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The Effects Of Vibration Exercise On Anaerobic Performance Using The Wingate Test

Daniel Duane Veith

THE EFFECTS OF VIBRATION EXERCISE ON ANAEROBIC PERFORMANCE USING THE WINGATE TEST

by

Daniel Duane Veith
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This thesis, submitted by Daniel D. Veith in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done, and is hereby approved.

Dr. Joshua Guggenheimer

Dr. Sandra Short

Dr. Martin Short

This thesis is being submitted by the appointed advisory committee as having met all of the requirements of the Graduate School at the University of North Dakota and is hereby approved.

Dr. Wayne Swisher
Dean of the Graduate School

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ABSTRACT

The aim of this study was to investigate whole-body vibration (WBV) and its effects on anaerobic performance using the Wingate test, specifically the changes in peak and mean power. Thirty five collegiate students completed three days of training in which they performed 3 different weighted exercises under vibratory or non-vibratory conditions. Participants then performed a Wingate. Two 2 x 2 mixed-design ANOVAs were used to examine the influence of the independent variables of sex, protocol, and order on peak and mean power output (SPSS 18.0; $p \leq 0.05$). Results indicated a significant main effect of sex in regards to peak power output, as well as a main effect for sex regarding mean power output. These findings suggest that following an acute session of WBV, performance differences between sexes exist while performing lengthier anaerobic activities as assessed by using the Wingate test.

CHAPTER I

INTRODUCTION AND REVIEW OF LITERATURE

The use of vibration exercise has been touted as a way to improve everything from strength to hormones levels (Wolkodoff, 2007). Whole body vibration (WBV) is a method of applying vibratory waves to the body through mechanical means (Cardinale & Bosco, 2003). Vibration platforms are used to produce either a side-to-side alternating vertical sinusoidal movement, or a vertical simultaneous movement (Gerodimos, 2010). WBV was originally developed for clinical use in the 1970's by the Russian space program when their scientists were looking for a way to combat the negative effects of a zero gravity environment (Wolkodoff, 2007). Prolonged space flight decreases the gravitational stress imposed on bone which causes alterations in bone density to accommodate the lower strength demands; there is also significant atrophy seen within the muscles that control postural stability because of the decrease in gravitational stress during space flight (Cheung, 2010). WBV has been shown to combat the negative effects of microgravity by increasing both bone mass and strength (Jordan, Norris, Smith, & Herzog, 2005). Since its initial introduction to combat the negative side effects of space flight, WBV has transitioned into a popular method of exercise training (Annino, 2007; Cardinale & Bosco, 2003).

Using WBV as an application of exercise is a relatively recent idea. WBV equipment is not only available for clinical and research use, but less expensive versions are also available for home use. WBV can be applied through a variety of exercises that assist with stretching, balance and resistance training. Their primary use has been in rehabilitation scenarios as well as professional training for athletes (Cardinale & Bosco, 2003).

How WBV works has been an area of interest for researchers. Some have speculated that the results are due to the neuromuscular adaptations occurring in response to the increased gravitational load that was placed on the system. As mentioned above, a microgravity environment causes a decrease in muscle mass and force-generating capability; conversely, WBV creates a hypergravity stimulus which may increase the cross-sectional area of a given muscle, thus increasing the ability to generate force (Cardinale & Bosco, 2003).

Further explanation for the proposed mechanism behind WBV is called the "Tonic Vibration Reflex." Typically, vibration apparatuses create minute oscillations that produce short and fast changes in the length of the muscle tendon complex. It is theorized that these mechanical vibratory waves enhance excitation among muscle tissues which generates a reflex response from the muscle tissues named the "Tonic Vibration Reflex," or a sustained muscle contraction (Cardinale & Bosco, 2003). This reflex action occurs in response to the increased excitability of the gamma and alpha motor neurons, which convey electrical signals to and from the muscle spindle, respectively. The response of muscle spindles to changes in length is important for regulating the contraction of muscles as they activate motor neurons which are continually communicating with the central nervous system (Cardinale & Bosco, 2003). This increased excitability allows for a larger recruitment of the muscle motor units, and this larger activation of motor units is noticeable with an increased electromyography (EMG) response (Jordan et al., 2005).

Initial findings of potential benefits with WBV have led to a variety of apparatuses being designed in order to exploit these potential adaptations. Direct vibration (DV) application is used to accurately target a specific muscle or muscle group and is applied with a smaller vibratory machine to discourage interaction with areas of the body that are not under focus. Vibration units have also been constructed to be used with resistance training equipment. Transmission of the vibratory waves is accomplished either through pulley and cable systems or platforms. The two main designs of platforms that are used in the research or fitness industry are sinusoidal vibration and vertical synchronous vibration (Cochrane, 2010).

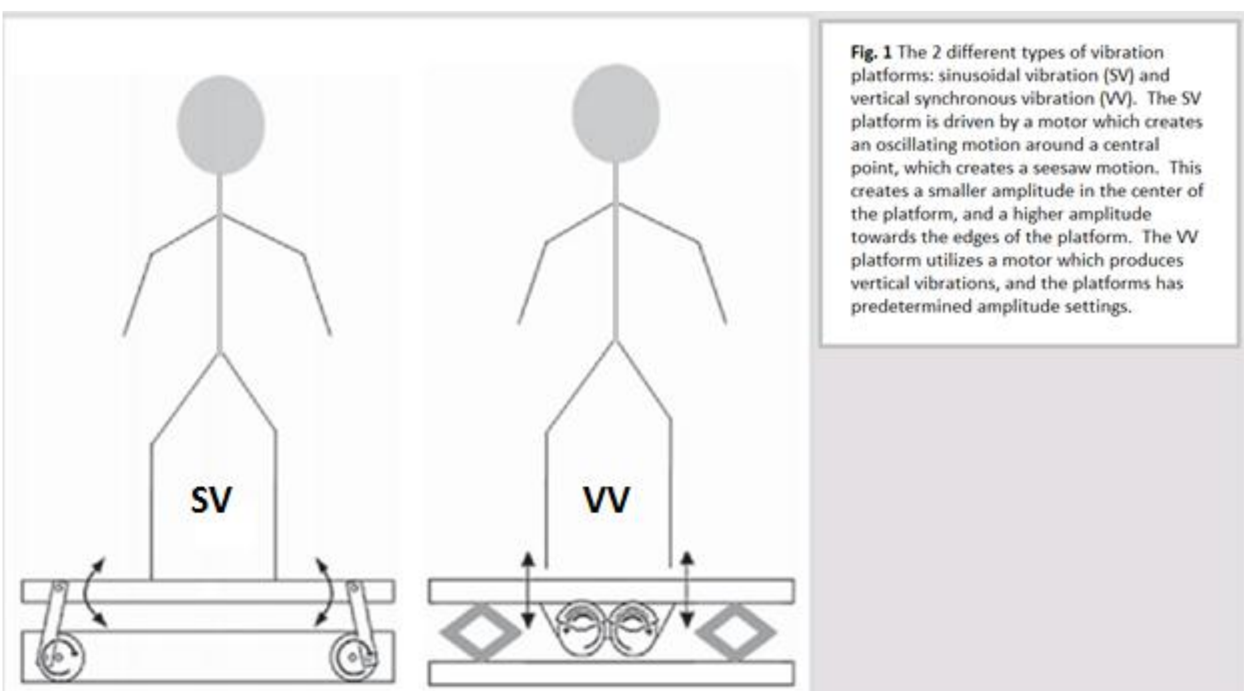

Fig. 1 The 2 different types of vibration platforms: sinusoidal vibration (SV) and vertical synchronous vibration (VV). The SV platform is driven by a motor which creates an oscillating motion around a central point, which creates a seesaw motion. This creates a smaller amplitude in the center of the platform, and a higher amplitude towards the edges of the platform. The VV platform utilizes a motor which produces vertical vibrations, and the platforms has predetermined amplitude settings.

Figure 1: Vibration Platform Design Comparison: Sinusoidal and Vertical Vibration

Figure 1 shows vertical synchronous vibration (VV) which uses only a vertical motion as the platform applies a symmetrical movement to both sides of the body, while sinusoidal vibration (SV) uses a minute teetering affect that utilizes side-to-side alternating vibration. Therefore when the feet are in the center of the platform the amplitude of the vibration motion is less than it would be if the feet were spaced on the edges of the platform.

Tables 1, 2 and 3 illustrate a meta-analysis that shows the wide range of application for WBV (Abercromby et al., 2007). Data from Table 1 focuses on the difference between SV and VV application with lower limb muscles, suggesting positive results for both forms of WBV that included changes in strength, power, jumping performance, and EMG readings, (Abercromby et al., 2007). However, it was concluded that VV stimulation shows greater transmission through the trunk and upper body because SV causes the pelvis to rotate slightly which dampens the vibratory waves. It was also found that VV platforms have a larger effect size for long-term protocol while the SS platforms have a greater effect size for acute treatments, which may be due to the mechanical differences between the platforms (Marin & Rhea, 2010). For research studies it is a common approach to use VV because of the symmetrical vibratory actions on the body, compared to the oscillating motion seen with SV, which assures that the amplitude can be controlled more effectively.

Not only can WBV be accomplished through a wide variety of apparatuses and exercises, but also through different exercise modes of vibration application by varying the frequencies and amplitudes as well. Frequency, expressed in hertz (Hz), describes how often the platform moves for a given unit of time, while the amplitude describes the amount of vertical displacement the platform performs. Vibration is generally applied through pulley systems to the upper body and through platforms for the lower body. Participants may then perform the required movement or hold a certain body position as the vibration stimulus is applied. Through performance improvements, most exercise protocols suggest that the vibratory device be set to a frequency range of 15-44Hz with amplitude of 3-10mm (Abercromby, 2007; Adams, 2009; Cardinale & Bosco, 2003; Cardinale & Lim, 2003; Delecluse, 2005; Jordan et al., 2005).

Researchers have made attempts at determining an optimal WBV prescription. In an examination of exercise protocols, Enoka (2008) suggested utilizing a moderate frequency of 30Hz in conjunction with higher amplitude of 8mm versus using other common frequencies of 40Hz or 50Hz, and amplitudes of 2mm or 4mm. Enoka's (2008) results showed that force production was increased overall, but the rate of force production, or the timing of the muscle contractions, was not affected. Gerodimos et al. (2010) examined differing amplitudes and frequencies with a single bout of WBV to determine a precise training load for exercising purposes by examining flexibility and squat jump performance. They used 25 athletic females involved in a WBV training protocol for 6 minutes at a fixed frequency of 25Hz across different amplitudes of 4mm, 6mm, and 8mm. The researchers correspondingly examined 18 different athletic females involving them in a WBV training protocol for 6 minutes at a fixed amplitude of 6mm across different frequencies of 15Hz, 20Hz, and 30Hz. Using a standard sit-and-reach test, the authors concluded that increases in flexibility after a single bout of WBV were found across all parameters in both the amplitude and frequency studies compared to control parameters in which no vibration training was used, but the participants still performed the same exercises. No conclusions could be made on which protocol would elicit the most improvements over others. Using the squat jump as the dependent variable, results did not show significant differences between protocols when examining the differing amplitude and frequencies after one bout of WBV. The researchers concluded that amplitude and frequency differences do have an immediate effect on flexibility, but long term exposure is needed to facilitate changes within specific strength performances.

Cochrane (2010) completed a meta-analysis examining the physiological effects of WBV and its potential use with exercise performance. Summaries of Cochrane's findings are displayed in tables 1,2 and 3. In table 1, 8 studies are presented out of the original 14 studies to provide a synopsis of varying frequencies and amplitudes. In table 2, 10 studies are presented out of the original 16 studies to present the common findings of acute application of WBV. Lastly in table 3, 8 studies are presented out of the original 12 studies to present the common findings of chronic (long-term) application of WBV. Some notable findings are not presented in this review, and the meta-analysis should be consulted for more information.

While isolating a specific combination of frequency and amplitude for optimal influence on force, velocity, and power has not been conclusively agreed upon, there are several research studies that provide a suggested optimal range for these variables. Additionally, Table 1 shows a handful of studies that have examined different frequencies and amplitudes and their direct effect on strength performance. Specifically, there are multiple studies that conclude through anaerobic performance changes and

Table 1: Summary of vibration frequency and amplitude (Cochrane, D. J., 2010)

Author	Type of Experiment	Participants	Conditions	Exercise Type	Frequency (Hz)	Amplitude (mm)	Duration	Results
Abercromby et al. (2007)	Randomized	16 H	VV, SV	IT (10-35º)	30	4	30sec	SV showed higher EMG compared to VV
Adams et al. (2009)	Randomized	20 UT	VV	IM (2.27 rad)	30, 35, 40, 45	2-4; 4-6	30,45,60sec	Higher freq. pair better with higher amp. (vice versa)
Bazett-Jones et al. (2008)	Randomized	44 UT	VV	IM (90 º)	0, 30, 35, 40	2-4; 4-6	9 x 5sec	No sign. differences found
Bosco et al. (1998)	Randomized	14 RA	SV	IM (100 º), standing, lunge	26	10	5 x 90sec	CMJ improved by 12%
Cardinale & Lim (2003)	Randomized	16 EL	VV	IM (100 º)	30, 40, 50	10	4 x 60sec	30 Hz elicited highest EMG readings
DaSilva et al. (2006)	Randomized	31 NR	VV	NR	20, 30, 40	4	6 x 60sec	30 Hz elicited CMJ, strength, and power increases
Delecluse et al. (2005)	Randomized	18 UT	VV	IM, lunge	35-40	2.5-5.0	1-3 x 2-6 x 30-60sec	EMG readings increased
Pel et al. (2009)	Randomized	NR	VV	IM (150 º)	25-50	1.2	10sec	Frequencies of 25-50Hz and 5-40Hz showed similar performance results

UT=Untrained; **EL=**Elite; **RA=**Recreationally active; **SV=**Side Alternating vibration; **VV=**Vertical vibration; **IT=**Isotonic squat; **IM=**Isometric squat; **CMJ=**Counter movement jump; **H=**Healthy; **NR**=Not Reported electromyography readings that 30-40Hz is a frequency that has elicited positive changes (Bosco, 1998; Cardinale & Lim, 2003; Da Silva et al., 2006). While looking at amplitude, studies examining the differences between oscillating heights have also produced mixed results. Researchers have found an altering effect on performance across a variety of amplitudes while examining performance changes following WBV exercise however optimal amplitude could not be concluded (Cardinale, Leiper, Erskine, Milroy & Bell 2006; & Rittweger et al. 2002). According to one study, higher frequencies and amplitudes cause greater muscle activation when using WBV exercise (Pollock, Woledge, Mills, Martin, & Newham, 2010), however the functional implications of such a protocol has yet to be clearly defined. Results vary largely between participants from body mass and position stance, but general support for frequencies above 25Hz and below 50Hz can be found (Tables 1 & 2). It is apparent that differences do exist between varying amplitudes and frequencies, but increases in strength and flexibility are found across a range of applications.

There is further variability within other WBV exercise parameters such as body positions, duration of treatment, types of vibration exercise and the frequency and amplitude of the actual vibration stimulus. Differences within these parameters can deliver inconsistent results and, in extreme cases, have negative implications on strength performance (Jordan et al., 2005). Therefore specific parameters must be controlled to facilitate a particular training effect. For example, Rohmert, Wos, Norlander and Helbig (1989) found differences in EMG readings with different arm positions while a vibration stimulus was applied; they also proclaimed that the extent of the tonic vibration reflex was dependent upon the frequency of the vibrations. The theory behind WBV is that the

Table 2: Acute Effects of Whole Body Vibration on Lower Body Power (Cochrane, D. J., 2010)

Author	Type of Study	Participants	Conditions	Exercise Type	Frequency (Hz)	Amplitude (mm)	Duration	Results (significant)
Bazett-Jones et al. (2008)	Randomized	44 UT	VV	IM (90º)	40	2-4; 4-6	9 x 5sec	Women had inc. in CMJ height (9%)
Bosco et al. (1999)	Randomized	6 EL	SV	IM (100 º)	26	10	10 x 60sec	Inc. average force, velocity, power (6%)
Bosco et al. (2000)	Controlled	14 RA	VV	IM (100 º)	26	4	10 x 60sec	Inc. leg press (7%) and CMJ height (4%)
Cochrane et al. (2008)	Cross-Over	8 RA	SV	IT	26	6	1 x 5min	Inc. CMJ height (9.3%) and CMJ power (4.4%)
Cochrane & Stannard (2005)	Randomized – Cross Over	16 EL	SV	IT,IM,lunge	26	6	5 x 1min	Inc. CMJ height (8.1%)
Cormie et al. (2006)	Randomized	9 RA	VV	IM (100 º)	30	2.5	30sec	Inc. CMJ height
Luo et al. (2008)	Randomized	14 H	DV	IM (100 º)	65	1.2	Exercise time	No changes
Rhea & Kenn (2009)	Randomized	8 RA	VV	IT	35	4	30sec	Inc. squat power (5.2%)
Torvinen et al. (2002)	Randomized – Cross Over	16 H	SV	IT, jumping, heels, erect	15-30	10	4min	Inc. CMJ (2.5%)
Torvinen et al. (2002)	Randomized – Cross Over	16 H	VV	IT, jumping, heels, erect	25-40	2	4min	No Changes

UT=Untrained; **EL=**Elite; **RA=**Recreationally active; **BW=**Body weight; **SV=**Side Alternating vibration; **VV=**Vertical vibration; **IT=**Isotonic squat; **IM=**Isometric squat; **CMJ=**Counter movement jump; **H=**Healthy; **DV=**Direct vibration generated tonic vibration reflex may increase voluntary muscle contractions because of the increased motor unit recruitment and synchronization (Jordan et al., 2005). This theory is the basis for the chronic application of WBV in athletic populations with the hope of developing more muscle power and maximal strength. Therefore if an ideal body position can be found for a particular exercise, it should be utilized to reap the most benefits.

Acute exposure to WBV has recently been shown to improve muscle performance. A summary of studies that have examined the acute effects of WBV can be found in Table 2, which provides strong evidence that acute application of WBV can enhance lower-body power. In female volleyball players that were exposed to a vibration stimulus frequency of 26Hz and amplitude of 10mm, increases in average power, average velocity, and average force while performing leg presses across 4 different loads (70, 90, 110 and 130 kg) were shown (Bosco etal., 1999). These results were compared against a control group that completed the same exercise protocol without the vibration stimulus, and gains in performance were not seen within this group. Similar performance increases were shown with other anaerobic performances such as a study that examined vertical jumping height in female field hockey players (Cochrane & Stannard, 2005). The researchers applied a training protocol at 26Hz with 6mm amplitude through 6 different positions on a vibration platform. All of the participants showed an increase in arm countermovement vertical jump (ACMVJ) height and sit-and-reach flexibility. Using a vibratory pulley system for biceps curls, Issurin and Tenenbaum (1999) examined the difference between WBV and non-WBV training with elite and amateur athletes. Using a "Power Teach" device that measures mechanical power, the elite trained group that received the WBV intervention did show increases in maximal power (10.4%) and mean power (10.2%), and the WBV amateur trained group showed an increase in maximal power (7.9%) and mean power (10.7%) when compared against the non-WBV training group for both skill levels. Bosco, Cardinale, and Tsarpela (1999) examined WBV on elbow flexion by comparing intra-subject results. Twelve international level boxers were examined while performing elbow flexion while one arm received the vibration stimulus and the other arm did not. EMG recordings of the biceps brachii showed an increase in neural activity amongst the active muscles, which can be attributed to the increase in mechanical power that was seen following WBV (Bosco et al., 1999).

The effects of WBV have also been examined with maximal strength performance. Ronnestad (2009b) examined 1-repetition maximum (1RM) half-squats in both trained and untrained subjects across a range of vibration frequencies. The same exercise protocol was used for all of the participants, but different frequencies of 20, 35, 50 and 0Hz all at amplitude of 3mm were applied in a randomized sequence. The authors concluded that 1RM half-squat was significantly improved only with the vibratory stimulus of 50Hz in both trained and untrained subjects. Overall it appears that acute application of WBV can be utilized across a wide range of protocols to elicit positive changes in strength performance. The above results related to the short-term application of WBV have led researchers to examine the implications of long term exposure to WBV and its potential benefits.

When comparing conventional strength and flexibility exercise protocols against WBV protocols, significant differences in lower body muscle power were found following a long term training protocol (Issurin, Liebermann, & Tenenbaum, 1994).

Table 3: Chronic (Long-Term) Effects of WBV on Lower Body Power (Cochrane, D. J., 2010)

Author	Type of Study	Participants	Conditions	Exercise Type	Frequency (Hz)	Amplitude (mm)	Duration	Results
Annino et al. (2007)	Randomized Controlled	22 RA	VV	IM (100º)	30	5	5x40sec, 3/wk, 8wks	Inc. CMJ height (6.3%), leg-press power (8-18%), velocity (8-26%)
de Ruiter et al. (2003)	Randomized Controlled	10 RA	SV	IM (110 º)	30	8	3/wk, 11wks	No changes
Delecluse et al. (2003)	Randomized Controlled	18 UT	VV	IT, IM, lunge	35-40	2.5-5.0	30-60sec, 3/wk, 12 wks	Inc. vertical jump height (7.6%)
Fagnani et al. (2006)	Randomized Controlled	13 EL	VV	lunge (90 º)	30	4	15-60sec, 3/wk, 8 wks	Inc. CMJ height (8.7%)
Roelants et al. (2004)	Randomized Controlled	24 PM	VV	IM, lunge	35-40	2.5-5.0	30-60sec, 3/wk, 24wks	No differences between VbX and RT
Russo et al. (2003)	Randomized Controlled	14 PM	SV	IM	12-28	NR	3x1min (1month), 3x2min (5months)	Inc. vertical jump velocity and power
Torvinen et al. (2002)	Randomized Controlled	26 H	VV	IT, standing, jumping	25-35	2	3-5x/wk, 4 month	Inc. CMJ height (10.2%)
Torvinen et al. (2003)	Randomized Controlled	27 H	VV	IT, standing, jumping	25-45	2	3-5x/wk, 8 month	Inc. CMJ height (7.8%)

UT=Untrained; **EL=**Elite; **RA=**Recreationally active; **SV=**Side Alternating vibration; **VV=**Vertical vibration; **IT=**Isotonic squat; **IM=**Isometric squat; **CMJ=**Counter movement jump; **H=**Healthy; **ST=** Sprint Trained; **RT=** Resisted Trained; **PM=**Postmenopausal; **NR=**Not Reported

WBV has also been shown to have the potential to elicit a chronic training effect through programs that last several days or even several weeks (Table 3). There is some indication that WBV can enhance lower body muscle power after a longer period of training. For example, a vibratory stimulus was applied at 44Hz with amplitude of 3mm 3 times a week for duration of 3 weeks (Issurin et al., 1994). While keeping the exercise protocols the same between the two groups, the conventional strength training group showed an isotonic maximum strength increase of 16.1%, while the WBV group showed an increase of 49.8%. Issurin et al. (1994) also found increases in flexibility between the conventional flexibility training group and the WBV flexibility training group of 2.4% and 8.7% respectively. It was also noted by Liebermann and Issurin (1997) that participants perceived their maximal repetition efforts to be less while under the WBV protocol. This perception is likely thought to occur from the increased activity of the Ia afferents which directly affect the perception of difficulty and ultimately reduces the sensation of perceived exertion. While examining untrained females over a 12 week training protocol, Delecluse, Roelants, and Verschueren (2003) found significant increases in isometric and isotonic knee-extensor strength which was measured by a motor-driven dynamometer. The researchers compared a WBV group against a resistance-training group, a placebo group that performed similar exercises, and a control group that did no activity. Increases in isometric and isotonic knee-extensor strength were seen in both the WBV group as well as the resistance-training group; however WBV elicited greater strength improvements (Delecluse et al., 2003). Not only did a vibration stimulus of amplitude ranging from 2.5-5mm and a frequency between 35-40Hz elicit strength increases,but it was the only training protocol that resulted in significant increases of counter-movement jump height. These results suggest that a long-term application may be utilized across a wide range of protocols to elicit positive changes in strength and power performances.

The majority of WBV studies have involved anaerobic performance activities such as 1-RM lifts and vertical jumping. Anaerobic performances involve immediate and short-term energy systems. Adenosine-triphosphate and phosphocreatine (ATP, PCr) are the main energy suppliers for near instantaneous energy release (McArdle, Katch, & Katch, 2007, p. 166). Maximal effort and high-intensity performance tests will quickly utilize the ATP supply from both energy systems' forcing another energy source to supply the necessary ATP. A tremendous amount of power can be created in a few seconds during an all-out effort activity. When high intensity efforts continue for more than a few seconds, the anaerobic glycolytic pathway assists to generate the needed ATP. Such "switching" of energy systems is not a distinct shift but rather a gradual transition with significant overlap between systems. This transition phase supports the participant's need for maintaining continuous power output. The ATP and PCr energy systems can provide energy for a high intensity activity for about 10 seconds before the energy system quickly fades with a maximal working capacity around 30-40 seconds before fatigue sets in, so another energy system is used to continue the activity (McArdle, 2007). This metabolic response is the foundation behind the idea that WBV may be utilized to have an altering effect on longer duration, anaerobic activities.

Anaerobic work capacity can be defined as the maximal amount of work performed during an exhaustive work bout from the anaerobic energy systems (Green, 1995). As mentioned previously, the short duration ACMVJ utilizes the ATP and PCr energy systems for the activity because of its high intensity movement lasting only a second or two (Cochrane & Stannard, 2005). A recent study found that after a period of WBV was applied to female field hockey players, their ACMVJ results were significantly higher (8.1 ± 5.8%) than the non-WBV group results. Considering such findings, it is plausible that a direct connection between WBV training and improved anaerobic performance exists.

As previously mentioned, an increase in contraction strength induced by the tonic vibration reflex has been widely documented for several anaerobic activities. The Wingate Anaerobic Test (WAnT) is a popular anaerobic cycling test because the data it provides can be used to determine peak anaerobic power, mean anaerobic power, total work output, and fatigue index (Beam & Adams, 2011). The WAnT is a 30 second maximal effort test performed on a cycle-ergometer pedaling against a resistance of 7.5% of the participant's body weight. The WAnT's duration of 30 seconds is ideal to consume significant amounts of anaerobic energy as that time frame utilizes the anaerobic energy supply which relates to mean anaerobic power. The entire 30 seconds requires both ATP and PCr energy systems which totals about 2/3 of the energy supplied with aerobic energy systems beginning to contribute after the initial few seconds for the remaining 1/3 energy supply.

Peak and mean anaerobic power can be derived using the WAnT. Power is determined by the total force generated over the total amount of revolutions during the 30 seconds of the test. Therefore, the WAnT is a method of determining leg strength and endurance based on the results of peak and mean anaerobic power. The protocol of the WAnT creates a scenario where the participant produces power by drawing from anaerobic energy stores. In theory the WAnT is used to predict anaerobic performance, and correspondingly, can be used to predict performances in shorter duration anaerobic activities. Furthermore, anaerobic activities such as 1RM lifts, vertical jumping, bicep curls, and squats have all been improved through the use of vibration training (Cochrane, D. J., 2010). If the tonic vibration reflex has the ability to augment strength for activities lasting only a few seconds, then there might be a helpful link for WBV training and its effects on a longer anaerobic activity such as the WAnT cycling test. With the right protocol, WBV might be able to increase peak and mean power output for the anaerobic cycling test. Including WBV could therefore be a helpful performance enhancer in athletic events requiring a maximum effort for more than a few seconds such as races to the finish line in cycling, speed skating, and sprinting, which all use the anaerobic energy system for more than a few seconds. WBV training has been shown to increase strength output with both acute and chronic application, with variability in performance dependent on the duration of the treatment, length of time between the treatment to the activity, and frequency and amplitude of the WBV treatment. Higher power output on the WAnT is interpreted as higher anaerobic fitness, and with the addition of WBV, active muscles may be able to produce greater power output, thus facilitating performances that are quicker and stronger.

The purpose of this study is to determine whether there are differences in power output using the WAnT following both WBV and a non-WBV training stimulus. Because acute and chronic exposure to WBV have been shown to elicit positive changes in short duration (1-2 sec) anaerobic activities, it is plausible that WBV can also positively affect longer duration, anaerobic activities, lasting longer than 10 seconds. By using WBV as supplemental training method, increases in both peak and mean power may be derived as positive benefits. It is hypothesized that the use of WBV, when compared to non-WBV exercises, will enhance anaerobic performance as shown by significant increases in peak and mean power output during the WAnT.

CHAPTER II

METHODOLOGY

Experimental Approach to the Problem

In order to determine the impact of acute WBV on anaerobic power output, participants were asked to take part in a WAnT, on two separate occasions, in which they participated in WBV or non-WBV interventions, respectively.

Participants

Thirty five recreationally active males and females (who participated in physical activity at least 30 minutes a day 3 times a week) aged 18-25 years were asked to volunteer for this study. Volunteers were recruited from the department of Physical Education, Exercise Science, and Wellness program at the University of North Dakota. Participants were asked to complete an interview with the researchers in order to divulge pertinent past medical history to meet the inclusion criteria for this study. Exclusion criteria included cardiovascular disease, musculoskeletal problems and any other conditions that could affect performance such as broken bones, pregnancy, joint sprains, arthritis, tendonitis, fibromyalgia, etc. All participants were required to be healthy and regularly engaging in resistance training (1-2 times a week) and with no previous experience in WBV. Prior to data collection subjects were informed of the requirements and risks associated with participation in this study and were asked to provide written informed consent. Participants were asked to not alter their sleeping, drinking, or eating habits during the duration of the study, but were asked not to consume food, alcohol, or nicotine one hour before each laboratory session.

Exercise Protocol

Each participant attended three testing sessions: one session to familiarize themselves with the equipment and testing protocol, and two more for data collection involving the non-WBV and WBV protocols. The participants selected for the study completed the tasks asked of them in a counterbalanced measures design. The order in which the interventions were completed was randomized. At the start of each testing session, all participants performed a warm-up on a 824E Monark cycle ergometer (Monark, Stockholm, Sweden) at low to moderate intensity (50-60 rpm with no resistance) for 5 minutes: including dispersed bouts of sprinting lasting 4-6 seconds at the prescribed resistance of 7.5% of the participant's body weight. Following the warm-up, participants were exposed to three different exercises during each day of testing through one of two exercise modes: WBV or non-WBV intervention. The three different exercise loads that were performed are isotonic and isometric squats, both at a resistance of 40% of the participant's body weight, and lunges at a resistance of 20% of one's body weight. For the WBV intervention, participants completed the required exercises with peak-to-peak oscillations (amplitude) of 4mm with a frequency of 30Hz using the PneuVibe Pro vibrating platform (PneuMex, Sandpoint, ID). For all three resistance activities, the loads were placed on a weight bar and held behind the neck upon the shoulders and contained within a standard squat rack (Yukon Fitness Equipment, Cleveland, OH). During both of the interventions, WBV and non-WBV, participants were asked to complete all three exercises, each of which will be followed by a rest period of 1 minute. The WAnT was then performed following the final 1 minute rest period. The resistance weight was then dropped at the start of the test and removed at the end of 30 seconds. Participants were encouraged to reach maximal repetitions on the cycle-ergometer 1-2 seconds before the start of the WAnT and to continue to give maximal effort throughout the duration of the test. Participants were asked to remain seated on the cycle ergometer throughout the duration of the test. Peak and maximal power data was calculated upon completion of the WAnT using SMS Power software (SMS Power, St. Cloud, MN). Participants were instructed to cool-down for a period of their discretion following the WAnT. After each participant completed their first intervention, WBV or non-WBV, they returned to the laboratory one week later to complete the same format with all three resistance loads using the opposite intervention protocol. A summary of the experimental procedures can be found in Figure 2.

Isotonic Squats

Isotonic squats were completed to a knee angle of 120º while supporting a load of 40% of the participant's body weight, and with the legs approximately shoulder width apart (see Image 1a). Joint angle was measured using a digital inclinometer (Acumar, Lafayette, IN), and an adjustable metal bar was used to provide tactile feedback to the participant when they have reached the 120º angle during both the isometric and isotonic squats. Participants were instructed to squat to a tempo of 2 seconds during the downward phase of the squat, and 2 seconds during the upward phase of the squat. Tempo was monitored using a digital metronome (Seiko, Japan). The isotonic squats were terminated after 1 minute, for a total of 15 squats. The participants then rested for one minute, with the option to move around if they desired to do so.

Isometric Squats

Isometric squats were completed to a knee angle of 120º with the legs shoulder width apart. Participants were instructed to hold 40% of their body weight at the 120º knee angle for 10 seconds (see Image 1a), then return to upright standing position for 5 seconds while still holding the weight. This process was completed 4 times, totaling 1 minute of activity. The participants were given another 1 minute bout of rest where they can move around if they desired to do so.

Image 1: Demonstration of Laboratory ; (1a; left) Isometric and isotonic squats will be completed to a knee angle of 120°, (1b; right) left and right leg lunges should be completed in alternating fashion.

Lunges

The participants completed both right and left leg lunges in alternating fashion while supporting 20% of their body weight (see Image 1b). Participants were instructed

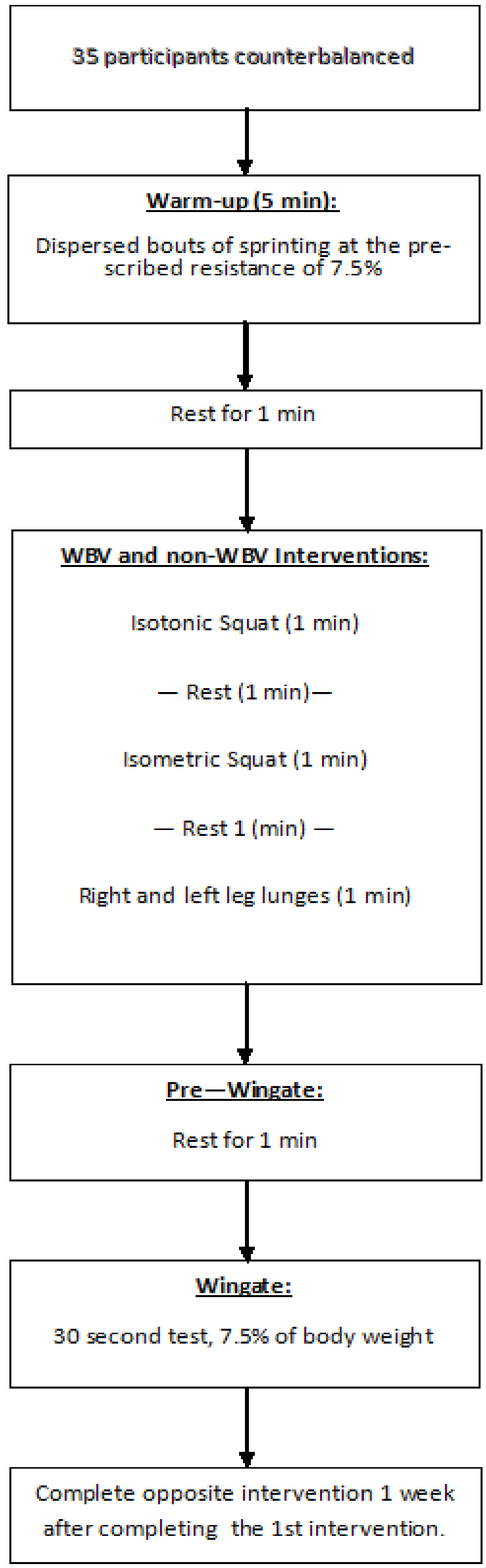

Figure 2: Experimental procedures

to lunge onto the vibration platform with their front foot, while keeping their knee overtop of the corresponding ankle. Each individual lunge was completed in 3 seconds before switching to the opposite leg to complete another 3 second lunge. This process was completed 10 times for each leg, totaling 1 minute of activity.

Measures

Power Output: Peak and mean power variables were calculated from the total revolutions performed during the duration of the WAnT at the prescribed resistance, and were expressed in watts. Peak power is the largest power instantaneously achieved while mean power is the average force produced over the total distance.

Statistical Analysis

Two 2 x 2 mixed-design ANOVAs were used to examine the influence of the independent variables of sex, protocol, and order on peak and mean power output. Statistical Package for Social Sciences version 18.0 was used. Significance level was set at $p \leq 0.05$.

CHAPTER III

RESULTS

Two 2 x 2 mixed-design ANOVAs were calculated to examine the effects of protocol (WBV, non-WBV) and sex on peak and mean power outputs while accounting for testing order. Female participants who volunteered to partake in this study had a mean weight of 67.35kg, whereas men had a mean weight of 85.52kg. Mean and standard deviation results can be found in Table 4 for peak and mean power output for both WBV and non-WBV laboratory sessions.

Table 4: Peak and mean power output results for WBV and non-WBV protocols

	Sex	Mean (W)	Std. Deviation (W)	N
WBV Peak	**Male**	1093.95	211.46	20
	Female	733.80	130.51	15
	Total	939.60	254.27	35
Non-WBV Peak	**Male**	1087.95	189.49	20
	Female	737.53	138.89	15
	Total	937.77	242.83	35
WBV Mean	**Male**	699.25	113.34	20
	Female	466.00	61.00	15
	Total	599.29	149.75	35
Non-WBV Mean	**Male**	696.60	106.00	20
	Female	470.13	71.86	15
	Total	599.54	146.06	35

W = watts

Regarding peak power output data, a significant main effect for sex was present ($F(1,33) = 36.75$, $p < .001$). However, significant main effects for protocol and order were not found. Furthermore, a significant interaction was not found between the independent variables of protocol and order.

Regarding mean power output, a significant main effect for sex was again present ($F(1,33) = 52.62$, $p < .001$). However, significant main effects for protocol and order were not found, and again no significant interaction was found between the independent variables regarding their influence on mean power output.

CHAPTER IV

DISCUSSION

This is one of the first studies to investigate the effects of an acute session of WBV on anaerobic performance using the WAnT. The key finding in this study was that following an acute session of WBV, performance differences between sexes existed while performing lengthier anaerobic activities as assessed by using the Wingate test on healthy collegiate participants. Specifically, there was a significant main effect for sex when assessing both peak and mean power output, respectively.

Examination of peak power outputs indicated a significant difference in power output between sexes. While this study did not specifically focus on the examination of the interaction between sex and WBV and its implications on anaerobic performance, there could be an existing link between sex and the potential benefits of WBV. Similar to peak power, a significant main effect existed for sex when examining mean power output. Compared to females, males have a larger percentage of lean body mass, due primarily to a larger muscle mass (Cheung, 2010; Enoka, 2008). This discrepancy may enhance the male participant’s ability to perform high intensity exercises compared to females as females have to work against an amount of resistance relative to their overall body mass with a lower proportion of that mass consisting of muscle mass.

Regardless of sex, a similar number of motor units, which consist of a motor neuron and all of the muscle fibers it innervates, exist for both sexes when examining specific muscles. Generally speaking, males have a larger cross sectional area of muscle mass corresponding to larger muscle fibers within a given motor unit, which allows them to generate more force with the same number of motor units that were recruited to complete a specific action, when compared to women (Cheung, 2010; Enoka, 2008). The neuromuscular potentiation effect of either intervention protocols may therefore be more significant in males due to the larger amount of muscle tissue, which may leave greater room for potentiation, and would therefore allow them to perform better on the WAnT. When combined with either intervention protocol, acknowledgement of this potential sex link could prove beneficial to improving anaerobic performance for proper exercise prescription. For example, larger muscles have by definition a higher number of crossbridges being formed within the sarcomere, which makes them capable of producing more power. Therefore, if male participants can produce a higher power output instantaneously once the WAnT starts it seems likely that they may be able to continue this higher power production for the entire duration of the test because of their larger amount of lean muscle mass.

The data from the present study may support the idea that males receive a greater training stimulus through exposure to either intervention protocol. If this is true the hypothesis of this study, which claimed exposure to the intervention protocol would improve performance on the WAnT, would not be correct. However, it appears male participants would be more likely to see anaerobic performance changes compared to their female counterparts.

Further Considerations

There are several explanations for why the WBV protocol did not have an influence on peak and mean power outputs. Current research has not conclusively determined an optimal or ideal prescription of frequency and amplitude of vibration (Cochrane, 2010), however this study utilized a frequency of 30Hz and an amplitude of 4mm, similar to those protocols used previously in studies examining the effects of WBV on anaerobic performance (Abercromby et al., 2007; Adams et al., 2009; Bosco et al., 2000; Cochrane, 2010; DaSilva et al., 2006; Delecluse et al., 2003; Fagnani et al., 2006; Rhea & Kenn, 2009). In theory, the vibration values used in the present study should have promoted anaerobic training benefits as they have with previous research through neuromuscular adaptations. The high accelerations occurring from the frequency of 30Hz at the amplitude of 4mm is known to generate a hypergravity scenario at the muscular level, as indicated by the fast, short changes in length occurring within the muscle fibers (Cardinale & Bosco, 2003). As previously mentioned, these neuromuscular adaptations are thought to occur in response to the increased gravitation load placed on the activated muscles, similar to changes noted during a resistance-training regimen. The chronic adaptation that occurs in response to such an enhanced stimulus is thought to result in an increase in skeletal muscle cross-sectional area and corresponding force-generating capacity (Cardinale & Bosco, 2003). Numerous examples of anaerobic training benefits through WBV can be found in Tables 1, 2 and 3. If the proposed mechanism of WBV training is accurate, and the prescription of frequency and amplitude is appropriate, the neuromuscular adaptations needed to improve anaerobic performance may be found in future work utilizing similar protocols.

The load bearing exercises of isometric and isotonic squats and lunges have been used numerous times in previous WBV research with varying results (see Tables 1,2, and 3). Power by definition is the product of force and time; therefore in an athletic setting power is contingent upon the two components of strength and speed of force production. The power needed to perform isometric squats, isotonic squats and lunges comes from large muscles located in the thighs, hips, buttocks, lower back, and the abdominals. By training or subjecting these muscles to WBV, one can examine the effects of the WBV stimulus through the analysis of certain parameters such as velocity, force and power. While previous research has measured the effects of WBV solely on force, velocity, or power production (Annino et al., 2007; Bosco et al., 2000; Dasilva et al., 2006; Rhea & Kenn, 2009; Russo et al., 2009), this study examined peak and mean power output following isometric and isotonic squats and lunges as part of the training stimulus in conjunction with WBV or non-WBV. The influence of WBV was assessed by measuring a cycling performance known as the WAnT which uses similar muscles that squatting and lunging do to perform the cycling actions (e.g., quadriceps, hamstrings, calf, and glutes). While the use of various squat and lunge exercises have been applied to WBV to yield anaerobic performance gains in previous research, the outcomes have been variable when these particular exercises are combined with WBV to elicit anaerobic performance changes (Bazett-Jones et al., 2008; Bosco et al., 1998; Cardinale & Lim, 2003; Cochrane et al., 2008; Cochrane & Stannard, 2005; de Ruiter et al., 2003; Delecluse et al., 2005; Pel et al., 2009; Torvinen et al., 2002). Of interest to the present study, it appears that WBV did not have a positive influence on the WAnT performances through the utilization of similar muscular activations of squatting and lunging. Therefore, this deduction does not support the theory that WBV could positively alter anaerobic performances through the use of the WAnT.

The majority of research that has been published utilizing WBV for anaerobic performance gains involved exposure to WBV anywhere from 5 seconds to 5 minutes (Annino et al., 2007; Bazett-Jones et al., 2008; Bosco et al., 1998; Bosco et al., 1999; Bosco et al., 2000; Cochrane & Stannard, 2005; Cormie et al., 2006; DaSilva et al., 2006; Pel et al., 2009; Rhea & Kenn, 2009; Torvinen et al., 2002). Optimal duration of exposure to WBV is therefore difficult to discern and is of paramount importance for determining the proper exercise prescription needed to enhance performance. As previously mentioned, chronic exposure to an increased gravitational load may increase the cross-sectional area of a specific muscle, which theoretically allows for a greater force-generating capacity of a particular muscle (Cardinale & Bosco, 2003). WBV creates this hypergravity stimulus due to the high accelerations from the mechanical action of the WBV platform. In regards to the present study, the participants performed isometric squats, isotonic squats, and lunges on the WBV platform, which created the hypergravity environment that could have allowed for a potentiated force-generating capacity. However, it is important to note that while a hypergravity environment may produce acute changes to the neuromuscular system, changes in cross-sectional area would only be found following chronic application.

Performance alterations thus occur by two different mechanisms, both of which potentially result in increased force production (Cardinale & Bosco, 2003). By standing near the center of the WBV platform, the targeted muscles of the legs were exposed directly to a hypergravity stimulus. The duration that an athlete is exposed to the hypergravity stimulus may determine the effectiveness, or potentiation, of WBV on anaerobic performance (Marin & Rhea, 2010). The duration of exposure to WBV, although different in many cases has been shown to enhance anaerobic performance in a variety of studies. As seen in tables 1, 2, and 3, the majority of current research uses an acute exposure time in combination with several repetitions over the span of one day or several weeks. The present study used a WBV exposure time of 1 minute for 3 repetitions for a total exposure time of 3 minutes for each laboratory session. This exposure time does not appear to have elicited slight anaerobic performance changes, which is not congruent with previous research findings (Adams et al., 2009; Bosco et al., 1999; Bosco et al., 2000; Cardinale & Lim, 2003; Cochrane et al., 2008; DaSilva et al., 2006; Delecluse et al., 2003; Fagnani et al., 2006; Roelants et al., 2004; Russo et al., 2003). Adams et al. (2009) examined various durations (30, 45, and 60 seconds) in order to determine an optimal exposure time for WBV. The researcher's findings suggest that optimal acute effects from using WBV can be attained through exposure as little as 30 seconds, but they did not conclude a maximum exposure time. However it has been mentioned in previous studies that overexposure to WBV can lead to fatigue and in several cases result in negative complications such as edema, localized pain, and erythema (Cheung, 2010; Cochrane 2010; Marin & Rhea, 2010). While it is important to elicit neuromuscular changes within the activated muscles when studying WBV, researchers should note that overexposure could potentially "wash out" any potentiation effect, or in some cases cause bodily harm. The notion that exposure to WBV for 30 seconds to 5 minutes may elicit anaerobic performance changes supports the protocol used for the present study in which the selected exposure time was 3 consecutive 1-minute bouts.

In the present study, the knee angle at which both of the squat exercises were performed on the vibration platform was 120°. The meta-analysis published by Cochrane (2010) comprises a wide range of angles that were used during squatting and lunging exercises to possibly elicit the potentiation effect of WBV. The majority of the current research uses an angle around 90°; however an optimal range for squats to be performed to elicit performance changes has not been decided upon (Bazett-Jones et al., 2008; Bosco et al., 1999; Bosco et al., 2000; Cormie et al., 2006; de Ruiter et al., 2003; Fagnani et al., 2006; Luo et al., 2008). It is assumed that this angle of approximately 90° was chosen to safely maximize the muscular contraction, and to expose these contracting muscles to WBV throughout the entire exercising motion which would be similar to the exercises that were performed for the current data collection. Within the current research study, a knee angle of 120° was chosen because it closely resembles the knee angle used for cycling purposes. However adjusting for a deeper knee angle around 90° may have elicited larger anaerobic performance changes, as performing an isometric squat to a deeper angle would further activate the muscles needed to perform the action (e.g., quadriceps, hamstrings, calf, and glutes). Further activating these muscles may have promoted a potentiation effect through WBV, the net outcome of which might have produced a greater change in anaerobic performance.

Another variable that largely determines the potentiation effect of WBV is the load placed on the participant while they perform the chosen exercises on the vibration platform. Previous research has used various loads while the participants performed the required exercises (Bosco et al., 1999; Cochrane, 2010; Issurin & Tenenbaum, 1999; Luo et al., 2008; Rhea & Kenn, 2009). Limited research exists for determining an optimal load to elicit increases in anaerobic performance due to the plethora of factors involved: the physical fitness of participants, the exercises performed, one's body position on the vibration platform, and the specific vibration parameters. Bosco et al. (1998) examined average force, velocity, and power production across 4 different loads (70kg, 90kg, 110kg, and 130kg), and found significant improvements with the use of four loads. Their findings led the authors to conclude that a truly optimal prescription might not exist or be necessary to elicit anaerobic performance changes following exposure to WBV. In the present study, 20% and 40% of body weight was used as an external load. Such a load may not be challenging to an athlete who regularly participates in weight lifting, but to the average student who is regularly active, these selected loads were thought to be enough to induce potentiation following WBV exposure, while at the same time ensuring little fatigue. As Bosco et al. (1998) have demonstrated, it appears that seeking anaerobic performance changes is not exclusively determined by the load placed on the participant while they are exposed to WBV, rather it is contingent upon the combination and volume of exercises performed as well as the total exposure time of WBV. While an optimal load for weight bearing activities in conjunction with WBV has yet to be determined for exercise prescription it is apparent that it is an important variable that could significantly affect the extent of potentiation resulting from WBV.

The participants that were recruited for this study were required to be regularly physically active. However, most participants had little to no experience with the WAnT and WBV. A period of familiarization could exist with a participant's first WAnT in which they discover the intensity of the test and the strength required as it is a maximal effort test, and what further physical and mental demands it entails. Therefore, after the first data collection session, which was either WBV or non-WBV, the second data collection session could have facilitated an improvement on the WAnT based on the performance realizations that were gained from the first session, rather than solely the use of a specific intervention. For example, performing the non-WBV protocol during the first laboratory session followed by performing the WBV protocol during the second laboratory session could have influenced the participant's performance due to the familiarized response to the WAnT, rather than the exposure to WBV. Combining the realizations gained from performing the three exercises and the WAnT during the first laboratory session and the unfamiliar nature of WBV could have skewed performances by the participants during the second data collection session. However, according to Beams & Adams (2011), the variability in day-to-day testing of anaerobic power ranges between 5-6%, assuming a maximal effort is given. This variability in day-to-day testing does not suggest lack of familiarization is always the cause, but could also be due to other factors related to the parameters of any study involving maximal efforts. Therefore, the variability in anaerobic performances could have been due to a number of causes such as physiological fluctuations, or experience with a specific exercise, rather than familiarization to the testing conditions.

Through comparison of the means, it appears that most participants improved their peak power output performance in the second session (71%) regardless of which intervention they were completing. Even though this simple observation does not directly support the need to include a familiarization session prior to maximal effort testing, it does point out that there is a separation between laboratory session performances. Concerning the present study, no matter which intervention protocol the participants completed first, insights may have been gathered for performing the WAnT to use with future sessions. Therefore, future studies should integrate the use of a familiarization session prior to the collection of data to void a possible confounding order effect.

Limitations

Participant recruitment was conducted through courses within the Physical Education, Exercise Science & Wellness programs at the University of North Dakota. Recruitment could have expanded to other programs located on campus to ensure a larger sample group. A requirement to participate in this research study was to be regularly physically active, and to be able to withstand the physical demands of a WAnT and the lifting exercises contained within the intervention protocols. These inclusion criteria inevitably reduced the acquired sample due to the required physical demands.

Participants were not given the opportunity to experience a trial WAnT before the two data collection sessions. As discussed previously, the implications of experiencing a WAnT for the first time, and the possible insights gained from this familiarization, could have influenced the participant's performance for the second day of data collection. A WAnT familiarization session could have been performed during the initial screening of participants, which would have avoided the influence of a familiarization effect noted by the order-protocol interaction.

Participants were encouraged to not alter their normal living activities during the duration of the study. However, because data collection took place throughout the course of a week, participants could have varied their actions prior to either data collection session, in a manner that may have influenced their ensuing performance. Conversely, participants may not have altered their daily actions, but participated in an event such as heavy weight lifting or a lengthy run before a session, which may have hindered their performance. Changes in the participant's diet, sleep schedule, physical activity amounts, and minor illnesses could have confounded the data. Most of the participants that were recruited for this study regularly participated in physical activity well above the requirements for this study, as the majority of the participants belonged to a university athletic team or club sport. Therefore the possibility of WBV enhancing anaerobic performance may have been dependent upon the participant's level of physical activity at the time. For example, very athletic individuals could see a change in their anaerobic performance following the use of WBV, while recreational active individuals may not have seen this alteration in performance, or vice versa. Athletic discrepancies may exist for college athletes due to their potential exposure to intense, collegiate workouts, which theoretically would result in better performances in activities that involve high-intensity activities such as the WAnT. Conversely, through future research it may be discovered that recreationally active individuals may benefit from WBV training more than highly athletic population because they have larger performance gain possibilities.

Lastly, because the WAnT is a maximal effort test gauged at determining one's anaerobic fitness, the participant's effort levels undoubtedly play a role in their corresponding performance. Since data was collected over two laboratory sessions, participants may not have delivered similar levels of intensity across the two tests.

Similarly different participants may have been more inclined to give maximal efforts, while others may have been putting forth only near-maximal efforts.

While there has been an abundance of WBV research published in recent years, there are still several regions within the realm of WBV that have yet to be fully explored. For example, while several studies have attempted to determine an optimal frequency and amplitude for WBV training, a conclusive prescription has yet to be determined. Similarly, the types, duration, and repetitions of physical movements used to elicit performance changes while on a WBV platform have also not been conclusively decided upon either. Several stances exists that support establishing accurate WBV protocols to elicit performance alterations; while many different approaches to prescription currently exist, there appears to be no consistent application across protocols (Adams et al., 2009; Bazett-Jones et al., 2008; Bosco et al., 1998; Cardinale et al., 2006; Cardinale & Bosco, 2003; Cochrane, 2010; Da Silva et al., 2006; Marin & Rhea, 2010). Specifically the present study examined the effects of WBV on an anaerobic activity that lasted for more than a few seconds. The unique application of WBV as a training alternative is still in its infancy and will need to be expanded upon so that future studies can fully grasp the concept of WBV and the optimal prescription necessary to maximize performance.

Future Research

Although several different exercises involving WBV are associated with alterations in athletic performances, the specific properties that can elicit performance changes have not been clearly delineated. It is clear from the current research that further investigation is needed in order to properly develop a prescription of WBV as a training alternative. In the present study there are several parameters that could be further explored to better understand WBV as a training method such as the differences between sexes, the use of a familiarization session, differences between recreational and elite athletes, and the general timeline for the testing protocol and between data collection sessions. Besides investigation into the types, duration, and frequency of activities that can cause performance alterations, it is important that the variables of the tonic vibration reflex be further explored. Variables such as the frequency, amplitude, the level of precontraction in the activated muscles, and the position of these activated muscles appear to affect the amount of the tonic vibration reflex seen (Cardinale & Bosco, 2003), as shown in this study. There may be differences between very athletic individuals and recreational active individuals that could affect the potential benefits gained from using WBV as a training alternative. Lastly, the WAnT was chosen to represent a lengthy anaerobic activity because it challenges the totality of the anaerobic energy systems. Other activities similar to the WAnT, or variations of the WAnT could be used to determine the breadth of applicable situations for WBV as an anaerobic training alternative.

Conclusions

The purpose of this study was to determine whether there are differences in power output using the WAnT following both WBV and a non-WBV training stimulus. It was hypothesized that with the use of WBV, when compared to non-WBV, anaerobic performance would be improved as shown by significant increases in peak and mean power output during the WAnT. The results of this study did not indicate any beneficial performance alterations for peak and mean power output following exposure to the WBV protocol. Because acute and chronic exposure to WBV has been shown to elicit positive changes in short duration (1-2 sec) anaerobic activities, it was believed that WBV would also positively affect longer duration, anaerobic activities. However, considering the many variables involved with WBV prescription, it is difficult to determine which factors prevented the proposed hypothesis. Most likely, the parameters of the exercises used during the intervention protocols, the duration of WBV exposure, and the intense nature of performing a maximal effort test for data collection confounded the chance of achieving an altering effect on anaerobic performance. Furthermore, the results of the present study revealed that an application of a bout of WBV at a frequency of 30Hz and amplitude of 4mm generated performance differences between sexes while performing lengthy anaerobic activities such as the WAnT with healthy collegiate participants. While this study did not specifically focus on the examination of the interaction between sex and WBV and its implications on anaerobic performance, there could be an existing link between sex and the potential benefits of WBV. WBV exercise prescription variables such as exercises performed, frequency, amplitude, duration and joint angle could all be influential in determining the effectiveness of WBV on anaerobic performance. Therefore, further exploration into the many parameters of WBV as a training method should be performed so that proper prescription can be given to athletes and recreational users alike.

APPENDICES

Appendix A
Consent Form

INFORMED CONSENT

TITLE: The effects of vibration exercise on anaerobic performance using the Wingate test

PROJECT DIRECTOR: Daniel Veith

PHONE # 701-777-2988

DEPARTMENT: Physical Education, Exercise Science, and Wellness

STATEMENT OF RESEARCH

A person who is to participate in the research must give his or her informed consent to such participation. This consent must be based on an understanding of the nature and risks of the research. This document provides information that is important for this understanding. Research projects include only subjects who choose to take part. Please take your time in making your decision as to whether to participate. If you have questions at any time, please ask the lead researcher, Daniel Veith.

WHAT IS THE PURPOSE OF THIS STUDY?

You are invited to be in a research study about whole body vibration in combination with resistance training to seek greater gains in muscular performance, because you have been identified as an active student currently enrolled in the Physical Education, Exercise Science and Wellness program.

The purpose of this research study is to determine whether or not whole body vibration training influences power output. It is hypothesized that exercising with whole body vibration will increase peak and mean power output. This information may provide insight into the performance capabilities during longer lasting, high-intensity activities following vibration exercise.

HOW MANY PEOPLE WILL PARTICIPATE?

20 people (males and females) are taking part in this study at the University of North Dakota.

HOW LONG WILL I BE IN THIS STUDY?

Your participation in the study will last for 3 weeks. You will need to visit the exercise physiology lab located in the Hyslop building on the UND campus in room 301 for a total of 3 sessions. Each visit will take about 30 minutes.

WHAT WILL HAPPEN DURING THIS STUDY?

Prior to beginning testing, you will be asked to fill out a health history questionnaire; you are allowed to skip any question that you prefer not to answer.

You will be asked to attend three laboratory testing sessions: one to familiarize yourself with the equipment and testing protocol, and two more for data collection involving the whole body vibration and non-whole body vibration interventions. At the start of each testing session, you will perform a warm-up on a cycle ergometer at low intensity for 5 minutes. Following the warm-up, you will be exposed to three different resistance loads through one of two exercise modes: whole body vibration or non-whole body vibration intervention.

The three different resistance loads that you will perform are stationary and moving squats, both at a resistance equal to 40% of your body weight, and lunges at a resistance equal to 20% of your body weight. You will complete 1 minute of each activity, each of which will be followed by 1 minute of rest. For all three different resistance activities, you will have the loads placed on a weight bar and held behind the neck upon the shoulders and contained within a standard squat rack.

The Wingate anaerobic test (WAnT) will be performed as soon as the last 1 minute of rest is over. The resistance weight of 7.5% of your body weight will be dropped at the start of the test and removed at the end of 30 seconds. You are encouraged to reach maximal repetitions on the cycle-ergometer 1-2 seconds before the start of the WAnT test.

Wingate Anaerobic Test (WAnT): The WAnT is a test that is performed on a cycle-ergometer. Participants will give a maximal effort while pedaling against 7.5% of their body weight. The test lasts for a total of 30 seconds.

Whole-Body Vibration: A machine is used to administer a vibrating stimulus while a participant is positioned on a platform. The vibration stimulus can vary in frequency (the amount of vibrations) and amplitude (the displacement the vibration platform moves with each movement). Whole body vibration works by activating muscle spindles in the muscles receiving exposure. This activation in turn triggers a mini stretch reflex, causing the muscle to contract, and thereby increasing the force of contraction. Theoretically, this increased force of contraction should result in increased power output in high-intensity activities relying on high levels of force output such as those used in this study.

WHAT ARE THE RISKS OF THE STUDY?

There is minimal risk from your participation in this study. Possible risks may include muscular injuries associated with squatting, lunging, or cycling movements; however, these risks are unlikely. Wingate tests are regularly performed in undergraduate exercise physiology classes with no injuries or complications. Also, the loads that will be performed during the resistance training portion of the intervention are relatively low, and therefore not likely to induce soreness or discomfort of any kind.

You may also become faint, fatigued, light-headed, or nauseous after completing the Wingate test, as it is a maximal effort test. You may also feel disruptions with your balance, light-headedness, numbness in your limbs, or ringing in your ears following the vibration stimulus; again this is uncommon. Psychological damage is not expected in any manner. There are also no foreseeable risks with legal and privacy issues. In addition to anticipated/expected risks, participation in this study may involve unforeseen risk.

WHAT ARE THE BENEFITS OF THIS STUDY?

You will not benefit personally from being in this study. However, we hope that, in the future, other people might benefit from this study because WBV might be able to increase peak and mean power output for high-intensity performances. By implementing WBV it could be a helpful performance enhancer in athletic events requiring a maximum effort for more than a few seconds such as races to the finish line in cycling, speed skating, and sprinting, which all use the high-intensity energy system for more than a few seconds.

ALTERNATIVES TO PARTICIPATING IN THIS STUDY

If you choose not to participate in this study, you may earn extra credit in your course in other ways. Please ask your instructor, who will provide you with comparable assignments that you may choose to complete (e.g. writing assignments, participation in other research experiments etc.).

WILL IT COST ME ANYTHING TO BE IN THIS STUDY?

You will not have any costs for being in this research study.

WILL I BE PAID FOR PARTICIPATING?

You will not be paid for being in this research study. However, extra credit will be offered to undergraduate students as an incentive for participation in this study. Courses that extra credit will be offered in are not lead by the lead investigator.

WHO IS FUNDING THE STUDY?

N/A

CONFIDENTIALITY

Your participation records from this study will be kept private to the extent permitted by law. In any report about this study that might be published, you will not be identified. Your study record may be reviewed by Government agencies, and the University of North Dakota Institutional Review Board

Any information that is obtained in this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of identifying participants by numbers (Ex: Male 1 = M1). Data will be stored on laboratory computers and in folders that will be stored in the office of Dr. Josh Guggenheimer. Access will only be granted to Daniel Veith and Dr. Joshua Guggenheimer. If we write a report or article about this study, we will describe the study results in a summarized manner so that you cannot be identified.

IS THIS STUDY VOLUNTARY?

Your participation is voluntary. You may choose not to participate or you may discontinue your participation at any time. The extra credit offer for participation in this experiment will be rescinded if participants drop out. Your decision whether or not to participate will not affect your current or future relations with the University of North Dakota.

You will be informed by the research investigators of this study of any significant new findings that develop during the study which may influence your willingness to continue to participate in the study.

CONTACTS AND QUESTIONS?

The researchers conducting this study are Daniel Veith and Dr. Joshua Guggenheimer. You may ask any questions you have now. If you have questions, concerns, or complaints about the research please contact Daniel Veith at 507-380-9727 anytime during the day. Dr. Josh Guggenheimer can also be contacted at 701-777-2988.

If you have questions regarding your rights as a research subject, or if you have any concerns or complaints about the research, you may contact the University of North Dakota Institutional Review Board at (701) 777-4279. Please call this number if you cannot reach research staff, or you wish to talk with someone else.

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Subjects Name: ____

______________________________ ________________

Signature of Subject Date

______________________________ ________________

Signature of Researcher Date

Appendix B
Participant Data Sheet

Participant Code:__________

Gender:___________

Week 1 Group:___________

Week 2 Group:___________

Cycle Ergometer:

Seat Height:___________

7.5% of Body Weight (kg):___________

	Week 1	Week 2
Body Weight (kg)		
40% of Body Weight (kg)		
20% of Body Weight (kg)		

Vibration Platform:

Bar Position:___________

Frequency:___________

Amplitude:___________

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