Title: The effect of whole body vibration as a warm up for Olympic weightlifting.

Author: Kwok Hong Andy Tsang,

This Research Project is submitted as partial fulfilment of the requirements for the degree of Master of Science, St Mary's University

First supervisor: Stephen D Patterson

Second supervisor: Phil Price.

Mailing address: Kwok Hong Andy Tsang 259 Garryduff Road, Ballymena, County Antrim, Northern Ireland.

Telephone: +44 7515 281 238 **Email:** info@andytsang.co.uk

Title: The effect of whole body vibration as a warm up for Olympic weightlifting.

CONTENTS

FIGURES

Figure 1. Change in PF (N) of each frequency compared 0Hz

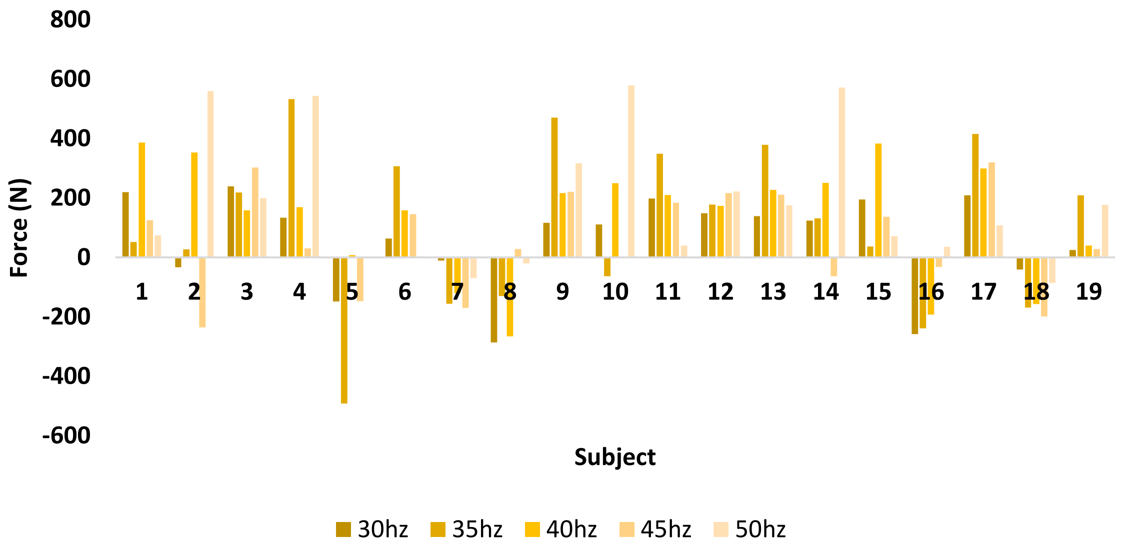
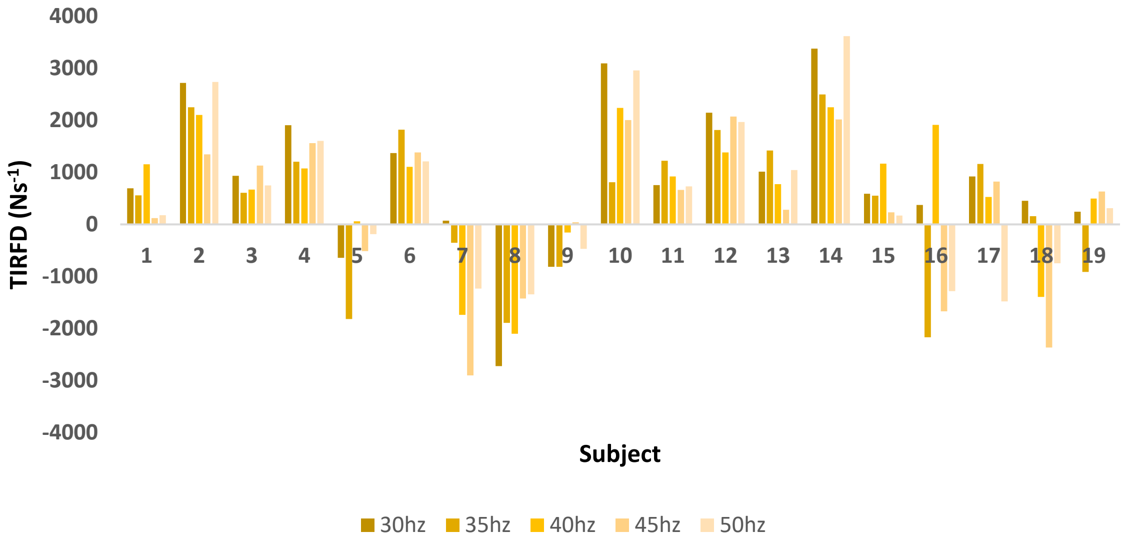


Figure 2. Change in TIRFD (Ns^{-1}) of each frequency compared to 0Hz



TABLES

Table 1. Force outputs for each vibration frequency after warm up

	0hz	**30hz**	**35hz**	**40hz**	**45hz**	**50hz**
PF (N)	1546.3 ± 398.9	1606.5 ± 342.9	1654.5 ± 402.2	1680.3 ± 394.7	1605.8 ± 331.0	1730.3 ± 514.2
TIRFD (Ns^{-1})	5261.8 ± 1434.8	6129.9 ± 1754.0	5689.2 ± 1466.1	5916.4 ± 1731.1	5547.0 ± 1726.7	5816.3 ± 1905.8

PF = peak force

TIRFD= time interval rate of force development

Table 2. Heat and flexibility scores before and after warm up

0hz		**30hz**		**35hz**		**40hz**		**45hz**		**50hz**	
FB	**FA**	**FB**	**FA**	**FB**	**FA**	**FB**	**FA**	**FB**	**FA**	**FB**	**FA**
2.6 in ± 6.3in	4.3 in ± 5.7 in	3.6 in ± 5.6 in	5.3 in ± 5.4 in	3.6 in ± 5.5 in	5.6 in ± 4.9 in	3.3 in ± 5.3 in	5.6 in ± 5.0 in	3.3 in ± 5.7 in	5.7 in ± 4.9 in	2.9 in ± 5.6 in	5.5 in ± 5.6 in
HB	**HA**	**HB**	**HA**	**HB**	**HA**	**HB**	**HA**	**HB**	**HA**	**HB**	**HA**
28.6° ± 1.8°	29.1° ± 1.7°	28.3° ± 1.3°	29.5° ± 1.2°	28.0° ± 1.3°	28.7° ± 1.4°	28.2° ± 1.3°	28.7° ± 1.4°	28.3° ± 1.2°	29.0°±1.3°	28.3° ± 1.4°	29.5° ± 1.5°

FB = flexibility before

FA = flexibility after

HB = heat before

HA = heat after

Acknowledgements

The main author would like to thank their supervisor and Strength Farm Gym for their cooperation and patience. The authors did not affiliate or obtain any involvement with any other organisation or entity and no financial interests or funding was received. The corresponding author may be contacted via post at Kwok Hong Andy Tsang, 259 Garryduff Road, Ballymena, County Antrim, Northern Ireland, BT44 9EE and email: info@andytsang.co.uk and telephone: +44 7515 281 238

ABSTRACT

Recent studies have shown whole body vibration training (WBV) to be an effective training modality for producing an acute response to performance. Benefits can be seen in multiple physical qualities such as strength, speed, flexibility and countermovement jump (CMJ) performance. Since Olympic weightlifting requires many of these attributes, the potential for WBV usage within this population warrants further investigation.

The purpose of this study was to look at the acute response of WBV warm up in Olympic weightlifters and compare the effect of different vibration frequencies (30Hz, 35Hz, 40Hz, 45Hz, 50Hz) to non-vibration (0Hz). 19 Olympic weightlifters (13 male and 6 female, 27 ± 4 years, 174.4 ± 7.5 cm, 77.3 ± 18.6 kg) underwent 6 consecutive sessions over 6 days consisting of a warm up on a randomly assigned WBV frequency followed by 3 repetitions of a mid-thigh clean pull (60% of one-repetition maximum clean) with 4 minutes rest between attempts. Time interval rate of force development and peak force data was recorded for analysis. To assist in understanding the mechanisms behind WBV, skin temperature and a v-sit and reach test were also conducted before and after the warm up.

One-way analysis of variance (ANOVA) test was revealed no significant differences were seen in peak force or time interval rate of force development. The mean percentage change in skin temperature when compared to 0Hz showed a significance (0.011° C). No significance was seen in the mean percentage change in flexibility (0.821in) when compared to 0Hz.

Key words: Strength, Power, Flexibility, Heat

INTRODUCTION

Whole body vibration (WBV) training has been referred to as the use of mechanical vibrations (with or without additional load), induced via plates, belts, cables and most notably platforms, and performing exercises on the equipment (13). There has been a recent rise in popularity of WBV training within the rehabilitation and fitness industry and as a result, has become commercially available within rehabilitation clinics and gyms worldwide (13). This form of training has also become a popular topic of discussion among strength and conditioning (S&C) coaches with many employing WBV for increasing performance in athletes (9).

Vibration platforms normally produce motion by either oscillating vertically or alternating from side to side with amplitude ranging from 1mm to 15mm and frequency of oscillations ranging from 15Hz to 60Hz (16, 57). Issurin, Liebermann, & Tenenbaum, (38) claim that WBV was first used by the Russians during the 1980s for S&C training and more recently, it has been suggested that WBV training may be useful for improving acute performance outcomes in multiple physical qualities, such as power (8), strength (31) and flexibility (23). With regards to usage, the subject usually performs dynamic or static exercises on the oscillating platform for a period of time to acquire the desired training stimulus (1). It is theorised that the mechanical vibrations induce sinusoidal oscillations to the muscle due to the constant changes in velocity and direction (9). This creates short and rapid changes in the muscle tendon complex, increasing muscle contractibility (57). If the stimulus is adequate, there exists the potential to increase performance due to neurological and physiological changes that occur (13) however, if accelerations of the platform are exceedingly high, there is also the potential for increasing the risk of injury, fatigue or a reduction in performance (41).

The mechanisms behind WBV training have been a topic of discussion amongst researchers and it remains a controversial subject. It has been suggested that the improvements in performance via WBV training may be attributed to neurogenic potentiation (14, 56). Researchers have proposed that the increased neuromuscular activation is commonly attributed to the reflexive muscle contraction known as the tonic vibration reflex (TVR) in response to vibratory stimulus (55). The TVR theory was initially proposed by Eklund and Hagbarth (32) and was based upon vibrations that were applied directly to a tendon. Theoretically, the local muscle and tendon vibrations induce activity of the muscle spindle fibres primarily through la afferents and the activation of the muscle fibres through motor neurons mediated by monosynaptic and polysynaptic pathways (57). Through reciprocal inhibition, the motor neurons innervating the antagonist muscles reduce in excitability (19, 28, 48) as well as suppression of the monosynaptic stretch reflexes of the vibrated muscle (19, 28 51). However, Luo, McNamara and Moran (50) in recent years demonstrated that in order to determine spinal reflexes to be the causal mechanism, higher frequencies are required (>100 Hz), which raises doubt regarding the practical element of the TVR theory. Since most vibrating training methods are at lower frequencies (20Hz - 45Hz), one would question the TVR involvement. Furthermore, when a subject performs WBV training, both agonists and antagonists will be vibrated as it is near impossible to isolate only the intended muscle which again raises concerns regarding the TVR theory (20). For the TVR theory to occur, certain conditions need to be present for it to be effective which makes it seem unlikely that it is the main causal mechanism for increases in performance. TVR may however play a role in the involvement of muscle spindles indirectly, where other sensory inputs may influence gamma (γ) motoneuron activity, causing changes to spindle input such as load and duration of activity (19, 35).

Alternative research suggests, in response to the mechanical vibrations, the body can fine tune itself and reduce the amount of vibrations that pass through the soft tissue (65). The muscle-tuning hypothesis proposes that the neuromuscular system causes muscular contractions to dampen the soft tissue oscillations that occur in response to mechanical vibrations (8,13,16, 65). The individual's stiffness, muscle spindles, receptors of the skin and joints, and the proportion of type II muscle fibres all play a role in the dampening of the vibrations (15, 16). When vibrations are applied to the area, muscles will alter their activity to dampen the vibrations, preventing any resonance phenomenon (65). With the auto-regulating features associated with the muscle-tuning hypothesis, the dampening effect can lead to a more efficient recruitment and synchronization of the related motor unit populations (19). The muscle-tuning hypothesis relies on the input force, the vibration response and the level of muscle activity, which is difficult to analyse as the vibrations cause movement artefacts that may interfere with measuring activity (16). Other mechanisms have also been proposed by researchers with regard to WBV training. Increases in temperature and blood flow (39), psychological changes (49), and changes to the secretion of hormones (14) have all been suggested and analysed. Consequently, there is an abundance of research in the area of WBV training however, due to the multifactorial nature of the acute changes in WBV, there is not a clear consensus on the exact mechanisms underlying WBV training (52).

Despite its debate behind its exact mechanism, WBV training has been shown to increase structural adaptations in the muscle with acute WBV exposures related to altering motor recruitment as part of an intervention protocol (1). Positive adaptations as a result of WBV have been observed in muscular strength (1, 29, 58, 62), power generation (8, 15), flexibility (23) and balance (7). A significant proportion of the benefits can be seen in improved countermovement jump (CMJ) performance and has been summarised in recent review articles (20, 57). Previous studies on WBV training using frequencies ranging from 25Hz to 40Hz (and unloaded) reported improvements in vertical jump ranging from 7.6% to 16% (59, 61, 63). Bosco et al. (10) has also shown increases in CMJ height, using a protocol consisting of 60 second bouts of WBV, with 60 second intervals for a duration of 10 minutes. Cardinale and Lim (15), found that using 5 minutes of WBV training in a semi squat position with a low frequency (below 20Hz) increased jump performance. Torvinen et al. (61) elicited improvements in CMJ height (2.5% increase) using a 4 minute WBV session with general light exercise movements. Cormie, Deane, Triplett and McBride (24) found that using only a single bout of WBV training at 30Hz with an amplitude of 2.5mm for a short duration (30 seconds) in a half squat position can increase CMJ height. These studies demonstrate that employing a WBV protocol before performing a CMJ can significantly increase CMJ height compared to control groups even with such variety in protocols. As it has been shown that Olympic weightlifting has a high correlation to CMJ performance (17), WBV training may serve as a useful tool for Olympic weightlifting performance.

Not all investigators however have noted positive benefits to WBV as there have been several studies that report no improvements or even a decline in performance (22, 23, 32, 33). In artistic gymnastics, WBV training was not shown to be the most effective strategy in improving flexibility (27). Bullock et al. (12) measured the acute effects of WBV training on elite skeleton athletes and reported no effects on 30m sprint performance with Kavanaugh et al. (42) also reporting similar results on NCAA Division I collegiate sprinters and jumpers. Turner, Sanderson and Attwood also report WBV having no effect on sprinters (63). This potentially leads to confusion amongst S&C coaches regarding WBV and its effectiveness for improving performance. A potential explanation may be due to the level of ability an athlete may possess.

The studies outlined above were all performed on athletes of a high calibre, and it may seem that for those that possess a higher level of neuromuscular ability, WBV creates very little stimulus.

A key reason for the inconsistencies in scientific data regarding the effects of WBV is the variations in each study. Previous research on WBV varies in frequency (15Hz – 65Hz) and in amplitude (1mm - 10mm), incorporating different populations with varying durations and recovery periods. Each of these factors have the ability to impact upon the biological response of WBV training, leading to inconsistency in the results (50). Luo et al. (50) recommend that although there are a variety of combinations, using a frequency between 30Hz and 50Hz is the most effective stimulus for use with WBV training. A study by Hazell, Jakobi and Kenno (37) suggests that vertical oscillating frequencies of 35Hz or greater, with an amplitude of 4mm, seem to have the greatest ability to increase lower body muscle activity and contributions to strength during both dynamic and static contractions during WBV Bazett-Jones et al. (6) suggest that 40Hz with amplitudes of 2mm - 4mm and 50Hz with amplitudes of 4mm - 6mm are most effective for increasing CMJ performance which is highly correlated to explosive strength (19). Consequently, the above examples show that more clarity is required within the body of knowledge regarding frequency, amplitude and duration within the athletic population, to determine a more accurate dose-response relationship.

An aspect of WBV training that warrants further investigation, is the use of WBV within a warm-up strategy (21). Warm-up before performance is often recommended to prevent injury and to prepare the body for activity and improve performance. Since WBV can increase the acute performance of aspects such as flexibility and neuromuscular activation (13), it has been suggested that WBV can be used as an active warm-up (with and without additional load) in place of traditional active warm-ups for sports (26). In S&C, coaches typically utilise a general warm-up to elevate heart rate, blood flow and increase core temperature, followed by specific dynamic exercises (52). Some also involve biomechanically similar strength exercises along with ballistic or plyometric exercises to increase the neuromuscular potentiation and familiarise the athlete with the task ahead (3). A short, acute exposure to vibration may elicit post activation potentiation, though it must be used with caution as too long a duration may cause too great a fatigue and reduce the force production capabilities (13). Rittweger et al. (55, 56) have also reported similar findings of increased fatigue effects due to WBV. Over exposure to WBV may therefore not only decrease the subject's performance capability, it could also increase the risk of injury through fatigue and should therefore be avoided (41). It must also be recognised that if the stimulus is not sufficient, then increases in performance may not occur, which would make WBV impractical as a warm up. As Olympic weightlifting is a sport that is largely determined by the amount of force an athlete can produce, WBV warm ups could create advantageous environments for a weightlifter, thus increasing their chances of success. The use of WBV training as a warm up strategy may be appropriate for the Olympic weightlifter however, the duration and intensity must be considered with caution.

At present, the use of WBV as a warm up modality for increasing the performance of Olympic weightlifting has not been tested. Since WBV has been used successfully for improving many physical qualities outlined above, WBV could potentially induce positive adaptations for Olympic weightlifting as many of these physical qualities are required for success. Although research such as the Avelar study (5) may suggest that it can be used as an effective warm up strategy, as well as the acute effects WBV has on CMJ performance (6), the assumption that a

WBV warm up must also transfer to Olympic weightlifting given its high correspondence (17). Therefore, the objective of this study is to determine whether the use of WBV can be of benefit for Olympic weightlifting and at what frequency. Since a variable frequency is available, and there appears to be a lack of clarity about which is the optimal stimulus, this study will test frequencies between 30Hz and 50Hz with a 4mm amplitude based on recommendations by Luo et al (50) for best eliciting strength and power improvements. It is hypothesised that utilising a WBV warm up with additional load will produce better potentiating effects to force production compared to non-vibration warm ups.

METHODS

Experimental Approach To The Problem

To investigate the effects of WBV compared to non-vibration, a standardised warm up protocol was performed by the test subject followed by a mid-thigh clean pull at 60% of their 1 repetition maximum (RM) with force, heat and flexibility samples recorded for analysis. A RM was taken two weeks prior to testing and will be used to predict their 1RM using the Brzycki formula $w \div (1.0278 - (0.0278 \times n))$, where w is the weight used and n is the number of reps (11). The mid-thigh clean pull was chosen because it represents the portion of the clean where the highest velocities and forces are generated (36) as well as reducing the technical difficulty of the lift. Sixty percent of 1 repetition maximum was chosen based on the research by Kawamori et al (43). The dependent variables will be flexibility score, heat score, peak force (PF) and time interval rate of force development (TIRFD) in the first 300 milliseconds. The independent variables will be the different frequencies (30Hz, 35z, 40Hz, 45Hz and 50Hz) using a 4mm amplitude and non-vibration. Testing was performed over 6 consecutive days with each variable (non-vibration, 30Hz, 35Hz, 40Hz, 45Hz and 50Hz) being tested on each of the days. These will be randomised over the 6 days to avoid any potential practice effect. Subjects will then have 24 hours for recovery between testing sessions and refrain from any additional training. Considering the weight selection and minimal volume (60% of 1RM) within our population group (well-trained weightlifters), this should not increase fatigue and affect the experiment (see Kraemer and Ratamess, (47)).

Subjects

19 amateur, national and international weightlifters (13 male and 6 female, 27 ± 4 years, 174.4 ± 7.5 cm, 77.3 ± 18.6 kg) were recruited for the study. This age range replicates the requirement of weightlifters competing in senior level Olympic weightlifting. The subjects were required to have a minimum of two years Olympic weightlifting experience and currently train a minimum of 2 sessions per week. All participants filled in a pre-activity questionnaire's prior to testing in conjunction with informed consent forms. Subjects were all reported to be healthy and had no injuries or conditions that would prevent participating in the study. Prior to testing, each subject was given a participant information sheet explaining the experimental procedures. This study was carried out in accordance with the declaration of Helsinki principles, along with the ethics approval that was obtained from St Mary's University's institutional review board.

Procedures

Subjects were asked to wear loose clothing and their weightlifting shoes to perform the warm up. The equipment used for testing will be a vibration plate (Power Plate Pro 7, London, United Kingdom), force plate (PASCO, Roseville, CA, USA), Olympic weightlifting bar (Eleiko, Halmstad, Sweden), Olympic Plates (Eleiko, Halmstad, Sweden) and weightlifting platform, measuring tape, markers, sensors and a skin thermistor (Edale CD, Cambridge, UK). All subjects were taught the warm-up prior to the test day to familiarise themselves with the warm-up. They warm-up was also performed on the vibration plate to familiarise themselves with the vibration platform. Subjects were attached to a heat thermistor with the probes placed on the right bicep femoris muscle to measure skin temperature before and after the warm-up. The probe was placed directly halfway between the origin (tuberosity of the ischium) and the insertion (lateral tibial epicondyle) of the Biceps femoris. This was performed by marking out the origin and insertion points and then measuring the distance between both points and placing the probe directly in the halfway point on the muscle belly. Skin temperature was measured as it has been shown to have a significant correlation to power output (reference)

Prior to the warm-up, subjects performed a v-sit and reach test to measure flexibility which has been shown to have a high individual reliability r = 0.98 based on research by Cuberek, Machova and Lipenska (25). The subjects thereafter performed the warm-up comprising of 10 Romanian deadlifts, 10 deep barbell back squats, 10 good mornings, and 10 clean pulls with a 20kg barbell on a randomly selected variable (frequency) that is tested on the day. After the warm-up, subjects performed another v-sit and reach test then was given 2 minutes rest. The test subjects then performed a mid-thigh clean pull on a force plate (PASCO, Roseville, CA, USA) to collect force output data. The mid-thigh clean pull was performed by lowering the bar to mid-thigh followed by a violent extension of the lower limbs perform, ensuring triple extension of the ankle, hip and knee and ensuring that the bar moves in a vertical plane whilst maintaining elbow extension. The subjects performed 3 repetitions with 4 minutes rest between each repetition to minimise fatigue. The order of tests was randomised for the 6 consecutive sessions over 6 days. Samples that produced the highest peak force output out of the three attempts for each subject was used for statistical analysis. Subjects were required to refrain from intense exercise for the duration of the study as well as no caffeine 3 hours before the study.

Statistical Analysis

Sample size estimations were performed using G*Power (version 3.0.10) which gave a moderate effect size (f = 0.4), with a power of 80%, assuming an alpha-level of 0.05. The number of subjects recruited for the study fell within this range (n=19). Statistical analysis was performed utilising SPSS software (IBM, SPSS Statistics 21) and Excel (Microsoft, 2013). A one-way analysis of variance (ANOVA) was used to look the multivariate differences between conditions and to determine if statistical significance could be reached. Any value of $p \leq 0.05$ suggested statistical significance.

Finally, a Wilson Signed ranks test was employed to look at the percentage of change in heat and flexibility when using the various warm up protocols.

RESULTS

PF and TIRFD

The results of PF AND TIRFD are presented in table 1. Significance was not reached using WBV for PF *(F*(5,108) = 0.49, p = 0.78, partial η^2 = 0.22*)* and TIRFD (*F*(5,108) = 0.62, p =0.69 partial η^2 = 0.28).

Table 1. Force outputs for each vibration frequency after warm up

	0hz	**30hz**	**35hz**	**40hz**	**45hz**	**50hz**
PF (N)	1546.3 ± 398.9	1606.5 ± 342.9	1654.5 ± 402.2	1680.3 ± 394.7	1605.8 ± 331.0	1730.3 ± 514.2
TIRFD (Ns^{-1})	5261.8 ± 1434.8	6129.9 ± 1754.0	5689.2 ± 1466.1	5916.4 ± 1731.1	5547.0 ± 1726.7	5816.3 ± 1905.8

PF = peak force

TIRFD= time interval rate of force development

Skin Temperature

The results of heat before and after WBV are presented in table 2. ANOVA results show no significance in heat before (*F*(5,108) = 0.403, p = 0.85, partial η^2 = 0.018) and in heat after (*F*(5,108) = 1.128, p = 0.35, partial η^2 = 0.050) warm up. Finally, a Wilson Signed Ranks test was also performed to look at how vibration affected the percentage of change in heat within all subjects before and after warm up. A significance *p* value of 0.011 was seen in the percentage of change in heat and that WBV does increase heat values more than non-vibration.

Table 2. Heat and flexibility scores before and after warm up

0hz		**30hz**		**35hz**		**40hz**		**45hz**		**50hz**	
FB	**FA**	**FB**	**FA**	**FB**	**FA**	**FB**	**FA**	**FB**	**FA**	**FB**	**FA**
2.6 in ± 6.3in	4.3 in ± 5.7 in	3.6 in ± 5.6 in	5.3 in ± 5.4 in	3.6 in ± 5.5 in	5.6 in ± 4.9 in	3.3 in ± 5.3 in	5.6 in ± 5.0 in	3.3 in ± 5.7 in	5.7 in ± 4.9 in	2.9 in ± 5.6 in	5.5 in ± 5.6 in
HB	**HA**	**HB**	**HA**	**HB**	**HA**	**HB**	**HA**	**HB**	**HA**	**HB**	**HA**
28.6° ± 1.8°	29.1° ± 1.7°	28.3° ± 1.3°	29.5° ± 1.2°	28.0° ± 1.3°	28.7° ± 1.4°	28.2° ± 1.3°	28.7° ± 1.4°	28.3° ± 1.2°	29.0°±1.3°	28.3° ± 1.4°	29.5° ± 1.5°

FB = flexibility before

FA = flexibility after

HB = heat before

HA = heat after

Flexibility

The results of Flexibility before and after when compared with WBV warm up are presented in table 2. One-way ANOVA results did not show significance in flexibility before (F(5,108) = 0.11, p = 0.99, partial η^2 = 0.005) and in flexibility after (F(5,108) = 0.185, p = 0.97, partial η^2 = 0.008) the warm up. A Wilson Signed Ranks test was also used looking at the percentage of change in flexibility within subjects. No statistical significance was seen within the subjects (p = 0.82).

DISCUSSION

The purpose of this study was to compare WBV warm up to a traditional warm up and its potential for increasing the force producing capabilities in Olympic weightlifters. In this experiment, no statistically significant differences were shown between non-vibration and different vibration frequencies in PF and TIRFD during the mid-thigh clean pull. Skin temperature and flexibility measurements were also taken to assist in understanding the physiological adaptations of utilising a WBV warm up. In our study we also compared the differences of each subjects' WBV warm up to their 0Hz warm up. The percentage difference was calculated and analysed. Statistical differences were obtained in skin temperature, but not in flexibility when the subjects compared it to their own 0Hz WBV warm up.

The greatest differences found in the literature were observed using a frequency of 50Hz for PF and 30Hz for TIRFD after performing a multiple comparisons test. PF attained a mean difference of -184.0N and TIRFD -868.09N. Although the findings did not show significance, there was some data within the experiment that may suggest WBV can provide positive adaptations when used as part of a warm up. When analysing PF, comparisons of the different frequencies to 0Hz showed 11 subjects had an increase in PF. The greatest change produced with 35Hz and 50Hz with 6 individuals having increases of over 300N, and 3 individuals had over 500N increase for 50Hz (figure 1). In regards to TIRFD, 10 of the subjects had increases across all frequencies compared to 0Hz, with 30Hz being the most effective at producing positive change shown in figure 2. Using the figures to calculate mean percentage of change, 40Hz and 50 Hz had over 10% increases compared to 0Hz in PF. For TIRFD, all frequencies showed increases of above 10% with 30Hz showing 24.74% average increase. This would support some of the research where minor improvements were apparent in using WBV although significance was not met across the sample (42).

Figure 1. Change in PF (N) of each frequency compared 0Hz

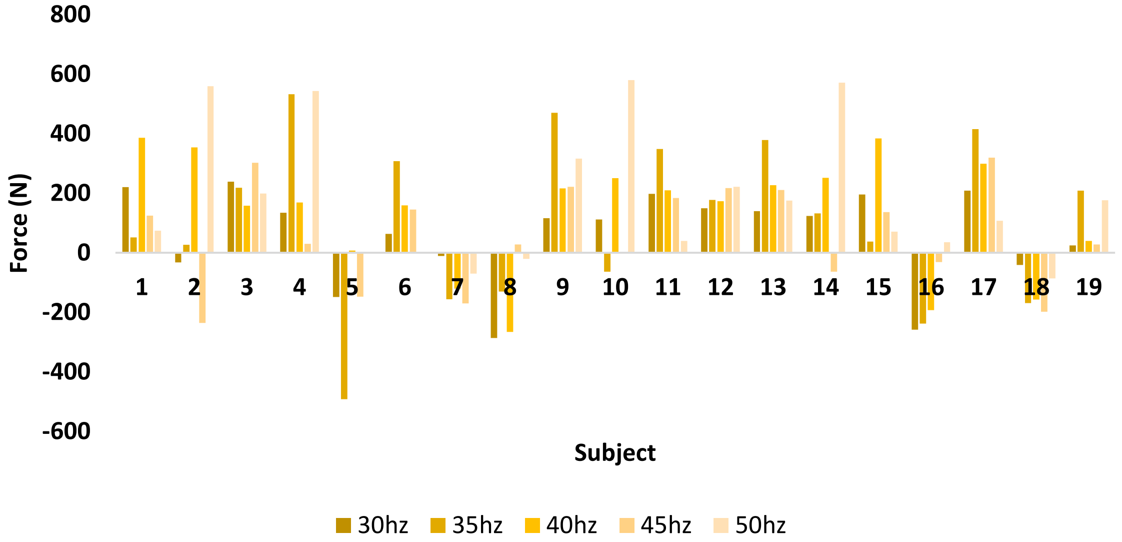
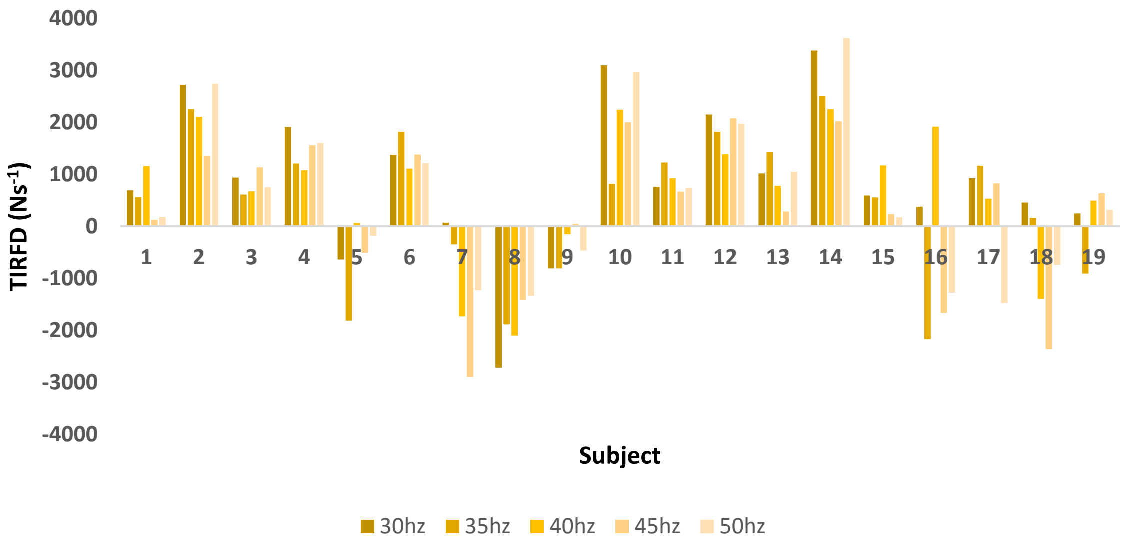


Figure 2. Change in TIRFD (Ns^{-1}) of each frequency compared to 0Hz



In previous research, WBV was shown to be effective in providing a positive acute response in force output (24). Bosco et al (9) has proposed previously that using vibration may allow for preferential recruitment of the fast twitch fibres and may be useful for activities that require explosive strength. Many other researchers have also found improvements in explosive movements, mainly in CMJ performance. Cardinale and Lim (15) reported 30Hz produced the highest EMGrms values in professional women volleyball players compared to higher frequencies. Cormie et al (24) have seen positive adaptations utilising frequencies of 30Hz and 2.5mm amplitudes for 30 second durations (0.7% increase in performance). Bosco et al (9) employed a WBV session consisting of multiple 60 second exposures with 60 second rest intervals, resulting in increased CMJ height. Torvinen et al. (61) also produced a 2.5% improvement on vertical jump performance using a protocol consisting of 4, 1 minute intervals with 1 minute rest on a vibration plate. Bazzett et al (6) showed significant improvements to CMJ performance using vibration frequencies of 40Hz (2mm - 4mm amplitude) and 50Hz (4mm - 6 mm amplitude) vibration sessions however, lower frequencies and vibrations did not cause any changes. Based on previous studies, it was anticipated that WBV would have had a positive impact on PF and TIRFD compared to 0Hz and with higher frequencies resulting in higher force outputs. In this study, significance was not demonstrated across the different frequencies and therefore cannot support the previous studies showing benefits of using a WBV warm up.

One possible explanation as to why significance was not met may be due to the population. Olympic weightlifting is a sport based on the ability to generate large amounts of force in a relatively short time frame. The criteria for our group required subjects to have a minimum of two years' experience and training at least twice per week. The experience of our group (high level weightlifters) could have already been highly efficient at explosive strength movements.

Highly trained athletes may require more volume and intensity in order to achieve the appropriate stimulus from WBV. This could have reduced the amount of response the WBV warm up may have had on the subjects during the experiment since they are already efficient at explosive movements. Delecluse et al. (30) utilised a WBV with sprinters also did not find any additional benefits and has also suggested that this might be a potential conclusion. It is also worth noting however, not all the individual responses in our research matches up to the weightlifting experience. Some subjects responded to WBV that had higher 1RM and some did not respond even though their 1RM was lower. This may contradict the potential of the proposed explanation however, the possibility of this cannot be ruled out (as this could be part of a multifactorial reason), which may explain the marginal yet insignificant results within the study. The subjects chosen for the study have had a lengthy period of training with the Olympic lifts. This implys that although there was difference in ability (even though all had minimum 2 years' experience), the subjects could have been efficient in explosive movements due to the amount of exposure they have had in their training. This also imply that in well trained weightlifters, WBV provides no additional benefits. Furthermore, our test group comprised of both male and female and there is a possibility that gender may have an impact on test results. The differences of ability between genders can be seen based on the Sinclair coefficient formula that is used for calculating differences in results between different weight classes in Olympic weightlifting. Consequently, more research may be required to look at between gender differences to provide a clearer understanding.

Some researchers have previously suggested that frequency may be the most important variable for increasing performance (41). It has also been recommended that higher frequencies may provide the best stimulus (6). This research cannot support or contradict this as the results are inconsistent across subjects and highly individualised. This study also saw decreases in performance with some subjects when using higher frequencies. Frequencies of 50Hz showed some potential that it could be effective at improving PF but results were not significant. Due to the amount of variance in results within previous research (yet many showing positive adaptations), WBV may be highly individualised with regards to dose-response and different frequencies. A decrease of 5.1% in men and 1.2% in women using a protocol of 30Hz (2-4mm amplitude) was also seen in the Bazett et al. (6) whereas Cardinal and Lim (15) showed the highest electromyography root mean square readings using 30Hz which again adds to the confusion as to what frequencies may be best. Different population groups may also respond differently to using WBV training with athletes showing less adaptations. Inconsistencies, variations and discrepancies in results from previous data alongside this research, makes it difficult to provide a recommendation with regards to frequency, amplitude and increasing explosive force. Although statistical significance was not found, the findings would suggest WBV training may provide some marginal benefits to Olympic weightlifters, nevertheless it remains unclear and further investigation is required.

Heat is a by-product of physical activity due to the increase in blood flow to the working muscles, raising the temperature closer to that of the core (52), which is usually regulated at around 37 degrees. The increase in blood flow and heat within the localised muscles would result in an increase in muscle elasticity and an increase in power output. This has been suggested as being one of the potential mechanisms behind WBV training (39). In our study, skin temperature was measured during the study before and after a v-sit and reach test. In previous research, skin temperature has been correlated to muscular power and activity (54, 60). Since heat is a by-product of muscular effort (52), and skin temperature has been linked to muscular activity (60), measuring skin temperature would help the understanding of using WBV training in a warm up. Statistical differences were seen in the percentage of change in heat when looking at before and after vibration when compared to 0Hz. This would suggest that heat may contribute to increasing force output in WBV as previous research suggests (38). Heat did increase across all frequencies and non-vibration, which is to be expected due to increased work within the targeted muscles. Vibration did however create a bigger change to temperature compared to non-vibration and therefore suggests that increased blood flow and heat may attribute to the increased power output. With regards to practical application, practitioners must proceed with caution as a meta-analysis conducted by Games (34) suggests that a peripheral blood flow can increase from using vibration devices that exhibit a side alternating vibration but may not occur in platforms that produce a vertical vibration. The power plate pro 7 vibrates in a tri-planar manner, which may have contributed to the results, but it must be noted that all plates do not vibrate in the same way. Games proposes that that the type of vibration may play a key role in increasing peripheral blood flow which would affect heat and force output. More research is required in the understanding of how different vibration types may affect the physiological response to WBV training. If athletic trainers choose to use WBV for increasing localised heat and blood flow to working muscles, side alternating platforms are currently the recommended type of device.

In this study, no significant differences were noted in flexibility with the addition of WBV compared to non-vibration. In the flexibility test, a v-sit and reach test which has a reliability of (r = 0.98) was used and specifically measures the flexibility in the subject’s low back and hamstrings. The mean scores off the V-sit and reach test however, were higher in frequencies 40Hz, 45Hz and 50Hz, when compared to non-vibration against their pre-test measures shown in table x. There is also a trend where higher frequencies did show a higher mean increase in flexibility scores compared to non-vibration. In previous studies, there has been evidence to suggest flexibility increases using WBV application (22, 38, 40, 46). Dallas (26) showed a

6.35% improvement in flexibility in gymnasts with other research presenting increases as much as increases as 13% (33). This research fails to support this although minor improvements were seen with a trend of higher frequencies showing better results, similar to a study produced by Cole and Mahoney (23).

The proposed mechanisms behind WBV and flexibility has been a topic of discussion amongst researchers. The TVR is one proposed mechanism that contributes towards increasing flexibility due to neurophysiological changes that occur in WBV training (9, 13, 19). As discussed previously, the changes in soft tissue caused by the vibration can lead to activation of the muscle spindle via la afferents which can positively affect the stretch reflex loop. Muscle activation would increase as a result, through motor neurons facilitated by monosynaptic and polysynaptic pathways (59) and reciprocal inhibition would occur and reduce the excitability in the antagonists (19, 28, 48). Since our results did not contain data that could suggest that the TVR mechanism occurs or not, it is difficult to provide insight into this theory. Giving that previous research have proposed high frequencies of above 100Hz is required for the TVR response to occur (50), this makes it highly unlikely to be the main causal mechanism – even though there was however a trend in our research flexibility (although non-significant) towards higher frequencies resulted in better increases in flexibility.

Increased blood flow has also been proposed previously as a mechanism for increasing flexibility as shown by Kerschan-Schindl et al (44). Increasing localised blood volume and flow may lead to increased muscle elasticity with additional heat as being one of the key reasons to the explanation of increased muscle elasticity. Our heat samples indicate that increased heat and blood flow contributes to WBV but only minor changes were seen in flexibility. This creates confusion as it has been shown that heat also increases the elastic properties of the body. An alternative theory is the possibility that the proprioceptive feedback of inhibition of pain could also have contributed to the increase in flexibility. By increasing the pain threshold, it would increase the tolerance and perception of pain. This would alter the position where the pain or stretch would have been felt and thereby increase range of motion (4). Again, this is logical in theory however it was not controlled during our experiment and therefore remains unknown. WBV training lends itself towards neurological, psychological and muscular changes. This research showed heat samples to be positively correlated with WBV whereas flexibility did not (only marginal increases were seen). This creates confusion as how heat and flexibility play a role in WBV as previous research would suggest its' correlation (22, 38, 40, 46). Further research is required within this area for clarity behind the mechanisms of WBV.

A potential drawback from our study was that the control of time was not accounted for within our warm up. Although we used a standardised warm up protocol across all subjects and frequencies, time was not controlled as it would have potentially created issues with regards to intensities. The differences in individuals may have resulted in some working at higher intensities and some not being able to perform the desired repetitions within the time frame, hence why it was not controlled. It is important to note that it may play a key role in the dose response relationship as fatigue may have had impact on certain subjects causing a reduction in performance. Previously, there has been very little continuity in research with regards to time and fatigue in WBV training. Jordan et al, (41) has previously shown that over exposure to WBV training may increase the potential for injury. Rittwegar et al. (54) has also publicised that too long on a vibration plate may lead to an increase in fatigue. Rittweger et al (54) used a WBV protocol which ranged between 200 – 475 seconds which resulted in a significant decline in CMJ performance, whereas Bosco et al (10) found improvements using a WBV protocol of multiple sets equating to 10 minutes resulting in a 3.9% increase in CMJ performance. The huge variances in results and protocols from previous research may suggest that WBV may be highly individualised and dose response may differ between subjects. Our research resulted in non-significant results, which does not support the use of WBV training. Furthermore, given that genetics, training age and chronological age plays a role in an individual's ability to respond to training stimulus, these may compound the reason that WBV training must be individualised for it to be successfully employed.

Another potential issue with our study is a methodological one. Our warm up consisted only of 10 Romanian deadlifts, 10 barbell deep squats, 10 good mornings and 10 clean pulls (total of 40 repetitions) with a 20kg bar. They then went from the warm up into 60% of their 1RM for 3 repetitions with the highest sample taking for analysis. There is a possibility that the duration and intensity of the warm up prior to performing at 60% of their 1RM may be too intense of a jump which may have affected the study. This would be a lot more prominent for the lifters that have a high 1RM. It is important to note however, that for the population studied, a mid-thigh clean pull is regarded as a movement, it is quite simple, which reduces the likelihood of its impact. Another factor worth mentioning is that 3 repetitions (with rest in between each one) was performed at 60% (which is still a relatively light load for weightlifters who spend a lot of their time training in much greater intensities), and the repetition with the highest values was taking for analysis. If the warm up was not sufficient, then logically you would have expected most the subjects' 3rd rep to have been their best as they would have already had 2 exposures to the weight, which was not the case. Nevertheless, this methodological issue needs to be raised as its impact cannot be completely ruled out.

In this study the objective was to look at how WBV may play a role in Olympic weightlifting. If the sample size was larger which would allow us more data to analyse across different levels of ability, it could have potentially produced more meaningful data to interpret. For example, Cardinale and Bosco (13) has shown that in untrained individuals WBV is extremely effective at increasing force. It would have been interesting to experiment and see whether it would have been different in beginner level Olympic lifters, and to compared to different levels of ability. Finally, this research was not able to shed light in regards to the mechanisms behind WBV training, however it has provided some insight into the use of WBV and Olympic weightlifting, thus warrants further investigation.

PRACTICAL APPLICATION

WBV warm up was not found to increase the PF and TIRFD in Olympic weightlifters. Although benefits were noted across the WBV application with 50Hz showing the highest response, they were marginal at best. Frequency, amplitude, magnitude and duration all play a key role in the use of WBV yet due to the degree of variety within these variables, further investigation is required to gain a better insight into standardising a protocol that can be used for weightlifters. Another consideration for coaches and athletes is the practicality of using WBV as a warm up tool. Vibration devices may not be cost effective especially if only marginal benefits can be seen (if any) and therefore question the requirement of such warm up methods for Olympic weightlifting. The mechanisms behind WBV are still unclear (although based on this research heat plays a role) and further research is required to improve the body of knowledge.

REFERENCES

1. Adams, JB, Edwards, D, Serviette, D, Bedient, AM, Huntsman, E, Jacobs, KA, et al. Optimal frequency, displacement, duration, and recovery patterns to maximize power output following acute whole-body vibration. *J Strength Cond Res* 23: 237-245, 2009.
2. Ahlborg, L, Andersson, C, and Julin, P. Whole-body vibration training compared with resistance training: effect on spasticity, muscle strength and motor performance in adults with cerebral palsy. *J Rehab Med* 38: 302-308, 2006.
3. Andrade, DC, Henriquez-Olguin, C, Beltran, AR, Ramirez, MA, Labarca, C, Cornejo, M, et al. Effects of general, specific and combined warm-up on explosive muscular performance. *Biol Sport* 32: 123-128, 2015.
4. Atha, J, and Wheatley, DW. Joint mobility changes due to low frequency vibration and stretching exercise. *Brit J Sports Med* 10: 26–34, 1976.
5. Avelar, NC, Costa, SJ, da Fonseca, SF, Tossige-Gomes, R, Gripp, FJ, Coimbra, CC, & Lacerda, AC. The effects of passive warm-ups vs. whole-body vibration on high-intensity performance during sprint cycle exercise. *J Strength Cond Res* 26: 2997-3003, 2012.
6. Bazett-Jones, DM, Holmes, WF, and Dugan, EL. Comparing the effects of various whole-body vibrations on countermovement jump performance. *J Sports Sci Med* 7: 144-150, 2008.
7. Bogaerts, A, Delecluse, C, Claessens, AL, Coudyzer, W, Boonen, S, and Verschueren, SM. Impact of whole-body vibration training versus fitness training on muscle strength and muscle mass in older men: a 1-year randomized controlled trial. *Biol Sci Med Sci* 62: 630-635, 2007.

8. Bosco, C, Cardinale, M, Tsarpela, O, Colli, R, Tihanyi, J, von Duvillard, SP, and Viru, A. The influence of whole body vibration on jumping performance. *Biol Sport* 15: 157-164, 1998.
9. Bosco, C, Cardinale, M., Tsarpela, O, & Locatelli, E. New trends in training science: the use of vibrations for enhancing performance. *New Stud Athlet* 14: 55-62, 1999.
10. Bosco, C, Lacovelli, M, Tsarpela, O, Cardinale, M, Bonifazi, M, Tihanyi, J, et al. Hormonal responses to whole-body vibration in men. *Eur J Appl Phys* 81: 449-454, 2000.
11. Brzycki, M. Strength testing – predicting a one-rep max from reps to fatigue. *J Phys Ed Dance* 64: 88-90, 1993.
12. Bullock, N, Martin, DT, Ross, A, Rosemond, CD, Jordan, MJ, and Marino, FE. Acute effect of whole-body vibration on sprint and jumping performance in elite skeleton athletes. *J Strength Cond Res* 22: 1371-1374, 2008.
13. Cardinale, M and Bosco, C. The Use of Vibration as an Exercise Intervention. *Ex Sport Sci Rev* 31: 3–7, 2003.
14. Cardinale, M, Leiper, J, Erskine, J, Milroy, M, and Bell, S. The acute effects of different whole body vibration amplitudes on the endocrine system of young healthy men: A preliminary study. *Clin Physiol Funct Imaging* 26: 380-384, 2006.
15. Cardinale, M, and Lim, J. The acute effects of two different whole body vibration frequencies on vertical jump performance. *Med Sport* 56:287-92, 2003.
16. Cardinale, M, and Wakeling, J. Whole body vibration exercise: are vibrations good for you? *Brit J Sport Med* 39: 585-589, 2005.
17. Carlock, JM, Smith, SL, Hartman, MJ, Morris, RT, Ciroslan, DA, Pierce, KC et al. The relationship between vertical jump power estimates and weightlifting ability: a field-test approach. *J Strength Cond Res* 18: 534-539, 2004.

18. Chiu, LZF. A primer on weightlifting: from sport to sports training. *Strength Cond* 27: 42-48, 2005.
19. Cochrane, DJ. The potential neural mechanisms of acute indirect vibration. *J Sport Sci Med* 10: 19-30, 2011.
20. Cochrane, DJ, and Hawke, EJ. Effects of acute upper-body vibration on strength and power variables in climbers. *J Strength Cond Res* 21: 527-531, 2007.
21. Cochrane, DJ, Legg, SJ, and Hooker, MJ. The short-term effect of whole-body vibration training on vertical jump, sprint, and agility performance. *J Strength Cond Res* 18: 828-832, 2004.
22. Cochrane, DJ, and Stannard, S. Acute whole body vibration training increases vertical jump and flexibility performance in elite female field hockey players. *Brit J Sport Med* 39: 860-865, 2005.
23. Cole, KJ, and Mahoney, SE. Effect of five weeks of whole body vibration on speed, power, and flexibility. *Clin Kinesiol* 64: 1-7, 2010.
24. Cormie, P, Deane, RS, Triplett, NT, and McBride, JM. Acute effects of whole-body vibration on muscle activity, strength, and power. *J Strength Cond Res* 20: 257-261, 2006.
25. Cuberek, R, Machova, I, and Lipenska, M. Reliability of v sit-and-reach test used for flexibility self-assessment in females. *Acta Universitatis PalackiaNAe Olomucensis. Gymnica* 43: 35-39, 2013.
26. Dallas, G, Kirialanis, P, and Mellos, V. The acute effect of whole body vibration training on flexibility and explosive strength of young gymnasts. *Biol Sport* 31: 233-237, 2014.

27. Dallas, G, Paradisis, G, Kirialanis, P, Mellos, V, Argitaki, P, and Smirniotou, A. The acute effects of different training loads of whole body vibration on flexibility and explosive strength of lower limbs in divers. *Biol Sport* 33: 235-241, 2015.
28. De Gail, P, Lance JW. and Neilson, PD. Differential effects on tonic and phasic reflex mechanisms produced by vibration of muscles in man. *J Neurol Neurosurg Psychiatry* 29: 1-11, 1966.
29. Delecluse, C, Roelants, M, and Verschueren, S. Strength increase after whole-body vibration compared with resistance training. *Med Sci Sport Exerc* 35: 1033-1041, 2003.
30. Delecluse, C, Roelants, M., Diels, R, Koninckx, E, and Verschueren, S. Effects of whole body vibration training on muscle strength and sprint performance in sprint trained athletes. *Int J Sport Med* 6: 662-668, 2005.
31. De Ruiter, CJ, Van Der Linden, RM, Van Der Zijden, MJ, Hollander, AP, and De Haan, A. Short-term effects of whole-body vibration on maximal voluntary isometric knee extensor force and rate of force rise. *Eur J App Physiol* 88: 472-475, 2003.
32. Eklund, G, and Hagbarth, KE. Normal variability of tonic vibration reflexes in man. *Exp Neurol* 16: 80-92, 1996.
33. Fagnani, F, Giombini, A, Di Cesare, A, Pigozzi, F, and Di Salvo, V. The effects of a whole-body vibration program on muscle performance and flexibility in female athletes. *Am J Physiol Med Rehab* 85: 956-962, 2006.
34. Games, KE. Whole-body vibration and blood flow and muscle oxygenation: a meta-analysis. *J Athl Train* 50: 542-549, 2015.
35. Gandevia, SC. Spinal and supraspinal factors in human muscle fatigue. *Physiol Rev* 81: 1725-1789, 2001.

36. Garhammer, J. A review of power output studies of Olympic and powerlifting: methodology, performance prediction, and evaluation tests. *J Strength Cond Res* 2: 76-78, 1993.

37. Hazell, TJ, Jakobi, JM, and Kenno, KA. The effects of whole-body vibration on upper- and lower-body EMG during static and dynamic contractions. *Appl Physiol Nutr Metab* 32: 1156-1163, 2007.

38. Issurin, V, Liebermann, D, and Tenenbaum, G. Effect of vibratory stimulation training on maximal force and flexibility. *J Sport Sci* 12: 561-566, 1994.

39. Issurin VB. Vibrations and their applications in sport. A review. *J Sports Med Phys Fit* 45(3):324-36, 2005.

40. Jacobs, PL, and Burns, P. Acute enhancement of lower-extremity dynamic strength and flexibility with whole-body vibration. *J Strength Cond Res* 2: 51–57, 2009.

41. Jordan, MJ, Norris, SR, Smith, DJ, and Herzog, W. Vibration training: an overview of the area training consequences, and future considerations. *J Strength Cond Res* 19: 459-466, 2005.

42. Kavanaugh, AA, Ramsey, MW, Williams, DA, Haff, GG, Sands, WA, and Stone, MH. The acute effect of whole body vibration on 30 meter fly sprint performance in ncaa division I sprinters and jumpers. *J Strength Cond Res* 25: S43B, 2011.

43. Kawamori, N, Rossi, SJ, Justice, BD, Haff, EE, Pistilli, EE, O'Bryant, HS, et al. Peak force and rate of force development during isometric and dynamic mid-thigh clean pulls performed at various intensities. *J Strength Cond Res* 20: 483-491, 2006.

44. Kerschan-Schindl, K.,Grampp, S, and C. Henk, C. Whole-body vibration exercise leads to alterations in muscle blood volume. *Clin Physiol* 21: 377–382. 2001.

45. Kiiski, J, Heinonen, A, Järvinen, A, Kannus, P, and Sievänen, H. Transmission of vertical whole body vibration to the human body. *J Bone Miner Res* 23: 1318-1325, 2008.
46. Kinser, AM, Ramsay, MW, O' Bryant, HS, and Ayres, CA. Vibration and stretching effects on flexibility and explosive strength in young gymnasts. *Med Sci Sports Exerc* 40: 133-140, 2008.
47. Kraemer, WJ, and Ratamess, NA. Fundamentals of resistance training: progression and exercise prescription. *Med Sci Sports Exerc* 36: 674-688, 2004.
48. Lance, JW, De Gail, P, and Neilson, PD. Tonic and Phasic spinal cord mechanisms in man. *J Neurol Neurol Psychiatry* 29: 535-544, 1966.
49. Liebermann, DG, and Issurin, V. Effects of vibratory stimulation on the perception of effort during isotonic contractions. *J Hum Mov Stud*, 32: 171–186 1997.
50. Luo, J, McNamara, B, and Moran, K. The use of vibration training to enhance muscle strength and power. *Sport Med* 35: 23-41, 2005.
51. Marsden, CD, Meadows, JC, and Hodgson, HJ. Observations on the reflex response to muscle vibration in man and its voluntary control. *Brain: J Neurol* 92: 829-846, 1969.
52. McGowan, CJ, Pyne, DB, Thompson, KG, and Rattray, B. Warm-up strategies for sport and exercise: mechanisms and applications. *Sport Med* 45: 1523-1546, 2015.
53. Nordlund, MM, and Thorstensson, A. Strength training effects of whole-body vibration? *Scand J Med Sci Sport* 17: 12-17, 2007.
54. Priego Qesada, JL, Carpes, FP, Bini, RR, Salvador Palmer, R, Perez-Soriano, P, and Cibrian Ortiz de Anda, RM. Relationship between skin temperature and muscle activation during incremental cycle exercise. *J Therm Biol* 48: 28-35, 2014.
55. Rittweger, J, Beller, G, and Felsenberg D. Acute physiological effects of exhaustive whole-body vibration exercise in man. *Clin Physiol* 20: 134-142, 2000.

56. Rittweger, J, Mutschelknauss, M, and Felsenberg, D. Acute changes in neuromuscular excitability after exhaustive whole body vibration exercise as compared to exhaustion by squatting exercise. *Clin Physiol Funct Imaging,* 23: 81-86, 2003.

57. Rittweger, J. Vibration as an exercise modality: how it may work, and what its potential might be. *Eur J Appl Physiol* 108: 877-904, 2010.

58. Roelants, M, Delecluse, C, Goris, M and Verschueren, S. Effects of 24 weeks of whole body vibration training on body composition and muscle strength in untrained females. *Int J Sport Med* 25: 1-5, 2004.

59. Seidel, H. Myoelectric reactions to ultra-low frequency and low-frequency whole body vibration. *Eur J Appl Physiol Occup Physiol* 57: 558-562, 1988.

60. Temfemo, A, Carling, C, and Ahmaidi, S. Relationship between power output, lactate, skin temperature, and muscle activity during brief repeated exercises with increasing intensity. *J Strength Cond Res* 25: 915-21, 2011.

61. Torvinen, S, Kannu, P, Sievänen, H, Järvinen TA, Pasanen, M, Kontulainen, S, et al. Effect of a vibration exposure on muscular performance and body balance. Randomized cross-over study. *Clin Physiol Funct Imaging* 22: 145-152, 2002.

62. Torvinen, S, Kannu, P, Sievänen, H, Järvinen, TA, Pasanen, M., Kontulainen, S, et al. Effect of 8-month vertical whole body vibration on bone, muscle performance, and body balance: a randomized controlled study. *J bone miner res* 18: 876-884, 2003.

63. Turner, AP, Sanderson, MF, and Attwood, LA. The acute effect of different frequencies of whole-body vibration on countermovement jump performance. *J Strength Cond Res* 25: 1592-1597, 2011.

64. Verschueren, SM, Roelants, M, Delecluse, C, Swinnen, S, Vanderschueren, D, and Boonen, S. Effect of 6-month whole body vibration training on hip density, muscle

strength, and postural control in postmenopausal women: a randomized controlled pilot study. *J Bone Miner Res* 19: 352-359, 2004.

65. Wakeling, JM, and Nigg, BN. Muscle activity damps the soft tissue resonance that occurs in response to pulsed and continuous vibrations. *J Appl Physiol* 93: 1093-1103, 2002.

APPENDICES

Appendix 1. Approval Sheet

Name of applicant: Kwok Hong Andy Tsang

Name of supervisor: Stephen Patterson

Programme of study: MSc S&C

Title of project: The use of whole body vibration as a warm-up for Olympic weightlifting

Supervisors, please complete section 1 or 2. If approved at level 1, please forward a copy of this Approval Sheet to the School Ethics Representative for their records.

SECTION 1

Approved at Level 1
Signature of supervisor (for student applications
Date: 22/1/16

SECTION 2

Refer to School Ethics Representative for consideration at Level 2 or Level 3

Signature of supervisor..

Date...

SECTION 3

To be completed by School Ethics Representative

Approved at Level 2

Signature of School Ethics Representative: J Hill
Date 21/11/2016

Appendix 2. Information sheet

Participant Information Sheet

'The use of whole body vibration as a warm-up for Olympic weightlifting'

You are being invited to participate in a research study as part of an MSc dissertation. However, before you agree to take part it is vital that you understand why the research is being carried out and what will be involved in the study. Please take a few minutes to read the following information before deciding if you would like to take part in this study. If there are any questions please do not hesitate to ask.

Purpose and value of study

The purpose of this research is to look at the use of whole body vibration training as a warm up modality and whether it is of benefit to Olympic weightlifters. Whole body vibration has been seen to improve many physical qualities such as countermovement jump performance and flexibility. There is however a lack of consensus regarding what is optimal due to the amount of variability in frequency and amplitude and duration. Furthermore, there is also at present, no research regarding its use within the Olympic weightlifting population. Therefore the purpose of this study is to shed light on its impact within this population group and also to add to the current body of knowledge regarding this topic.

Who is organising the research?

An Msc student is organising the research and the research has been reviewed by a dissertation supervisor as well as an ethics committee.

What will happen to the results of the study?

The results will be published as part of an Msc postgraduate dissertation.

Source of Funding for the Research

There is no requirement for funding for this research.

Contact for further information

Kwok Hong Andy Tsang

St Marys University

Waldergrave Road

Twickenham

TW1 4SX

Email: 144637@live.stmarys.ac.uk

Invitation – why I'm I been chosen to participate?

You have been chosen as you fit the target population of the research.

Can I chose not to take part or can I withdraw from the study?

It is entirely up to you whether or not you decide to take part in this study. If you decide to take part you will be given this information sheet to keep and asked to sign a consent form. If you decide to take part in the research you are free to withdraw from the study at any time and you are not obliged to give a reason.

What will happen if you agree to take part?

You will be required to participate in 6 consecutive days' worth of exercise. Each day will require you to perform a warm-up (either on a vibration plate or non-vibration) then followed by performing 3 repetitions of a mid-thigh clean pull on a force plate using 60% of your 1 rep maximum. We will then gather up the force plate data and analyse to see which type of warm up produced the greatest results.

Whether there are any risks involved (e.g. side effects) and if so, what will be done to ensure your wellbeing/safety

There is some light strenuous exercise required by yourself however, based on the population group this should not pose any risks to yourself as the intensity and volume is minimal.

Will agreeing to participate potentially compromise my legal rights?

This type of research should not compromise any of your legal rights if something were to go wrong.

Are there any safety precautions should I be beware of or any measures I should be taking before participating in this study?

You should refrain from any stimulants or engaging in strenuous exercise whilst participating in this research as it could affect the results.

What will happen the results collected from you?

It will be published as part of an MSc dissertation project.

Are there any benefits in taking part?

This research will shed light on whether the use of whole body vibration training can be a useful warm-up protocol for weightlifting. This information may potentially aid you in the understanding of warm-ups for performance which may help your training.

How much time to I need to give up?

This will be done over a period of 6 days and would require you to commit to 6 days' worth of testing. Each session will be relatively short and should not last longer than 20-30 mins.

Will I be kept anonymous?

Yes, all information will be kept confidential.

YOU WILL BE GIVEN A COPY OF THIS FORM TO KEEP TOGETHER WITH A COPY OF YOUR CONSENT FORM

Appendix 3. Consent form

St Mary's University Twickenham London

Name of Participant: ____

Title of the project: ____

Main investigator and contact details: __________________________________

Members of the research team:

1. I agree to take part in the above research. I have read the Participant Information Sheet which is attached to this form. I understand what my role will be in this research, and all my questions have been answered to my satisfaction.
2. I understand that I am free to withdraw from the research at any time, for any reason and without prejudice.
3. I have been informed that the confidentiality of the information I provide will be safeguarded.
4. I am free to ask any questions at any time before and during the study.
5. I have been provided with a copy of this form and the Participant Information Sheet.

Data Protection: I agree to the University processing personal data which I have supplied. I agree to the processing of such data for any purposes connected with the Research Project as outlined to me.

Name of participant (print)………………………………………………………………………..

Signed……………….………………… Date…………………………........

If you wish to withdraw from the research, please complete the form below and return to the main investigator named above.

Title of Project: ____

I WISH TO WITHDRAW FROM THIS STUDY

Name: ____________________________________

Signed: ______________________________