Effects of Postactivation Potentiation Succeeding Glute Bridge Exercise on Multiple Jump Performance in Recreationally Trained Individuals

Anthony Warpecha
Eastern Illinois University

This research is a product of the graduate program in Kinesiology and Sports Studies at Eastern Illinois University. Find out more about the program.

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Effects of Postactivation Potentiation Succeeding Glute Bridge Exercise on Multiple Jump Performance in Recreationally Trained Individuals

(TITLE)

BY

Anthony Warpecha

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EFFECTS OF POSTACTIVATION POTENTIATION SUCCEEDING GLUTE BRIDGE EXERCISE ON MULTIPLE JUMP PERFORMANCE IN RECREATIONALLY TRAINED INDIVIDUALS

A THESIS SUBMITTED TO THE FACULTY OF THE DEPARTMENT OF KINESIOLOGY AND SPORTS STUDIES AT EASTERN ILLINOIS UNIVERSITY

BY

ANTHONY J. WARPECHA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

Dr. Jeffrey Willardson, Adviser

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ABSTRACT

The purpose of this study was to test multiple jump performance subsequent to glute bridges performed with and without whole body vibration (WBV). Multiple jump performance was assessed via a four-hop test to examine average jump height, ground contact time, and the explosive leg power factor. Twenty recreationally active subjects, ages 18-42, with more than one year of consistent recreational resistance training experience participated. Prior to testing, one familiarization session took place that involved explanation of procedures. This included practice of glute bridging on the vibration plate and the multiple hop performance test. After the familiarization session, two testing sessions then took place 72 hours apart to allow for proper recovery. In each testing session, a pre-test of 4 countermovement jumps (CMJs) were performed, followed by a rest time of 2 minutes, followed by glute bridging, followed by a rest time of 4 minutes, and then a post-test of 4 CMJs were again performed. All subjects performed glute bridges in both conditions: on the vibration plate (experimental) and on a bench step (control). Subjects were randomly assigned to a condition for the 1st testing session, and then participated in the other condition for the second testing session. The results indicated no significant differences between the vibration and control conditions in ground contact time, explosive leg power factor, and jump height (p > 0.05). Furthermore, there were no significant differences in ground contact time and the explosive leg power factor from the pre-test to the post-test, irrespective of whether the condition was vibration or control (p > 0.05). However, there was a significant difference decrease in jump height from the pre-test to the post-test across the vibration and control conditions (p = 0.037). The findings suggest performing 4 sets of glute bridges with WBV preceding 4 countermovement jumps (CMJs) did not increase jump height, ground contact time, and explosive leg power factor compared to not using WBV.
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Although having the ability to produce a great deal of force is beneficial in sports, explosive power and speed has also become a key factor in effective performance (Young, 1993). For example, power output from the lower extremities is crucial in maximizing speed off the ground, and vertical jump height (Izquierdo, Hakkinen, Gonzalez-Badillo, Ibanez, & Gorostiaga, 2002).

A proper warm-up has been shown to improve these abilities and is essential for eliciting the post activation potentiation (PAP) response (Hilfiker, Hubner, Lorenz, & Marti, 2007). PAP can be described as a warm-up or preceding activity used to enhance the effects of subsequent exercise performance (Evetovich, Conley, & McCawley, 2015). The PAP response has been shown to “enhance subsequent force generation and improve strength and power performance” (Esformes, Keenan, Moody, & Bampouras, 2011) or “an increase in force production after a maximal or near-maximal muscle action” (Stieg et al., 2011).

The mechanisms that mediate the PAP have been postulated to involve increased phosphorylation of myosin light chains and an increase in motor unit recruitment (Gullich & Schmidbleicher, 1996). Enhancing the light chain phosphorylation enhances the sensitivity of actin and myosin activity to calcium. The faster rate of myosin binding to actin produces a quicker cycling of cross bridges and a stronger binding affinity between actin and myosin, thus contributing to quicker and greater force production (Gullich & Schmidbleicher, 1996). Another theory that has been suggested is the enlargement of the potential which lasts for numerous
minutes at the spinal cord level due to larger postsynaptic potentials (Okuno et al., 2013). There are many factors which have been shown to affect the magnitude of the PAP response. Some of these include: amount of rest, training status, intensity, volume, type of conditioning activity, and level of muscular strength (Wilson et al., 2013).

Fatigue and PAP are both the result of skeletal muscle contraction. The ratio of these two factors is pivotal in understanding the potential for improved contractile performance via a PAP protocol. Both fatigue and PAP levels are elevated following a pre-conditioning activity; and then return back to normal levels. The timing of both the deterioration of PAP and diversion of fatigue are critical for the optimal recovery time or window (Robbins, 2005). Successful PAP occurs within a strict time window where the rest intervals are long enough for the effects of potentiation to be greater than the fatigue effects, but not too long so that the potentiation effects also decrease back to baseline.

Whole Body Vibration (WBV) is a mechanical stimulus from oscillatory motions defined by amplitude and frequency. WBV has been shown to improve neural factors such as increased motor unit synchronization, stretch reflex potentiation, increased synergist muscle activity, and increased inhibition of the antagonist muscles (Bullock et al., 2008). Changes to such factors can result in the following: enhanced muscle stimulation noted from increased electromyography (EMG) activity, increased respiration, increased energy expenditure, increased cutaneous blood flow, increased anabolic hormone response, and increased activation of the tonic vibration reflex (McBride et al., 2010).

The hip extensors are major determinants of performance from the lower limbs involving jumping, sprinting, and weightlifting (Newton & Kraemer, 1994). The gluteal muscle group is part of the hip extensors, and is a highly responsible for explosive movements involving the
lower limbs. During a countermovement jump (CMJ) the gluteus maximus, medius, and minimus are all highly activated (Crow, Buttifant, Kearny, & Hrysomallis, 2012).

Experimental Purpose

The purpose of this study was to test multiple countermovement jump (CMJ) performance subsequent to glute bridges with and without whole body vibration (WBV) used during the glute bridges. Multiple jump performance was assessed via a four-jump test to examine average jump height (JH), ground contact time (GCT), and explosive leg power factor (ELPF).

Hypothesis

It was hypothesized including whole body vibration with glute bridges would be enhanced at a frequency of 40 Hz multiple jump performance in countermovement jumps (CMJs) compared to performing glute bridges without whole body vibration.
CHAPTER II

REVIEW OF LITERATURE

This literature review examines research related to post activation potentiation (PAP). PAP has been shown to enhance short-term muscle force output by pairing heavy resistance exercises with explosive movements (Robbins, 2005). The main factor in whether PAP is elicited is based on the balance between both fatigue and the PAP response after a contractile activity. There will not be a high potentiation effect if too much fatigue is still present and if the PAP response has dissipated. Additionally this review will examine the variables associated with PAP and how they are different.

Training Background

Training background in terms of strength training has been shown to influence PAP. Studies have shown stronger more experienced subjects exhibit a greater PAP response versus weaker subjects with less experience (Chiu et al., 2003). Duthie, Young, and Aitken (2002) found stronger subjects increased their performance in vertical jumping after a 5RM set in the back squat significantly more than weaker subjects. Peak power and force were also shown to increase in stronger subjects following a set of 3RM back squats, whereas peak power and force levels went down in weaker subjects (Duthie, Young, & Aitken, 2002).

Similar findings were found by Young et al. (1998), Gullich and Schmidtbleicher (1996), and Chiu et al. (2003). Sequentially following a set of 5RM back squats, stronger subjects
showed greater improvements in jump squats (Young et al., 1998). When comparing highly trained athletes and physical education students, a significant potentiation response was demonstrated via the H-reflex with the highly trained athletes, but not with the physical education students (Gullich & Schmidtbleicher, 1996). Duthie, Young, and Aitken (2002) theorized the stronger subjects in their study may have had greater potentiation effects versus fatiguing effects; whereas the weaker subjects displayed the opposite trend. The weaker subjects were not accustomed to lifting high intensity loads, which may have prevented them from reaching sufficient exertion levels to induce a potentiating response.

Muscle Fiber Composition

The percentage of fast twitch muscle fibers may also determine the magnitude of the PAP response. Stronger people may possess a higher percentage of fast-twitch (type II) fibers, which have a higher rate of ATPase activity and cross-bridge cycling. Therefore, a potentiating response might be more readily evident in stronger subjects with repeated application of higher intensity loads (Duthie, Young, & Aitken, 2002).

Chiu et al. (2003) compared recreationally trained individuals and athletes who were currently engaged in explosive sports. Similar findings in regards to strength training background were found. The athlete group had a significantly greater potentiation response than the recreationally trained group. The athletes in this study were all currently in sports in which explosive strength was required. In theory, subjects who were more explosively trained would have a greater H-reflex response and myosin regulatory light chain phosphorylation. As described above, the H-reflex may help by imposing on the motor signal to activate the contractile apparatus. This would help activate the muscle better and produce higher potentiation (Trimble & Harp, 1998).
Tillin & Bishop (2009) state about the phosphorylation of myosin regulatory light chains:

RLC phosphorylation is catalyzed by the enzyme myosin light chain kinase, which is activated when Ca$^{2+}$ molecules, released from the sarcoplasmic reticulum during muscular contraction, bind to the calcium regulatory protein calmodulin. RLC phosphorylation is thought to potentiate subsequent contractions by altering the structure of the myosin head and moving it away from its thick filament backbone. It has also been shown that RLC phosphorylation renders the actin-myosin interaction more sensitive to myoplasmic Ca$^{2+}$. Consequently, RLC phosphorylation has its greatest effect at relatively low concentrations of Ca$^{2+}$, as is the case during twitch or low-frequency tetanic contractions (p. 148-149).

Tillin & Bishop also describe the H-reflex as:

The H-wave (H-reflex) is recorded at the muscle fibres using electromyography, and is the result of an afferent neural volley in response to single-pulse submaximal stimulation of the relevant nerve bundle. An increase in H-wave following a conditioning contraction may therefore represent a decrease in transmitter failure at synaptic junctions, and a subsequent increase in higher order motorneuron recruitment.

Greater phosphorylation results in greater muscle activation, which results in quicker contraction and faster tension development rates (Houston, Green, & Stull, 1985). It seems power and strength athletes develop resistance to fatigue due to the nature of high intensity
training, and therefore helps explain why they experienced PAP better than untrained persons (Stone & Fry, 1998).

Whole-Body Vibration (WBV)

Vibration has been thought to increase muscle performance as a result of evoking involuntary reflex contractions (Mester et al. 1999) from the tonic vibration reflex (Hagbarth & Eklund, 1966). Increasing reflex contractions may help facilitate voluntary contractions which would enhance muscle performance (Cardinale & Lim, 2003). Hazell, Jakobi, and Kenno (2007) used WBV while measuring electromyography (EMG) activity in the vastus lateralis and biceps femoris muscles during a static semi-squat and dynamic squat. They found increased muscle activity in both muscles and the results showed a continued increase as the frequency from the WBV increased. They concluded it may have been from fast involuntary changes in muscle length from the tonic vibration reflex. Another possible reason was that a larger fraction of motor units were activated from a decrease in the recruitment threshold of the motor unit pool, and therefore resulted in the increase in EMG activity (Issurin & Tenebaum, 1999).

McBride et al. (2010) had subjects perform static body weight squats at 30 Hz after a pre and posttest of ballistic isometric maximum voluntary contractions (MVC). Peak force was measured highest shortly after and 8 minutes after. The control group which did not use vibration did not show any improvements in peak force. However, WBV has also been found to increase at different levels (Hz).

Ronnestad (2009) found that 50 Hz significantly increased peak average power in trained and untrained subjects when performing squat jumps compared to 20 and 35 Hz. It was concluded that 50 Hz was enough of a stimulus to create a large overload to activate the
neuromuscular system of the extensors in the leg. This helps to activate more motor units or fire them faster which would result in above average production of force and power. Additionally, the muscles of the quadriceps are at their maximum force rate of motor units at about 50-60 impulses per second. The vibration at 50 Hz may have helped to stimulate the muscle spindles in the quadriceps muscles to 50 impulses and therefore increase the stimulus in the motor neuron pool than at lower frequencies (Edwards, Hill, Jones, & Merton, 1977). It was also suggested the untrained subjects’ lack of ability to recruit the high threshold motor units may explain why they showed significant improvements in peak average power produced during submaximal loaded countermovement jumps, where the trained subjects did not (Ronnestad, 2009). Forty meter sprint times were significantly lower preceding body loaded half squats at WBV of 50 Hz in comparison to 30 Hz (Ronnestad & Ellefsen, 2011).

Finally, in national level male power lifters, WBV at 50 Hz increased peak power output during squat jumps of 65 and 100 kg. However, peak power output from squat jumps did not show any improvements at 30 Hz (Ronnestad, Holden, Samnoy, & Paulsen, 2012). Increased EMG activity in the thigh muscles were also recorded at 50 Hz compared to 30 Hz. Similar results were suggested as to why there were increases in peak power output. Bosco et al. (2000) demonstrated significant improvements in jump height and power at 26 Hz when subjects held static squats for 60 seconds while performing 10 sets.

However, other studies have shown no increase or a reduction in performance after employing WBV. When assessing isometric squat peak force, vertical jump peak power, and muscle activation, no significant differences were found between the group who used vibration and the control group from immediately post to 30 minutes after (Cormie, Deane, Triplett, & McBride, 2006). De Ruiter, van der linden, van der Zijden, Hollander, & de Haan (2003) had
subjects perform 5 sets of static squats for 1 minute at 30 Hz. Significant reductions were found in muscle force output and muscle activation starting from 90 seconds post vibration to 180 minutes post vibration. The excitation of motor neurons can be measured by a process called tibial nerve stimulation. There are two wave patterns that show during this technique. A single twitch of the electrically stimulated muscle is called the M wave, and the wave pattern resulting from activation of monosynaptic reflex response from electrical stimulation to the same muscle is the H reflex (Holterman, Roeleveld, Engstrom, & Sand, 2007).

Rest Intervals between Heavy Load Exercise and Power Exercise of PAP response

Rest periods have been shown to be highly individual based on effectiveness of PAP. In a meta-analysis by Wilson et al. (2013), the authors concluded optimal recovery time relies between the existence of muscular fatigue and potentiation to maximize power and performance. It was also concluded that moderate rest periods of 7-10 minutes maximized potentiation. Kilduff et al. (2007) had subjects perform seven countermovement jumps after a 3RM back squat and ballistic ball throws after a 3RM bench press. Times were measured at 15 seconds, 4, 8, 12, 16, and 20 minutes. Optimal recovery time for PAP effect was found to be 8-12 minutes for lower body activities. Similar findings were found by Lowery et al. (2012), Jo, Judelson, Brown, Coburn, and Dabbs (2010), after testing subjects' vertical jump height 0, 2, 4, 8, and 12 minutes performing a back squat at 56%, 70%, and 93% of their 1RM. Vertical jump height and power peaked at 4 minutes until 8 minutes for 70% of 1RM, and till 12 minutes at 93% of 1RM. The authors concluded the high intensity loads may have extended the length of PAP. This has been called the fitness model of performance (Banister, Carter, & Zarkadas, 1999).

According to this model, fatigue is generated in the form of consumption of substrate, a buildup of hydrogen ions, or the mechanical disruption of the makeup of myofibrillars after a
heavy conditioning stimulus. The effects after heavy loading are thought to stem from phosphorylation of myosin regulatory light chains, which results in the increased recruitment of higher order motor units (Wilson et al., 2013). Chatzopoulos et al. (2007) found improvements in sprints of 0-10 and 0-30 meters 5 minutes after preceding 10 singles of back squats on a smith machine at 90% 1RM. However, no improvements were found after 3 minutes. The reason for the time improvements after 5 minutes were thought to be from the complete restoration of creatine phosphate and that 5 minutes was enough to reduce fatigue (Gullich and Schmidtbleicher, 1996). Analogous results were found by Turner, Bellhouse, Kilduff, and Russell (2015). Subjects performed 20 meter sprints 15 seconds, 2, 4, 8, 12, and 16 minutes after a preload stimulus of walking (control), performing alternate leg bounds with body weight (plyometric), and with body weight plus 10% (weighted plyometric). The weighted plyometric stimulus caused an impairment in sprint velocities after 15 seconds. However, sprint velocities for 10 and 20 meters were improved after 4 and 8 minutes after using weighted plyometric bounding compared to walking. There were also improvements in 10 meters after the body weight plyometric stimulus. This demonstrates that a preload stimulus does not need to be of a high intensity load such as a 5 or 3RM squat or bench to produce PAP as was shown by Wilson et al. (2013).

Bounding is an explosive activity characterized by the preferred recruitment of type II motor units (Desmedt & Godaux, 1977), which have been shown to be paramount for activating PAP (Hamada, Sale, MacDougall, & Tarnopolsky, 2000). It may also be theorized that bounding increased sprint velocities because of the similar horizontal impulses bounding has with sprinting. The beginning phase of a sprint constitutes maximal horizontal motions while vertical motions are minimized (Hunter, Marshall, & McNair, 2004). As stated earlier, bounding as a
plyometric exercise maximizes horizontal motions similar to sprinting which may have explained the improvement in sprint velocities among the subjects. However, the results also indicated that the existence of PAP was highly individual with more than half of the participants responding best after 8 minutes. These results were similarly found in Bevan et al. (2010) as well as Wilson et al. (2013). Nonetheless, no improvements in 10 and 20 meter sprint times were found by Till and Cooke (2009) when subjects performed 5 tuck jumps before the 10 and 20 meter sprints. It was concluded the vertical direction of the tuck jumps interfered with the specificity horizontal direction of the sprints which may have caused no improvement in performance.

Similar rest periods have also been shown to result in null effects or decrements in performance. Mangus et al. (2006) had subjects execute 3 countermovement jumps and then either quarter or half squats. Jump height was found to not be altered among the subjects after a rest interval of 3 minutes. The authors suggested a rest time of 3 minutes may have been too long for the subjects, although other studies have shown PAP to still be effective at 12 minutes (Kilduff, Bevan, & Kingsley, 2007). Identical results were also found in McCann and Flanagan (2010) with some subjects showing a performance increase in vertical jump height after 4 minutes preceding a 5RM set of back squats, and some subjects exhibited an increase in vertical jump height after 5 minutes preceding a set of 5RM power cleans. These confounding results were explained by the authors that PAP was found to be highly individual, and many variables exist to what can be done to maximize PAP. In order for PAP to be successful, there must be a strict time window for rest intervals to be long enough for the effects of potentiation to be greater than the fatigue effects, but not so extensive that the potentiation effects also decrease back to standard.
Intensity of 1RM Load

Gullich and Schmidtbleicher (1996); Jensen and Ebben (2003); and Young, Jenner, and Griffiths (1998) found an intensity of 80% 1RM was imperative for bringing about PAP with resistance training. Hanson, Leigh, and Mynark (2007) had subjects perform a single squat intervention sets in 2 conditions: 8-10 reps at 20-40% 1RM and 4-5 repetitions at 40-80% of 1RM. It was found subjects’ net impulse and peak vertical ground reaction force (VGRF) did not improve along with ground contact time. It was suggested that the workload was not heavy enough to induce high enough levels of PAP to combat the levels of fatigue, and movements performed at high velocities may allow small assistance to PAP because motor units are discharging at very high rates (Sale, 2002). Similar findings were established by Khamoui et al. (2009), Wilson et al. (2013), and Mangus et al. (2006). These authors did not find PAP to evoke a response to improve the activity or exercise performed after the preload stimulus. Khamoui et al. (2009) had subjects use single sets of 2, 3, 4, and 5 reps in back squats with 85% of 1RM. No significant interactions were found in eliciting a PAP response. A meta-analysis by Wilson et al. (2013) also found multiple sets to be more effective at evoking PAP than single sets. However, it was also found moderate intensities (60-84%) were more effective than higher intensities (>85%). Mangus et al. (2006) used quarter and half squats at an intensity of 90% for 1 repetition. There were no increases in jump height found after the quarter and half squat preload stimulus. The authors speculated the superior stimulus intensity may have been a factor along with the fact the subjects used free weights for the squats.

Young, Jenner, and Griffiths (1998), Hrysomallis and Kidgell (2001), and Radcliffe and Radcliffe (1996) did not use free weights and used a lower intensity than 90% 1RM in their studies. Hamada, Sale, and MacDougall (2003) had subjects perform 16 five second isometric
muscular voluntary contractions (MVC) knee extensions with a three second rest interval after each MVC. The twitch response was highest and peaked after the first three MVCs were done. This showed PAP was more effective at the beginning when the volume of MVCs was less. The twitch response slowly began to decrease after each MVC and was measured at 32% below the baseline after the last MVC was performed. These results indicated the appearance of fatigue gradually started to increase proportionally with the volume. It is therefore plausible to use an acceptable amount of volume where PAP will not dissipate faster than fatigue after performing a stimulus.

Jumping, sprinting, and other weightlifting activities (Izquierdo, Hakkinen, Gonzalez-Badillo, Ibanez, & Gorostiga, 2002) are highly dependent upon the power output of the lower extremity explosively in many sports (Newton & Kraemer, 1994). Countermovement jumps (CMJ) have been used by researchers to test power output of the lower extremity. A CMJ is at least 2 jumps done in succession without resting in between jumps. The central nervous system may be activated with light loads during exercise to create an opportunity for explosive movements (Verkhoshansky, 1986). Sprinting and jumping is helped by the gluteal muscles, which are key determinants of explosive power of the lower limbs (Mero & Komi, 1994). All three muscles of the glutes (maximus, medius, and minimus) are highly activated during a CMJ (Izquierdo et al., 2002) (Nagano, Komura, Fukushiro, & Himero, 2005).

Although the gluteus maximus contributes a large amount of force and work output in the sagittal plane, the gluteus medius and minimus also have significant roles in stabilizing the movement of the hip joint when jumping (Newton & Kraemer, 1994). Crow, Buttifant, Kearny, and Hrysomallis (2012) had subjects perform 3 different warm-up protocols consisting of light load exercises that targeted the gluteal muscles, a WBV session of having subjects stand on a
vibrating platform for 30-45 seconds, and a control condition. The subjects then executed 5 consecutive CMJs on a smith machine with a bar mass of 20 kg. It was found peak power was significantly higher after the group performed exercises that targeted the gluteal muscles than the group who used vibration and the group who had the control condition.

Besides the present study, this seems to be the only study where subjects performed exercises that focused on the gluteal muscles to induce a PAP response for increasing power output. As stated above, the gluteal muscle group is a significant factor in jumping (Mero & Komi, 1994). In agreement with findings above in regards to the use of WBV and the findings from Crow et al. (2012), the current investigation will use vibration with a frequency of 40 Hz and use an exercise to target the gluteal muscle group to produce a PAP effect as the preload stimulus. A CMJ will be used to assess the enhancement of the preload stimulus effect. A supine or glute bridge was used as the exercise for the preload stimulus.

Overall, the studies mentioned above show how individualized PAP responds in individuals and athletes alike. There are many factors that can affect a PAP response in an individual. These factors include: gender, rest periods, WBV, type of conditioning activity, training background, muscle fiber composition, and intensity.
CHAPTER III
METHODS

Experimental Purpose

The purpose of this study was to test multiple jump performance subsequent to glute bridges with and without whole body vibration (WBV) used during the glute bridges. Multiple jump performance was assessed via a four-jump test to examine average jump height (JH), ground contact time (GCT), and explosive leg power factor (ELPF).

Experimental Approach

Prior to testing, one familiarization session took place that involved an explanation of procedures, practice of glute bridges on the vibration plate, and the multiple jump performance test. Subjects were then scheduled for two testing sessions that would take place 72 hours apart to allow for proper recovery. Subjects were asked to abstain from strenuous lower body activity 24 hours before testing sessions and to maintain their normal nutrition and hydration levels. In each testing session, a pre-test of four CMJs were performed, followed by glute bridging, and then a post-test of four CMJs were again performed. All subjects performed glute bridges in both conditions, on the vibration plate (experimental) and on a bench step (control). Subjects were randomly assigned to a condition for the first testing session, and then participated in the other condition for the second testing session.
Subjects

Twenty recreationally trained subjects, ages 18-42, with more than one year of consistent recreational resistance training experience participated. Subjects attended a familiarization session during which they were educated on testing procedures and signed an informed consent. Each subject also filled out a Physical Activity Readiness Questionnaire (PAR-Q) before participation. The study procedures were approved by the Institutional Review Board at Eastern Illinois University. Subjects were asked to abstain from strenuous lower body activity 24 hours before testing sessions and to maintain their normal nutrition and hydration levels. Each subject’s height and weight were measured before each testing session. Table 1 shows the demographics of each subject.
Table 1. Demographics.

<table>
<thead>
<tr>
<th>Subject Number</th>
<th>Gender</th>
<th>Age (yr)</th>
<th>Height (in)</th>
<th>Body Weight (lbs)</th>
</tr>
</thead>
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<td>71.00</td>
<td>228.50</td>
</tr>
<tr>
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<td>159.00</td>
</tr>
<tr>
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<td>M</td>
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<td>66.00</td>
<td>149.60</td>
</tr>
<tr>
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<td>M</td>
<td>23.00</td>
<td>71.00</td>
<td>216.30</td>
</tr>
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</tr>
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<td>M</td>
<td>25.00</td>
<td>67.50</td>
<td>161.80</td>
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<td>66.50</td>
<td>114.50</td>
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<td>F</td>
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<td>F</td>
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<td>19</td>
<td>F</td>
<td>42.00</td>
<td>64.50</td>
<td>162.20</td>
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<tr>
<td>20</td>
<td>F</td>
<td>22.00</td>
<td>66.25</td>
<td>166.00</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>23.00</td>
<td>68.53</td>
<td>173.07</td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td>4.79</td>
<td>3.44</td>
<td>32.52</td>
</tr>
</tbody>
</table>
Familiarization

The protocol was reviewed with each subject prior to the first training session. Subjects practiced glute bridging on the vibration plate and practiced the multiple jump test until a level of comfort was reached where each subject was co

Protocol

Prior to each testing session, subjects warmed up on a cycle ergometer with no resistance for five minutes, followed by 10 submaximal jumps. A pre-test of four countermovement jumps (CMJ) on the Just Jump Mat were executed after a two minute rest. The mat recorded the mean ground reaction time (GCT), explosive leg power factor (ELPF), and jump height (JH) for each jump. Two minutes after the pre-test, the exercise protocol consisted of four sets of glute bridges performed on the vibration plate (experimental—see Figure 1). Each glute bridge was held with an isometric action for 20 seconds, with one minute rest in between each set. The rest time was determined from no external loading used, and therefore would not need as much rest time. The vibration frequency was set at 40 Hz which has been shown high enough to induce increased muscle activity, but not so high where negative effects on the body would occur (Jordan et al., 2005 and Hazell et al. 2007). A stopwatch was used to keep track of the time for the entire protocol. After the exercise protocol, a four minute rest period was ensued based on prior literature showing a PAP effect (McCann & Flanagan, 2010). A post-test of four CMJs were again performed on the Just Jump Mat. The mean GCT, ELPF, and JH were recorded each jump. The same procedure was used with the bench step (control—see Figure 2) for each subject.
Figure 1. Experimental Vibration condition.
Data Analysis

To compare the post-activation potentiation differences between glute bridges with or without vibration on multiple-hop performance, a two-way repeated analysis of the variance [2 (vibration vs. control) x 2 (pre-test vs. post-test) ANOVA] was utilized. The independent variables were the supine bridges performed with or without vibration and the measurement of multiple hop performance prior to (pre-test) and following (post-test) the supine bridges. The between-subjects’ factor was the difference in multiple hop performance between the supine bridges performed with or without vibration. The within subjects’ factor was the difference in multiple hop performance from the pre-test to the post-test. The dependent variables assessed
with the multiple hop test included: average ground contact time (four hops), average vertical jump height (four hops), and the explosive leg power factor. The explosive leg power factor was calculated by dividing the average jump height by the average ground contact time. Thus, the greater the average jump height and the smaller the average ground contact time, the higher the explosive leg power factor. For all statistical comparisons, an alpha level of $p < 0.05$ was adopted to establish significance.
CHAPTER IV
RESULTS

Experimental Purpose

The purpose of this study was to test multiple jump performance subsequent to glute bridges with and without whole body vibration (WBV) used during the glute bridges. Multiple jump performance was assessed via a four-jump test to examine average jump height (JH), ground contact time (GCT), and explosive leg power factor (ELPF).

All twenty subjects successfully completed the protocol. The two-way repeated analysis of the variance [2 (vibration vs. control) x 2 (pre-test vs. post-test) ANOVA] indicated no significant differences between the vibration and control conditions in ground contact time, explosive leg power factor, or jump height (p > 0.05). Furthermore, there were no significant differences in ground contact time and the explosive leg power factor from the pre-test to the post-test, irrespective of whether the condition was vibration or control (p > 0.05). However, a significant difference was found in jump height from the pre-test to the post-test across the vibration and control conditions (p = 0.037). This result indicated that jump height was significantly less at the post-test versus the pre-test across the vibration and control conditions. The probability levels are reported in Table 2.
Table 2. Within Subjects and Between Subjects Probability Levels.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Ground Contact Time</th>
<th>Explosive Leg Power Factor</th>
<th>Jump Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Subjects Comparison</td>
<td>.628</td>
<td>.467</td>
<td>.037*</td>
</tr>
<tr>
<td>Between Subjects Comparison</td>
<td>.977</td>
<td>.798</td>
<td>.982</td>
</tr>
</tbody>
</table>

Note. Within-subjects compared pre-test versus post-test; Between-subjects compared vibration versus control condition. *Significantly reduced jump height pre-test versus post-test, irrespective across vibration and control conditions.

The raw scores for ground contact time (GCT) are displayed in Table 3. These scores show the duration of time each subject was in contact with the ground between multiple hops. Thus, a lower score indicates a better ground contact time than a higher score as this would indicate a more rapid transition from the landing phase to the take-off phase. In Table 3, a negative absolute difference between the pre- versus post-test score indicates decreased ground contact time from the training protocol. Conversely, a positive absolute difference represents increased ground contact time from the training protocol. For the control, nine subjects responded positively and 11 subjects responded negatively. For the vibration, 11 subjects responded positively and nine subjects responded negatively.
Table 3. Raw Scores Ground Contact Time. In seconds

<table>
<thead>
<tr>
<th>Subject Number</th>
<th>Control Pre GCT</th>
<th>Control Post GCT</th>
<th>Control Absolute Difference Pre versus</th>
<th>Vibration Pre GCT</th>
<th>Vibration Post GCT</th>
<th>Vibration Absolute Difference Pre versus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.70</td>
<td>0.66</td>
<td>-0.04</td>
<td>0.67</td>
<td>0.66</td>
<td>-0.01</td>
</tr>
<tr>
<td>2</td>
<td>0.81</td>
<td>0.79</td>
<td>-0.02</td>
<td>0.75</td>
<td>0.86</td>
<td>+0.11</td>
</tr>
<tr>
<td>3</td>
<td>0.57</td>
<td>0.56</td>
<td>-0.01</td>
<td>0.58</td>
<td>0.51</td>
<td>-0.07</td>
</tr>
<tr>
<td>4</td>
<td>0.43</td>
<td>0.42</td>
<td>-0.01</td>
<td>0.54</td>
<td>0.57</td>
<td>+0.03</td>
</tr>
<tr>
<td>5</td>
<td>0.47</td>
<td>0.56</td>
<td>+0.09</td>
<td>0.30</td>
<td>0.35</td>
<td>+0.05</td>
</tr>
<tr>
<td>6</td>
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<td>0.37</td>
<td>-0.04</td>
<td>0.36</td>
<td>0.36</td>
<td>0.00</td>
</tr>
<tr>
<td>7</td>
<td>0.68</td>
<td>0.71</td>
<td>+0.03</td>
<td>0.64</td>
<td>0.69</td>
<td>+0.05</td>
</tr>
<tr>
<td>8</td>
<td>0.48</td>
<td>0.43</td>
<td>-0.05</td>
<td>0.42</td>
<td>0.39</td>
<td>-0.03</td>
</tr>
<tr>
<td>9</td>
<td>0.33</td>
<td>0.40</td>
<td>+0.07</td>
<td>0.38</td>
<td>0.38</td>
<td>0.00</td>
</tr>
<tr>
<td>10</td>
<td>0.38</td>
<td>0.43</td>
<td>+0.05</td>
<td>0.44</td>
<td>0.37</td>
<td>-0.07</td>
</tr>
<tr>
<td>11</td>
<td>0.59</td>
<td>0.60</td>
<td>+0.01</td>
<td>0.54</td>
<td>0.51</td>
<td>-0.03</td>
</tr>
<tr>
<td>12</td>
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<td>-0.05</td>
<td>0.61</td>
<td>0.58</td>
<td>-0.03</td>
</tr>
<tr>
<td>13</td>
<td>0.65</td>
<td>0.67</td>
<td>+0.02</td>
<td>0.61</td>
<td>0.62</td>
<td>+0.01</td>
</tr>
<tr>
<td>14</td>
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<td>0.64</td>
<td>-0.02</td>
<td>0.64</td>
<td>0.67</td>
<td>+0.03</td>
</tr>
<tr>
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<td>0.53</td>
<td>0.54</td>
<td>+0.01</td>
</tr>
<tr>
<td>16</td>
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<td>+0.01</td>
<td>0.60</td>
<td>0.50</td>
<td>-0.10</td>
</tr>
<tr>
<td>17</td>
<td>0.42</td>
<td>0.48</td>
<td>+0.06</td>
<td>0.64</td>
<td>0.69</td>
<td>+0.05</td>
</tr>
<tr>
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<td>0.71</td>
<td>-0.02</td>
<td>0.76</td>
<td>0.78</td>
<td>+0.02</td>
</tr>
<tr>
<td>19</td>
<td>0.40</td>
<td>0.35</td>
<td>-0.05</td>
<td>0.29</td>
<td>0.36</td>
<td>+0.07</td>
</tr>
<tr>
<td>20</td>
<td>0.60</td>
<td>0.62</td>
<td>+0.02</td>
<td>0.62</td>
<td>0.69</td>
<td>+0.07</td>
</tr>
<tr>
<td>Mean</td>
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<td>0.00</td>
<td>0.55</td>
<td>0.55</td>
<td>0.00</td>
</tr>
<tr>
<td>SD</td>
<td>0.13</td>
<td>0.13</td>
<td>0.00</td>
<td>0.14</td>
<td>0.15</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

Note.
The raw scores for the explosive leg power factor (ELPF) are displayed in Table 4. The explosive leg power factor is measured in seconds by dividing the air time by the ground time. The objective was to jump as high as possible on each of the four hops, but also achieve minimal ground contact time between hops. A higher ELPF was representative of better reactivity versus a lower ELPF number. A positive absolute difference indicates an enhancement of ELPF from the training protocol, and a negative ELPF indicates a decrement from the training protocol. For the control, 13 subjects responded positively and seven subjects responded negatively. For the vibration, nine subjects responded positively and 11 subjects responded negatively.

Table 4. Raw Scores Explosive Leg Power Factor. In seconds

<table>
<thead>
<tr>
<th>Subject Number</th>
<th>Control Pre ELPF</th>
<th>Control Post ELPF</th>
<th>Control Absolute Difference Pre versus</th>
<th>Vibration Pre ELPF</th>
<th>Vibration Post ELPF</th>
<th>Vibration Absolute Difference Pre versus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.91</td>
<td>0.96</td>
<td>+0.05</td>
<td>0.94</td>
<td>0.92</td>
<td>-0.02</td>
</tr>
<tr>
<td>2</td>
<td>0.80</td>
<td>0.82</td>
<td>+0.02</td>
<td>0.85</td>
<td>0.74</td>
<td>-0.11</td>
</tr>
<tr>
<td>3</td>
<td>1.16</td>
<td>1.20</td>
<td>+0.04</td>
<td>1.15</td>
<td>1.32</td>
<td>+0.17</td>
</tr>
<tr>
<td>4</td>
<td>1.53</td>
<td>1.49</td>
<td>-0.04</td>
<td>1.19</td>
<td>1.11</td>
<td>-0.08</td>
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<tr>
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<td>-0.25</td>
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<tr>
<td>6</td>
<td>1.76</td>
<td>1.90</td>
<td>+0.14</td>
<td>1.86</td>
<td>1.88</td>
<td>+0.02</td>
</tr>
<tr>
<td>7</td>
<td>1.15</td>
<td>1.11</td>
<td>-0.04</td>
<td>1.20</td>
<td>1.10</td>
<td>-0.10</td>
</tr>
<tr>
<td>8</td>
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<td>1.38</td>
<td>+0.18</td>
<td>1.47</td>
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<td>+0.06</td>
</tr>
<tr>
<td>9</td>
<td>1.70</td>
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<td>-0.20</td>
<td>1.56</td>
<td>1.64</td>
<td>+0.08</td>
</tr>
<tr>
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<td>-0.28</td>
<td>1.44</td>
<td>1.73</td>
<td>+0.29</td>
</tr>
<tr>
<td>11</td>
<td>1.15</td>
<td>1.12</td>
<td>-0.03</td>
<td>1.29</td>
<td>1.36</td>
<td>+0.07</td>
</tr>
</tbody>
</table>
The raw scores for jump height (JH) are displayed in Table 5. This number is the jump height in inches. It measures the average height each subject jumped from the 4 jumps. A higher number means a higher jump height. A positive absolute score indicates a higher jump height enhanced by the training protocol, and a negative absolute score means jump height was not enhanced by the training protocol. For the control, 5 subjects responded positively and 14 subjects responded negatively. For the vibration, 7 subjects responded positively and 13 subjects responded negatively.

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td>1.07</td>
</tr>
<tr>
<td>13</td>
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<td>1.07</td>
<td>-0.05</td>
<td>1.19</td>
<td>1.15</td>
</tr>
<tr>
<td>14</td>
<td>0.97</td>
<td>0.99</td>
<td>+0.02</td>
<td>1.00</td>
<td>0.95</td>
</tr>
<tr>
<td>15</td>
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<td>1.42</td>
<td>+0.14</td>
<td>1.31</td>
<td>1.23</td>
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<td>0.92</td>
<td>+0.01</td>
<td>0.90</td>
<td>1.12</td>
</tr>
<tr>
<td>17</td>
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<td>1.09</td>
<td>-0.17</td>
<td>0.83</td>
<td>0.72</td>
</tr>
<tr>
<td>18</td>
<td>0.80</td>
<td>0.83</td>
<td>+0.03</td>
<td>0.78</td>
<td>0.73</td>
</tr>
<tr>
<td>19</td>
<td>1.16</td>
<td>1.25</td>
<td>+0.09</td>
<td>1.58</td>
<td>1.27</td>
</tr>
<tr>
<td>20</td>
<td>0.90</td>
<td>0.86</td>
<td>-0.04</td>
<td>0.88</td>
<td>0.75</td>
</tr>
<tr>
<td>Mean</td>
<td>1.20</td>
<td>1.19</td>
<td>+0.01</td>
<td>1.23</td>
<td>1.22</td>
</tr>
<tr>
<td>SD</td>
<td>0.30</td>
<td>0.27</td>
<td>+0.03</td>
<td>0.38</td>
<td>0.38</td>
</tr>
</tbody>
</table>
Table 5. Raw Scores Jump Height.

<table>
<thead>
<tr>
<th>Subject Number</th>
<th>Control Pre JH</th>
<th>Control Post JH</th>
<th>Control Absolute Difference Pre versus Post</th>
<th>Vibration Pre JH</th>
<th>Vibration Post JH</th>
<th>Vibration Absolute Difference Pre versus Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19.40</td>
<td>19.40</td>
<td>0.00</td>
<td>19.30</td>
<td>17.90</td>
<td>-1.40</td>
</tr>
<tr>
<td>2</td>
<td>20.50</td>
<td>20.20</td>
<td>-0.30</td>
<td>20.00</td>
<td>19.40</td>
<td>-0.60</td>
</tr>
<tr>
<td>3</td>
<td>21.30</td>
<td>21.40</td>
<td>+0.10</td>
<td>21.60</td>
<td>22.10</td>
<td>+0.50</td>
</tr>
<tr>
<td>4</td>
<td>20.60</td>
<td>19.20</td>
<td>-1.40</td>
<td>20.50</td>
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<td>-1.30</td>
</tr>
<tr>
<td>5</td>
<td>22.40</td>
<td>23.00</td>
<td>+0.60</td>
<td>22.60</td>
<td>23.40</td>
<td>+0.80</td>
</tr>
<tr>
<td>6</td>
<td>24.90</td>
<td>23.80</td>
<td>-1.10</td>
<td>22.10</td>
<td>22.40</td>
<td>+0.30</td>
</tr>
<tr>
<td>7</td>
<td>29.80</td>
<td>29.60</td>
<td>-0.20</td>
<td>28.60</td>
<td>27.90</td>
<td>-0.70</td>
</tr>
<tr>
<td>8</td>
<td>16.00</td>
<td>16.90</td>
<td>0.90</td>
<td>18.40</td>
<td>17.60</td>
<td>-0.80</td>
</tr>
<tr>
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CHAPTER V
DISCUSSION

Experimental Purpose

The purpose of this study was to test multiple jump performance subsequent to glute bridges with and without whole body vibration (WBV) used during the glute bridges. Multiple jump performance was assessed via a four-jump test to examine average jump height (JH), ground contact time (GCT), and explosive leg power factor (ELPF).

Multiple jump performance was assessed via a four jump test to examine average jump height, ground contact time, and the explosive leg power factor. It was hypothesized WBV while performing glute bridges at a frequency of 40 Hz would enhance multiple jump performance in CMJs than glute bridges without WBV. The results indicated no significant differences between the WBV and control conditions in multiple jump performance for the three variables assessed (i.e. average jump height, ground contact time, and the explosive leg power factor). Furthermore, there were no significant differences from the pre-test to the post-test (WBV and control conditions) in ground contact time and the explosive leg power factor.

Furthermore, a significant decline was observed from the pre-test to the post-test in average jump height for the multiple hop test for the WBV and control conditions. These results were in agreement with Magnus et al. (2006), Khamoui et al. (2009), Till & Cooke (2009), Mola et al. (2014), Bullock et al. (2008), and Batista et al. (2011). The results in these studies found little improvement to decreased performance in the CMJ. One reason for the decrements could have resulted from too much fatigue still present in each subject (at the post-test) or the amount of PAP had dissipated.
In the current study, subjects rested for four minutes after performing four sets of glute bridges. Magnus et al. (2006) had subjects rest three minutes after performing quarter and half squats; however, there was no effect on average jump height. The authors concluded the rest time may have been too long and any PAP effects were lost during the rest time. A four minute rest period was chosen in the present study because no external loading was used and therefore would not require as much rest. Till and Cooke (2009) used a seven minute rest period and found no improvements in the vertical jump. They speculated the rest period may have been too long and any PAP effect has dissipated. Along with rest period length, the authors noted intensity and volume could also have been a factor. It could have been that the volume was not high enough to elicit a PAP response, or the volume was too much and caused fatigue.

Training background has been shown in several studies to be responsible for affecting PAP. Duthie et al. (2002) found stronger subjects by relative strength had better improvements in peak force and power during jump squats, where the weaker subjects showed decrements in peak force and power. Relative strength was defined as the amount of weight lifted divided by the subject’s body weight. These findings are also in agreement with Young et al. (1998) who found stronger subjects having bigger increases on the vertical jump following a PAP activity than weaker subjects. Although there were only two current athletes that participated in this study, all the subjects had at least one year of prior resistance training experience. Strength levels were not assessed during the current study, nor what sports the subjects had participated in previously.

It has been shown in studies by Golhoffer, Schopp, Rapp, and Stroinik (1998), Grange and Houston (1991), Gullich and Schmidbleicher (1996) and Trimble and Harp (1998) there was an enhancement in twitch tension after performing high-intensity voluntary contractions, and maximal voluntary contractions (MVCs) produced short-term increases in explosive force in the
upper and lower body. This is thought to be associated with “an improved neuromuscular activation due to neuronal post tetanic potentiation (PTP) effects.” PTP occurs predominately in type II fast-twitch fibers and therefore athletes in anaerobic dominant sports may display a greater potentiation response compared to non-athletes. The subjects who did not show an increase may not have a high abundance of fast-twitch fibers, and therefore would have more fatigue than potentiation, as opposed to stronger subjects.

Chiu et al. (2003) divided subjects into either an athlete group or recreationally trained group. The subjects in the athlete group were currently involved in sports where the ability to produce explosive and high force in a small amount of time were required. The subjects in the athlete group were found to have a significantly higher force and power measures than the subjects in the recreationally trained group. In the current study, only two subjects were currently involved in a sport. Of the two subjects, one subject did respond positively with having a higher jump height from pre-test to post-test. The other subject involved in a sport responded negatively with having a lower jump height from pre-test to post-test. These findings show that although both subjects were athletes, sports which contain explosive and high force attributes may contribute to the PAP effect to a higher quality than athletes not involved in these sports.

The vibration frequency used in this study was 40 Hz, and jump performance was not improved as stated above. This finding is in disagreement with findings by Ronnestad (2009), Ronnestad and Ellefsen (2011), and Ronnestad et al. (2012) who found improvements in peak power, muscle EMG activity and improved 40 meter sprint times at a frequency of 50 Hz compared to no vibration, 20 Hz, and 35 Hz. These improvements were found in both trained and untrained subjects. Ronnestad (2009) concluded “if the main aim of WBV is to increase the
stimulus to the neuromuscular system to a greater extent than traditional power training, then WBV must create a larger overload.”

The subjects in the current study who did not show an improvement in jump height may not have been able to induce neural activation of the muscle, which would activate more motor units and the firing frequency of the motor units. Training status could have been one reason for this. Ronnestad (2009) also stated “the facilitating effect of vibration seems to be more pronounced in the high-threshold motor units than in the low-threshold motor units.” The present study used CMJs to assess multiple jump performance. The stretch reflex is utilized more efficiently during a CMJ than a squat jump (SJ), and therefore might be difficult for trained subjects to show an increase in the potentiation of the muscles (Bobbert, 2005).

The subjects in the present study performed bodyweight glute bridges, so no external load was used. Although an increase in EMG activity of the quadriceps has been shown with no external load and vibration compared to no vibration, the optimal vibration frequency for muscle activation and vibration transfer was found to be between 44-50 Hz by Issurin and Tenenbaum (1999). This vibration frequency of 40 Hz used in the present study may have been too low to elicit more muscle activity and therefore a PAP response. Although Cardinale and Lim (2003) found EMG activity of the vastus lateralis to be highest at a frequency of 30 Hz compared to 40 and 50 Hz with submaximal isometric actions and no external loads. This finding suggests the frequency used in the current study may have been too high, which has shown to have negative effects as well.

However, the findings above are in contrast with that of Cormie et al. (2006) who found no significant differences in isometric squat peak force, vertical jump peak power, and muscle activation among subjects who used vibration and in the control group assessed immediately and
30 minutes after. De Ruiter et al. (2003) found significant decrements in muscle force output and muscle activation after subjects performed 5 sets of static squats for 1 minute at 30 Hz. subjects rested 90 seconds to 180 seconds post-vibrations. The conflicting findings found from using different frequencies suggest high individuality of responses when used with vibration, and not one frequency alone is responsible.

The rest periods used in the current study between the preloading activity and multiple hop test was four minutes, and performance was not increased with and without vibration. These results are indistinguishable with Kilduff et al. (2007), Jo et al. (2010), and Lowery et al. (2012) who found potentiation to be highest at 4-12 minutes, with greater effects observed closer to 12 minutes. On the other hand, the rest period of four minutes used in the present study may have been too long since no external load was used, and any potentiation effect that was present may have dissipated within the four minutes. In a meta-analysis by Wilson et al. (2013), the authors concluded a moderate rest period of 7-10 minutes was found to be best for maximizing a PAP effect. The authors also stated “the efficacy by which a conditioning activity can stimulate PAP mechanisms and acutely enhance muscular performance ultimately depends on the balance between fatigue and potentiation.” Therefore, it is also possible the rest period used in the current study was not long enough for the potentiation to evolve, and therefore no increase in performance was shown. Chatzopolous found similar results when comparing rest periods of 3 and 5 minutes. Subjects improved their sprint times 5 minutes after executing back squat singles at 90% of their 1RM. Turner et al. (2015) found sprint times to be improved after 4 and 8 minutes with using body weight and 10% of body weight during a jump squat. There were also conflicting findings by Magnus et al. (2006) and McCann and Flanagan (2010) with some participants showing no response after 3 minutes, to some subjects both showing and not
showing a response after 4 and 5 minutes, respectively. The amount of conflicting findings show again the high individuality of PAP, different protocols used by researchers, and fitness levels of the subjects.

The type of conditioning activity may have had an effect on the performance of the subjects in eliciting a PAP response. Hamada et al. (2000) found positive increases in performance with pairing explosive bounding with sprints. The authors' theorized sprint velocities were increased because of the similar horizontal motions that bounding has in common with sprinting. Both bounding and sprinting have minimal vertical impulses and maximal horizontal impulses. This is in agreement with Till and Cooke (2009) who found subjects’ 10 and 20 meter sprint times to improve preceding a set of 5 tuck jumps. The authors concluded the decreases in sprint times could have resulted from the vertical direction of the tuck jumps intercepting with the horizontal component of sprinting and therefore no increase in performance among the subjects.

In the current study, glute bridges were paired with CMJs. Glute bridges are performed from a supine position and executed with the hips extending straight up. Although this is a vertical motion, it was still different from a CMJ with a maximal vertical direction and minimal horizontal direction. Each subject was laying on his or her back while performing a glute bridge and was standing when performing the CMJs. It is plausible that, as cited above, that no performance improvement was found because of the non-specificity pairing of a glute bridge and CMJ. Although the muscles involved in jumping include the gluteal muscles which are highly responsible for explosive power in the lower extremities, non-specific motions of a resistance exercise and explosive movement may not elicit a PAP response.
The current study used four sets of glute bridges with a 20 second hold at the top position where the hips were extended. Although a meta-analysis by Wilson et al. (2013) showed multiple sets to be superior to single sets for inducing a PAP response. The authors concluded less experienced individuals experienced a higher percentage of PAP with single sets over multiple sets, and more experienced individuals experienced a higher percentage of PAP with multiple sets over single sets. The authors believed the reason for this was because of the increase in fatigue outweighing the effect of PAP in less experienced individuals, and the amount of PAP outweighing the effect of fatigue in more experienced trained individuals. The four sets used in the current study may have provoked too much fatigue, which masked the PAP response, with a decrease in jump performance. Clark, Bryant, and Reaburn (2006) had subjects perform one preloading set of loaded CMJs and found improved jump height for a lower body power session compared to the control group. These results were in disagreement with Magnus et al. (2006), Hanson et al. (2007), and Khamoui et al. (2009) who found no improvements in jump performance and PAP response after having subjects perform single sets. However, Gullich and Schmidtbleicher (1996), Jensen and Ebben (2003), and Young et al. (1998) found improvements in jump performance and a PAP to be elicited with subjects performing single sets. These conflicting findings in studies show again how the PAP response is highly individual and the methodological factors stated earlier are responsible.
Limitations

The current study had many limitations. Subjects were told to refrain from strenuous lower body exercise 48 hours prior to testing and maintain their normal hydration, sleep, and nutrition levels. Each testing session took place at the same time separated by 72 hours. Body weight was also recorded and measured before each testing session. It is possible some subjects did not get much sleep or eat a normal amount the day before or day of a testing session. This would have impacted their jump performance and recovery for the next testing session. It is also possible subjects did not refrain from intense lower body exercises 48 hours before each testing session, and therefore could have impacted the variables assessed in multiple jump performance.

Another limitation of the current study is the familiarity the subjects had with glute bridges and CMJs. Although one familiarization session was conducted as practice, some subjects did not perform the glute bridges or CMJs well. The glute bridge and CMJ do not seem to be exercises many people perform regularly, and therefore would need an adequate amount of time to do them well. Certainly more familiarity and better skill at these movements could have resulted in more improved jump variable scores. This is in agreement with Chiu et al. (2003) who showed athletes that were currently involved in sports requiring explosive movements like running and jumping improved their power and force more than recreationally trained individuals who were not currently involved in sports. The athletes were accustomed to regularly jumping, which made their skill level high at performing them in this study.
Conclusions

The current study indicates performing four sets of glute bridges with WBV and then performing four CMJs did not improve jump height, explosive leg power factor, or ground contact time compared to not using WBV. However, this is not to say the glute bridge and CMJ are not effective exercises and shouldn’t be examined in future studies. The glute bridge may be useful for strengthening the gluteus muscles, and the CMJ can be used as an effective plyometric exercise. The effect of PAP vary between individual testing protocols. Future research should be focused on manipulating volume, type of conditioning activity used, intensity, rest periods, different populations, and gender to see further differences and improvements.
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targeting the gluteal muscle group acutely enhance explosive power output in elite

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enhances upper-and lower-body athletic performance in collegiate males and

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CONSENT TO PARTICIPATE IN RESEARCH

Effect of Postactivation Potentiation Succeeding Glute Bridge Exercise on Multiple Jump Performance in Recreationally Trained Individuals

You are invited to participate in a study by Dr. Jeffrey Willardson, an associate professor at the Kinesiology and Sports Studies Department at Eastern Illinois University, and Anthony Warpecha, a graduate student at Eastern Illinois University. Your participation in this study is entirely voluntary. Please ask questions about anything you do not understand, before deciding whether or not to participate.

Purpose

The purpose of this study is to test jump height performance subsequent to glute bridges with and without whole-body vibration.

Procedures

If you volunteer to participate in this study, you will be asked sign a consent form before participating. After signing you will then be split up randomly into two groups. One familiarization session will take place where proper form of the glute bridge is shown, and the procedure of the study. One group will be the control group which will consist of glute bridging on a step platform with no vibration. The second group will be the experimental group which will consist of glute bridging on a step platform with a vibration of 40 Hz. You will hold the glute bridge for twenty seconds with a minute of rest in between each set for a total of four sets. After about four minutes of rest, you will then be asked to jump as high and fast off the ground as possible on a just jump mat. You will perform this study twice with seventy-two hours of rest in between each session. Results will be documented and given to the head researcher to be saved.

Potential Risks and Discomforts

There will be minimal risk involved in this study. Some muscle soreness may result from performing a glute bridge and jumping during each session. In case of injury, you may seek immediate medical care at your own expense at the EIU Student Health Center (581-3014). The participant will also be monitored if any signs of abnormal breathing, feelings of nausea, dizziness, muscle cramps, or fatigue are shown and assessed accordingly. If you feel you are in a situation that may result in any kind of increased risk, let us know and we will stop the test immediately. There will be a team member present at all times who is certified in CPR, First Aid, and Automated External Defibrillator (AED) administration. If you wish to withdraw your participation in the study, you may do so.

Potential Benefits
The benefits of participation in the proposed research project with respect to increasing
generalizable knowledge outweigh the risks of participation since those risks are minimal. You
will learn proper glute bridge technique, and well as understanding how this affects jump height.
You will also gain insight into the research process.

Confidentiality

Any information that is obtained in connection with 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 storing the data in a folder and put in a drawer.
The data will also be in a backpack when used to record data, and will remain confidential from
the other participants and public. The records of this study will be kept private. In any sort of
report we might publish, we will not include any information that will make it possible to
identify a participant.

Participation and Withdrawal

Participation in this research study is voluntary and not a requirement or a condition for being the
recipient of benefits or services from Eastern Illinois University or any other organization
sponsoring the research project. If you volunteer to be in this study, you may withdraw at any
time without consequences of any kind or loss of benefits or services to which you are otherwise
entitled. There is no penalty if you withdraw from the study and you will not lose any benefits to
which you are otherwise entitled.

Contact Information

I understand that if I have any questions concerning the purposes or the procedures associated
with this research project, I may contact:

Principal Investigator: Dr. Jeffrey Willardson
Phone Number: (217) 581-7592
Email: jmwillardson@eiu.edu

Co-Investigator: Anthony Warpecha
Phone Number: (815) 501-7801
Email: ajwarpecha@eiu.edu

Rights of Research Subjects

If you have any questions or concerns about the treatment of human participants in this study, you
may call or write:

Institutional Review Board
Eastern Illinois University
600 Lincoln Ave.
You will be given the opportunity to discuss any questions about your rights as a research subject with a member of the IRB. The IRB is an independent committee composed of members of the University community, as well as lay members of the community not connected with EIU. The IRB has reviewed and approved this study.

I voluntarily agree to participate in this study. I understand that I am free to withdraw my consent and discontinue my participation at any time. I have been given a copy of this form. However, I understand what is expected if I agree to participate and will diligently follow the procedures for the group to which I am assigned.

______________________________
Printed Name of Participant

______________________________      ____________
Signature of Participant          Date

I, the undersigned, have defined and fully explained the investigation to the above participant.

______________________________      ____________
Signature of Investigator          Date
Data Collection Sheet

NAME: ____________________________ DATE: ________________

HEIGHT: _______ in. WEIGHT: _________ lbs. AGE: _________

PHYSICIANS NAME: __________________ PHONE: ____________

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

Questions Yes No

1 Has your doctor ever said that you have a heart condition and that you should
only perform physical activity recommended by a doctor?

2 Do you feel pain in your chest when you perform physical activity?

3 In the past month, have you had chest pain when you were not performing any
physical activity?

4 Do you lose your balance because of dizziness or do you ever lose
consciousness?

5 Do you have a bone or joint problem that could be made worse by a change in
your physical activity?
6 Is your doctor currently prescribing any medication for your blood pressure or for a heart condition?

7 Do you know of any other reason why you should not engage in physical activity?

If you have answered “Yes” to one or more of the above questions, consult your physician before engaging in physical activity. Tell your physician which questions you answered “Yes” to. After a medical evaluation, seek advice from your physician on what type of activity is suitable for your current condition.

GENERAL & MEDICAL QUESTIONNAIRE

Occupational Questions Yes No

1 What is your current occupation?

2 Does your occupation require extended periods of sitting?

3 Does your occupation require extended periods of repetitive movements? (If yes, please explain.)
4 Does your occupation require you to wear shoes with a heel (dress shoes)?

5 Does your occupation cause you anxiety (mental stress)?

Recreational Questions  Yes  No

6 Do you partake in any recreational activities (golf, tennis, skiing, etc.)? (If yes, please explain.)

7 Do you have any hobbies (reading, gardening, working on cars, exploring the Internet, etc.)? (If yes, please explain.)

Medical Questions  Yes  No

8 Have you ever had any pain or injuries (ankle, knee, hip, back, shoulder, etc.)? (If yes, please explain.)
9 Have you ever had any surgeries? (If yes, please explain.)


10 Has a medical doctor ever diagnosed you with a chronic disease, such as coronary heart disease, coronary artery disease, hypertension (high blood pressure), high cholesterol or diabetes? (If yes, please explain.)


11 Are you currently taking any medication? (If yes, please list.)


