE

No significant differences were found between Groups for percent change in force at initial peak from weeks 1 to 7 (p > 0.050).

Table 31. Time at initial peak in force at weeks 1 and week 7 (m/s) and percent change between weeks 1 and 7 for each Group.

Weeks 1 and 7				% Change in	Relative change in
Group	N	Time ini P	Time ini P	Time ini P	Time ini P
		(Week 1)	(Week 7)	(Weeks 1 – 7)	(Weeks 1 – 7)
Control	6	204.67 ± 17.01	284.58 ± 43.67	+ 28.08	+ 79.91
Squat + V	13	352.35 ± 39.17	313.19 ± 31.95	- 12.50	- 39.16
Squat	11	342.45 ± 57.67	416.61 ± 57.43	+ 17.80	+ 74.16

Values expressed as Means ± SE

No significant differences were seen between Groups for percent change in time at initial peak in force (p > 0.050).

Table 32. MVC force at weeks 1 and week 7 (N) and percent change between weeks 1 and 7 for each Group.

Weeks 1 and 7				% Change in	Relative change in
Group	N	MVC Force	MVC Force	MVC Force	MVC Force
		(Week 1)	(Week 7)	(Weeks 1 – 7)	(Weeks 1 – 7)
Control	6	2497.44 ± 291.43	2558.51 ± 265.12	+ 1.40	+ 61.07
Squat + V	13	2121.65 ± 181.18	2302.95 ± 212.80	+ 8.07	+ 181.3
Squat	11	1435.07 ± 86.37	1658.34 ± 101.26	+ 15.61	+ 223.27

Values expressed as Means ± SE

No significant differences were seen between Group for percent change in MVC force between weeks 1 and weeks 7 (p > 0.050). Although no significant differences were seen between Groups, the Squat Only Group improved the most relative to their week I (baseline) MVC measures (+ 15.61%).

Table 33. MVC time at weeks 1 and week 7 (ms) and percent change between weeks 1 and 7 for each Group.

Weeks 1 and 7				% Change in	Relative change in
Group	N	MVC Time	MVC Time	MVC Time	MVC Time
		(Week 1)	(Week 7)	(Weeks 1 – 7)	(Weeks 1 – 7)
Control	6	2537.22 ± 184.19	2422.01 ± 274.28	- 4.76	- 115.21
Squat + V	13	2574.35 ± 199.55	2643.69 ± 120.66	+ 2.62	+ 69.34
Squat	11	2376.37 ± 195.33	2469.38 ± 178.62	+ 3.77	+ 93.01

Values expressed as Means ± SE

No significant differences were seen between Groups for percent difference in MVC time (p > 0.050). Both experimental Groups increased slightly from week 1 to week 7 (G2 + 2.62%, G3 + 3.77%) with the control Group decreasing slightly (- 4.76%).

Percent change in Body composition parameters of interest

Table 34. Total Body fat percentage (%) weeks 1 and week 7 and percent change between weeks 1 and 7 for each Group.

Week 1 and 7				% Change in	Relative change in
Group	N	Total BF %	Total BF %	Total BF %	Total BF %
		(Week 1)	(Week 7)	(Weeks 1 – 7)	(Weeks 1 – 7)
Control	6	15.15 ± 3.53	14.82 ± 3.95	- 2.23	- 0.68
Squat + V	13	15.10 ± 1.41	14.56 ± 1.34	- 3.71	- 0.54
Squat	11	15.65 ± 1.58	15.56 ± 1.42	- 0.58	- 0.09

Values expressed as Means ± SE

No significant differences were seen between Groups for percent change in percent body fat between week1 1 and week 7 (p > 0.050). The greatest relative change was seen for the Squat + Vibration Group (- 3.71%) but was not found to be significantly less than either Group 1 (-2.23 %) or Group 3 (- 0.58%) (p > 0.050).

Table 35. Leg percentage (%) fat weeks 1 and week 7 and percent change between weeks 1 and 7 for each Group.

Weeks 1 and 7				% Change in	Relative change in
Group	N	Leg Fat %	Leg Fat %	Leg Fat %	Leg Fat %
		(Week 1)	(Week 7)	(Weeks 1 – 7)	(Weeks 1 – 7)
Control	6	14.77 ± 3.76	14.12 ± 3.74	- 4.60	- 0.65
Squat + V	13	15.79 ± 1.57	15.09 ± 1.43	- 4.64	- 0.70
Squat	11	16.85 ± 1.74	16.64 ± 1.58	- 1.26	- 0.21

Values expressed as Means ± SE

No significant differences were seen between groups for percent change in percent body fat (p > 0.050). The Control group and the Squat + Vibration Group recorded similar percent change values (G1 - 4.60%, G2 -4.64%).

Table 36. Trunk percentage (%) fat weeks 1 and week 7 and percent change between weeks 1 and 7 for each Group.

Week 1 and 7				% Change in	Relative change in
Group	N	Trunk Fat %	Trunk Fat %	Trunk Fat %	Trunk Fat %
		(Week 1)	(Week 7)	(Weeks 1 – 7)	(Weeks 1 – 7)
Control	6	17.33 ± 3.59	17.15 ± 4.44	- 1.05	- 0.18
Squat + V	13	17.08 ± 1.70	16.64 ± 1.66	- 2.64	- 0.44
Squat	11	17.28 ± 1.76	17.25 ± 1.57	- 0.17	- 0.03

Values expressed as means ± SE

No significant differences were seen between groups for percent change in trunk fat percentage (p > 0.050). The greatest actual percent change was seen for the Squat + Vibration Group (-2.64%).

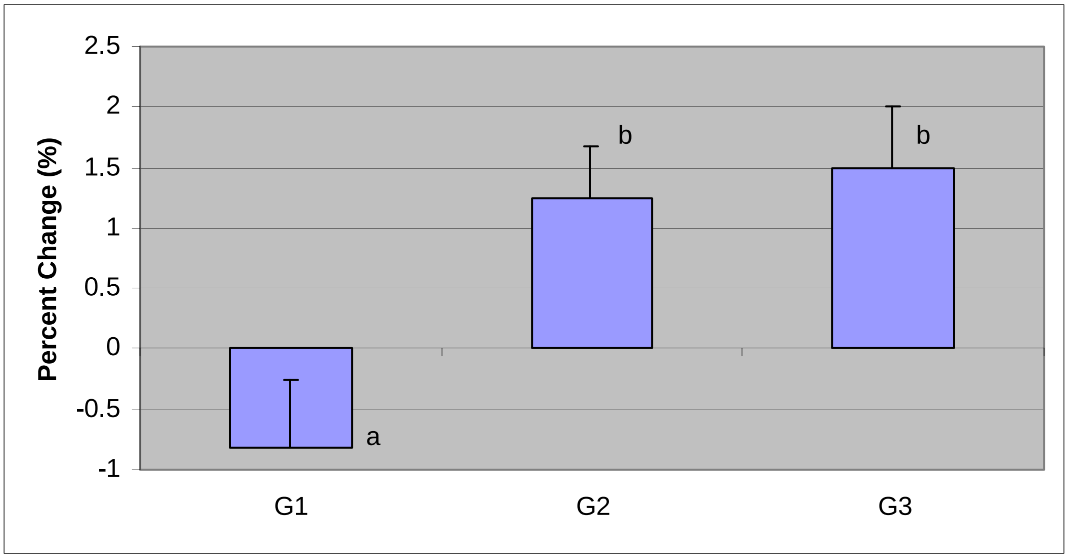
Table 37. Total Bone Free – Fat Free Lean Body Mass (g) weeks 1 and week 7 and percent change between weeks 1 and 7 for each Group.

Week 1 and 7				% Change in	Relative change in
Group	N	Total L (g)	Total L (g)	Total L (g)	Total L (g)
		(Week 1)	(Week 7)	(Weeks 1 – 7)	(Weeks 1 – 7)
Control	6	69897.17 ± 1521.49	69310.33 ± 1425.98	- 0.85	- 586.84
Squat + V	13	67086.15 ± 2410.39	67877.54 ± 2369.16	+ 1.17	+ 791.39
Squat	11	58810.91 ± 1901.64	59704.64 ± 1986.34	+ 1.50	+ 893.73

Values expressed as means ± SE

A significant difference was seen between groups between weeks 1 and 7 ($p \leq 0.050$) with the Squat + Vibration condition and the Squat Only condition improving significantly more than the Control group ($p \leq 0.050$).

Figure 39. Percent change in Total Bone Free – Fat Free Lean Body Mass (%).



Values expressed as means ± SE
[a,b] denotes G1 % change significant less than G2 and G3 ($p \leq 0.05$), b denotes groups G2 and G3 statistically similar to one another ($p > 0.05$), but statistically different from G1 ($p \leq 0.05$).

Table 38. Leg Bone Free – Fat Free Lean Body Mass (g) weeks 1 and week 7 and percent change between weeks 1 and 7 for each Group.

Week 1 and 7				% Change in	Relative change in
Group	N	Leg L (g) (Week 1)	Leg L (g) (Week 7)	Leg L (g) (Weeks 1 – 7)	Total L (g) (Weeks 1 – 7)
Control	6	21257.50 ± 570.47	21064.67 ± 454.92	- 0.92	- 192.83
Squat + V	13	21602.08 ± 770.54	22066.08 ± 784.60	+ 2.10	+ 464.00
Squat	11	18779.00 ± 780.05	19034.91 ± 742.11	+ 1.44	+ 255.91

Values expressed as Means ± SE

No significant differences were seen between groups for Leg Bone Free – Fat Free lean Body Mass. The Squat + Vibration Condition produced the greatest relative percent change between weeks 1 and weeks 7 (+ 2.10).

Table 39. Trunk Bone Free – Fat Free Lean Body Mass (g) weeks 1 and week 7 and percent change between weeks 1 and 7 for each Group.

Week 1 and 7				% Change in	Relative change in
Group	N	Trunk L (g) (Week 1)	Trunk L (g) (Week 7)	Trunk L (g) (Weeks 1 – 7)	Trunk L (g) (Weeks 1 – 7)
Control	6	34767.17 ± 1003.60	34568.33 ± 862.10	- 0.58	- 198.84
Squat + V	13	32167.92 ± 1266.06	32381.08 ± 1139.68	+ 0.66	+ 213.16
Squat	11	28489.46 ± 990.84	28989.00 ± 1096.83	+ 1.72	+ 499.54

Values expressed as means ± SE

No significant differences were seen between groups between weeks 1 and 7 for percent change in Trunk Bone Free – Fat Free lean body mass. The greatest actual percent change was seen for the Squat Only group (+ 1.72 %). The Control group saw a non-significant reduction in trunk lean body mass (-0.58%) between weeks 1 and week 7.

DISCUSSION

The results from the current study provide interesting and thought provoking insight into the combined effects of periodised strength/power specific resistance training with or without the addition of low frequency vibration. Previous research has shown positive significant improvements in 1RM strength, Depth and Squat Jump performance as well as force velocity characteristics during sub maximal, and maximal, multi joint and single joint dynamic and isometric tests (Bosco *et al*., 1998, 1999 and 2000; Issurin *et al*., 1994; Delecuse *et al*., 2003; Muller et al., 2003; Kleinoder *et al*., 2003). The use of vibration in conjunction with resistance training interventions in an attempt to increase acute, and chronic neural and hormonal responses to resistance training is growing in its scientific base (Roenstad *et al*., 2004; Kvorning *et al*., 2006; Delecluse *et al*., 2005). Results from the current study provided both significant ($p \leq 0.05$) and non significant ($p > 0.05$) data supporting the role of Whole body low frequency vibration used prior to, and then in between sets of heavy and moderate load Smith Machine Squats with loading periodised over a six week period.

Increased descending cortical drive, alpha motor input, increased motor unit firing rates and preferential motor unit synchronization as well as decreased activation threshold for type 11 motor units have all been cited as key central and peripheral adaptations to resistance training (Enoka *et al*., 2002; Selmer *et al*., 2000 and 2002 Stone *et al*., 1995; Kraemer *et al.,* 1996; Aagarrd *et al.,* 2002, and 2003; Moritani *et al*., 2001; Bawa 2002; Jordan *et al*., 2005; Mester *et al*., 2006; Delecluse *et al*., 2003). Whole body vibration has also been shown to stimulate both mono and polysynaptic reflex pathways leading to acute and chronic adaptations similar to resistance training. (Bosco *et al.,* 1998, 1999 and 2000 Cardinale *et al*., 2002 and 2003; McBride *et al.,* 2004; Roenstand *et al*., 2004, Rittweger *et al.,* 2002; Delecluse *et al*., 2003; Jordan *et al*., 2005). The addition of vibration may have lead to increased reflex excitation of alpha motor neurons within the targeted musculature as well as increased synchronizing of certain populations of motor units prior to back squat exercise. Mc Bride *et al.,* (2004) suggested that vibration may lead to increased synchronization of motor units allowing for enhanced performance during ballistic movements as well as movements performed with maximal movement intent. Behm *et al*., (1993) suggested that movement intent is as important as actually movement velocity so applying maximal exertion against a load can lead to training adaptations in acceleration and shortening velocity. Resistance training has been shown to increase the probability and frequency of short interspike doublets prior to initiation of ballistic actions (Van Cutsem *et al.,* 1998, and 2005; Aaggard *et al*., 2002; Dechateu *et al*., 1996). The application of vibration prior to and in-between sets of resistance training may enhance doublet discharge probability and frequency leading to greater average power ouput during multiple sets of squats. A combination of the aforementioned factors coupled with possible stretch reflex potentiation following with drawl of the vibration stimulus may help explain the increases in the early force time integrals seen after only six weeks of training. Vibration effects both polysynaptic and monosynaptic pathways which initially depress both the stretch reflex and the Hoffman reflex (Jordan *et al*., 2005; Desmedt *et al*., 1978; Flieger *et al*., 1998; Arcangel *et al*., 1971; Martin *et al*., 1986)

Training adaptations taking place during the first 1- 4 weeks are commonly attributed to “neuromuscular adaptations” in previously untrained subjects and subjects returning to a training program following a period of no resistance training longer than a month (Aaggard *et al*., 2003; Anderson *et al*., 2005; Stone *et al.,* 2003) and not to increases in cross sectional or physiological surface area of a muscle (Enoka *et al*., 2002; Haikkinen *et al*., 1985, 1987, 1989, 2003; Moritani *et al*., 2001). As no electromyographical recordings were taken during the current study such assertions can only be speculative regarding these data however.

Training induced changes in Smith Machine Squat 1RM with or with out whole body low frequency vibration.

Changes in 1RM Smith Machine Squat would appear to be partially biased as baseline 1RM measures were statistically different between the three groups ($p \leq 0.05$). The Control and Squat + Vibration conditions were found to be statistically similar (139. 29 ± 14.79 and 120.22 ± 7.41 respectively) ($p > 0.05$) but significantly greater than the Squat Only condition (139. 29 ± 14.79, 120.22 ± 7.41, and 91.36 ± 5.68 respectively). The higher starting values for the Control and Squat Only group could have impacted the respective subject's ability to incase their 1RM measure with the relatively short 6-week period. Percent change data was used in an attempt to provide data based upon the subjects initial strength capability at baseline. The largest percent increase in back Squat 1RM during the first three weeks of the training intervention was seen for the Squat Only Group (9.80%) although not significantly different from the Control (2.44%) and Squat + Vibration condition (9.36%). These large increases in 1RM following only three weeks (4 workouts) are considerable but not uncommon (Roenstad *et al*., 2004; Kraemer *et al*., 1996 and 1998; Harris *et al*., 2000; Stone *et al.,* 2001; Haikkinen *et al*., 1986). From weeks 3–7 the Squat Only Group continued to improve at a similar rate (8.34%) while the

Squat + Vibration Group continued to increase strength at a slower rate (4.4%). It is possible that the application of whole body vibration in conjunction with the Squat exercise after week three partially impeded maximal strength improvement. As mentioned elsewhere in this discussion the Squat + Vibration Group were stronger at baseline which may in part account for the slowing down in maximal strength gains from week three onwards. Analysis performed on percent change data from weeks 3 to 7 revealed however that this increase was not significantly greater than either of the remaining groups (p = 0.064). Analysis at week seven did reveal significant differences between groups with regards to percent increase from week 1 (base line) (p = 0.009) with the Squat Only group making significant improvement compared to the Control Group (p = 0.007, 14.63% greater improvement than the Control condition), but no different form the Squat + Vibration Group (p = 0.569, 4.74% greater improvement than the Squat + Vibration Group). The Squat + Vibration group improvement in 1RM Squat was 9.89% greater than the Control condition at week 7 but was not found to be significant (p = 0.082). The Control subjects taking part within the current study were active controls in that they continued to perform their own training regimens while abstaining from heavy squat or leg press exercises. Statistical significance may have been seen between the Control and Squat + Vibration Group at week 7 if the Control group was non-exercising. The 18.97 ± 3.04 % increase seen in 1RM between weeks 1 and weeks 7 was substantial but not as great as that seen during 5 weeks of combined resistance training and whole body vibration application (during the Squat exercise at a frequency of 40 Hz) (Roenstand *et al.,* 2004). While vibration application during the current study did not appear to convey any additional training stimulus with regards to maximal strength development some interesting findings were seen with subject's ability to generate sub maximal forces quickly. This would agree with previous studies using PAP interventions in that the greatest performance enhancing effects are seen low in frequency force rather than high frequency force (1RM or MVC force) with primary performance enhancement manifesting as an improvement in the rate of force development. It is possible that the acute state produced by vibration manifest also as a chronic adaptation, that is, high frequency force development was compromised slightly in favor of a preferential improvement in rates of force development over the 6 week training period.

Training induced changes in Jump performance.

Two separate jump test were used to assess differing aspects of explosive power generation. The 30 CM Depth Jump was used as its performance requires subjects to place the target musculature under an eccentric loaded pre stretch prior to entering the concentric propulsive phase of the jump (Komi *et al.,* 1977; Young *et al*., 1999). Such a jump has previously been reported to rely upon high level of reflex contraction utilizing a short latency stretch reflex (Komi *et al*., 1986 and 1998; Nicol *et al*., 2000; Bove *et al.,* 2003) The second jump condition was a Squat jump performed with a 20kg Olympic sized barbell which required subjects to hold a fixed position for three seconds before moving explosively through just a concentric propulsion phase without a prior eccentric pre load phase. Such a jump condition has been used during previous studies to assess power generated without utilizing a stretch shortening cycle (McBride *et al*., 2000 and 2003; Young *et al*., 1999; Newton *et al*., 1998; Coninn *et al*., 2003; Stone *et al.,* 2001 and 2003; Kraemer *et al.,* 1996 and 1998). The two different jump types were used to see if the addition of vibration to the 6 week periodised resistance training would affect the jump types in a similar of different manner.

Analysis of Depth Jump height at week 1, 3, and 7, pre and post vibration application revealed some interesting findings. Repeated measures ANOVA analysis of Depth Jump height recorded prior to vibration on weeks 1, 3, and 7 revealed significant Trial ($p = 0.00$) and Trial*Group Interaction ($p = 0.041$) but no significant differences between Groups ($p = 0.119$). Measures recorded on week seven were significantly greater than measures recorded on both week 1 ($p = 0.000$) and 3 ($p =0.002$). Measures at week 3 were found to be similar to measures taken at week 1 ($p \leq 0.050$). When groups were further analyzed no significant differences were seen between measures recorded on weeks 1, 3, and 7 for the Control Group ($p = 0.952$). This would suggest that the Control Group did not improve Depth Jump height over the 7-week period. A significant trial effect was seen for the Squat + Vibration Group for trial ($p = 0.000$) which suggests that the training intervention significantly increased Depth Jump height over the trials at week 1, 3, and 7. Similar results were seen for the Squat Only Group. The Squat + Vibration Group and the Squat Only Group improved Depth jump height (pre vibration measures) by 8.49% and 9.45% respectively. Such an increase is in line with that reported by Ronestand *et al.,* (2004) following a somewhat similar 5 week training intervention (9% increase in counter movement vertical jump).

The periodized plan of the workout, which first emphasized maximal force development during the first three weeks followed, by maximal power and rate dynamic rate of force development during the final 3 weeks would appear to have facilitated explosive power adaptation. No significant difference was seen in jump height between week 1 and week 3 ($p > 0.05$), which suggests that the resistance training and vibration did not enhance explosive power generation during a stretch shortening jump task during this period. The periodiszed plan of the workout would appear to have facilitated explosive power adaptation during the final three weeks. The lack of significant adaptation seen during the first three weeks may have been due to the heavy loads used. An increase in strength alone within the targeted musculature of the lower extremities, even if relative to body mass does not necessarily transfer to increased jump performance. Bobbert *et al*., (1996) carried out a simulation study were a 20% increase in maximal strength in the lower extremity was factored in a biomechanical simulation of a vertical jump. The results indicated that jump height might actually go down in there isn't a concomitant increase in power and motor coordination specific to optimizing jump height.

The significant increase seen between weeks 3 and 7 may in part be due to the shift from heavy load resistance training (up to 90% of 1RM) to lighter load resistance training (loads reduced as low as 55% of 1RM) and the performance of speed squats. The speed squats required subjects to squat upwards continuing up onto their toes while at the same time minimizing the time in-between repetitions (in an attempt to utilize a loaded stretch shortening cycle to optimize power. Such a motion shares some biomechanical similarity to the Depth Jump, which could explain the significant increases in jump height seen between weeks 3 and 7. The Squat Only Group also produced similar significant increases in Depth Jump height from week 1 to 7 ($p = 0.001$) and weeks 3 – 7 (0.017).

When measures of Depth Jump peak power were analyzed a significant Group*Trial intersection ($p = 0.040$) plus a significant Trial effect was seen ($p = 0.000$).

Measures taken at trial 3 (week 7) were shown to be significantly greater than measures taken at weeks 3 and 1. When the analysis was further split by Group no significant differences were seen for the Control Group over the 7-week period ($p > 0.050$) suggesting no increase in Depth Jump power. The squat + Vibration Group measures at week 7 were greater than measures taken at week 3 and 1. A similar pattern of improvement was seen for the Squat Only Group also ($p \leq 0.050$). Peak power was significantly greater for the Control and Squat + Vibration conditions when compared with the Squat Only Group at week 1 which makes direct comparison more difficult. Because of this discrepancy, analysis of percent change data helps provide more representative data of changes between Groups. Both experimental Groups increased jump power by nearly 7% over the 7-week period (G2 = 6.94% increase, G3 = 6.62% increase), which was found to be statistically similar. Both groups improved significantly more than the Control Group from week 1 to 7 ($p \leq 0.050$) as well as the Squat Only Group improving more than the Control Group between weeks 3 to 7 ($p \leq 0.050$). This near 7% increase is in line with other studies looking at changes in Jump power over a similar time period (McBride *et al.,* 2002).

Analysis of changes in Depth Jump mean power revealed significant differences between Groups and Trials ($p \leq 0.050$). Again both GI and G2 measures at baseline (week 1) were found to be significantly greater than G3 measures ($p \leq 0.050$). The Control showed no change in mean power over the 7 week period suggesting no preferential adaptations had taken place which would at each testing time point (week1, 3, and 7) suggesting that the resistance training and vibration intervention significantly affected mean power adaptation from pre to mid to post testing. The Squat Only Group also saw a significant improvement in Depth Jump mean power with week 7 measures greater than week 1 measures, however week 3 measures were shown to be similar to both baseline (week 1) measures taken at the mid point of the training program (week 3). This would suggest that the addition of vibration to the 6-week resistance-training program lead to a preferential increases in mean power output during the depth jump not afforded by Squat Training alone. However, most of the percent increase in mean power seen for the Squat + Vibration Group was seen between weeks 3 and 7 (5.44%), with little improvement seen from weeks 1 to 3 (0.27%).

Measures of Squat Jump height (pre vibration) revealed that there were significant differences between Groups and Trials ($p \leq 0.050$). Jump height collapsed over trials at weeks 1, 3, and 7 revealed that G2 and G1 were similar with G2 significantly greater than G3 ($p \leq 0.050$). Change over week's analysis revealed that the Control Group did not change in measures of Squat Jump height ($p > 0.050$) suggesting no preferential training adaptation had occurred for this Group over the 7-week program. Squat Jump height was significantly greater for the Squat + Vibration Condition when compared to the Squat Only condition at baseline ($p \leq 0.050$) which may have lead to different response patterns of neuromuscular adaptation over the 6 week training period. For the Squat + Vibration Group Squat Jump height was 11.75% greater at week 7 when compared to week 1 ($p > 0.050$). An even greater percent change was seen for the Squat Only Group between weeks 1 and 7 equal to a 14.75% improvement but this measure was not found to be significantly different from The Squat + Vibration increase in Squat Power ($p > 0.050$).

Most of the percent improvement in Squat Jump height for the Squat + Vibration Group came between weeks 1 to 3 (7.27% increase) while the greatest percent increase in

Squat Jump height for the Squat Only Group came between weeks 3 and 7 (11.58% increase). These discrepancies between Groups during the first three weeks of the training program may have been due to the addition of vibration to the resistance training. Maximal jump height is strongly related to the maximal velocity at take off (Newton *et al.*, 1997; Young *et al.*, 1999). Measures of peak power expressed relative to body mass have also been shown to be highly correlated to maximal height jumped (Young *et al.*, 1999; Carlock *et al.*, 2003; Moir *et al.,* 2004). A similar pattern of increase was seen for Peak power/Kg for the Squat + Vibration Group between weeks 1 and 3 although as well as differences seen between weeks 3 and 7. Vibration appeared to help accelerate initial improvements in Squat Jump height (as it did Depth Jump height) during the heavy resistance training (Weeks 1 to 3) period but then afford no advantage during the Speed squat training period (Weeks 3 – 6). As stated elsewhere this periodised transition was designed in an attempt to initially improve force-generating capability and then concentrate on power production. The addition of vibration to the heavy resistance training may have lead to greater levels of motor unit synchronization than the heavy resistance training, alone which could have resulted in preferential training adaptations in explosive power expression.

Squat Jump power assessed at weeks 1, 3 and 7, pre and post vibration revealed significant interaction for Time *Group ($p = 0.017$) as well as Time (p 0.00) and Group effects ($p = 0.009$). The control group was found to be statistically similar to the Squat + Vibration Group ($p \geq 0.05$) but significantly greater than the Squat Only Group ($p \leq 0.05$). The Squat + Vibration Group Peak power (W) was significantly greater than The Squat Only Group (0.016). When the data file was split by Group no significant differences were seen for the control group ($p \geq 0.05$). The Squat + Vibration Group produced a significant Time effect ($p = 0.00$) with week 7 measures being greater than measures taken on weeks 3 and week 1 ($p \leq 0.05$). A time effect was also seen for the Squat Only Group ($p = 0.000$) with power at week 7 significantly greater than weeks 1 ($p = 0.001$) and weeks 3 ($p = 0.003$). Power at weeks 3 and 1 were not different. One-way ANOVA analysis performed on Squat power percent difference between weeks 3 and 7 revealed significant differences between groups (p 0.026). Further post hoc analysis revealed no significant differences although the Squat + Vibration condition approached significance over both the Control Group ($p = 0.066$) and the Squat Only Group ($p = 0.076$). The Squat Only group produced its greatest gains in Jump Squat Height, Peak power, and peak power / kg of body mass between weeks 3 and 7 which was most likely due to the shift in emphasis from heavy loads to more moderate emphasizing power generation.

Jump measures following acute vibration exposure

Analysis performed on post vibration measures for Depth Jump height revealed both a significant Trial ($p = 0.011$) and a significant Group effect (0.047) but no Group*Trial interaction ($p = 0.190$). Week 7 measures of Depth Jump height were greater than week 1 but similar to week 3. When the analysis was split by Group no significant differences were seen for the Control Group for Trial ($p = 0.886$) but significant Trial effects were seen for the Squat + Vibration ($p = 0.011$) and Squat Only Groups ($p = 0.014$). Post hoc analysis revealed that for the Squat + Vibration Group significance was approached in favor of week 7 measures being greater than week 1 measures ($p = 0.057$). A similar trend was seen for the Squat Only group ($p = 0.088$). One way-ANOVA analysis performed between Groups at week one revealed no significant differences between groups (p = 0.079) but a significant difference was seen between the Squat + Vibration Group and the Squat Only Group (p = 0.035) (mean difference 8.84 cm) at week 3. The difference seen in post vibration measures at week 3 suggests that the Squat + Vibration group responded more favorably to the vibration exposure compared to the Squat Only Group.

The addition of vibration to the 6 week resistance training program for the Squat + Vibration Group may have produced a chronic adaptation to the vibration stimulus leading to greater relative jump performance post vibration exposure. Such a chronic neuromuscular adaptation may have occurred due to a down regulation in the initial stretch reflex depression seen during vibration application. A decreased attenuation of the stretch reflex to a similar vibration exposure due to habitualization over the 6 week training program for the Squat + Vibration Group may have produced a more favorable environment for super compensation of the stretch reflex and Hoffman reflex to take place. Also habitualization to the vibration stimulus at a number of sensory (Meissner corpuscles, Pacinian Corpuscles, Ruffini nerve endings, Renshaw cells) receptors involved in afferent information relay could help off set some of the potential disruptions to proprioceptive sense seen following exposures to higher vibration frequencies (Mester *et al*., 2005; Issurin *et al*., 2005; Cardinale *et al*., 2001 and 2003; Brooke *et al*., 2006). It would appear that the vibration frequency, and/or the amplitude used during the current study was to great a stimulus for the less well trained subjects at baseline.

Post activation depression within the Squat Only Group coupled with a light state of post activation potentiation within the Squat + Vibration Group appears to have lead to the significant difference between the two Groups at week 3. At week 7 significance was approached (p = 0.054) for the Squat + Vibration Group Jump height over the Squat Only Group Jump height (cm).

Measures of Peak power (W) recorded prior to and then following vibration exposure revealed significant interaction between Time point*Group (p = 0.049), and Trial*Group (p = 0.010). Significant main effects were also seen for Time point (p = 0.000), and Trial (0.000). However no significant effects were seen for trial for the Squat + Vibration Group indicating that there was not any significant post activation potentiation or post activation depression following vibration exposure (p > 0.05). The Squat Only Group produced significant Trial (p = 0.00) and Time effects (p = 0.000). Interestingly the significant trial effect (p 0.000) after further pair wise comparison analysis revealed post activation depression PAD (- 104.42 ± 8.45 W post vibration) for the Squat Only Condition. Training status has previously been suggested to affect ones responsiveness to an intended PAP stimulus (Hammada *et al.,* 2000; Cardinale *et al*., 2003; Bosco *et al*., 1998), which in this instance may partly explain the depression rather, than potentiation seen with the Squat Only Group. It could also be argued that as the Squat Only Group did not receive the chronic exposure to the vibration stimulus over the 6 week training period they were not acclimated to the vibration as the Squat + Vibration Group may have been. Post activation depression (PAD) may have arisen due to a number of factors. It is possible that there was significant pre synaptic inhibition at type 1a afferents induced by inhibitory inputs via interneurons from Golgi Tendon organs. Pre synaptic inhibition results in reduced neurotransmission between the sensory afferent (in this case primarily type 1a afferents) and the target cell at the axonal terminal (Brooke *et* *al.*, 2006). Also postsynaptic inhibition may have been bought about leading to a decrease in excitability of an entire neuron. Resistance training has previously been stated to desensitize, somewhat Golgi Tendon organ feedback thus reducing potential pre synaptic inhibition at type 1a afferents (Aaggard *et al.*, 2002; Aaggard 2003; Bawa *et al.*, 2002). However, the Squat Only Group had significantly lower squat strength at baseline indicating a lesser training state than the Squat + Vibration Group. It is possible that the vibration frequency (50 hz) coupled with the high amplitude (6 – 8 mm) was to strong a stimulus leading to type 1b afferent inhibitory feedback leading to decreased alpha motorneuron firing frequency resulting in a down regulation in motor unit recruitment.

The analysis of 20kg Squat Jump data revealed interesting different responses to the vibration stimulus. While all three Groups primarily responded to the vibration exposure in a negative manner (resulting in PAD) during the Depth Jump condition responses differed between Groups for the Squat Jump condition. Percent change data (pre to post vibration) revealed large, non significant changes in Jump height (cm), Jump power (W), and Peak power per kilogram of body mass (W/kg). Although 1-way ANOVA initially found significant differences between Groups for percent change at week three, pair wise comparisons revealed no significant differences ($p > 0.050$) The Squat + Vibration Group approached significance for percent change in Jump height (cm) over the Squat Only Group at week 3. In real terms the Squat + Vibration Group showed just over a 2% non significant state of PAP, with the Squat Only Group showing a similar percent (2%) decline in jump height as a result of PAD. The Control Group exhibited an even greater relative reduction in Squat Jump height (2.8%). Further to this finding, non-significant PAP was only seen for the Squat + Vibration Condition for Peak power (W)

(0.80%), and Peak power/kg (0.75%). The non-significant differences seen between Groups may in part be attributed to high individual subject variability in response to vibration exposure. The differences in responses for the two Jump conditions is interesting as this author believed prior to the study that potentiation would be more readily seen with the Depth Jump condition rather than the Squat Jump condition due to the greater reliance upon reflex induced contraction during the former (Nicol *et al* 2000). It is possible that the vibration exposure disrupted proprioceptive sense in such a way, which was more detrimental to Depth Jump performance when compared with Squat Jump performance. Depth jumps require a greater degree of inter and intra muscular co-ordination between individual muscles and their interaction with agonists and antagonists to produce muscular moments (Challis *et al*., 2000; Hertzog *et al.,* 2000). Disruptions to both afferent and efferent pathways via pre synaptic, and postsynaptic inhibitory mechanisms may have lead to the differences seen regarding vibration responses for the two jump conditions. Disruption to concentric impulse generation during the depth jump condition may have arisen due to a decreased eccentric/concentric transitional phase (amortization phase). The vibration exposure could have lead to presynaptic inhibition of type 1a afferents coupled with increased type 1b afferent feedback from Golgi Tendon Organs (GTO). This could have potentially lead to decrease alpha motor neuron firing resulting in decreased subsequent power production during the Depth Jump condition. The imposed stretch loads during Depth Jumps from a height of 30 cm have been previously reported to range between 1.5 – 3.0 times body mass (Nicol *et al*., 2000; Young *et al.,* 1999).

This imposed stretch load under "normal" conditions has been shown to produce greater jump heights and power outputs than subjects counter movement vertical jumps without an initial drop (Nicol *et al*., 2000; Komi *et al*., 2002). Possible GTO mediated afferent inhibition may have caused disruption to force coupling during the stretch shortening cycle. As the Squat Jump condition was not performed with a pre preparatory stretch shortening cycle this may have reduced the potential for force reduction as the subjects jumped with a starting load of their body mass plus 20kg. As the rate of stretch during this jump condition is considerably less than during the Depth Jump condition less type less reliance upon type 1a afferent activity may have been seen with more afferent feedback from Type 11 afferents playing a positive role.

Training induced changes in isometric rate of force development form the onset of contraction to Maximal Voluntary Contraction

Previous research has reported resistance training induced improvements in both dynamic and isometric rates of force development following heavy load and lighter load ballistic resistance training (Aagaard *et al*., 2002 and 2003; Haikkinen *et al*., 1985, 1986, 1998; Haff *et al.,* 1997, 2004; Stone *et al*., 1988 and 1995; Zehr *et al.,* 1994 and 1997). Pervious training studies have varied from 4 to 24 weeks in length using a progressive over load, or a periodised plan with varying loading schemes (Harris *et al.,* 2000). Aagaard *et al.,* (2002) carried out a 14-week resistance training study utilizing heavy load resistance for a total of 38 workouts. The authors reported significant increases in force in integrals from the onset of contraction to a time point of 200 ms. Significant increases were also reported in contractile impulse (time integrated force) and electromyography (EMG) signal amplitude and rate of EMG rise. The current study was of a shorted duration (6 weeks in length with 12 total workouts) and was periodised to emphasize maximal strength development during the first three weeks and than maximal power during the final three weeks. During the first three weeks when heavy loads were used relative to 1RM measures (70% - 88% of 1RM) subjects were instructed to push as forcefully as possible against the bar in an attempt to maximize dynamic rates of force development and acceleration against the heavy load. Roennstad *et al.*, (2004) used a 5-week periodized Smith Machine training protocol with, and without whole body low frequency applied during squat exercise. The periodised program used was similar in length as well as (5 versus 6 weeks of training) the total number of workouts performed per week (13 versus 12 work outs). The present study differed primarily in the nature of vibration application (applied prior to, and then in-between sets compares with vibration applied during the performance of the back squat exercise) utilizing a higher frequency (50 Hz versus 40 Hz) and a different time course of application (3*10 second bouts during interest rest periods vs continuous vibration exposure through out the duration of each set of Squat Exercise). Although the Roennstad study did not measures rates of force development during an isometric or dynamic task the authors did see large non-significant increases in Smith Machine Back Squat 1RM ($p > 0.050$) and counter movement vertical jump height. The group receiving vibration recorded a 32.4% in 1RM as well as a 9.1% increase in counter movement vertical jump following the 5-week training intervention.

Measures of RFD taken during the early stages following the onset of contraction revealed interesting between group differences. Rate of force development between 0 – 30 milliseconds was to be significantly reduced (- 30.41%) at week 7 compared to week 1 for the control group ($p = 0.035$). No such differences were seen for the Squat + Vibration or the Squat Only Groups ($p > 0.050$). The Squat + Vibration Group showed a non significant ($p > 0.050$) 10.33% reduction in RFD at 30ms post contraction onset. This value was considerably less than the 36.57% reduction seen for the Squat Only Group. Resting tension at week 7 for the Squat only group was 65% higher (non significant) than their respective week 1 value. For the Squat + Vibration Group resting tension was only 12.53% higher than the respective week one value. As mentioned elsewhere such an increase in resting tension can negatively impact upon the early rise in force, also but preferential neurological adaptation may also have played a part in the greater, non significant increase in RFD 30ms seen with the addition of vibration. An increase in motor unit synchronization following vibration exposures up to 100 hz have been reported in scientific literature (Mester *et al*., 1999). Such synchronization has been shown to be especially prevalent during high power, high velocity actions (Zehr *et al.,* 1994 and 1997). The addition of vibration over the 6 week training period may have altered the neuromuscular adaptation produced in response to the resistance training program helping to maintain very early force generating capability above that produced by resistance training alone.

Analysis of RFD250ms revealed that the Control condition was significant greater than both other conditions at week 1 ($p > 0.050$) although both experimental groups were found to be similar ($p > .050$). At week 7 the Squat + Vibration group was no longer statistically different from the control group ($p > .050$) while the same group approached significance over the Squat Only group ($p = 0.059$). Percent differences revealed that the Squat + Vibration Group increased by 19.29% at week 7 (non significant $p > 0.050$). The

Squat Only Group increased by 12.74%, both these week 7 increase were the greatest seen for both experimental groups. The control condition showed a non-significant -5.82% reduction in RFD250ms at week 7, this represented the least decrement for all the RFD variables for the Control condition (not significant p > 0.050). Schmidtbleicher *et al.,* (1993 and 1996) suggested that force produced at time integrals 250ms and higher from the onset of contraction is highly dependent upon MVC force. Haff *et al.,* 1997 and 2004 further suggested that maximal force generating capability is more important to sports which have action times (wrestling, judo, powerlifting) or ground contact times 250 ms seconds and greater. Anderson *et al*., (2005) suggest that the ability to generate maximal isometric force correlates with increasing r-values with force generated at 90ms upwards. Contractile properties such as the total amount of sarcomeres parallel to one another available to produce force producing cross bridges as well as optimal muscle length may start to contribute increasingly more to force production following 90 100 ms have elapsed. Force development during the first 90 seconds following contraction may be more dependent upon high motor unit firing rates, increased doublet discharge and motor unit synchronization as well as myosin light chain phosphorylation rates (Davies *et al.,* 2000; Selmer *et al*., 2002; Hammada *et al.,* 2000).

The rate of force development at the first peak in the force time curve (defined as a data point at least 10 Newton's greater than the next sampled data point) was recorded as it provides a representation of the subject's initial accelerative burst against a fixed object (Fixed Smith Machine bar in this instance). Some authors have referred to this quality as "explosive strength" (Zatsiorsky *et al*., 1995) and that it is indirectly related to the ability to recruit many high threshold motor units while simultaneously increasing their firing frequency (Siff *et al.,* 2000; Stone *et al*., 2004). The greatest non significant increase was seen for the Squat + Vibration Group (8.35% increase) while the Control Group (-23.15%) and the Squat Only Group showed decreases at week 7 (-15.72%). Aaagard *et al*., (2002) have previously shown preferential increases in RFD150 - 200MS following the onset of contraction following a 14 week heavy resistance training intervention in younger men. The same author reported a 15% increase in RFD when normalized to MVC during single joint exercise (Knee extension). The time frame and training program used during the current study does not allow direct comparisons but certain parallels can be made. It is possible that a longer time frame is need to see greater delineation at the earlier time points from the onset contraction due to the neurological specificity so such force generating capabilities.

When Peak isometric rates of force development where compared between groups following the completion of the 6 week training block the control group had significantly higher values both at week 1 (pre training) and week 7 (post testing) than the other two groups ($p \leq 0.050$). However post hoc analysis revealed that Peak RFD significantly decreased for the control group from week 1 (17373.43 n/s) to week 7 (13952 n/s, 19.69% decrease). The control group for this study was an active control who continued to perform their regular resistance exercise routine. It is possible that Peak RFD declined due to changes in training not controlled for by this researcher. The Squat + Vibration group showed a non significant ($p > 0.05$) 25.28% increase in Peak RFD at week 7 (week 1 10461.40 n/s, week 7 12164.891 n/s) compared to their week one (base line) values. It is possible that the added vibration stimulus increased alpha motor neuron excitability prior to, and then in between sets of resistance training leading to an increased neuromuscular training stimulus above and beyond that afforded by the resistance training alone. The Squat only group showed a non significant ($p > 0.05$) decrease in Peak RFD of – 5.30 % (week 1 8172.45 n/s, and week 7 7739.53 n/s). One- way ANOVA analysis performed at weeks 1 and 7 revealed that Peak RFD was statistically similar for the Squat + Vibration Group and the Squat Only Group ($p = 0.457$) but different at week 7 (p .020). This would suggest that although no significance was seen within groups the addition of vibration lead to significant improvement from week 1 to week 7 over the Squat Only group (between groups). Such findings are interesting as the resistance training intervention was specifically designed in an attempt to maximize the force/velocity profile during a Smith Machine Squat exercise. Such findings would argue practically for the inclusion of vibration prior to, and in between sets of resistance training if increases in Peak RFD are sought after. The lack of significance seen for measures of Peak RFD within group appear to be due to very high inter subject variability during the isometric quarter squat test. Also resting tension differed none significantly between groups prior to the onset of contraction during the isometric squat test. Rates of force development have been shown to be negatively impacted when pretension within the targeted musculature exceeds 10% of peak force (Van Cutsem *et al.*, 2005). Although no significant differences were seen between groups for resting tension a trend was seen for decreased RFD and subsequent force production during the early stages of contraction (0 – 80 milliseconds.). The time at which Peak RFD onset occurred did not differ significantly within or between groups between groups from week 1 to week 7 ($p > 0.050$). A One-way ANOVA performed on percent change data for time of onset of peak RFD (ms) revealed a non significant ($p = 1.00$) 6.66 ± 16.19 % reduction for the Squat + Vibration Group when compared to the Squat only group statistic. As with other RFD measures high inter subject variability may have lead to the non-significant result. Although selecting the onset of contraction from force/time readings negates the contribution of electromechanical delay seen with natural movements, the data do suggest that vibration has a performance enhancing effect upon early force generating capability.

The average rate of force development data for the MVC (0.5 second average) provided interesting results. No significant differences were seen between groups at week 1 ($p > 0.050$). No significant differences were seen between groups at week 7 although percent differences varied considerably (not significant $p > 0.050$). The Control group showed a 29.92% increase in average RFD MVC whiles the Squat + Vibration Group showed a non-significant 0.49% decrease in RFD MVC. The Squat Only group showed a 11.35% increase in RFD MVC at week 7. It would appear that the addition of vibration had a more meaningful effect upon early force time integrals and did not add any addition benefit when the time course of contraction exceed 250 ms. This is demonstrated when comparing the percent differences in MVC av between the Squat + Vibration (8.34%) and Squat Only Groups (13.52%). Increased synchronization at the beginning of the MVC may lead to increasing fatigue later on during the MVC which over time (6 weeks training) may lead to a slight reduction in maximal strength (force) adaptability to the resistance training program. Practically, if maximal strength is the main outcome measure sort after, asynchronous firing of motor units appears to be more economical than stimulus driven motor unit synchronization. The opposite would appear to be true if high rates of force development over short time periods are required such as during high power ballistic actions (Stone *et al*., 2003; Sale *et al*., 1995; Behm *et al.,* 1998; Zehr *et al.,* 1997).

Changes in force from the onset of contraction to MVC.

Analysis of force/time data starting at resisting tension (Force at 0ms) up to MVC Peak (highest single data point) revealed similar non significant changes both within and between groups for the majority of the force/time integrals ($p > 0.050$). For force measures at baseline (F0ms) prior to the onset of contraction no significant differences were seen for Group*Trial interaction ($p > 0.050$) but significant main effect for Trial was seen ($p \leq 0.050$) with Trial 2 being significantly greater than Trial 1. As mentioned elsewhere the higher the starting tension at baseline (F0ms) the greater the chance for reduction in early RFD and force during the first 30 – 80ms (Aagaard *et al*., 2003; Van Cutsem *et al*., 2005). Although there was not found any significant differences, a trend was seen for decreased force production at 30ms from the onset of contraction if resting tension increased.

Measures of force recorded at 30 ms following the onset of contraction revealed no significant differences between time points (week 1 and week 7) Groups or Groups*Time point interaction. A non-significant trend was seen for a reduction in force at 30 ms for both the Control Group (Week 1, 76.48 ± 18.07 N vs Week 7, 53.94 ± 11.77) and Squat Only Group (Week 1, 39.79 ± 13.34 N vs Week 7, 25.75 N). The Squat + Vibration Group also showed a small reduction in force generated at 30 ms during week seven testing but to lesser extent than that seen for the other two groups (Week 1, 41.39 ± 12.27 vs Week 7 39.83). Differences in resting tension, increased doublet discharge at the onset of contraction and differing motor unit firing patterns between the groups may in part explain the trends noted.

The ability to produce high forces at 250 ms form the onset of contraction has previously been shown to be related to subject’s maximal force generating capabilities (Haff *et al*., 1997 and 2004; Mirkov *et al.,* 2002 and 2003). The significant difference found between groups during current study ($p = 0.00$) however again appear due to higher initial values at baseline for the Control and Squat + Vibration Groups. Percent change data revealed no significant differences between groups from week 1 to week 7 although the Control Group and Squat + Vibration Group % changes were shown to be 18% and 20 % higher than the Control group ($p \geq 0.05$). The greatest actual increase from week 1 to week 7 was 122.70 N for the Squat + Vibration Group; a decrease of 83.56 N was seen for the control condition.

Measures of maximal isometric force generation (MVC) revealed significant differences between groups and Trials (Trial 2 greater than trial 1) ($p \leq 0.05$). The Squat + Vibration Group increased MVC force by 181.30 ± 73.76 N (Week 1, 2121.65 ± 181.18 vs Week 7, 2302.95 ± 212.80) and the squat Only Group by 223.27 N (Week 1, 1435.07 ± 86.37 vs Week 7, 1658.34 ± 101.26). Only the two training groups had significant increases in MVC force (N) at week 7. One-way ANOVA analysis performed on percent change data (%) failed to find any significant differences between Groups although the Squat only Group improved 14.21 ± 8.72% and 7.54 ± 7.04 % more than the Control and Squat + Vibration Groups respectively ($p \leq 0.05$).

A decrease in the time it takes to reach MVC following a training intervention would appear to be a preferential adaptation if attempting to reach maximal force quickly is the primary performance out come. Such ability has less practical significance than being able to reach levels of sub maximal force quickly as most sporting events and every day activities require the latter. No significant differences were seen between groups or testing time points although a trend was seen for a reduced time to MVC for the Control Group (Week 1, 2537.22 ± 265.58 ms vs Week 7, 2422.013 ± 222.74 ms). Both training Groups increased none significantly ($p \geq 0.05$) the time that they reached MVC. High inter subject variability may be a primary cause for the non-significant differences seen between the Control Group and the two training groups. The time course for the MVC test was 3.5 seconds from the onset of contraction, it is possible that the greater strength seen for the Control group affected this parameter.

Training induced changes in Body composition

Changes in body composition from week 1 to week seven as assessed by DXA revealed a number of significant group differences ($p \leq 0.05$). A significant Trial*Group interaction was seen ($p = 0.017$) as well as a significant group effect ($p = 0.009$) for changes in body mass from week 1 to week 7. The Control Group and Squat + Vibration group were shown to have significantly more lean tissue than the Squat Only group ($p \leq 0.05$). One – way ANOVA analysis performed on week 1 measures of total lean body mass revealed significant differences between groups ($p = 0.007$) with the Control and Squat + Vibration groups having significantly more total lean body mass than the Squat only Group. A similar analysis performed on week 7 measures revealed similar significant differences although the Squat Only Group had improved more in actual terms than the other two groups.

When the data was further split by group no significant differences were seen between week1 and week 7 lean body mass for the Control Group (p = 0.197) suggesting that no muscular hypertrophy had taken place over the 6 week period. The Squat + Vibration Group saw significant increases in lean body mass which equaled 791.39 ± 285.88 grams (0.791.39 Kg). A similar statistically significant increase in total lean body mass was seen for the Squat Only Group (p = 0.015) which equaled 893.73 ± 304.66 grams (0.893.73 Kg). This amounted to a higher relative percent increase in total lean body mass for the Squat Only Group. The greater increase seen in total lean body mass in the Squat Only group may be attributed to there lower initial training status and uncontrolled dietary intake. As diet was not controlled for during the current study it is difficult to comment on the differences seen with any authority. As both training groups significantly increased total lean body mass it could be argued that the 6 week training program produced a more favorable anabolic hormonal environment (elevated testosterone and Human Growth Hormone, decreased Cortisol) for gains in muscular hypertrophy to be seen. As no blood hormone samples were taken during the current study however such assertions can only be speculative. Previous work by Bosco *et al*., (2000) and Kvorning *et al*., 2006 suggest that low frequency vibration elevated levels of Human Growth hormone and Testosterone when applied in multiple bouts (5 – 10 bouts) for between 30 and 60 seconds at a time. This may impart explain the trend towards greater muscle mass increase within the legs for the Squat + Vibration Group.

No significant differences were seen in total body fat percentage or for regional trunk fat percentage but a significant difference (Trial effect) was seen for leg fat percentage ($p \leq 0.05$) in favor of week 7 being significantly less than week 1 ($p = 0.047$)

(mean difference .520%). Although no significant differences were seen between groups the greatest actual reduction in leg percent fat was seen for the Squat + Vibration Group (0.7%) with the least change in the Squat Only Group (0.191%). It is possible that the addition of vibration elevated Human Growth hormone levels above and beyond that produced by resistance training alone leading slightly greater fat mobilization. Human Growth hormone has regulatory effects upon both protein synthesis and lipid mobilization with lipids subsequently being utilized as a fuel source. This would agree with Bosco *et al.,* (2000) who found significant increases in Human Growth Hormone release in response to repeated bouts of whole body low frequency vibration. One-way analysis of variance was performed on percent change in lean tissue revealed that the Squat + Vibration Group and the Squat Only Groups were significantly greater than the control ($p \leq 0.05$) but no different from one another ($p > 0.05$). No significant difference were seen for percent change in leg lean tissue although the Squat + Vibration Group percent change was 3.02% and 0.72 % greater than the Control and Squat Only Groups ($p > 0.05$).

There appears to be trend in favor of the addition of whole body low frequency vibration with regards to facilitating muscle growth and fat metabolism. Potential elevations in anabolic hormones could have lead to a more favorable anabolic environment while at the same time utilizing more fat as fuel both during and following exercise sessions. Applying vibration for multiple trials over long time courses of exposure (30 – 60 seconds per exposure) may have lead to greater acute anabolic hormone responses but could have negatively impacted the neuromuscular system lead to considerable force and power decrements during subsequent sets of Squats.

CHAPTER V

CONCLUSIONS

The purpose of the present investigation was to test the following research hypotheses:

Research Hypothesis 1. It was hypothesized that 6 weeks of periodised squat training with low frequency (50Hz) whole body vibration would increase measures of lower body strength and power to a greater degree than squat training alone.

No, the research hypothesis is not upheld. The results of the current study suggest that the addition of whole body low frequency vibration (50 Hz 6-8 mm amplitude) prior to and then in between sets of Squats added no additional benefit than Squat training alone when measures of 1RM were the outcome variable. Trends were seen towards significance in favor of the addition of vibration to squat training increasing isometric Force/Time properties and 20kg Squat Jump tests although significance was not reached ($p > 0.05$). The vibration frequency (50 hz) coupled with the high amplitude appears to induced states of PAP in subjects with more resistance training experience, and PAD in subjects with less resistance training experience. Large inter subject variability may be primarily responsible for the non-significant findings due to differing individual subject responses to the vibration exposure.

Research Hypothesis 2a. It was hypothesized that acute application of low frequency (50Hz) whole body vibration would result in a state of post activation potentiation (PAP) leading to enhanced jump performance.

No, the majority of subjects did not respond favorably to the vibration frequency, amplitude and time course of exposure used. The addition of low frequency whole body vibration following and prior to 30 cm Depth Jumps and 20 kg Squat Jumps lead to non significant ($p > 0.05$) PAD for the Depth Jumps and non significant PAP for Squat Jumps for the Squat + Vibration group. No statistical differences were seen for the Control Group and significant, ($p \leq 0.05$) and non-significant ($p > 0.05$) post activation depression (PAD) was seen for the Squat Only Group. Significant differences were seen between groups at weeks 3 and weeks 7 following vibration exposure for the Depth Jumps ($p \leq 0.05$) with the squat only Group producing the greatest PAD. The vibration frequency and amplitude used appear have been to strong a stimulus for the less trained individuals within the Squat Only Group. The physiological consequence of this was states of PAD rather than the hypothesized PAP state.

Research Hypothesis 2b. It was also hypothesized that exposure to chronic low frequency (505Hz) whole body vibration along with squat training would augment to acute effects of vibration resulting in a greater PAP state that could lead to better jump performance.

Yes, it would appear that the addition of vibration to resistance training lead to a chronic adaptation above and beyond that afforded by resistance training alone. It was found that the addition of whole body low frequency vibration to Squat training (G2) lead to significant differences when compared to the Squat Only Group (G3) at weeks 3 ($p \leq 0.05$) and approached significance on week 7 ($p = 0.054$). Analysis of 20Kg Squat Jump group differences revealed that Jump height following vibration on week 1 was significantly greater for the Squat + Vibration Group when compared to the Squat Only Group ($p \leq 0.05$). A chronic adaptation within the central nervous system as well as within the peripheral musculature may have been responsible for the different responses seen between the Training groups.

Research Hypothesis 3a. It was hypothesized that 6 weeks of periodised squat training with low frequency (50Hz) whole body vibration would enhance lower body muscle hypertrophy when compared to Squat Training alone.

No, muscle hypertrophy was statistically similar between the two experimental groups. No significant differences where seen between the Squat + Vibration Group or the Squat Only Group although the Squat + Vibration Group saw a significant difference when compared to the Control group for percent change in lean tissue between weeks 1 and 7. Non-significant trends were seen for percent change in leg lean tissue (g) for the Squat + Vibration Group over the Squat Only Group ($p \geq 0.05$). An increase in acute hormonal responses during the 12 workouts for the Squat + Vibration Group may be in part responsible for the non significant trends seen towards greater lean leg tissue.

Research Hypothesis 3b. It was further hypothesized that the group receiving the 6 weeks of low frequency (50Hz) whole body vibration would significantly lose body fat.

No, changes in body fat percentage did not differ between groups. No significant differences were seen between Groups for changes in Total Body Fat percentage ($p \geq 0.05$). A trend was seen for a greater percent decrease in leg fat percentage for the Squat + Vibration group when compared to the Control and Squat Only Groups. Increased Human Growth Hormone release above and beyond that afforded by resistance training alone may be responsible for the trends seen in favor of the addition of whole body low frequency vibration to resistance exercise. However dietary intake may have also contributed to the trends seen. As dietary intake was not monitored during the current study possible changes due to differing calorific intake between Groups cannot be discussed.

LIMITATIONS

One of the key limitations of the current study was the semi randomization of subjects to there respective groups. Such a semi – randomized approach was taken so that the maximum number of subjects could be retained over the Spring beak Vacation as the subjects used were College Ages males. This design led to a number of significant differences between groups at base line making group comparisons more difficult, potentially impacting upon what may have been significant differences between groups. The use of percent change analysis in part helped to address this problem but difference may still have arisen at post test due to varying muscle mass, strength, power, and training status at baseline. Although the selection criteria for training status was recreational trained males who worked out no more than 3 times per week with at least 1 years training experience some subjects were at the upper limit of the criterion (3 workouts per week) while others where at the lower limit (2 workouts per week). This could have affected their response to the resistance training and vibration over the 6-week training period. Although the DXA was used to look at changes in lean and fat tissue no blood hormone tests were carried out so changes in body composition could only be speculated to be as a result of increased acute hormone release. The large variability seen for force/Time measures may have been due to a number of factors including level of individual effort during weeks 1 and weeks 7, slight variations in anatomical position of the body between weeks 1 and 7 as well as the inherent variability seen when using multi joint exercises versus single joint exercises. Also the addition of EMG and MMG to the analysis would have provided unique data concerning both the acute and chronic effects of vibration exposure upon indices of neuromuscular activation.

FUTURE RESEARCH DIRECTIONS

Future research using combined whole body low frequency vibration and resistance interventions could utilize periodized plans for both the resistance training and vibration applications in an attempt to facilitate greater gains in explosive strength beyond that afforded by resistance training alone. A gradual increase in Frequency and amplitude in conjunction with changes in resistance training volume load and intensity could provide valuable data concerning the interaction between these two differing neuromuscular stimuli. Combinations of vibration applied prior to, during resistance exercise , as well as in between sets of resistance exercise may prove to be the most beneficial course of action when attempting to further facilitate the positive effects of resistance training.

The use of different populations of subjects with varied background training status and fiber composition could help produce important normative data concerning vibration dose responses.

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Appendices

Appendix A. Sample Study Flyer.

Appendix B. Pre-Exercise Testing Health and Exercise Status Questionnaire.

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Appendix K. Data

Appendix A

Sample Study Flyer.

Are you interested in increasing your lower body strength and jumping ability??

Participants needed for study looking at the combined effects of lower body resistance training and low frequency vibration upon vertical jump performance

- A study examining the effects of **6 weeks** of heavy lower body resistance exercise with or with out imposed low frequency vibration is looking for volunteers. **(8 weeks total time commitment).**
- The study will be carried under the supervision of **Dr Michael Bemben, PhD, and Hugh Lamont M S.** in the neuromuscular physiology laboratory at the University of Oklahoma.
- **The researchers are seeking men aged between 18-30 years who have been weight training at least twice a week for at least a year with exercises targeting both the upper and lower body.**

- **Individuals with the following conditions will be excluded from the study.** Those taking beta-blockers, CNS stimulants, or any other medications, which may affect central nervous system excitability.
- Those with existing orthopedic conditions within the hip, spine, neck as well as lower and upper extremities.
- Those with a history of thyroid disease, epilepsy, kidney stones, cerebrovascular disease, heart disease, and motor neuron disease.
- Those who participate in a resistance-training program more than four times per week.
- Sedentary men (inactive).

Participants will receive information about their power and force producing capability during jump performance as well as their body composition and individual responsiveness to the vibration stimulus.

Interested men who meet the qualifications are asked to contact Hugh Lamont at hslamont@ou.edu, tel 405 325 2720 or 405 325 1368 for more information. Thank you.

Appendix B

Pre-Exercise Testing Health and Exercise Status Questionnaire.

Name ______________________________ Date __________

Home Address ______________________________________

Work Phone ______________ Home Phone ______________

Person to contact in case of emergency ____________________

Emergency Contact Phone ______________ Birthday (mm/dd/yy)____/_____/_____

Personal Physician ______________ Physician's Phone__________

Gender________ Age ______(yrs) Height ______(ft)______(in) Weight______(lbs)

Does the above weight indicate: a gain____ a loss____ no change____ in the past year?
If a change, how many pounds?___________(lbs)

A. JOINT-MUSCLE STATUS (✓Check areas where you currently have problems)

Joint Areas
( ) Wrists
( ) Elbows
( ) Shoulders
( ) Upper Spine & Neck
( ) Lower Spine
( ) Hips
( ) Knees
( ) Ankles
( ) Feet
( ) Other____________________

Muscle Areas
( ) Arms
( ) Shoulders
( ) Chest
( ) Upper Back & Neck
( ) Abdominal Regions
( ) Lower Back
( ) Buttocks
( ) Thighs
( ) Lower Leg
( ) Feet
( ) Other____________________

B. HEALTH STATUS (✓Check if you currently have any of the following conditions)

( ) High Blood Pressure
( ) Heart Disease or Dysfunction
( ) Peripheral Circulatory Disorder
( ) Lung Disease or Dysfunction
( ) Arthritis or Gout
( ) Edema
( ) Epilepsy
( ) Multiply Sclerosis
( ) High Blood Cholesterol or Triglyceride Levels
( ) Allergic reactions to rubbing alcohol

( ) Acute Infection
( ) Diabetes or Blood Sugar Level Abnormality
( ) Anemia
( ) Hernias
( ) Thyroid Dysfunction
( ) Pancreas Dysfunction
( ) Liver Dysfunction
( ) Kidney Dysfunction
( ) Phenylketonuria (PKU)
( ) Loss of Consciousness

* *NOTE: If any of these conditions are checked, then a physician's health clearance will required.*

( ) Heart Disease or Dysfunction Abnormality
( ) Peripheral Circulatory Disorder
( ) Lung Disease or Dysfunction
( ) Arthritis or Gout
( ) Edema
( ) Epilepsy
( ) Multiply Sclerosis
( ) High Blood Cholesterol or Triglyceride Levels
( ) Allergic reactions to rubbing alcohol
( ) Diabetes or Blood Sugar Level
( ) Anemia
( ) Hernias
( ) Thyroid Dysfunction
( ) Pancreas Dysfunction
( ) Liver Dysfunction
( ) Kidney Dysfunction
( ) Phenylketonuria (PKU)
( ) Loss of Consciousness

* *NOTE: If any of these conditions are checked, then a physician's health clearance will required.*

C. PHYSICAL EXAMINATION HISTORY

Approximate date of your last physical examination______________________________

Physical problems noted at that time____

Has a physician ever made any recommendations relative to limiting your level of physical exertion? _________YES __________NO

If YES, what limitations were recommended?___________________________________

____

D. CURRENT MEDICATION USAGE (List the drug name and the condition being managed)

MEDICATION	CONDITION
__________________________	_____________________________________
__________________________	_____________________________________
__________________________	_____________________________________

E. PHYSICAL PERCEPTIONS (Indicate any unusual sensations or perceptions. ✓Check if you have recently experienced any of the following during or soon after *physical activity* (PA); or during *sedentary periods* (SED))

PA SED
( ) ( ) Chest Pain
( ) ( ) Heart Palpitations
( ) ( ) Unusually Rapid Breathing
( ) ( ) Overheating
( ) ( ) Muscle Cramping
( ) ( ) Muscle Pain
( ) ( ) Joint Pain
( ) ( ) Other______________________

PA SED
( ) ( ) Nausea
( ) ( ) Light Headedness
( ) ( ) Loss of Consciousness
( ) ( ) Loss of Balance
( ) ( ) Loss of Coordination
( ) ( ) Extreme Weakness
( ) ( ) Numbness
( ) ( ) Mental Confusion

F. FAMILY HISTORY (✓Check if any of your blood relatives . . . parents, brothers, sisters, aunts, uncles, and/or grandparents . . . have or had any of the following)

( ) Heart Disease
( ) Heart Attacks or Strokes (prior to age 50)
( ) Elevated Blood Cholesterol or Triglyceride Levels
( ) High Blood Pressure
( ) Diabetes
( ) Sudden Death (other than accidental)

G. EXERCISE STATUS

Do you regularly engage in aerobic forms of exercise (i.e., jogging, cycling, walking, etc.)? YES NO

How long have you engaged in this form of exercise? ______ years ______ months

How many hours per week do you spend for this type of exercise? _______ hours

Do you regularly lift weights? YES NO

How long have you engaged in this form of exercise? ______ years ______ months

How many hours per week do you spend for this type of exercise? _______ hours

Do you regularly play recreational sports (i.e., basketball, racquetball, volleyball, etc.)? YES NO

How long have you engaged in this form of exercise? ______ years ______ months

How many hours per week do you spend for this type of exercise? _______ hours

Appendix C
1RM Assessment Data Sheet

1RM SMITH MACHINE BACK SQUAT ASSESSMENT.

5 MINUTE WARM UP ON CYCLE ERGOMETER

LIGHT STRETCHING.

Name.
Age.
Height.
Weight.

Smith Machine back squat. **(Week 1)**

Warm Up sets	**(8)**	**(5)**	**(3)**	**(Repetitions)**
	1 **(50%)**	**2** **(70%)**	**3** **(90%)**	

Attempts	**1**	**2**	**3**	**4**	**5**	**MAX (Kg)**

Smith Machine Back Squat **(Week 3)**

Warm up sets			
	1 **(50%)**	**2** **(70%)**	**3** **(90%)**

Attempts	**1**	**2**	**3**	**4**	**5**	**MAX (Kg)**

Smith Machine Back Squat **(Week 7)**

Warm up sets			
	1 **(50%)**	**2** **(70%)**	**3** **(90%)**

Attempts	**1**	**2**	**3**	**4**	**5**	**MAX (Kg)**

Appendix D

30 CM Depth Jump assessment data sheet

30 CM Depth Jump pre/post vibration PAP data sheet. Subject information. (Week 1, 3 and 7)

Name.
Age.
Height.
Weight.

Procedures

5 min cycle > Sit for 3 min > Perform 2 pre vibration depth jumps > sit for 3 min > apply vibration 50Hz*10 secs*3 exposures with 1 min rest in-between exposures > sit for 3 min > Perform 2 post vibration depth jumps.

Pre vibration (Week 1)
30 cm Depth Jump

Height (Inches)	**1.**	**2.**
Flight time (s)	**1.**	**2.**
Fit Power (W)	**1.**	**2.**
Fit Velocity (m/s)	**1.**	**2.**

(45 secs rest in-between jump trials)

Post Vibration (Week 1)
30 cm Depth Jump

Height (Inches)	**1.**	**2.**
Flight time (s)	**1.**	**2.**
Fit power (W)	**1.**	**2**
Fit velocity (m/s)	**1.**	**2.**

(45 secs rest in-between jump trials)

Appendix E
20 kg Squat Jumps assessment data sheet

20 kg Squat Jump pre/post vibration PAP data sheet. Subject information. (Weeks 1, 3, and 7)

Name.
Age.
Height.
Weight.

<u>Procedures</u>

5 min cycle > Sit for 3 min > Perform 2 pre vibration Squat jumps > sit for 3 min > apply vibration 50Hz*10 secs*3 exposures with 1 min rest in-between exposures > sit for 3 min > Perform 2 post vibration Squat Jumps.

Pre vibration (Week 1)
20 kg Squat Jump

Height (Inches)	**1.**	**2.**
Flight time (s)	**1.**	**2.**
Fit Power (W)	**1.**	**2.**
Fit Velocity (m/s)	**1.**	**2.**

(45 secs rest in-between jump trials)

Post Vibration (Week 1)
20 kg Squat Jump

Height (Inches)	**1.**	**2.**
Flight time (s)	**1.**	**2.**
Fit power (W)	**1.**	**2**
Fit velocity (m/s)	**1.**	**2.**

(45 secs rest in-between jump trials)

Appendix F
MVC Quarter Squat Force/Time Integrals Data Sheet

MVC SQUAT DATA SHEET
(Weeks 1 and 7)

Name
Weight
Age

Resting tension (n)

Peak RFD (N/S)

Peak MVC FORCE (N) (0.5 sec av)

Peak MVC FORCE (N) (single point)

Time at Peak MVC (ms) from onset of contraction.

Time at 50% of MVC (ms)

Force at initial peak (N)

Time at initial peak (ms)

Force time Integrals

Force at 30 ms	**RFD (n/s) 0 – 30 ms**
Force at 50 ms	**RFD (n/s) 0 – 50 ms**
Force at 80 ms	**RFD (n/s) 0 – 80 ms**
Force at 100 ms	**RFD (n/s) 0 – 100 ms**
Force at 150 ms	**RFD (n/s) 0 – 150 ms**
Force at 250 ms	**RFD (N/S) 0 – 250 ms**

Appendix H
HIPPA Form

INFORMED CONSENT
TO PARTICIPATE IN A RESEARCH STUDY

PROJECT TITLE:	**THE EFFECTS OF WHOLE BODY VIBRATION INDUCED POST-ACTIVATION POTENTIATION UPON INDICIES OF ISOMETRIC AND DYNAMIC FORCE PRODUCTION DURING, AND FOLLOWING A SIX WEEK PERIODIZED SMITH MACHINE BACK SQUAT PROTOCOL.**
PRINCIPAL INVESTIGATOR:	**Hugh Lamont. Ph.D Candidate.**
CONTACT INFORMATION:	**Dept. of Health and Exercise Science** **1401 Asp Avenue, Huston Huffman room 112.** **Tele: 405 325 2720** **Email: hslamont@ou.edu**

You are being asked to volunteer for a research study. This study is being conducted at The Neuromuscular research laboratory at the University of Oklahoma. You were selected as a possible participant because you were between the ages of 18 and 30, male, in good health with at least 1 year's resistance training experience. Please read this form and ask any questions that you may have before agreeing to take part in this study.

The sponsor of the study is: Dr Michael Bemben 1401 Asp Avenue, Huston Huffman room 120.

Purpose of the Research Study

The purpose of this study is: **To investigate whether** vibration **applied** prior to, and then in between sets of heavy Smith Machine squats enhances the training effect beyond that seen with resistance training **alone**.

Procedures

If you agree to be in this study, you will be asked to do the following things: You will be randomly assigned to one of three groups which included a resistance training group, resistance training + vibration group, and a none exercising control group which will just perform testing. You will be required to perform 6 weeks of intensive back squat training performing 2 workouts per week for a total of 12 workouts. You will be required to perform a series of strength and jump tests during weeks 1, 3, and 6 as well as undergo low level X-RAY scan (DXA) the week prior to, and the week following completion of the training protocol.

Risks and Benefits of Being in the Study

The study has the following risks. **You may experience mild nausea and localized itching and redness due to increased localized blood flow as well as temporary visual distortion. This will dissipate immediately following removal of the vibration stimulus. You will experience waves of vibration passing up from a vibration plate, through the feet all the way to the top of your head. This may cause your teeth to chatter during exposure to higher frequencies and amplitudes (50 Hz at amplitude equal to 4 – 6 mm). You will be warned of this ahead of time so that you can open your mouth slightly, preventing contact between the upper and lower sets of teeth. Exposure time to the vibration stimulus will not exceed more than 30 seconds at any one time. You will be required to put forth maximal efforts both during training and testing which will require high levels of physical exertion. You may experience post workout muscular soreness as a result of such high levels of physical exertion. The research study involves exposure to radiation from two DXA scans, which is a type of x-ray procedure. This radiation exposure is not necessary for medical care and is for research purposes only. You will receive exposure from the two DXA scans that is equivalent to the radiation exposure Americans receive in several days from natural background radiation (~300mrem/year) from sources such as radioactivity in the soil. Any risk from this amount of radiation is too small to be measured directly, and is small when compared to other every day risks. Although the amount of radiation exposure received in this study is minimal, it is important for you to be aware that the risk from the exposure is cumulative over a time. If you participate in the research you will receive two DXA scans (a type of x-ray) that you would not have received if you chose to not participate. The amount of radiation exposure associated with each DXA scan is less than 5% of the amount of radiation to which the average American is exposed to from background radiation in one year.** .

The benefits to participation are: **Benefits are possible but not assured.**

Compensation

NO compensation will be available from the University of Oklahoma unless the subject otherwise qualifies for the University's health insurance or other employee benefits. Emergency medical treatment in the form of first aid, CPR, and contacting medical personnel will be given as needed. No other financial aid will be provided for any long-term injury that may occur from participation in this study.

Voluntary Nature of the Study

Participation in this study is voluntary. Your decision whether or not to participate will not result in penalty or loss of benefits to which you are otherwise entitled. If you decide to participate, you are free to not answer any question or withdraw at any time. **You participate at your own risk; The University of Oklahoma does not accept responsibility and is not liable for any injury that may occur.**

Confidentiality

The records of this study will be kept private. In published reports, there will be no information included that will make it possible to identify the research participant. Research records will be stored securely. **Your name will not be used to identify individual data, only group mean data will be presented in manuscript form. All materials related to you as a subject will be**

shredded after a period of 5 years. All personal data such as ID numbers, data sheets, and your contact infromation will be kept in a locked cabinet within the PI'S office. Laboratories housing DXA equipment are locked when not in use prevent un authorised personel from accessing the equipment. The DXA machine will be turned off when not in use.

Contacts and Questions:

The researcher(s) conducting this study can be contacted at (Hugh Lamont) 405 325 2720 (office) 405 325 8638 (home) email; hslamont@ou.edu. Dr Michael Bemben 405 325 2717 (office) 405 364 7030 (Home) email mgbemben@ou.edu . You are encouraged to contact the researcher(s) if you have any questions.

If you have any questions about your rights as a research participant, you may contact the University of Oklahoma – Norman Campus Institutional Review Board (OU-NC IRB) at 405.325.8110 or irb@ou.edu.

You will be given a copy of this information to keep for your records. If you are not given a copy of this consent form, please request one.

STATEMENT OF CONSENT

I have read the above information. I have asked questions and have received satisfactory answers. I consent to participate in the study.

Signature	Date

Appendix I
DXA Body composition data sheet

UNIVERSITY OF OKLAHOMA – NORMAN CAMPUS
INSTITUTIONAL REVIEW BOARD

AUTHORIZATION TO USE or DISCLOSE PROTECTED HEALTH INFORMATION FOR RESEARCH

An additional Informed Consent Document for Research Participation may also be required.

Title of Research Project:	**THE EFFECTS OF WHOLE BODY VIBRATION INDUCED POST-ACTIVATION POTENTIATION UPON INDICIES OF ISOMETRIC AND DYNAMIC FORCE PRODUCTION DURING, AND FOLLOWING A SIX WEEK PERIODIZED SMITH MACHINE BACK SQUAT PROTOCOL.**
Principal Investigator:	**Hugh Lamont**
IRB Number:	
Address:	**316 A Wadsack Drive, Norman, OK, 73072**
Phone Number:	**405 325 8638**

If you decide to join this research project, University of Oklahoma (OU) researchers may use or share (disclose) information about you that is considered to be protected health information for their research. Protected health information will be called private information in this Authorization.

Private Information To Be Used or Shared. Federal law requires that researchers get your permission (authorization) to use or share your private information. If you give permission, the researchers may use or share with the people identified in this Authorization any private information related to this research from your medical records and from any test results. Information, used or shared, may include all information relating to any tests, procedures, surveys, or interviews as outlined in the consent form, medical records and charts, name, address, telephone number, date of birth, race, and government-issued identification number.

Purposes for Using or Sharing Private Information. If you give permission, the researchers may use your private information to analyze the data from the project and present the information in aggregate form.

Other Use and Sharing of Private Information. If you give permission, the researchers may also use your private information to develop new procedures or commercial products. They may share your private information with the research sponsor, the OU Institutional Review Board, auditors and inspectors who check the research, and government agencies such as the Food and Drug Administration (FDA) and the Department of Health and Human Services (HHS). The researchers may also share your private information with all researchers collaborating on this project.

Confidentiality. Although the researchers may report their findings in scientific journals or meetings, they will not identify you in their reports. The researchers will try to keep your information confidential, but confidentiality is not guaranteed. Any person or organization receiving the information based on this authorization could re-release the information to others and federal law would no longer protect it.

YOU MUST UNDERSTAND THAT YOUR PROTECTED HEALTH INFORMATION MAY INCLUDE INFORMATION REGARDING ANY CONDITIONS CONSIDERED AS A COMMUNICABLE OR VENEREAL DISEASE WHICH MAY INCLUDE, BUT ARE NOT LIMITED TO, DISEASES SUCH AS HEPATITIS, SYPHILIS, GONORRHEA, AND HUMAN IMMUNODEFICIENCY VIRUS ALSO KNOWN AS ACQUIRED IMMUNE DEFICIENCY SYNDROME (AIDS).

Voluntary Choice. The choice to give OU researchers permission to use or share your private information for their research is voluntary. It is completely up to you. No one can force you to give permission. However, you must give permission for OU researchers to use or share your private health information if you want to participate in the research and if you revoke your authorization, you can no longer participate in this study.

Refusing to give permission will not affect your ability to get routine treatment or health care from OU.

Revoking Permission. If you give the OU researchers permission to use or share your private information, you have a right to revoke your permission whenever you want. However, revoking your permission will not apply to information that the researchers have already used, relied on, or shared.

End of Permission. Unless you revoke it, permission for OU researchers to use or share your private information for their research will end when all data from the project has been analysed and all reports have been published. You may revoke your permission at any time by writing to:

Privacy Official
University of Oklahoma
1000 Stanton L. Young Blvd., STE 221, Oklahoma City, OK 73117
If you have questions call: (405) 271-2511

Giving Permission. By signing this form, you give OU and OU's researchers led by Hugh Lamont MS and Dr Michael Bemben PhD, permission to share your private information for the research project called THE EFFECTS OF WHOLE BODY VIBRATION INDUCED POST-ACTIVATION POTENTIATION UPON INDICIES OF ISOMETRIC AND DYNAMIC FORCE PRODUCTIÓN DURING, AND FOLLOWING A SIX WEEK PERIODIZED SMITH MACHINE BACK SQUAT PROTOCOL.

Subject Name:

Signature of Subject or Parent if Subject is a child	Date

Or

Signature of Legal Representative**	Date

**If signed by a Legal Representative of the Subject, provide a description of the relationship to the Subject and the Authority to Act as Legal Representative:

OU may ask you to produce evidence of your relationship.

A signed copy of this form must be given to the Subject or the Legal Representative at the time this signed form is provided to the researcher or his representative.

Appendix G
Informed Consent

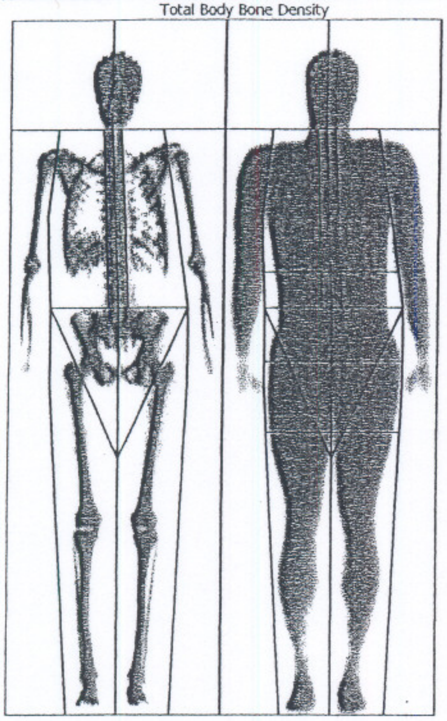
[redacted]

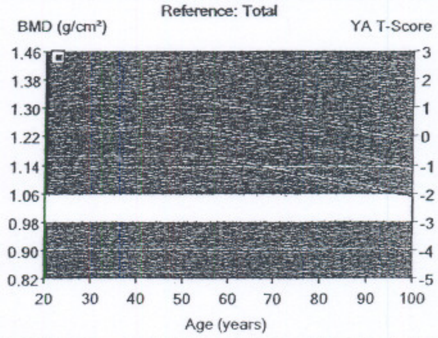
(Week 1)

Bone Density Laboratory

Dept. of Health & Sport Sciences
University of Oklahoma, Norman, OK. 73019

Patient: [redacted]
Birth Date: [redacted]
Height / Weight: [redacted]
Sex / Ethnic: [redacted]
Patient ID:
Physician:
Measured: [redacted] (8.80)
Analyzed: [redacted] (8.80)


Total Body Bone Density



	BMD [1]	**Young-Adult** [2]		**Age-Matched** [3]	
Region	**(g/cm²)**	**(%)**	**T-Score**	**(%)**	**Z-Score**
Head	2.195	-	-	-	-
Arms	1.087	-	-	-	-
Legs	1.803	-	-	-	-
Trunk	1.175	-	-	-	-
Ribs	0.844	-	-	-	-
Pelvis	1.549	-	-	-	-
Spine	1.349	-	-	-	-
Total	1.443	118	2.8	116	2.5

COMMENTS:

Image not for diagnosis

Printed: 05/11/2006 11:56:49 AM (8.80) 76:0.15:153.85:31.2 0.00:-1.00
4.80x13.00 13.8:%Fat=14.6%
0.00:0.00 0.00:0.00
Filename: jsaoxdb93.dfb
Scan Mode: Standard 0.04 mrem

[1] -Statistically 68% of repeat scans fall within 1SD (± 0.010 g/cm² for Total Body Total)

[2] -NHANES (ages 20-30) / USA (ages 20-40) Total Body Reference Population (v102)

[3] -Matched for Age, Weight (males 25-100 kg), Ethnic

GE Medical Systems
LUNAR

Prodigy
DF+14583

Bone Density Laboratory

Dept. of Health & Sport Sciences
University of Oklahoma, Norman, OK. 73019

Patient:	[redacted]	**Patient ID:**	
Birth Date:	[redacted]	**Physician:**	
Height / Weight:	[redacted]	**Measured:**	[redacted] (8.80)
Sex / Ethnic:	[redacted]	**Analyzed:**	[redacted] (8.80)

BODY COMPOSITION

Region	Tissue (%Fat)	Region (%Fat)	Tissue (g)	Fat (g)	Lean (g)	BMC (g)	Total Mass (kg)
Left Arm	6.8	6.5	4,925	337	4,588	277	-
Left Leg	13.4	12.6	12,693	1,697	10,997	794	-
Left Trunk	17.9	17.3	20,651	3,692	16,960	664	-
Left Total	14.6	13.9	41,096	5,983	35,113	2,041	-
Right Arm	6.8	6.4	4,781	324	4,457	270	-
Right Leg	13.4	12.6	12,707	1,697	11,010	791	-
Right Trunk	17.9	17.3	20,403	3,653	16,750	733	-
Right Total	14.7	14.0	39,911	5,860	34,051	2,016	-
Arms	6.8	6.4	9,706	661	9,045	548	-
Legs	13.4	12.6	25,400	3,394	22,006	1,585	-
Trunk	17.9	17.3	41,054	7,345	33,709	1,397	-
Android	19.9	19.6	5,562	1,106	4,456	82	-
Gynoid	17.9	17.3	12,926	2,315	10,611	437	-
Total	14.6	13.9	81,006	11,842	69,164	4,058	85.1

FAT MASS RATIOS

Trunk/ Total	Legs/ Total	(Arms+Legs)/ Trunk
0.62	0.29	0.55

---

2 -NHANES/USA Total Body Reference Population (v102)
3 -Matched for Age, Weight (males 25-100 kg), Ethnic

Institutional Review Board – Norman Campus Approval

The University of Oklahoma

OFFICE FOR HUMAN RESEARCH PARTICIPANT PROTECTION

IRB Number: 11155
Meeting Date: January 24, 2006
Approval Date: January 24, 2006

February 01, 2006

Hugh Lamont, M.S.
Health & Exercise Science
1401 Asp Avenue, HHC 112
Norman, OK 73019

RE: The Effects of Whole Body Vibration Induced Post-Activation Potentiation Upon Indicies of Isometric and Dynamic Force Production During, and Following a Six Week Periodised Smith Machine Back Squat Protocol

Dear Mr. Lamont:

The University of Oklahoma Norman Campus Institutional Review Board (IRB) reviewed the above-referenced research protocol at its regularly scheduled meeting on January 24, 2006. It is the IRB's judgement that the rights and welfare of the individuals who may be asked to participate in this study will be respected; that the proposed research, including the process of obtaining informed consent, will be conducted in a manner consistent with the requirements of 45 CFR 46, as amended; and that the potential benefits to participants and to others warrant the risks participants may choose to incur.

On behalf of the IRB, I have verified that the specific changes requested by the convened IRB have been made. Therefore, on behalf of the Board, I have granted final approval for this study.

As principal investigator of this protocol, it is your responsibility to make sure that this study is conducted as approved by the IRB. Any modifications to the protocol or consent form, initiated by you or by the sponsor, will require prior approval, which you may request by completing a protocol modification form.

The approval granted expires on January 23, 2007. Should you wish to maintain this protocol in an active status beyond that date, you will need to provide the IRB with an IRB Application for Continuing Review (Progress Report) summarizing study results to date. The IRB will request a progress report from you approximately two months before the anniversary date of your current approval.

If you have questions about these procedures, or need any additional assistance from the IRB, please call the IRB office at (405) 325-8110 or send an email to irb@ou.edu.

Cordially,

Lynn Devenport, Ph.D.
Vice Chair, Institutional Review Board

Ltr_Prot_Fappv_B

Appendix J. Data

	tfatpre	Tleanpre	trfatpre	Trleanpre	lfatpre	Lleanpre	tfatpos
1	13.9	69164.0	17.3	33709.0	12.6	22006.0	14.7
2	7.0	68274.0	7.5	33038.0	7.0	21350.0	6.5
3	8.5	72918.0	10.1	34832.0	8.2	22837.0	4.8
4	15.6	69032.0	19.4	33044.0	14.3	21139.0	15.3
5	14.6	64688.0	17.1	34416.0	14.0	18686.0	15.5
6	31.3	75307.0	32.6	39564.0	32.5	21527.0	32.1
7	15.5	65056.0	15.9	31773.0	19.2	20030.0	13.2
8	17.5	66117.0	20.8	31811.0	16.6	21799.0	14.8
9	23.0	60790.0	26.6	27828.0	23.5	20370.0	23.4
10	15.1	86041.0	19.6	43320.0	11.3	26679.0	15.8
11	16.4	56104.0	17.9	27208.0	18.9	17683.0	16.7
12	7.4	67193.0	8.4	31584.0	7.1	22447.0	6.9
13	7.2	56228.0	7.7	27829.0	7.6	18247.0	8.0
14	13.1	69623.0	15.8	33588.0	12.4	21817.0	13.9
15	7.5	59524.0	7.4	27587.0	9.1	19187.0	7.6
16	15.3	68543.0	15.8	32816.0	18.8	22407.0	14.6
17	19.2	80523.0	23.0	38327.0	17.6	26687.0	19.1
18	19.2	70939.0	20.3	33101.0	22.9	22976.0	17.4
19	19.9	65439.0	22.8	31411.0	20.3	20498.0	18.2
20	12.2	61024.0	14.5	30707.0	11.7	16963.0	14.2
21	12.2	70472.0	11.9	33906.0	15.5	23585.0	13.0
22	10.5	50084.0	12.0	24053.0	10.6	15880.0	9.9
23	8.0	55352.0	8.5	27378.0	8.7	17215.0	8.3
24	15.2	54788.0	16.7	26374.0	17.4	16777.0	13.7
25	17.0	61836.0	19.3	29956.0	17.2	20170.0	16.4
26	20.2	53870.0	23.0	25888.0	21.3	17436.0	21.8
27	18.2	59375.0	20.4	27753.0	20.2	19062.0	18.7
28	12.2	68444.0	13.1	34052.0	13.2	23221.0	13.4
29	25.6	53808.0	26.8	25872.0	28.5	17328.0	23.7
30	20.8	57867.0	23.9	27445.0	21.0	18932.0	18.0
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	Tleanpost	trfatpos	Trleanpost	lfatpos	Lleanpost	Djprev1	Djprev3
1	68242.0	18.3	33431.0	13.0	22261.0	50.67	50.17
2	69360.0	7.1	34539.0	6.5	21098.0	60.33	59.56
3	71193.0	4.7	35001.0	5.4	22256.0	48.26	52.07
4	68931.0	18.5	34093.0	14.7	20208.0	49.02	48.77
5	63774.0	19.0	32022.0	14.1	19446.0	46.61	46.48
6	74362.0	35.3	38324.0	31.0	21119.0	37.85	35.43
7	64512.0	13.3	30786.0	16.8	20576.0	59.82	63.63
8	66688.0	17.2	32562.0	14.6	21360.0	50.55	55.25
9	61332.0	27.3	28674.0	23.2	20288.0	53.21	52.07
10	87119.0	21.0	41764.0	12.0	28291.0	51.94	53.98
11	57130.0	17.9	27501.0	19.3	18498.0	38.99	42.80
12	69009.0	7.8	31909.0	6.7	23239.0	74.93	75.31
13	58187.0	9.1	27897.0	7.8	19802.0	48.01	50.29
14	69423.0	17.5	33541.0	12.2	21805.0	53.72	52.83
15	59806.0	7.6	28477.0	9.2	19206.0	34.04	39.88
16	70412.0	15.1	33606.0	17.8	23290.0	48.64	49.78
17	80500.0	23.0	38327.0	17.6	26687.0	41.40	48.77
18	70285.0	18.5	32854.0	20.8	22623.0	47.24	45.72
19	68005.0	21.0	33056.0	18.2	21194.0	45.21	42.55
20	62890.0	16.7	32379.0	13.5	17155.0	32.51	37.21
21	70230.0	13.5	33247.0	15.4	24201.0	47.37	48.39
22	49451.0	11.8	23321.0	9.5	15856.0	51.69	51.56
23	57612.0	9.0	28253.0	8.8	18142.0	43.18	43.18
24	55383.0	14.2	27074.0	16.6	16945.0	43.82	43.82
25	63025.0	18.8	30539.0	16.4	20675.0	46.86	46.23
26	54138.0	24.8	26561.0	22.6	17504.0	33.91	32.13
27	61678.0	20.5	28299.0	21.6	20126.0	48.51	52.96
28	69815.0	14.7	35545.0	14.2	21844.0	44.58	45.97
29	53706.0	25.2	25202.0	25.7	18062.0	40.26	43.82
30	58823.0	20.5	28459.0	18.7	18874.0	43.18	40.39
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	Djprev7	Djpostv1	Djpostv3	Djpostv7	SqJprev1	SqJprev3	SqJprev7
1	51.18	47.12	48.01	47.37	29.34	31.37	33.40
2	58.29	60.83	57.66	58.80	44.45	44.58	42.55
3	50.55	49.53	54.10	46.86	39.24	42.80	41.66
4	49.66	47.12	47.12	46.61	33.27	33.40	32.77
5	48.13	46.48	44.32	47.88	34.54	35.69	38.10
6	35.94	34.54	36.07	36.32	29.59	31.12	30.86
7	60.96	57.02	62.23	56.64	41.78	44.70	45.59
8	59.44	49.91	53.98	52.32	33.40	38.96	42.04
9	56.52	53.85	54.23	56.64	38.61	36.70	43.43
10	57.66	51.31	52.07	56.13	43.43	42.29	49.78
11	42.67	37.34	41.02	42.80	25.65	29.85	33.27
12	79.12	72.77	73.91	80.90	54.36	56.01	56.26
13	51.94	49.02	50.17	53.98	30.99	33.78	35.69
14	51.56	54.10	53.09	51.82	35.94	37.08	37.59
15	44.32	38.86	38.23	44.32	21.21	24.00	28.32
16	54.10	48.39	48.26	51.31	31.37	32.26	35.56
17	50.67	43.31	49.66	54.36	34.54	41.02	37.47
18	51.44	44.20	45.59	50.42	33.27	34.04	36.20
19	42.29	47.75	42.93	41.02	37.34	37.21	34.42
20	37.21	33.40	35.56	35.18	23.62	25.27	26.92
21	54.48	46.99	43.43	53.09	31.50	36.07	38.23
22	50.29	52.71	49.78	47.75	31.12	30.35	32.77
23	44.58	39.50	41.91	42.67	27.05	27.05	34.29
24	48.51	43.05	43.05	43.69	28.58	28.58	32.64
25	52.71	45.21	45.21	50.29	31.75	31.75	38.10
26	40.51	29.34	30.86	40.89	22.35	23.50	31.12
27	54.10	48.77	50.93	51.05	36.70	38.23	39.37
28	48.90	43.05	44.20	46.23	28.45	32.13	35.94
29	44.83	41.15	41.40	42.67	28.58	31.37	31.62
30	44.70	39.88	39.37	43.31	27.81	29.97	30.86
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	sqjpov1	sqjpov3	sqjpov7	SqmaxW1	SqmaxW3	SqmaxW7	FOmspre1
1	29.85	30.73	32.26	103.00	101.00	110.00	76.39
2	45.85	43.05	43.94	170.45	177.45	177.80	157.30
3	40.39	43.31	40.01	148.00	165.00	150.40	140.99
4	31.12	32.13	32.64	102.00	109.50	115.00	8.00
5	32.64	35.69	37.34	122.70	114.00	121.80	24.07
6	29.21	28.32	30.86	189.60	191.00	192.00	53.30
7	37.97	44.07	45.47	118.80	134.50	150.00	-43.63
8	34.80	40.13	40.13	100.00	115.00	118.50	26.72
9	39.12	38.48	41.91	113.80	119.80	128.40	67.57
10	41.28	44.07	48.01	146.00	158.00	170.00	213.27
11	26.67	28.83	33.27	99.00	111.00	118.00	35.77
12	55.50	54.74	56.01	128.00	132.00	145.20	158.60
13	31.62	35.31	36.96	78.60	95.00	98.00	201.56
14	36.96	38.74	39.37	141.00	158.10	159.00	.55
15	24.26	26.67	29.85	93.30	100.00	102.50	-41.76
16	30.86	33.02	35.56	98.00	113.00	120.00	-8.52
17	36.58	41.15	38.23	176.00	185.00	180.00	21.43
18	32.64	34.29	35.56	134.00	135.00	130.00	-13.20
19	36.58	36.70	34.16	136.36	141.00	149.00	313.06
20	22.86	24.13	26.29	93.00	96.00	100.60	39.51
21	32.13	35.43	37.21	82.00	93.00	103.00	160.62
22	33.91	31.62	30.99	88.40	97.00	93.00	53.57
23	27.18	28.45	33.27	80.00	85.00	100.00	-14.49
24	26.92	26.92	30.73	78.00	88.20	96.00	89.70
25	32.00	31.50	36.45	136.86	127.00	137.50	317.25
26	22.48	22.99	29.85	66.00	77.00	82.00	-11.74
27	34.80	38.10	40.01	111.37	123.00	136.60	-19.70
28	31.24	32.64	36.58	88.00	105.00	114.00	14.95
29	27.94	28.45	31.37	93.18	102.00	107.50	-9.32
30	27.56	27.81	30.99	88.18	100.00	114.00	-15.24
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	FOmspre2	FOmspre3	FOmspre4	fomspo1	FOmspo2	FOmspo3	FOmspo4
1	200.94	175.53	147.78	78.60	159.31	293.38	243.56
2	164.16	94.07	162.72	345.06	314.36	20.85	22.57
3	97.37	64.60	27.30	85.26	90.93	177.48	161.23
4	21.34	-34.38	27.87	102.38	-26.34	83.99	5.18
5	83.15	125.92	36.42	452.30	87.75	43.15	167.45
6	79.72	87.77	57.59	119.31	62.02	111.28	63.98
7	39.92	24.27	14.52	8.64	-22.29	72.10	121.92
8	263.05	102.58	174.45	3.78	65.75	47.60	62.70
9	40.07	160.77	136.96	-29.70	-28.29	66.95	223.69
10	113.52	366.78	529.67	520.93	300.43	104.00	125.97
11	6.07	198.36	149.26	83.15	-4.69	94.87	-21.49
12	78.50	185.00	109.85	120.38	69.27	23.18	-42.24
13	156.41	-16.85	144.62	184.93	152.62	115.67	151.38
14	34.35	52.36	17.42	-21.57	254.68	24.16	276.08
15	92.61	-22.36	-38.10	-44.51	106.60	293.74	106.60
16	182.06	18.09	71.67	70.65	132.44	65.20	-34.22
17	5.63	96.55	61.66	200.31	130.22	216.40	54.08
18	69.16	54.26	82.34	139.35	326.34	248.65	266.30
19	217.09	180.87	217.87	-41.41	208.81	212.60	204.37
20	36.60	45.41	108.73	225.43	74.26	111.52	93.75
21	13.85	24.11	23.13	18.93	10.66	43.32	43.29
22	77.84	50.20	-21.38	54.18	107.24	126.39	26.58
23	40.56	32.54	12.76	121.44	164.36	193.92	206.01
24	99.31	129.45	195.79	53.81	187.45	242.89	115.29
25	270.00	204.66	346.84	315.84	507.83	258.01	422.92
26	-3.55	-17.97	-.73	25.07	46.74	51.88	25.07
27	9.98	26.51	20.34	-19.08	1.70	38.74	-32.79
28	-14.20	15.91	54.04	-20.88	-14.20	.78	15.71
29	1.89	-11.34	-28.47	-38.59	-9.36	89.36	4.52
30	-27.57	64.56	108.10	136.45	-24.20	84.91	32.50
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	DjPpPre1	DjPpPre3	DjPpPre7	DjPpPo1	DjPpPo3	DjPpPo7	sqjppp1
1	4961.95	4885.82	4992.79	4746.10	4754.76	4761.52	4572.86
2	5094.83	5093.87	5016.79	5125.66	4978.24	5047.62	5037.22
3	4543.68	4774.95	4591.84	4620.77	4898.29	4368.28	4902.35
4	4771.14	4755.72	4854.98	4655.50	4655.50	4669.97	4721.23
5	4398.17	4390.46	4535.97	4390.46	4259.41	4520.56	4571.82
6	5497.05	5441.18	5290.82	5296.62	5479.73	5313.95	5901.97
7	5199.89	5340.56	5223.97	5030.30	5255.76	4961.87	5011.23
8	4863.64	5103.57	5357.97	4825.10	5026.48	4926.27	4728.94
9	5025.53	4956.15	5271.26	5064.07	5087.20	5278.97	5045.01
10	5899.74	6113.68	6291.94	5861.20	5998.05	6199.43	6289.24
11	3573.23	3804.50	3842.09	3473.02	3696.57	3849.80	3669.80
12	5981.35	6004.48	6281.04	5850.30	5919.68	6388.97	5638.51
13	3848.76	3806.32	4087.74	3910.44	3798.62	4211.08	3721.77
14	5056.36	5002.40	4970.61	5079.49	5017.82	4986.03	4883.12
15	3046.09	3400.69	3761.11	3339.02	3300.48	3761.11	3173.49
16	4793.31	4907.99	5170.09	4777.89	4815.48	5000.50	4650.90
17	5214.60	5525.82	5777.35	5330.23	5579.78	6000.91	5704.32
18	5070.91	4887.80	5189.40	4885.90	4880.10	5127.73	5128.93
19	4222.77	4468.58	4498.46	4376.95	4491.71	4421.37	4650.82
20	3315.98	3555.91	3646.51	3369.94	3455.69	3523.17	3682.36
21	4716.22	4823.19	5057.32	4693.09	4522.54	4972.52	4658.61
22	3800.52	3792.81	3715.72	3862.19	3684.89	3561.55	3457.68
23	3465.23	3465.23	3640.62	3241.67	3388.14	3524.99	3392.20
24	3730.27	3775.57	3970.20	3684.02	3729.32	3677.26	3711.20
25	4413.58	4375.04	4722.89	4313.37	4313.37	4576.42	4402.23
26	3310.18	3292.85	3756.34	3032.66	3215.76	3779.47	3514.67
27	4377.90	4738.31	4852.99	4393.32	4614.97	4667.98	4566.97
28	4456.02	4586.12	4808.73	4363.52	4478.20	4646.84	4382.99
29	3922.12	4047.37	4109.04	3976.08	3900.90	3977.99	4118.90
30	4054.13	3839.23	4146.63	3853.69	3777.56	4061.83	4027.35
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	sqjppp3	sqjppp7	SqJPpPo1	SqJPpPo3	SqJPpPo7	fddjmpp1	fddjmpp3
1	4650.90	4819.54	4603.69	4612.35	4750.16	1527.00	1595.00
2	5090.22	4966.88	5122.01	4997.72	5051.68	1457.00	1380.00
3	5118.20	4958.22	4971.73	5149.03	4858.00	1437.50	1532.50
4	4728.94	4735.70	4590.18	4651.85	4727.99	1450.50	1467.00
5	4641.20	4832.97	4456.19	4641.20	4786.72	1286.50	1309.50
6	6085.08	5888.46	5878.85	5915.48	5888.46	1871.50	1828.50
7	5097.93	5197.20	4779.96	5059.39	5189.49	1482.50	1506.50
8	5021.29	5207.85	4813.74	5092.21	5092.21	1583.50	1705.00
9	4929.37	5383.24	5075.84	5037.30	5290.74	1433.50	1559.00
10	6310.46	6719.99	6158.19	6418.39	6612.06	1850.00	1987.50
11	3924.19	4177.63	3731.47	3862.52	4177.63	1143.50	1080.00
12	5738.72	5799.44	5707.89	5661.64	5784.02	1647.00	1691.50
13	3710.17	4007.00	3760.32	3802.67	4084.09	1139.00	1117.00
14	4952.50	5028.63	4944.79	5052.71	5136.56	1567.00	1492.00
15	3343.08	3695.78	3358.50	3504.97	3788.29	1070.50	1031.50
16	4750.16	4950.59	4620.06	4796.41	4950.59	1686.50	1604.00
17	5961.57	5881.63	5827.66	5969.28	5927.88	1657.50	1730.00
18	5084.59	5170.34	5090.39	5100.00	5131.79	1659.50	1588.00
19	5050.81	4926.51	4604.56	5019.97	4911.09	1387.00	1331.00
20	3737.27	3928.09	3636.10	3667.89	3889.54	985.00	1015.50
21	4981.43	4976.58	4697.15	4942.88	4914.91	1492.50	1416.00
22	3411.43	3557.90	3627.28	3488.52	3449.97	959.00	1169.50
23	3392.20	3922.20	3399.90	3476.99	3860.53	1010.00	1085.50
24	3756.50	3912.59	3610.99	3656.29	3796.95	1136.50	1172.00
25	4402.23	4742.37	4417.64	4386.81	4642.15	1396.00	1388.50
26	3674.65	4091.88	3522.38	3643.81	4014.79	1052.50	1066.00
27	4750.08	4864.76	4451.34	4742.37	4903.30	1331.00	1448.50
28	4651.85	4928.42	4552.59	4682.69	4966.96	1416.50	1491.50
29	4197.90	4213.32	4080.36	4020.59	4197.90	1184.50	1167.50
30	4113.10	4212.36	4011.93	3982.05	4220.07	1301.50	1244.50
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	ID	AGE	Weightpre	Weightmid	Weightpost	Height	Group
1	1	22.6	85.5	84.5	84.4	189.0	1
2	2	23.0	77.0	77.3	77.7	171.0	1
3	3	23.3	80.4	80.4	78.5	171.0	1
4	4	23.8	84.5	85.0	86.0	188.5	1
5	5	18.8	80.0	80.1	80.2	173.5	1
6	6	25.4	115.5	117.0	114.1	173.0	1
7	7	22.1	81.5	82.4	78.6	172.0	2
8	8	21.9	84.8	84.1	83.5	190.5	2
9	9	28.5	84.2	84.5	85.3	181.0	2
10	10	30.1	106.3	104.9	107.5	185.0	2
11	11	21.1	71.7	71.6	72.9	174.5	2
12	12	25.0	76.2	76.3	77.5	183.0	2
13	13	19.7	64.9	64.3	66.4	188.0	2
14	14	26.5	84.4	84.7	85.8	180.5	2
15	15	21.9	67.0	67.2	67.8	169.0	2
16	16	22.2	86.1	85.9	86.8	192.0	2
17	17	23.7	103.8	104.2	104.3	181.0	2
18	18	22.9	92.3	91.7	89.7	184.5	2
19	19	27.2	86.6	86.2	87.6	183.5	2
20	20	20.6	72.7	73.5	76.6	176.0	3
21	21	18.7	83.6	83.5	84.1	195.5	3
22	22	22.0	59.8	60.1	59.9	172.5	3
23	23	22.3	63.7	64.2	66.4	177.5	3
24	24	25.3	68.8	68.2	67.2	174.5	3
25	25	27.9	78.1	79.4	79.0	176.5	3
26	26	27.9	71.7	73.7	72.5	177.0	3
27	27	23.7	76.8	78.8	79.5	182.5	3
28	28	22.1	83.5	83.8	84.7	187.0	3
29	29	21.7	76.1	77.2	75.1	178.0	3
30	30	23.3	77.7	76.1	76.4	175.0	3
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	fddjmpp7	FDjMpPo1	FDjMpPo3	FDjMpPo7	fsjmppr1	fsjmppr3	fsjmppr7
1	1612.50	1535.50	1535.00	1646.50	1287.50	1528.00	1542.50
2	1392.00	1411.50	1384.50	1392.00	1389.00	1412.50	1335.50
3	1503.00	1533.00	1533.00	1440.50	1446.00	1535.00	1582.50
4	1409.00	1400.00	1351.00	1391.00	1359.00	1397.00	1351.00
5	1366.00	1286.50	1270.50	1406.00	1276.00	1333.50	1356.50
6	1688.00	1820.00	1909.00	1777.50	1767.00	1732.00	1774.00
7	1526.00	1466.50	1529.50	1472.00	1402.50	1470.00	1534.00
8	1754.00	1533.50	1655.50	1779.00	1338.50	1499.00	1621.50
9	1585.00	1391.50	1491.50	1593.50	1379.50	1143.00	1435.50
10	2033.50	1871.00	1999.00	1906.00	1779.00	1832.50	1967.50
11	1173.50	1080.00	1136.50	1231.00	1145.50	1182.00	1221.50
12	1736.00	1639.50	1752.00	1683.00	1558.00	1683.50	1669.00
13	1217.00	1087.00	1173.00	1242.50	1079.00	1117.50	1214.00
14	1543.00	1559.00	1525.50	1562.00	1410.50	1431.00	1517.50
15	1158.00	1162.50	1077.50	1137.00	921.00	1049.50	1108.00
16	1740.50	1636.00	1521.00	1655.00	1403.00	1196.00	1500.50
17	1894.00	1719.50	1810.00	1946.00	1553.50	1998.00	1703.50
18	1677.00	1640.50	1542.50	1624.00	1319.00	1373.00	1542.50
19	1372.00	1425.00	1349.00	1294.50	1403.00	1416.50	1344.50
20	1095.50	978.00	986.50	1103.00	595.50	912.50	1016.50
21	1548.50	1441.50	1331.00	1499.00	1018.50	1458.50	1366.00
22	1041.00	1029.50	1076.50	1047.00	949.00	925.50	972.50
23	1100.00	1029.00	1010.00	1041.50	691.50	724.50	1146.50
24	1201.00	1183.50	1112.00	1113.50	1029.50	1032.50	1096.00
25	1417.50	1435.50	1412.00	1355.50	1362.50	1234.00	1359.00
26	1204.00	1052.00	1095.50	1240.00	956.50	1043.00	672.50
27	1427.50	1359.00	1431.00	1396.50	1432.00	1504.50	1520.00
28	1551.50	1350.50	1425.00	1526.50	1359.00	1328.50	1403.00
29	1177.50	1193.00	1167.00	1132.50	1191.00	1167.50	1195.50
30	1374.00	1239.00	1304.00	1288.00	1126.00	1233.00	1310.50
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	FSjMpPO1	FSjMpPO3	FSjMpPO7	trains	Sqch1to3	Sqch3to7	Sqch1to7
1	1301.00	1392.50	1448.00	2.00	98.06	108.91	106.80
2	1474.50	1384.00	1422.00	3.00	104.11	100.20	104.31
3	1515.50	1604.50	1543.50	3.00	111.49	91.15	101.62
4	1287.00	1356.50	1361.50	2.00	107.35	105.02	112.75
5	1196.50	1353.00	1376.00	2.00	92.91	106.84	99.27
6	1593.50	1664.50	1694.00	3.00	100.74	100.52	101.27
7	1353.00	1422.00	1417.00	2.00	113.22	111.52	126.26
8	1462.00	1499.00	1570.00	2.00	115.00	103.04	118.50
9	1349.00	1256.00	1301.00	2.00	105.27	107.18	112.83
10	1779.50	1908.00	2005.00	3.00	108.22	107.59	116.44
11	1037.00	847.00	1176.50	1.00	112.12	106.31	119.19
12	1656.50	1616.50	1681.50	2.00	103.13	110.00	113.44
13	1054.00	1166.00	1189.00	1.00	120.87	103.16	124.68
14	1328.00	1482.50	1476.00	3.00	112.13	100.57	112.77
15	989.50	1092.00	1152.00	2.00	107.18	102.50	109.86
16	1455.00	1500.50	1532.00	2.00	115.31	106.19	122.45
17	1642.00	1950.00	1728.50	3.00	105.11	97.30	102.27
18	1386.00	1406.00	1404.00	3.00	100.75	96.30	97.01
19	1403.00	1427.00	1376.50	3.00	103.40	105.67	109.27
20	894.00	884.50	1035.00	2.00	103.23	104.79	108.17
21	1112.00	1395.50	1193.00	1.00	113.41	110.75	125.61
22	933.50	956.50	996.00	2.00	109.73	95.88	105.20
23	938.50	746.50	1180.50	1.00	106.25	117.65	125.00
24	1029.50	935.50	983.50	2.00	113.08	108.84	123.08
25	1323.50	1117.50	1427.00	2.00	92.80	108.27	100.47
26	857.00	922.00	774.00	1.00	116.67	106.49	124.24
27	1354.50	1466.00	1510.00	2.00	110.44	111.06	122.65
28	1305.00	1482.50	1580.00	1.00	119.32	108.57	129.55
29	1176.50	1167.00	1176.50	2.00	109.47	105.39	115.37
30	1184.00	1205.00	1274.00	2.00	113.40	114.00	129.28
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	Dj1ch1	Dj1ch2	Dj1ch3	SqJ1ch1	SqJ1ch2	Sqj1ch3	DjPkgpr1
1	92.98	95.70	92.56	101.73	97.98	96.58	57.03
2	100.84	96.80	100.87	103.14	96.58	103.28	66.17
3	102.63	103.90	92.71	102.91	101.19	96.04	56.09
4	96.11	96.61	93.86	93.51	96.20	99.61	56.13
5	99.73	95.36	99.47	94.49	100.00	98.00	54.98
6	91.28	101.79	101.06	98.71	91.02	100.00	47.39
7	95.33	97.80	92.92	90.88	98.58	99.72	65.00
8	98.74	97.70	88.03	104.18	103.00	95.47	57.22
9	101.19	104.15	100.22	101.32	104.84	96.49	59.12
10	98.78	96.47	97.36	95.03	104.20	96.43	55.66
11	95.77	95.85	100.30	103.96	96.60	100.00	49.63
12	97.12	98.15	102.25	102.10	97.73	99.55	77.68
13	102.12	99.75	103.91	102.05	104.51	103.56	58.31
14	100.71	100.48	100.49	102.83	104.45	104.73	59.49
15	114.18	95.86	100.00	114.37	111.11	105.38	45.46
16	99.48	96.94	94.84	98.38	102.36	100.00	55.74
17	104.60	101.82	107.27	105.88	100.31	102.03	49.66
18	93.55	99.72	98.02	98.09	100.75	98.25	53.95
19	105.62	100.90	97.00	97.96	98.63	99.26	54.14
20	102.73	95.56	94.54	96.77	95.48	97.64	44.21
21	99.20	89.76	97.44	102.02	98.24	97.34	54.84
22	101.97	96.55	94.95	108.98	104.18	94.57	63.34
23	91.47	97.06	95.73	100.47	105.16	97.04	54.14
24	98.26	98.26	90.05	94.22	94.22	94.16	54.06
25	96.48	97.80	95.42	100.80	99.20	95.67	55.17
26	86.52	96.05	100.94	100.57	97.84	95.92	45.34
27	100.52	96.16	94.37	94.81	99.67	101.61	56.86
28	96.58	96.13	94.55	109.82	101.58	101.77	53.05
29	102.21	94.49	95.18	97.78	90.69	99.20	50.28
30	92.35	97.48	96.88	99.09	92.80	100.41	52.65
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	DjPkgpr3	DjPkgpr7	DjPkgpo1	DjPkgpo3	DjPkgpo7	SjPkgpr1	SjPkgpr3
1	56.81	57.39	54.55	55.29	54.73	52.56	54.08
2	65.31	64.32	66.57	63.82	64.71	65.42	65.26
3	58.95	58.12	57.05	60.47	55.29	60.52	63.19
4	55.95	56.45	54.77	54.77	54.30	55.54	55.63
5	54.88	56.00	54.88	53.24	55.81	57.15	58.02
6	46.11	46.41	45.66	46.44	46.61	50.88	51.57
7	68.47	66.13	62.88	67.38	62.81	62.64	65.36
8	60.76	63.79	56.77	59.84	58.65	55.63	59.78
9	58.31	61.29	59.58	59.85	61.38	59.35	57.99
10	56.61	58.80	55.29	55.54	57.94	59.33	58.43
11	52.84	52.63	48.24	51.34	52.74	50.97	54.50
12	77.98	80.53	75.98	76.88	81.91	73.23	74.53
13	61.39	61.94	59.25	61.27	63.80	56.39	59.84
14	58.85	57.80	59.76	59.03	57.98	57.45	58.26
15	50.76	54.51	49.84	49.26	54.51	47.37	49.90
16	56.41	59.43	55.56	55.35	57.48	54.08	54.60
17	54.17	55.02	50.76	54.70	57.15	54.33	58.45
18	53.13	57.03	51.98	53.04	56.35	54.56	55.27
19	51.36	51.12	56.11	51.63	50.24	59.63	58.06
20	48.05	47.98	44.93	46.70	46.36	49.10	50.50
21	55.44	60.21	54.57	51.98	59.20	54.17	57.26
22	63.21	61.93	64.37	61.41	59.36	57.63	56.86
23	54.14	55.16	50.65	52.94	53.41	53.00	53.00
24	53.94	58.39	53.39	53.28	54.08	53.79	53.66
25	54.69	59.78	53.92	53.92	57.93	55.03	55.03
26	43.90	50.76	41.54	42.88	51.07	48.15	49.00
27	59.98	60.66	57.06	58.42	58.35	59.31	60.13
28	53.95	55.92	51.95	52.68	54.03	52.18	54.73
29	53.25	54.07	50.98	51.33	52.34	52.81	55.24
30	50.52	53.85	50.05	49.70	52.75	52.30	54.12
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	SjPkgpr7	SjPkgpo1	SjPkgpo3	SjPkgpo7	PRFDprAV	TRFPprrAV	MCVmprA
1	55.40	52.92	53.63	54.60	14515.70	95.75	2402.18
2	63.68	66.52	64.07	64.77	16328.73	74.50	2703.63
3	62.76	61.38	63.57	61.49	22262.88	110.00	3312.80
4	55.07	54.00	54.73	54.98	14529.28	67.50	1416.29
5	59.67	55.70	58.02	59.10	12912.14	112.75	2004.51
6	51.65	50.68	50.13	51.65	23691.88	137.50	3145.21
7	65.79	59.75	64.86	65.69	20836.00	72.25	2914.65
8	62.00	56.63	60.62	60.62	7665.71	188.00	2036.35
9	62.60	59.72	59.26	61.52	8077.25	246.75	1618.32
10	62.80	58.10	59.43	61.79	9286.53	235.30	3038.28
11	57.23	51.83	53.65	57.23	7608.08	237.00	1601.36
12	74.35	74.13	73.53	74.15	12035.11	103.00	2041.98
13	60.71	56.97	61.33	61.88	8826.82	111.50	1760.92
14	58.47	58.17	59.44	59.73	10634.15	88.75	1887.02
15	53.56	50.13	52.31	54.90	12182.57	78.25	1074.87
16	56.90	53.72	55.13	56.90	7867.19	105.50	2152.82
17	56.02	55.50	58.52	56.46	10946.56	229.00	3373.81
18	56.82	54.15	55.43	56.39	7506.48	114.75	2395.10
19	55.98	59.03	57.70	55.81	12525.75	72.75	1685.95
20	51.69	48.48	49.57	51.18	6567.66	193.50	1387.45
21	59.24	54.62	56.81	58.51	3886.92	191.00	985.89
22	59.30	60.45	58.14	57.50	11353.28	90.25	1484.36
23	59.43	53.12	54.33	58.49	5637.13	202.00	1212.76
24	57.54	52.33	52.23	55.84	13583.68	128.75	1851.06
25	60.03	55.22	54.84	58.76	3059.74	458.50	1839.90
26	55.30	48.25	48.58	54.25	8021.47	78.25	1427.47
27	60.81	57.81	60.03	61.29	7135.37	108.25	1343.31
28	57.31	54.20	55.09	57.76	7683.21	112.25	1047.15
29	55.44	52.31	52.90	55.24	13961.55	69.75	1681.59
30	54.71	52.10	52.40	54.81	9006.90	84.00	1524.80
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	MVCPprA	MVCTprAV	MVC50prA	FiniPAV	TiniPAV	F30prAV	F50prAV
1	2526.67	2100.00	122.27	1382.75	179.75	62.64	201.04
2	2783.51	2372.50	184.64	1446.07	202.50	88.27	280.85
3	3544.48	2955.05	130.87	2225.97	244.50	67.80	196.64
4	1551.97	2824.00	133.16	1054.34	136.50	166.00	396.21
5	2084.46	3004.25	160.28	1285.21	220.50	42.84	135.47
6	3229.98	1967.50	162.24	2347.00	244.25	31.35	123.27
7	3032.18	3540.75	103.71	1857.03	256.25	164.10	461.08
8	2190.16	3153.25	247.18	1428.31	387.00	20.24	61.53
9	1675.21	2725.00	264.80	1222.53	449.75	4.64	19.53
10	3123.49	2861.00	295.36	1608.81	470.75	12.53	49.49
11	1662.34	2539.75	289.87	1180.05	495.25	3.62	8.80
12	2120.52	2158.75	145.98	1315.73	227.00	20.87	81.31
13	1808.08	3231.25	173.82	1013.29	238.50	28.53	86.50
14	2016.83	1913.50	109.08	1510.07	184.75	71.96	220.99
15	1114.38	727.25	87.14	1021.29	226.50	60.55	211.59
16	2222.20	2181.50	307.24	1257.51	458.50	25.93	77.49
17	3487.59	2765.04	337.86	1963.50	417.25	10.67	29.28
18	2467.44	2665.00	307.70	1607.86	602.25	50.66	118.62
19	1754.33	3004.50	82.83	1037.68	166.75	63.70	219.60
20	1417.96	2393.25	209.12	1038.17	566.50	6.95	16.24
21	1032.36	3127.00	267.56	678.29	478.25	3.32	7.93
22	1525.21	1484.25	102.85	1115.55	178.75	49.72	135.62
23	1280.95	1949.75	231.65	805.63	346.25	5.08	11.85
24	1878.07	2653.80	137.53	1267.92	196.50	23.91	94.06
25	1871.47	3408.25	507.28	1000.44	732.75	5.06	12.22
26	1472.54	2845.25	280.25	623.65	143.00	64.66	164.86
27	1389.46	2217.50	169.98	1163.43	399.50	15.34	47.42
28	1078.03	2742.25	154.10	762.68	325.00	115.74	221.90
29	1728.22	1890.00	165.02	1063.34	119.75	118.82	308.43
30	1586.98	1428.75	140.22	1257.64	280.75	29.07	105.94
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	F80prAV	F100prAV	F150prAV	F250prAV	RFD30prA	RFD50prA	RFD80prA
1	557.26	828.06	1188.69	1414.68	1948.48	3793.37	6864.90
2	750.72	1051.71	1183.02	1321.13	2739.58	5298.73	9389.67
3	555.11	898.78	1808.58	2146.15	2142.77	3725.62	6637.26
4	788.08	941.84	860.36	842.23	5357.68	7814.24	10457.12
5	379.84	566.34	891.24	1216.99	1335.33	2546.54	4650.06
6	452.69	770.00	1415.98	1966.93	939.69	2186.21	5152.10
7	1064.72	1405.43	1702.32	1560.95	5174.24	8861.13	13787.43
8	165.92	256.42	499.30	858.44	638.54	1182.05	2042.44
9	80.10	152.44	374.48	627.19	138.29	343.25	877.38
10	179.50	310.32	621.87	1006.25	375.68	886.55	2048.60
11	24.53	43.23	147.11	641.76	115.56	167.71	282.19
12	295.14	507.34	930.74	1194.52	626.04	1450.04	3364.92
13	256.10	404.59	716.17	956.63	893.57	1606.47	3040.96
14	639.07	960.69	1327.89	1233.09	2248.00	4102.42	7694.36
15	533.15	672.50	787.68	883.15	1837.07	3943.47	6973.33
16	235.14	380.99	684.73	898.38	816.03	1442.26	2756.09
17	85.46	149.02	418.35	1277.30	340.05	552.86	993.97
18	261.34	361.48	572.26	976.94	1644.41	2333.10	3296.47
19	587.06	814.74	965.85	999.57	1953.69	4154.25	7444.89
20	42.61	71.68	206.86	668.09	226.00	310.23	497.90
21	24.77	47.44	151.58	355.39	107.73	148.07	271.62
22	385.02	617.20	948.17	1062.45	1501.45	3005.91	5573.41
23	31.13	53.83	183.21	658.87	165.74	228.79	363.24
24	328.03	549.38	989.00	1082.21	714.17	1690.29	3799.10
25	28.10	40.29	70.37	195.63	192.18	254.56	357.74
26	375.80	495.03	574.03	642.79	2072.38	3191.83	4793.93
27	164.91	296.51	607.02	895.62	482.66	868.56	1841.73
28	331.59	355.76	377.30	577.61	3833.86	4575.50	4596.53
29	694.40	876.01	892.33	744.17	3802.67	5957.87	8966.17
30	329.14	505.52	751.87	1007.07	880.17	1938.10	3954.99
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	RFD100prA	RFD150prA	RFD250prA	FOprAV	RFDMprAV	PRFDpoAV	TRFPpoAV
1	8561.69	9757.61	6137.67	150.16	1377.83	15403.50	163.25
2	11287.67	10713.46	5391.99	144.56	1337.50	11111.48	62.50
3	8728.38	12923.21	11218.10	82.57	1260.91	15876.38	106.50
4	10791.40	7646.87	3198.32	5.71	552.70	12131.13	78.75
5	5834.06	6942.57	5516.51	67.39	696.13	6881.52	107.50
6	7390.66	10747.74	9466.00	69.60	1845.91	22310.20	111.50
7	15449.18	14306.88	6860.66	8.77	856.92	17002.83	97.25
8	2575.21	3557.47	3857.88	141.70	714.78	18173.90	87.50
9	1369.66	2563.36	3020.78	101.34	708.79	10826.30	157.50
10	2950.04	4550.17	4622.44	305.81	1181.24	11801.63	156.75
11	391.89	825.52	2630.69	97.37	759.91	9490.08	126.75
12	4836.34	7147.99	5446.39	132.99	1006.31	12564.37	69.25
13	4004.06	5372.81	4652.09	121.44	575.57	7430.10	214.00
14	9821.20	11148.20	5659.96	26.17	4024.89	16802.00	114.75
15	7769.35	6628.40	3825.02	1.20	1606.47	10150.10	127.50
16	3711.47	5135.31	4502.98	65.82	1040.05	10353.76	95.25
17	1375.63	2599.14	5235.89	46.32	1553.61	8345.85	228.00
18	3768.79	4198.02	4311.23	48.14	951.15	15323.68	127.00
19	8853.70	8529.54	4210.37	232.22	590.45	9878.99	67.25
20	663.81	1244.66	2758.57	57.56	605.07	8954.66	141.25
21	409.87	914.02	1621.31	55.43	332.04	7860.45	116.75
22	6949.05	8237.50	5418.22	40.06	1456.33	8642.73	106.00
23	490.38	1031.51	2748.01	17.84	747.80	6920.12	192.75
24	5325.27	7585.71	5525.11	128.56	905.64	7886.96	123.00
25	416.71	498.64	740.15	284.69	571.62	2680.93	424.00
26	5391.80	4857.34	2646.16	4.22	533.36	4272.53	135.25
27	2721.44	4440.38	4211.78	9.28	720.02	10409.76	103.25
28	4093.31	2683.60	1828.63	17.68	439.64	5453.86	125.50
29	9834.50	7876.03	3106.21	5.91	959.57	12397.74	63.50
30	5156.66	6127.03	4444.21	32.46	1616.69	9655.09	147.75
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	MVCMpoA	MVCPpoA	MVCTpoAV	MVC50poA	FiniPpoAV	TiniPpoAV	F30poAV
1	2571.02	2680.75	1734.75	132.71	1336.50	226.75	78.27
2	2792.57	2872.58	2885.50	205.68	1834.78	400.50	103.66
3	3284.88	3426.30	1805.21	168.88	2163.00	339.75	25.02
4	1659.08	1710.09	3135.75	104.99	996.74	141.50	57.89
5	1924.08	1996.62	3065.00	207.79	1001.20	390.25	31.50
6	3119.40	3152.37	1905.87	134.14	2035.47	208.75	27.30
7	3106.22	3202.23	2736.25	200.36	1900.96	334.00	39.02
8	2226.59	2326.22	2378.25	100.22	1809.89	226.50	84.78
9	1617.27	1648.10	2504.25	138.21	1252.88	282.00	49.72
10	3802.79	3995.60	3249.00	347.62	1815.04	399.50	19.40
11	1906.12	1946.56	2386.25	186.19	1267.38	353.50	22.64
12	2184.82	2256.19	2724.25	261.40	1146.64	178.75	67.85
13	1705.20	1743.57	3231.00	259.57	974.67	399.75	4.76
14	2509.83	2605.33	2402.50	133.71	1394.78	202.75	24.43
15	1189.39	1210.56	1722.50	107.60	903.09	214.50	58.00
16	2311.55	2385.05	2426.00	224.17	1591.47	446.75	36.59
17	3357.70	3439.57	3189.00	376.24	1477.99	560.25	12.45
18	2557.31	2596.80	2456.00	144.27	1394.65	197.00	22.15
19	1463.51	1511.94	2962.75	91.71	1011.36	276.25	76.05
20	2065.54	2128.17	2851.50	189.70	1181.83	535.75	34.49
21	1291.33	1336.29	1863.48	233.24	663.76	251.75	6.33
22	1525.15	1558.69	2766.25	173.05	910.77	256.50	23.63
23	2027.35	2102.91	1722.75	212.36	982.47	310.25	18.13
24	1874.58	1908.60	3204.50	222.38	1111.95	406.50	11.08
25	1822.70	1853.73	3247.50	475.75	824.38	870.75	6.31
26	1432.64	1455.76	2539.25	304.16	889.88	620.25	7.62
27	1708.92	1757.04	2392.00	165.67	1176.15	323.00	34.00
28	1176.06	1217.65	1824.00	220.33	779.33	363.50	11.15
29	2054.70	2119.66	2992.50	141.04	1295.97	262.00	113.55
30	1262.76	1334.49	1759.50	164.80	1207.37	382.50	16.98
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	F50poAV	F80poAV	F100poAV	F150poAV	F250poAV	RFD30poA	RFD50poA
1	242.01	639.17	897.12	1111.18	1694.38	2437.94	4567.31
2	285.58	622.71	784.41	957.07	1422.72	3291.73	5589.87
3	100.82	387.23	688.83	1381.35	1870.63	748.24	1782.01
4	188.56	525.15	740.56	921.07	904.63	1785.27	3499.26
5	90.93	249.48	382.73	645.54	845.60	996.45	1722.80
6	116.68	478.28	867.01	1681.50	1668.81	805.19	2020.72
7	158.14	550.83	888.98	1479.59	1613.69	1158.87	2818.55
8	265.54	741.69	1100.40	1687.37	1578.23	2640.76	4964.21
9	160.82	430.77	584.74	715.77	933.47	1541.34	2996.92
10	62.81	200.75	345.72	776.12	1246.04	604.69	1167.58
11	75.18	246.36	411.40	774.70	1128.37	700.67	1377.24
12	231.81	616.80	815.37	897.26	1281.56	2077.44	4332.67
13	18.22	69.11	130.25	362.92	690.27	144.36	327.13
14	101.37	391.21	685.06	1273.00	1334.38	726.11	1786.06
15	166.54	361.82	445.03	684.72	751.85	1822.95	3204.36
16	122.92	372.96	571.57	904.70	1100.34	1128.81	2266.34
17	32.63	87.57	138.18	317.69	979.12	397.74	617.73
18	86.91	305.89	515.54	1054.54	1204.09	663.21	1556.10
19	225.42	522.43	675.61	796.03	865.24	2393.67	4350.06
20	101.99	281.90	429.12	717.89	966.20	1085.72	1922.37
21	29.91	143.67	281.98	612.50	618.64	178.29	498.62
22	71.26	223.97	375.45	688.34	755.95	743.62	1322.67
23	52.84	150.66	242.58	491.34	914.77	572.47	996.83
24	42.35	158.95	285.01	613.70	838.17	343.14	759.17
25	14.31	30.86	45.71	90.76	198.37	246.84	309.67
26	20.59	61.24	109.77	308.12	564.18	243.72	388.66
27	117.23	347.97	525.44	831.70	961.09	1040.78	2157.25
28	34.85	116.68	204.24	436.43	679.55	348.43	637.28
29	323.52	704.39	862.61	985.08	1308.52	3575.76	6260.82
30	77.69	261.09	385.98	456.82	688.71	488.27	1386.23
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	RFD80poA	RFD100po	RFD150po	RFD250po	FOpoAV	RFDMpoAV	pdifrfd
1	7992.31	9586.38	9557.33	6354.90	193.71	2086.52	106.12
2	8243.84	8880.74	7711.94	5765.36	175.71	1020.53	68.05
3	4338.38	6439.07	10214.19	9338.50	128.73	2356.10	71.31
4	6501.51	7918.10	7923.84	4104.89	41.30	558.23	83.49
5	3022.61	3843.03	4907.33	3927.82	187.66	657.53	53.29
6	5270.41	8025.90	12759.37	9055.65	89.15	2507.48	94.17
7	6428.87	8827.06	11650.71	7991.08	45.09	1191.84	81.60
8	9080.57	11353.78	13312.13	8492.36	44.96	1062.35	237.08
9	5420.10	6403.03	6083.26	3960.43	58.16	755.30	134.03
10	2331.15	3261.09	5375.03	5924.44	262.83	1231.39	127.08
11	2853.39	3962.17	5746.59	5452.82	37.96	1031.24	124.74
12	7856.73	9131.16	7968.42	5024.13	42.65	850.23	104.40
13	769.46	1172.28	2336.34	3368.77	151.15	540.36	84.18
14	4395.26	6473.64	9756.75	6937.28	133.34	1138.67	158.00
15	4851.47	5121.20	4982.60	3524.01	115.61	804.19	83.32
16	4475.39	5808.36	7127.62	5173.31	58.52	1033.46	131.61
17	1046.57	1348.59	2061.45	3916.01	150.25	1093.02	76.24
18	3532.92	4973.49	7589.11	6653.63	245.16	1079.79	204.14
19	6846.25	7579.35	6710.43	3770.08	146.09	516.93	78.87
20	3422.83	4337.53	5453.17	4553.92	126.24	760.40	136.34
21	1510.59	2494.51	4491.21	3490.14	29.05	1163.59	202.23
22	2590.86	3586.09	5201.86	3958.65	78.59	571.32	76.13
23	1797.86	2364.63	3478.61	3952.90	171.43	1393.28	122.76
24	1784.48	2646.53	4398.33	4200.59	149.86	610.15	58.06
25	396.76	461.73	617.52	855.29	376.15	584.73	87.62
26	704.22	995.65	1951.82	2700.05	37.19	581.01	53.26
27	4226.84	5394.23	6557.37	4565.03	1.43	788.65	145.89
28	1325.23	1903.08	3108.71	3316.07	2.33	808.94	70.98
29	9406.75	9972.02	8143.36	5304.48	11.49	713.83	88.80
30	3141.48	4080.57	4134.13	2616.49	57.41	1920.90	107.20
31	.	.	.	.	.	.	.
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	pdtrfd	pdmm	pdmp	pdmt	pdm50t	pdfinip	pdtinip
1	170.50	107.03	106.10	82.61	108.54	115.30	126.15
2	83.89	103.29	103.20	121.62	111.39	121.96	197.78
3	96.82	99.16	96.67	61.09	129.04	100.35	138.96
4	116.67	117.14	110.19	111.04	78.85	93.26	103.66
5	95.34	95.99	95.79	102.02	129.64	93.75	176.98
6	81.09	99.18	97.60	96.87	82.68	85.78	85.47
7	134.60	106.57	105.61	77.28	193.19	105.29	130.34
8	46.54	109.34	106.21	75.42	40.55	124.23	58.53
9	63.83	99.94	98.38	91.90	52.20	92.76	62.70
10	66.62	125.16	127.92	113.56	117.69	109.66	84.86
11	53.48	119.03	117.10	93.96	64.23	102.27	71.38
12	67.23	107.00	106.40	126.20	179.07	79.33	78.74
13	191.93	96.84	96.43	99.99	149.34	105.40	167.61
14	129.30	133.00	129.18	125.56	122.58	108.01	109.74
15	162.94	110.65	108.63	236.85	123.48	97.76	94.70
16	90.28	107.37	107.33	111.21	72.96	124.88	97.44
17	99.56	99.52	98.62	115.33	111.36	90.62	134.27
18	110.68	106.77	105.24	92.16	46.89	98.84	32.71
19	92.44	86.81	86.18	98.61	110.72	94.52	165.67
20	73.00	148.87	150.09	119.15	90.71	141.10	94.57
21	61.13	130.98	129.44	59.59	87.17	110.65	52.64
22	117.45	102.75	102.19	186.37	168.25	83.28	143.50
23	95.42	167.17	164.17	88.36	91.67	159.56	89.60
24	95.53	101.27	101.63	120.75	161.69	86.00	206.87
25	92.48	99.07	99.05	95.28	93.78	107.79	118.83
26	172.84	100.36	98.86	89.25	108.53	168.73	433.74
27	95.38	127.22	126.45	107.87	97.47	98.75	80.85
28	111.80	112.31	112.95	66.51	142.98	105.29	111.85
29	91.04	122.19	122.65	158.33	85.47	126.75	218.79
30	175.89	82.81	84.09	123.15	117.53	89.42	136.24
31	.	.	.	.	.	.	.
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	pdf30	pdf50	pdf80	pdf100	pdf150	pdf250	pdrfd30
1	127.81	124.07	117.74	111.51	97.46	120.66	125.12
2	119.99	108.43	89.18	80.26	85.33	109.06	120.15
3	102.25	82.22	80.91	83.31	79.85	89.71	34.92
4	57.77	57.19	71.36	82.51	111.12	111.56	33.32
5	198.83	137.33	97.74	90.01	86.92	80.45	74.62
6	115.36	106.72	108.64	113.88	119.19	86.32	85.69
7	48.66	43.26	55.51	66.05	89.11	105.67	22.40
8	80.11	152.78	255.72	287.69	270.26	162.30	413.56
9	101.79	181.17	269.47	253.33	162.65	136.11	1114.53
10	88.66	91.65	95.52	98.77	111.99	115.00	160.96
11	60.01	106.57	233.24	319.62	332.41	157.80	606.34
12	71.82	128.07	154.03	134.00	88.36	99.75	331.84
13	103.96	81.45	58.34	53.50	61.37	78.05	16.16
14	160.78	94.96	78.85	82.93	103.86	116.55	32.30
15	298.54	134.88	89.95	83.66	101.92	98.49	99.23
16	103.66	126.60	143.37	141.02	128.34	120.19	138.33
17	285.51	241.91	180.48	147.66	100.71	85.32	116.96
18	270.54	199.13	178.06	185.71	209.50	141.38	40.33
19	75.07	82.23	81.60	78.48	78.64	82.10	122.52
20	249.15	309.25	407.43	429.72	319.24	150.55	480.41
21	60.22	93.06	215.38	302.35	309.92	157.66	165.49
22	113.87	85.30	71.18	69.08	77.61	75.69	49.53
23	827.05	755.23	657.73	577.62	329.65	160.51	345.41
24	105.56	86.34	67.63	64.15	68.32	81.60	48.05
25	132.00	131.51	130.12	129.82	131.50	119.61	128.44
26	79.79	36.95	26.80	30.20	61.06	94.81	11.76
27	126.47	201.71	198.12	170.90	134.49	105.89	215.63
28	4.87	12.61	32.08	53.45	109.32	113.37	9.09
29	116.85	112.94	104.88	101.15	113.18	180.24	94.03
30	120.90	97.62	88.08	82.42	65.56	71.78	55.48
31	.	.	.	.	.	.	.
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	pdrfd50	pdrfd80	pdrfd100	pdrfd150	pdrfd250	pdrfdini	pdrfdmvc
1	120.40	116.42	111.97	97.95	103.54	94.83	151.44
2	105.49	87.80	78.68	71.98	106.92	53.37	76.30
3	47.83	65.36	73.77	79.04	83.24	69.77	186.86
4	44.78	62.17	73.37	103.62	128.35	82.92	101.00
5	67.65	65.00	65.87	70.68	71.20	56.50	94.46
6	92.43	102.30	108.60	118.72	95.67	97.34	135.84
7	31.81	46.63	57.14	81.43	116.48	72.67	139.08
8	419.97	444.60	440.89	374.20	220.13	217.15	148.63
9	873.09	617.76	467.49	237.32	131.11	172.97	106.56
10	131.70	113.79	110.54	118.13	128.17	116.57	104.25
11	821.23	1011.16	1011.05	696.12	207.28	150.90	135.71
12	298.80	233.49	188.80	111.48	92.25	102.25	84.49
13	20.36	25.30	29.28	43.48	72.41	62.00	93.88
14	43.54	57.12	65.91	87.52	122.57	97.57	28.29
15	81.26	69.57	65.92	75.17	92.13	105.10	50.06
16	157.14	162.38	156.50	138.80	114.89	152.19	99.37
17	111.74	105.29	98.03	79.31	74.79	72.59	70.35
18	66.70	107.17	131.97	180.78	154.33	263.45	113.53
19	104.71	91.96	85.61	78.67	89.54	63.40	87.55
20	619.66	687.46	653.43	438.12	165.08	136.20	125.67
21	336.75	556.14	608.61	491.37	215.27	209.51	350.43
22	44.00	46.49	51.61	63.15	73.06	61.82	39.23
23	435.70	494.96	482.21	337.24	143.85	177.83	186.32
24	44.91	46.97	49.70	57.98	76.03	48.03	67.37
25	121.65	110.91	110.80	123.84	115.56	89.75	102.29
26	12.18	14.69	18.47	40.18	102.04	40.63	108.93
27	248.37	229.50	198.21	147.68	108.39	173.98	109.53
28	13.93	28.83	46.49	115.84	181.34	71.85	184.00
29	105.09	104.91	101.40	103.39	170.77	72.78	74.39
30	71.53	79.43	79.13	67.47	58.87	85.90	118.82
31	.	.	.	.	.	.	.
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SPSS amended data set for appendix

	pdf0	mvcfopr	mvcfopo	fopermvp	inipfopr	inipfopo	f30fopr
1	129.01	2376.51	2487.03	5.94	1382.75	1573.67	62.64
2	121.55	2638.95	2696.87	5.19	1446.07	1764.27	88.27
3	155.91	3461.92	3297.57	2.33	2225.97	2187.92	67.80
4	723.86	1546.26	1668.79	.37	1054.34	947.25	166.00
5	278.48	2017.07	1808.96	3.23	1285.21	1080.40	42.84
6	128.09	3160.38	3063.22	2.15	2347.00	1983.79	31.35
7	514.21	3023.41	3157.14	.29	1857.03	1919.39	164.10
8	31.73	2048.46	2281.26	6.47	1428.31	1905.39	20.24
9	57.39	1573.87	1589.93	6.05	1222.53	1169.80	4.64
10	85.95	2817.68	3732.77	9.79	1608.81	1836.78	12.53
11	38.99	1564.98	1908.60	5.86	1180.05	1268.40	3.62
12	32.07	1987.53	2213.54	6.27	1315.73	1106.60	20.87
13	124.47	1686.65	1592.42	6.72	1013.29	1044.91	28.53
14	509.52	1990.66	2471.99	1.30	1510.07	1525.91	71.96
15	9626.08	1116.78	1094.95	-.22	1021.29	880.41	60.55
16	88.90	2156.37	2326.54	2.96	1257.51	1594.02	25.93
17	324.39	3441.27	3289.31	1.33	1963.50	1671.09	10.67
18	509.28	2419.30	2351.64	1.95	1607.86	1391.66	50.66
19	62.91	1522.11	1365.84	13.24	1037.68	1054.18	63.70
20	219.31	1360.40	2001.93	4.06	1038.17	1419.83	6.95
21	52.41	976.94	1307.24	5.37	678.29	782.82	3.32
22	196.22	1485.15	1480.09	2.63	1115.55	883.78	49.72
23	960.78	1263.10	1931.48	1.39	805.63	1142.49	5.08
24	116.57	1749.50	1758.73	6.85	1267.92	1051.15	23.91
25	132.13	1586.78	1477.57	15.21	1000.44	1009.07	5.06
26	880.20	1468.31	1418.57	.29	610.93	1000.74	51.93
27	15.38	1380.18	1755.61	.67	1163.43	1156.58	15.34
28	13.15	1060.35	1215.33	1.64	762.68	819.33	115.74
29	194.43	1722.31	2108.17	.34	1045.62	1321.32	101.10
30	176.86	1554.52	1277.08	2.05	1257.64	1096.19	29.07
31	.	.	.	.	.	.	.
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	f50fopr	f80fopr	f100fopr	f150fopr	f250fopr	f30fopo	f50fopo
1	201.04	557.26	828.06	1188.69	1414.68	78.27	242.01
2	280.85	750.72	1051.71	1183.02	1321.13	103.66	285.58
3	196.64	555.11	898.78	1808.58	2146.15	25.02	100.82
4	396.21	788.08	941.84	860.36	842.23	57.89	188.56
5	135.47	379.84	566.34	891.24	1216.99	31.50	90.93
6	123.27	452.69	770.00	1415.98	1966.93	27.30	116.68
7	461.08	1064.72	1405.43	1702.32	1560.95	39.02	158.14
8	61.53	165.92	256.42	499.30	858.44	84.78	265.54
9	19.53	80.10	152.44	374.48	627.19	49.72	160.82
10	49.49	179.50	310.32	621.87	1006.25	19.40	62.81
11	8.80	24.53	43.23	147.11	641.76	22.64	75.18
12	81.31	295.14	507.34	930.74	1194.52	67.85	231.81
13	86.50	256.10	404.59	716.17	956.63	4.76	18.22
14	220.99	639.07	960.69	1327.89	1233.09	24.43	101.37
15	211.59	533.15	672.50	787.68	883.15	58.00	166.54
16	77.49	235.14	380.99	684.73	898.38	36.59	122.92
17	29.28	85.46	149.02	418.35	1277.30	12.45	32.63
18	118.62	261.34	361.48	572.26	976.94	22.15	86.91
19	219.60	587.06	814.74	965.85	999.57	76.05	225.42
20	16.24	42.61	71.68	206.86	668.09	34.49	101.99
21	7.93	24.77	47.44	151.58	355.39	6.33	29.91
22	135.62	385.02	617.20	948.17	1062.45	23.63	71.26
23	11.85	31.13	53.83	183.21	658.87	18.13	52.84
24	94.06	328.03	549.38	989.00	1082.21	11.08	42.35
25	12.22	28.10	40.29	70.37	195.63	6.31	14.31
26	152.14	363.08	482.31	561.31	630.06	7.62	20.59
27	47.42	164.91	296.51	607.02	895.62	29.72	112.95
28	221.90	331.59	355.76	377.30	577.61	4.17	27.88
29	290.71	676.68	858.29	874.61	726.45	113.55	323.52
30	105.94	329.14	505.52	751.87	1007.07	16.98	77.69
31	.	.	.	.	.	.	.
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	f80fopo	f100fopo	f150fopo	f250fopo	fopermvpo	totBFDiff	massDiff
1	639.17	897.12	1111.18	1694.38	7.23	105.76	99.65
2	622.71	784.41	957.07	1422.72	6.12	92.86	101.04
3	387.23	688.83	1381.35	1870.63	3.76	56.47	94.01
4	525.15	740.56	921.07	904.63	2.42	98.08	99.54
5	249.48	382.73	645.54	845.60	9.40	106.16	99.81
6	478.28	867.01	1681.50	1668.81	2.83	102.56	100.35
7	550.83	888.98	1479.59	1613.69	1.41	85.16	96.53
8	741.69	1100.40	1687.37	1578.23	1.93	84.57	97.65
9	430.77	584.74	715.77	933.47	3.53	101.74	101.44
10	200.75	345.72	776.12	1246.04	6.58	104.64	102.07
11	246.36	411.40	774.70	1128.37	1.95	101.83	102.10
12	616.80	815.37	897.26	1281.56	1.89	93.24	102.10
13	69.11	130.25	362.92	690.27	8.67	111.11	104.26
14	391.21	685.06	1273.00	1334.38	5.12	106.11	100.59
15	361.82	445.03	684.72	751.85	9.55	101.33	100.75
16	372.96	571.57	904.70	1100.34	2.45	95.42	101.75
17	87.57	138.18	317.69	979.12	4.37	99.48	99.81
18	305.89	515.54	1054.54	1204.09	9.44	90.63	96.86
19	522.43	675.61	796.03	865.24	9.66	91.46	101.63
20	281.90	429.12	717.89	966.20	5.93	116.39	105.36
21	143.67	281.98	612.50	618.64	2.17	106.56	100.72
22	223.97	375.45	688.34	755.95	5.04	94.29	98.15
23	150.66	242.58	491.34	914.77	8.15	103.75	104.24
24	158.95	285.01	613.70	838.17	7.85	90.13	99.27
25	30.86	45.71	90.76	198.37	20.29	96.47	101.15
26	61.24	109.77	308.12	564.18	2.55	107.92	101.80
27	343.68	521.16	827.42	956.80	.08	102.75	104.31
28	109.71	197.27	429.45	672.58	.19	109.84	103.29
29	704.39	862.61	985.08	1308.52	.54	92.58	97.26
30	261.09	385.98	456.82	688.71	4.30	86.54	98.20
31	.	.	.	.	.	.	.
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SPSS amended data set for appendix

	leanDiff	TrunBFDiff	TrunLDiff	LegBFDiff	LegLDiff	itenDIFF	mvcavdif
1	98.67	105.78	99.18	103.17	101.16	129.01	105.56
2	101.59	94.67	104.54	92.86	98.82	121.55	102.26
3	97.63	46.53	100.49	65.85	97.46	155.91	97.71
4	99.85	95.36	103.17	102.80	95.60	723.86	114.69
5	98.59	111.11	93.04	100.71	104.07	278.48	89.64
6	98.75	108.28	96.87	95.38	98.10	128.09	98.53
7	99.16	83.65	96.89	105.66	102.73	514.21	105.34
8	100.86	82.69	102.36	70.19	97.99	31.73	115.15
9	100.89	102.63	103.04	87.22	99.60	57.39	102.78
10	101.25	107.14	96.41	61.22	106.04	85.95	129.55
11	101.83	100.00	101.08	107.82	104.61	38.99	124.21
12	102.70	92.86	101.03	79.76	103.53	32.07	112.22
13	103.48	118.18	100.24	101.30	108.52	124.47	94.79
14	99.71	110.76	99.86	77.22	99.94	509.52	127.71
15	100.47	102.70	103.23	124.32	100.10	-481.30	99.68
16	102.73	95.57	102.41	112.66	103.94	88.90	107.96
17	99.97	100.00	100.00	76.52	100.00	324.39	96.39
18	99.08	91.13	99.25	102.46	98.46	509.28	98.52
19	103.92	92.11	105.24	79.82	103.40	62.91	90.62
20	103.06	115.17	105.45	115.38	101.13	219.31	145.82
21	99.66	113.45	98.06	99.35	102.61	52.41	135.66
22	98.74	98.33	96.96	89.62	99.85	196.22	100.16
23	104.08	105.88	103.20	101.15	105.38	960.78	155.32
24	101.09	85.03	102.65	95.40	101.00	116.57	100.13
25	101.92	97.41	101.95	95.35	102.50	132.13	93.01
26	100.50	107.83	102.60	106.10	100.39	-437.63	97.18
27	103.88	100.49	101.97	106.93	105.58	-30.76	128.32
28	102.00	112.21	104.38	107.58	94.07	-26.31	114.69
29	99.81	94.03	97.41	90.18	104.24	-97.22	120.66
30	101.65	85.77	103.69	89.05	99.69	176.86	80.77
31	.	.	.	.	.	.	.
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	mvcpdif	Finidiff	F30diff	f50diff	f80diff	f100diff	f150diff
1	104.65	96.66	124.96	120.38	114.70	108.34	93.48
2	102.19	126.88	117.44	101.68	82.95	74.58	80.90
3	95.25	97.17	36.90	51.27	69.76	76.64	76.38
4	107.92	94.54	34.87	47.59	66.64	78.63	107.06
5	89.68	77.90	73.54	67.12	65.68	67.58	72.43
6	96.93	86.73	87.08	94.65	105.65	112.60	118.75
7	104.42	102.37	23.78	34.30	51.73	63.25	86.92
8	111.36	126.71	418.85	431.59	447.02	429.13	337.95
9	101.02	102.48	1070.80	823.39	537.78	383.58	191.14
10	132.48	112.82	154.81	126.91	111.83	111.41	124.80
11	121.96	107.40	625.82	854.60	1004.15	951.76	526.63
12	111.37	87.15	325.19	285.09	208.98	160.72	96.40
13	94.41	96.19	16.68	21.06	26.98	32.19	50.68
14	124.18	92.37	33.95	45.87	61.22	71.31	95.87
15	98.05	88.43	95.78	78.71	67.87	66.17	86.93
16	107.89	126.56	141.12	158.63	158.61	150.02	132.13
17	95.58	75.27	116.69	111.44	102.47	92.73	75.94
18	97.20	86.74	43.71	73.26	117.05	142.62	184.28
19	89.73	97.46	119.38	102.65	88.99	82.92	82.42
20	147.16	113.84	496.31	628.09	661.54	598.69	347.05
21	133.81	97.86	190.53	377.25	580.10	594.37	404.08
22	99.66	81.64	47.52	52.54	58.17	60.83	72.60
23	152.92	121.95	357.10	445.81	484.01	450.63	268.18
24	100.53	87.70	46.34	45.02	48.46	51.88	62.05
25	93.12	82.40	124.52	117.12	109.79	113.47	128.96
26	95.78	142.69	11.79	12.49	16.30	22.17	53.68
27	127.51	101.09	221.60	247.21	211.01	177.21	137.01
28	115.27	102.18	9.63	15.71	35.19	57.41	115.67
29	121.16	121.88	95.57	104.89	101.44	98.47	110.39
30	82.15	96.00	58.41	73.34	79.32	76.35	60.76
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	f250diff	rdfinip1	rfdinip2	pddjw1	pddjw3	pddjw7	pdsqw1h
1	119.77	9299.04	8052.87	95.65	97.32	95.37	101.73
2	107.69	9618.56	5360.67	100.61	97.73	100.61	103.14
3	87.16	9898.35	6831.83	101.70	102.58	95.13	102.91
4	107.41	8584.68	7464.57	97.58	97.89	96.19	93.51
5	69.48	6608.73	3605.91	99.82	97.02	99.66	94.49
6	84.84	11512.82	11351.38	96.35	100.71	100.44	98.71
7	103.38	10666.00	7641.12	96.74	98.41	94.98	90.88
8	183.85	4381.51	9014.47	99.21	98.49	91.94	104.18
9	148.83	3261.02	5833.93	100.77	102.64	100.15	101.32
10	123.83	5083.39	5855.54	99.35	98.11	98.53	95.03
11	175.82	2927.05	4413.47	97.20	97.16	100.20	103.96
12	107.29	6661.97	7148.53	97.81	98.59	101.72	102.10
13	72.16	5314.54	3122.06	101.60	99.80	103.02	102.05
14	108.21	9243.63	8101.65	100.46	100.31	100.31	102.83
15	85.13	5685.76	5975.60	109.62	97.05	100.00	114.37
16	122.48	3062.02	4644.82	99.68	98.12	96.72	98.38
17	76.66	5106.73	3518.74	102.22	100.98	103.87	105.88
18	123.25	3325.67	8782.41	96.35	99.84	98.81	98.09
19	86.56	8546.78	5329.01	103.65	100.52	98.29	97.96
20	144.62	2127.37	2443.17	101.63	97.18	96.62	96.77
21	174.07	1730.86	2999.78	99.51	93.77	98.32	102.02
22	71.15	6466.32	4078.47	101.62	97.15	95.85	108.98
23	138.84	2392.68	3738.67	93.55	97.78	96.82	100.47
24	77.45	7705.02	4056.53	98.76	98.77	92.62	94.22
25	101.40	1804.76	1404.58	97.73	98.59	96.90	100.80
26	87.77	4453.79	1643.58	91.62	97.66	100.62	100.57
27	107.31	3001.24	5310.84	100.35	97.40	96.19	94.81
28	117.65	3475.08	2373.71	97.92	97.65	96.63	109.82
29	175.84	8870.49	6359.33	101.38	96.38	96.81	97.78
30	68.39	4771.64	5033.37	95.06	98.39	97.96	99.09
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	pdsqw3h	pdsqw7h	pdsqw1p	pdsqw3p	pdsqw7p	pdsqfpw1	pdsqfpw3
1	97.98	96.58	100.67	99.17	98.56	101.05	91.13
2	96.58	103.28	101.68	98.18	101.71	106.16	97.98
3	101.19	96.04	101.42	100.60	97.98	104.81	104.53
4	96.20	99.61	97.22	98.37	99.84	94.70	97.10
5	100.00	98.00	97.47	100.00	99.04	93.77	101.46
6	91.02	100.00	99.61	97.21	100.00	90.18	96.10
7	98.58	99.72	95.39	99.24	99.85	96.47	96.73
8	103.00	95.47	101.79	101.41	97.78	109.23	100.00
9	104.84	96.49	100.61	102.19	98.28	97.79	109.89
10	104.20	96.43	97.92	101.71	98.39	100.03	104.12
11	96.60	100.00	101.68	98.43	100.00	90.53	71.66
12	97.73	99.55	101.23	98.66	99.73	106.32	96.02
13	104.51	103.56	101.04	102.49	101.92	97.68	104.34
14	104.45	104.73	101.26	102.02	102.15	94.15	103.60
15	111.11	105.38	105.83	104.84	102.50	107.44	104.05
16	102.36	100.00	99.34	100.97	100.00	103.71	125.46
17	100.31	102.03	102.16	100.13	100.79	105.70	97.60
18	100.75	98.25	99.25	100.30	99.25	105.08	102.40
19	98.63	99.26	99.01	99.39	99.69	100.00	100.74
20	95.48	97.64	98.74	98.14	99.02	150.13	96.93
21	98.24	97.34	100.83	99.23	98.76	109.18	95.68
22	104.18	94.57	104.90	102.26	96.97	98.37	103.35
23	105.16	97.04	100.23	102.50	98.43	135.72	103.04
24	94.22	94.16	97.30	97.33	97.04	100.00	90.61
25	99.20	95.67	100.35	99.65	97.89	97.14	90.56
26	97.84	95.92	100.22	99.16	98.12	89.60	88.40
27	99.67	101.61	97.47	99.84	100.79	94.59	97.44
28	101.58	101.77	103.87	100.66	100.78	96.03	111.59
29	90.69	99.20	99.06	95.78	99.63	98.78	99.96
30	92.80	100.41	99.62	96.81	100.18	105.15	97.73
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

SPSS amended data set for appendix

	pdsqfpw7	pchfqsp1	pchfqsp2	pchfqsp3	pchDjw1	pchDjw3	pchDjw7
1	93.87	101.05	91.13	93.87	92.98	95.70	92.56
2	106.48	106.16	97.98	106.48	100.84	96.80	100.87
3	97.54	104.81	104.53	97.54	102.63	103.90	92.71
4	100.78	94.70	97.10	100.78	96.11	96.61	93.86
5	101.44	93.77	101.46	101.44	99.73	95.36	99.47
6	95.49	90.18	96.10	95.49	91.28	101.79	101.06
7	92.37	96.47	96.73	92.37	95.33	97.80	92.92
8	96.82	109.23	100.00	96.82	98.74	97.70	88.03
9	90.63	97.79	109.89	90.63	101.19	104.15	100.22
10	101.91	100.03	104.12	101.91	98.78	96.47	97.36
11	96.32	90.53	71.66	96.32	95.77	95.85	100.30
12	100.75	106.32	96.02	100.75	97.12	98.15	102.25
13	97.94	97.68	104.34	97.94	102.12	99.75	103.91
14	97.27	94.15	103.60	97.27	100.71	100.48	100.49
15	103.97	107.44	104.05	103.97	114.18	95.86	100.00
16	102.10	103.71	125.46	102.10	99.48	96.94	94.84
17	101.47	105.70	97.60	101.47	104.60	101.82	107.27
18	91.02	105.08	102.40	91.02	93.55	99.72	98.02
19	102.38	100.00	100.74	102.38	105.62	100.90	97.00
20	101.82	150.13	96.93	101.82	102.73	95.56	94.54
21	87.34	109.18	95.68	87.34	99.20	89.76	97.44
22	102.42	98.37	103.35	102.42	101.97	96.55	94.95
23	102.97	135.72	103.04	102.97	91.47	97.06	95.73
24	89.74	100.00	90.61	89.74	98.26	98.26	90.05
25	105.00	97.14	90.56	105.00	96.48	97.80	95.42
26	115.09	89.60	88.40	115.09	86.52	96.05	100.94
27	99.34	94.59	97.44	99.34	100.52	96.16	94.37
28	112.62	96.03	111.59	112.62	96.58	96.13	94.55
29	98.41	98.78	99.96	98.41	102.21	94.49	95.18
30	97.21	105.15	97.73	97.21	92.35	97.48	96.88
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	pchDjPp1	pchDjPp3	pchDjPp7	pchDjMp1	pchDjMp3	pchDjMp7	pchSJW1
1	95.65	97.32	95.37	100.56	96.24	102.11	100.67
2	100.61	97.73	100.61	96.88	100.33	100.00	101.68
3	101.70	102.58	95.13	106.64	100.03	95.84	101.42
4	97.58	97.89	96.19	96.52	92.09	98.72	97.22
5	99.82	97.02	99.66	100.00	97.02	102.93	97.47
6	96.35	100.71	100.44	97.25	104.40	105.30	99.61
7	96.74	98.41	94.98	98.92	101.53	96.46	95.39
8	99.21	98.49	91.94	96.84	97.10	101.43	101.79
9	100.77	102.64	100.15	97.07	95.67	100.54	100.61
10	99.35	98.11	98.53	101.14	100.58	93.73	97.92
11	97.20	97.16	100.20	94.45	105.23	104.90	101.68
12	97.81	98.59	101.72	99.54	103.58	96.95	101.23
13	101.60	99.80	103.02	95.43	105.01	102.10	101.04
14	100.46	100.31	100.31	99.49	102.25	101.23	101.26
15	109.62	97.05	100.00	108.59	104.46	98.19	105.83
16	99.68	98.12	96.72	97.01	94.83	95.09	99.34
17	102.22	100.98	103.87	103.74	104.62	102.75	102.16
18	96.35	99.84	98.81	98.86	97.13	96.84	99.25
19	103.65	100.52	98.29	102.74	101.35	94.35	99.01
20	101.63	97.18	96.62	99.29	97.14	100.68	98.74
21	99.51	93.77	98.32	96.58	94.00	96.80	100.83
22	101.62	97.15	95.85	107.35	92.05	100.58	104.90
23	93.55	97.78	96.82	101.88	93.04	94.68	100.23
24	98.76	98.77	92.62	104.14	94.88	92.71	97.30
25	97.73	98.59	96.90	102.83	101.69	95.63	100.35
26	91.62	97.66	100.62	99.95	102.77	102.99	100.22
27	100.35	97.40	96.19	102.10	98.79	97.83	97.47
28	97.92	97.65	96.63	95.34	95.54	98.39	103.87
29	101.38	96.38	96.81	100.72	99.96	96.18	99.06
30	95.06	98.39	97.96	95.20	104.78	93.74	99.62
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	pchSJW3	pchSJW7	pchSJPp1	pchSJPp3	pchSJPp7	pchSJMp1	pchSJMp3
1	99.17	98.56	100.67	99.17	98.56	101.05	91.13
2	98.18	101.71	101.68	98.18	101.71	106.16	97.98
3	100.60	97.98	101.42	100.60	97.98	104.81	104.53
4	98.37	99.84	97.22	98.37	99.84	94.70	97.10
5	100.00	99.04	97.47	100.00	99.04	93.77	101.46
6	97.21	100.00	99.61	97.21	100.00	90.18	96.10
7	99.24	99.85	95.39	99.24	99.85	96.47	96.73
8	101.41	97.78	101.79	101.41	97.78	109.23	100.00
9	102.19	98.28	100.61	102.19	98.28	97.79	109.89
10	101.71	98.39	97.92	101.71	98.39	100.03	104.12
11	98.43	100.00	101.68	98.43	100.00	90.53	71.66
12	98.66	99.73	101.23	98.66	99.73	106.32	96.02
13	102.49	101.92	101.04	102.49	101.92	97.68	104.34
14	102.02	102.15	101.26	102.02	102.15	94.15	103.60
15	104.84	102.50	105.83	104.84	102.50	107.44	104.05
16	100.97	100.00	99.34	100.97	100.00	103.71	125.46
17	100.13	100.79	102.16	100.13	100.79	105.70	97.60
18	100.30	99.25	99.25	100.30	99.25	105.08	102.40
19	99.39	99.69	99.01	99.39	99.69	100.00	100.74
20	98.14	99.02	98.74	98.14	99.02	150.13	96.93
21	99.23	98.76	100.83	99.23	98.76	109.18	95.68
22	102.26	96.97	104.90	102.26	96.97	98.37	103.35
23	102.50	98.43	100.23	102.50	98.43	135.72	103.04
24	97.33	97.04	97.30	97.33	97.04	100.00	90.61
25	99.65	97.89	100.35	99.65	97.89	97.14	90.56
26	99.16	98.12	100.22	99.16	98.12	89.60	88.40
27	99.84	100.79	97.47	99.84	100.79	94.59	97.44
28	100.66	100.78	103.87	100.66	100.78	96.03	111.59
29	95.78	99.63	99.06	95.78	99.63	98.78	99.96
30	96.81	100.18	99.62	96.81	100.18	105.15	97.73
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	pchSJMp7	Djh1to3	Djh3to7	Djh1to7	DjP1to3	DjP3to7	DjP1to7
1	93.87	99.00	102.03	101.00	98.47	102.19	100.62
2	106.48	98.74	97.87	96.63	99.98	98.49	98.47
3	97.54	107.89	97.07	104.74	105.09	96.17	101.06
4	100.78	99.48	101.82	101.30	99.68	102.09	101.76
5	101.44	99.73	103.55	103.27	99.82	103.31	103.13
6	95.49	93.62	101.43	94.97	98.98	97.24	96.25
7	92.37	106.37	95.81	101.91	102.71	97.82	100.46
8	96.82	109.30	107.59	117.59	104.93	104.98	110.16
9	90.63	97.85	108.54	106.21	98.62	106.36	104.89
10	101.91	103.91	106.82	111.00	103.63	102.92	106.65
11	96.32	109.77	99.70	109.45	106.47	100.99	107.52
12	100.75	100.51	105.06	105.59	100.39	104.61	105.01
13	97.94	104.76	103.28	108.20	98.90	107.39	106.21
14	97.27	98.35	97.60	95.98	98.93	99.36	98.30
15	103.97	117.16	111.15	130.22	111.64	110.60	123.47
16	102.10	102.35	108.67	111.23	102.39	105.34	107.86
17	101.47	117.79	103.91	122.39	105.97	104.55	110.79
18	91.02	96.77	112.50	108.87	96.39	106.17	102.34
19	102.38	94.10	99.40	93.54	105.82	100.67	106.53
20	101.82	114.45	100.00	114.45	107.24	102.55	109.97
21	87.34	102.14	112.60	115.01	102.27	104.85	107.23
22	102.42	99.75	97.54	97.30	99.80	97.97	97.77
23	102.97	100.00	103.24	103.24	100.00	105.06	105.06
24	89.74	100.00	110.72	110.72	101.21	105.15	106.43
25	105.00	98.64	114.01	112.47	99.13	107.95	107.01
26	115.09	94.76	126.09	119.48	99.48	114.08	113.48
27	99.34	109.16	102.16	111.52	108.23	102.42	110.85
28	112.62	103.13	106.35	109.69	102.92	104.85	107.92
29	98.41	108.83	102.32	111.36	103.19	101.52	104.77
30	97.21	93.53	110.69	103.53	94.70	108.01	102.28
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	DjMp1to3	DjMp3to7	DjMp1to7	Sjhpov1to3	Sjhpov3to7	Sjhpov1to7	Sjppv1to3
1	104.45	101.10	105.60	102.98	104.96	108.09	101.71
2	94.72	100.87	95.54	93.91	102.06	95.84	101.05
3	106.61	98.08	104.56	107.23	92.38	99.06	104.40
4	101.14	96.05	97.14	103.27	101.58	104.90	100.16
5	101.79	104.31	106.18	109.34	104.63	114.40	101.52
6	97.70	92.32	90.20	96.96	108.97	105.65	103.10
7	101.62	101.29	102.93	116.05	103.17	119.73	101.73
8	107.67	102.87	110.77	115.33	100.00	115.33	106.18
9	108.75	101.67	110.57	98.38	108.91	107.14	97.71
10	107.43	102.31	109.92	106.77	108.93	116.31	100.34
11	94.45	108.66	102.62	108.10	115.42	124.76	106.93
12	102.70	102.63	105.40	98.63	102.32	100.92	101.78
13	98.07	108.95	106.85	111.65	104.68	116.87	99.69
14	95.21	103.42	98.47	104.81	101.64	106.53	101.42
15	96.36	112.26	108.17	109.95	111.90	123.04	105.34
16	95.11	108.51	103.20	107.00	107.69	115.23	102.13
17	104.37	109.48	114.27	112.50	92.90	104.51	104.51
18	95.69	105.60	101.05	105.06	103.70	108.95	99.14
19	95.96	103.08	98.92	100.35	93.08	93.40	108.60
20	103.10	107.88	111.22	105.56	105.56	115.00	101.49
21	94.87	109.36	103.75	110.28	110.28	115.81	106.93
22	121.95	89.01	108.55	93.26	93.26	91.39	98.66
23	107.48	101.34	108.91	104.67	104.67	122.43	100.00
24	103.12	102.47	105.68	100.00	100.00	114.15	101.22
25	99.46	102.09	101.54	98.41	98.41	113.89	100.00
26	101.28	112.95	114.39	102.26	102.26	132.77	104.55
27	108.83	98.55	107.25	109.49	109.49	114.96	104.01
28	105.29	104.02	109.53	104.47	104.47	117.07	106.13
29	98.56	100.86	99.41	101.82	101.82	112.27	101.92
30	95.62	110.41	105.57	100.92	100.92	112.44	102.13
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	Sjppv3to7	Sjppv1to7	Sjppov1to3	Sjppov3to7	Sjppov1to7	Pdiffrfd1to7	Sjpkgdi1to3
1	103.63	105.39	100.19	102.99	103.18	106.12	101.35
2	97.58	98.60	97.57	101.08	98.63	68.05	96.32
3	96.87	101.14	103.57	94.35	97.71	71.31	103.57
4	100.14	100.31	101.34	101.64	103.00	83.49	101.34
5	104.13	105.71	104.15	103.14	107.42	53.29	104.15
6	96.77	99.77	100.62	99.54	100.16	94.17	98.92
7	101.95	103.71	105.85	102.57	108.57	81.60	108.56
8	103.72	110.13	105.78	100.00	105.78	237.08	107.04
9	109.21	106.70	99.24	105.03	104.23	134.03	99.24
10	106.49	106.85	104.23	103.02	107.37	127.08	102.30
11	106.46	113.84	103.51	108.16	111.96	124.74	103.51
12	101.06	102.85	99.19	102.16	101.33	104.40	99.19
13	108.00	107.66	101.13	107.40	108.61	84.18	107.65
14	101.54	102.98	102.18	101.66	103.88	158.00	102.18
15	110.55	116.46	104.36	108.08	112.80	83.32	104.36
16	104.22	106.44	103.82	103.21	107.15	131.61	102.62
17	98.66	103.11	102.43	99.31	101.72	76.24	105.44
18	101.69	100.81	100.19	100.62	100.81	204.14	102.37
19	97.54	105.93	109.02	97.83	106.66	78.87	97.74
20	105.11	106.67	100.87	106.04	106.97	136.34	102.24
21	99.90	106.83	105.23	99.43	104.64	202.23	104.02
22	104.29	102.90	96.17	98.90	95.11	76.13	96.17
23	115.62	115.62	102.27	111.03	113.55	122.76	102.27
24	104.16	105.43	101.25	103.85	105.15	58.06	99.81
25	107.73	107.73	99.30	105.82	105.08	87.62	99.30
26	111.35	116.42	103.45	110.18	113.98	53.26	100.69
27	102.41	106.52	106.54	103.39	110.15	145.89	103.84
28	105.95	112.44	102.86	106.07	109.10	70.98	101.65
29	100.37	102.29	98.54	104.41	102.88	88.80	101.13
30	102.41	104.59	99.26	105.98	105.19	107.20	100.56
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	Sjpkgdi3to7	Sjpkgdi1to7	djppkch1	djppkch3	djppkch7	SQjhch1	SQjhch3
1	101.80	103.18	95.65	97.32	95.37	101.73	97.98
2	101.08	97.36	100.61	97.73	100.61	103.14	96.58
3	96.74	100.19	101.70	102.58	95.13	102.91	101.19
4	100.45	101.80	97.58	97.89	96.19	93.51	96.20
5	101.86	106.09	99.82	97.02	99.66	94.49	100.00
6	103.04	101.92	96.35	100.71	100.44	98.71	91.02
7	101.27	109.94	96.74	99.24	94.98	90.88	98.58
8	100.00	107.04	99.21	101.41	91.94	104.18	103.00
9	103.81	103.02	100.77	102.19	100.15	101.32	104.84
10	103.98	106.37	99.35	101.71	98.53	95.03	104.20
11	106.68	110.42	97.20	98.43	100.20	103.96	96.60
12	100.85	100.03	97.81	98.66	101.72	102.10	97.73
13	100.89	108.61	101.60	102.49	103.02	102.05	104.51
14	100.48	102.67	100.46	102.02	100.31	102.83	104.45
15	104.95	109.53	109.62	104.84	100.00	114.37	111.11
16	103.21	105.92	99.68	100.97	96.72	98.38	102.36
17	96.47	101.72	102.22	100.13	103.87	105.88	100.31
18	101.73	104.14	96.35	100.30	98.81	98.09	100.75
19	96.72	94.54	103.65	99.39	98.29	97.96	98.63
20	103.25	105.56	101.63	98.14	96.62	96.77	95.48
21	102.99	107.13	99.51	99.23	98.32	102.02	98.24
22	98.90	95.11	101.62	102.26	95.85	108.98	104.18
23	107.67	110.11	93.55	102.50	96.82	100.47	105.16
24	106.90	106.70	98.76	97.33	92.62	94.22	94.22
25	107.16	106.41	97.73	99.65	96.90	100.80	99.20
26	111.67	112.44	91.62	99.16	100.62	100.57	97.84
27	102.10	106.02	100.35	99.84	96.19	94.81	99.67
28	104.84	106.56	97.92	100.66	96.63	109.82	101.58
29	104.41	105.59	101.38	95.78	96.81	97.78	90.69
30	104.60	105.19	95.06	96.81	97.96	99.09	92.80
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	SQhch7	SQpch1	SQpch3	SQpch7	Sqpkgch1	Sqpkgch3	Sqpkgch7
1	96.58	100.67	99.17	98.56	100.67	99.17	98.56
2	103.28	101.68	98.18	101.71	101.68	98.18	101.71
3	96.04	101.42	100.60	97.98	101.42	100.60	97.98
4	99.61	97.22	98.37	99.84	97.22	98.37	99.84
5	98.00	97.47	100.00	99.04	97.47	100.00	99.04
6	100.00	99.61	97.21	100.00	99.61	97.21	100.00
7	99.72	95.39	99.24	99.85	95.39	99.24	99.85
8	95.47	101.79	101.41	97.78	101.79	101.41	97.78
9	96.49	100.61	102.19	98.28	100.61	102.19	98.28
10	96.43	97.92	101.71	98.39	97.92	101.71	98.39
11	100.00	101.68	98.43	100.00	101.68	98.43	100.00
12	99.55	101.23	98.66	99.73	101.23	98.66	99.73
13	103.56	101.04	102.49	101.92	101.04	102.49	101.92
14	104.73	101.26	102.02	102.15	101.26	102.02	102.15
15	105.38	105.83	104.84	102.50	105.83	104.84	102.50
16	100.00	99.34	100.97	100.00	99.34	100.97	100.00
17	102.03	102.16	100.13	100.79	102.16	100.13	100.79
18	98.25	99.25	100.30	99.25	99.25	100.30	99.25
19	99.26	99.01	99.39	99.69	99.01	99.39	99.69
20	97.64	98.74	98.14	99.02	98.74	98.14	99.02
21	97.34	100.83	99.23	98.76	100.83	99.23	98.76
22	94.57	104.90	102.26	96.97	104.90	102.26	96.97
23	97.04	100.23	102.50	98.43	100.23	102.50	98.43
24	94.16	97.30	97.33	97.04	97.30	97.33	97.04
25	95.67	100.35	99.65	97.89	100.35	99.65	97.89
26	95.92	100.22	99.16	98.12	100.22	99.16	98.12
27	101.61	97.47	99.84	100.79	97.47	99.84	100.79
28	101.77	103.87	100.66	100.78	103.87	100.66	100.78
29	99.20	99.06	95.78	99.63	99.06	95.78	99.63
30	100.41	99.62	96.81	100.18	99.62	96.81	100.18
31	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.

	Sqmpch1	Sqmpch3	Sqmpch7
1	101.05	91.13	93.87
2	106.16	97.98	106.48
3	104.81	104.53	97.54
4	94.70	97.10	100.78
5	93.77	101.46	101.44
6	90.18	96.10	95.49
7	96.47	96.73	92.37
8	109.23	100.00	96.82
9	97.79	109.89	90.63
10	100.03	104.12	101.91
11	90.53	71.66	96.32
12	106.32	96.02	100.75
13	97.68	104.34	97.94
14	94.15	103.60	97.27
15	107.44	104.05	103.97
16	103.71	125.46	102.10
17	105.70	97.60	101.47
18	105.08	102.40	91.02
19	100.00	100.74	102.38
20	150.13	96.93	101.82
21	109.18	95.68	87.34
22	98.37	103.35	102.42
23	135.72	103.04	102.97
24	100.00	90.61	89.74
25	97.14	90.56	105.00
26	89.60	88.40	115.09
27	94.59	97.44	99.34
28	96.03	111.59	112.62
29	98.78	99.96	98.41
30	105.15	97.73	97.21
31	.	.	.
32	.	.	.
33	.	.	.
34	.	.	.