A Thesis

Entitled

Muscle Activity of Primary and Core Muscles of Seated Overhead Press with Unstable Load

By

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Submitted to the Graduate Faculty as partial fulfillment of the requirements for the Master of Science Degree in Exercise Science

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An Abstract of

Muscle Activity of Primary and Core Muscles of the Seated Overhead Press with Unstable Loads

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Core muscle strength and coordination are important components to resistance training and sports performance. Unstable training (UT), further divided into unstable surface training (UST) and unstable load training (ULT), is commonly chosen to improve core muscle strength. ULT has been accomplished by suspending resistance from a barbell with bands, allowing it to move vertically, but research has not been done on a horizontal type of ULT. The purpose of this study was to measure the impact of horizontal dynamic instability (HDI) on prime mover and core stabilizer muscle activity, during the seated overhead press, through use of electromyography (EMG). HDI was compared to a traditional type of ULT as well as stable load training (SLT). Thirteen resistance trained males (age = 24.1±2.4 years, height = 178±7.2cm, mass = 84.1±9.4 kg) participated in all three condition assignments. Subjects tested their 5-RM strength on the seated overhead press and performed five repetitions at 50% 5-RM strength for condition assignments. Electrodes were attached to 8 muscles (anterior deltoid, triceps brachii, upper trapezius, right & left external oblique, right & left rectus abdominis, erector
spinae). Concentric and eccentric muscle actions were analyzed separately across all repetitions. Mean voltage of activation was acquired and processed (band pass filter 10-500 Hz, rectified, RMS 50ms window and normalized) and significance was set at p <0.05. A two-way RM ANOVA was used to compare condition x muscle action.

Anterior deltoid and upper trapezius activity was higher during ULT concentric compared to SLT and HDI concentric. Erector spinae activity was higher during SLT and HDI concentric compared to ULT concentric. Left external oblique activity differed significantly between HDI and ULT eccentric, but no differences occurred at the right external oblique. These results suggest that HDI may require external oblique activity to a similar magnitude as traditional ULT. Continued research on HDI should address other exercises or loading intensities.
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Chapter One

Introduction

1.1 Introduction

The benefits of strengthening and proper coordination of core muscles are particularly applicable to the strength & conditioning community (Behm, Drinkwater, Willardson, & Cowley, 2011). A well-developed and well-coordinated selection of stabilizer muscles, ranging from limb stabilizers to trunk/spinal stabilizers (core muscles), has shown a reduction in low back pain (Chang, Lin, & Lai, 2015) and improvement in throwing velocity (Saeterbakken, van den Tillaar, & Seiler, 2011). Particularly, core stabilization can be effective in closed kinetic chain activities, in that stability within the trunk enables mobility and efficiency in the limbs (Kibler, Press, & Sciascia, 2006). In absence of stabilization or lack of core muscle coordination, limb movements can become inefficient and loss of force transfer occurs (Fredericson & Moore, 2005). As proposed by Fredericson & Moore (2005), strengthening and coordinating core muscles can improve efficiency and force transfer during closed kinetic chain tasks. To improve the strength of any type of skeletal muscle, resistance training is commonly used (Baechle & Earle, 2008). The mechanism by which resistance training can hypertrophy and strengthen skeletal muscle has been well established in research (Schoenfeld, 2010). Through muscle hypertrophy, the size and quantity of contractile units expands in a muscle, and performance improvements such as maximal muscle strength are achieved.
These improvements can certainly apply to core muscles if they are properly targeted and trained. Regarding the proper targeting of core muscles, one method consists of resistance training with some degree of instability, known as unstable training (UT). There are two further branched sections within UT; unstable surface training (UST) and unstable load training (ULT).

Of the two sections of UT, UST has been more thoroughly researched (Behm, Muehlbauer, Kibele, & Granacher, 2015). UST has been compared to a traditional stable surface in previous research. Electromyography (EMG), which is commonly utilized to report on neuromuscular voltage and activity (Kasman & Wolf, 2002), has shown significant decreases in activity when exercising on an unstable surface compared to a stable surface (Saeterbakken & Fimland, 2013b). The loss is commonly seen in prime mover muscles, which directly play a role in completion of movement (Saeterbakken & Fimland, 2013b). Findings on force output have been inconsistent, as it has been found to not change (Goodman, Pearce, Nicholes, Gatt, & Fairweather, 2008) or decrease despite maintaining EMG of muscles (K. G. Anderson & Behm, 2004). When comparing stable and unstable surfaces, as long as the loading intensity is similar between conditions, core muscle activity can be augmented by usage of UST, as seen in the chest press (Campbell, Kutz, Morgan, Fullenkamp, & Ballenger, 2014; Marshall & Murphy, 2006). Research findings such as those of Marshall & Murphy (2006) would establish the notion that usage of instability can stress the muscles of the core to improve upon coordination, neuromuscular control, and thus the improved transfer of power along the kinetic chain (Behm et al., 2011). Unstable surfaces, however, are not commonly encountered in daily living scenarios.
Most activities performed in sport or in daily living utilize stable surfaces and encounter instability in the form of unstable resistance. Examples exist in daily living when carrying grocery bags into the house or carrying a container full of objects, which displace unpredictably from within. Most athletic encounters utilize a stable surface as well, with a dynamic load against which the athlete resists such as an opponent player in football, rugby or martial arts. Some athletic endeavors utilize an implement such as a racquet, bat, or club against which dynamic objects (tennis ball, baseball etc.) are resisted. Thus, it would be more practical to approach core muscle strengthening and coordination from a ULT modality. This would be in accordance with the Specific Adaptation to Imposed Demands (SAID) principle (Baechle & Earle, 2008), which states that an organism will adapt to the specific stress that is utilized in a resistance training session. Highly intensive, high force-output exercises will necessitate adaptations for highly intensive sports scenarios such as a football play whereas long duration, steady state exercises necessitate endurance-based adaptations utilized by cross country and marathon athletes (Baechle & Earle, 2008). It is proposed that ULT will more specifically mimic an environment where core coordination and neuromuscular control are needed.

There are limitations on the research in ULT. The unstable component in ULT has only been achieved through a few select means. Kohler (2010) and Campbell (2014) have examined the uncoupling of left and right hand movements, as seen in dumbbell exercises. Initially, loss of EMG seems to occur for prime movers and core stabilizers alike when using ULT (Kohler, Flanagan, & Whiting, 2010), but utilizing a constant load between stable and unstable conditions demonstrated the same augmenting of core muscle activity as seen in UST protocols (Campbell et al., 2014). Another method of
achieving instability for ULT is through use of dynamic instability (DI). Particularly, DI can be achieved by suspending a percentage of the resisted weight via elastic bands from the resistance implement (Dunnick, Brown, Coburn, Lynn, & Barillas, 2015). The suspension of weight from the bar allows the weight to displace unpredictably in a vertical direction, thus falling in the category of ULT through use of vertical dynamic instability (VDI). When controlling for load, the notion is further proven that prime mover EMG is unchanged (Dunnick et al., 2015) and core muscle EMG is augmented (Lawrence & Carlson, 2015) through usage of VDI.

Presently, there is limited research on ULT and the DI subcategory. Current research relates ULT and DI to allowing the resistance to follow a vertical displacement path. Examples are seen with Dunnick (2015) and Lawrence (2015), where bands are utilized to suspend weight from the collars of a traditional bar. A flexible bar has been utilized in place of a traditional bar to further contribute to DI (Ostrowski, Carlson, & Lawrence, 2016). Even with reduced total load relative to a stable condition, flexible bar usage was shown to maintain EMG of limb stabilizers during the bench press exercise (Ostrowski et al., 2016). The flexible bar would similarly fall into the category of VDI. Research has yet to be performed on DI in the form of horizontal dynamic instability (HDI) and if it is capable of achieving a similar degree of core muscle stimulus as seen in ULT. HDI can be achieved by hollowing out an axle and putting wheel bearings inside of it, allowing for a horizontal direction in which the dynamic component of unstable resistance is created.

In addition, core muscle EMG electrode placement in ULT research has been approached in a unilateral perspective (Kohler et al., 2010; Lawrence & Carlson, 2015).
In research done by Lawrence (2015), the squat was analyzed through use of electrode placement on core muscles of only one side of the body. Due to the dynamic nature of ULT, core muscles may exhibit a side-to-side difference if exposed to instability. Based on this estimation, bilateral examination of the core is warranted in a research setting. Ostrowski (2016) performed a bilateral examination of the upper limb stabilizers during a ULT bench press while utilizing VDI. In this study, the left middle deltoid was found to have higher activation during the VDI protocol while the right middle deltoid was unchanged (Ostrowski et al., 2016). There may be a difference between left and right core muscle groups when utilizing an HDI mechanism.

The potential differences that HDI causes in a resistance exercise can be further comprehended if eccentric and concentric actions are analyzed separately. Lauver (2015) and Dunnick (2015) analyzed the bench press during different phases of the exercise to further quantify the relationship between muscle activity and angle of bench press (Lauver, Cayot, & Scheuermann, 2015) and usage of VDI (Dunnick et al., 2015), respectively.

DI has been investigated in the bench press (Ostrowski et al., 2016) and squat (Lawrence & Carlson, 2015). Based on the data reported by Lawrence (2015), resistance movements that have an inherent degree of instability (i.e. Squat) may show a stable vs. unstable difference in core muscles compared to more stabilized movements such as bench presses (Dunnick et al., 2015). Kohler (2010) had investigated the overhead press while seated and unsupported (no back support), but did not implement DI. Further, the extent of DI is limited to the vertical direction. Therefore, the purpose of this study was to use an EMG to investigate the impact of HDI on core and prime movers muscle activity...
of the seated, unsupported overhead press during eccentric and concentric actions to a stable load training (SLT) method and ULT.

1.2 Statement of Purpose

The purpose of the study was to investigate HDI’s impact on prime mover and core stabilizer muscles, during the seated unsupported overhead press, through use of EMG. HDI’s impact was compared to a stable bar’s impact and a pair of dumbbells’ impact on the same prime movers and core muscles. The stable bar served as the SLT control while the dumbbells served as a baseline ULT without DI, as seen in research by Kohler (2010). All conditions were broken into eccentric and concentric actions to further quantify any potential differences. The study was intended to address the lack of bilateral examination of core muscle EMG in recent studies of the overhead press as well as the implementation of HDI.

1.3 Significance of the Study

ULT’s efficacy in strength training protocols is relatively unknown to the strength and conditioning community, as more focus has been on UST in recent years (Behm et al., 2011). More research on the topic will further qualify its efficacy to training programs. Regarding efficacy, research must show which ULT implementations are capable of strengthening the core muscles and if they significantly differ from traditional training methods. If HDI is found to require significantly more core muscle activity compared to ULT, then HDI can be utilized in training programs in which core strengthening is a pertinent goal.

1.4 Hypotheses
Aim 1: *Compare HDI, ULT and SLT effect on muscle activity*

**H₁₁:** There will be a significant increase in the core muscle EMG (quantified by right RA, left RA, right EO, left EO, and ES) due to the HDI condition when compared to the SLT condition in the seated, unsupported overhead press.

**H₁₂:** There will be no significant difference in prime mover EMG (quantified by AD, TRAP, and TRI) when comparing the HDI condition to the SLT condition in the seated, unsupported overhead press.

**H₁₃:** There will be a significant increase in the core muscle EMG (quantified by right RA, left RA, right EO, left EO, and ES) due to the ULT condition when compared to the SLT condition in the seated, unsupported overhead press.

**H₁₄:** There will be no significant difference in prime mover EMG (quantified by AD, TRAP, and TRI) when comparing the ULT condition to the SLT condition in the seated, unsupported overhead press.

**H₁₅:** There will be no significant difference between any muscle EMG when comparing the ULT condition to the HDI condition.

Aim 2: *Compare concentric and eccentric effect on muscle activity across all conditions*

**H₂₁:** There will be a significant difference between all muscle EMG when comparing the concentric action of the lift to the eccentric action of the lift for all conditions (ULT, SLT, and HDI).
Chapter Two

Literature Review

2.1 Core

The literature on the subject of core musculature has consistently affirmed its importance in stabilization of the spine and pelvis (Behm et al., 2011; Willardson, 2007). Fredericson & Moore (2005) reported on the subject of strengthening the core for running performance, and specifically reported on a skill referred to as coordinating the core. A core that lacks coordination fails to efficiently transfer force through the limbs (Fredericson & Moore, 2005). Athletes ranging from novice and beginner to professional may potentially lack core coordination relative to their sports movements (Fredericson & Moore, 2005). Due to the inefficient transfer of force during sports movements, athletes begin to compromise their movement patterns, the implications of which include a below optimal performance and risk of injury (Fredericson & Moore, 2005).

Along with coordination, another tenant of core muscles is strength. Strengthening of the muscles within the core and improvement of the core’s coordination are in continuum (Saeterbakken, van den Tillaar, & Seiler, 2011). Saeterbakken (2011) proposed that progression in a core stability training program made for handball players is facilitated through improvement in core strength and/or coordination (Saeterbakken, van den Tillaar, & Seiler, 2011). The progression within the study consisted of added
challenges in the context of each exercise (incremental decreases in stability) along a 9-week training period. The end-result was a significantly increased handball velocity compared to a control group, whom participated in regular training, practice and gameplay (Saeterbakken, van den Tillaar, & Fimland, 2011). Strength in the core facilitates force production proximally, allowing more force to be outputted distally (Kibler et al., 2006; Saeterbakken, van den Tillaar, & Fimland, 2011). In the study by Saeterbakken (2011), it is reasoned that the core’s improved ability to produce force is what contributed to the improved velocity of the handball. The mechanisms by which core muscle strength can be improved is through hypertrophy (Schoenfeld, 2010) as well as through repeated exposure to core stabilizing tasks (Kibler et al., 2006).

The core has been described as a “tenant of functional movements” (Kohler et al., 2010). Most activities that occur in daily life would be described as functional, in accordance to Kohler’s (2010) definition. A functional movement is one in which multiple muscles and joints are utilized in a multi-planar setting (Kohler et al., 2010). Activities in sport and daily living both fit the definition of functional movements, with sports movements particularly occurring with higher intensity and thus with a higher risk for injury. Stability within the pelvis and spine can potentially improve through implementation of functional movements (Kohler et al., 2010). Muscles that stabilize the limbs, such as hip rotators, glutei and rotator cuffs are attached to the core, and these muscles are responsible for initiating the transfer of force to more distal segments such as the hands and feet (Kibler et al., 2006). Kibler et al. (2006) described the core as a foundational base for movement of the limbs. Regarding functional movements, the limbs would theoretically require mobility to effectively and efficiently navigate the
multi-planar setting. The core is thus said to provide distal mobility through implementation of proximal stability (Kibler et al., 2006). This is particularly necessary in multi-planar scenarios such as sports play and daily living tasks in which the core acts as a stable base to allow output of an optimal amount of force (Willardson, 2007).

The core has been identified as the lumbopelvic hip complex and its surrounding muscles (Saeterbakken & Fimland, 2012). More broadly, the core has been referred to as the axial skeleton and all soft tissue with origins located within it (Behm, Drinkwater, Willardson, & Cowley, 2010a). Superficial muscles (ie. rectus abdominis, erector spinae) have been termed “global muscles,” being responsible for producing and transferring force between the articulating body regions (Willardson, 2007) while “local muscles” (ie. multifidus, transverse abdominis) stabilize the core (Fredericson & Moore, 2005; McGill, 2001). Stabilizing the core is achieved by generating tension within the local muscles (McGill, 2001; Willardson, 2007). Once stabilization is achieved, neuromuscular control and feedback mechanisms such as muscle spindles function in a feed-forward way to adjust tension within the core as needed (Willardson, 2007). This muscle activity results in compression of the vertebrae, forcing them into stiffer and more stable links (Willardson, 2007). Souza (2001) reported that global muscles play just as significant a role in stabilizing the core as local muscles. Specifically, the rectus abdominis stabilizes the core in the anteroposterior direction while oblique muscles contribute to stabilization during mediolateral rotation (Souza, Baker, & Powers, 2001).

2.2 Kinetic Chain

Stabilization of the core, a skill which is improved through increasing core strength (Saeterbakken, van den Tillaar, & Seiler, 2011), coordination (Fredericson &
Moore, 2005), and exposure to core stabilizing tasks (Kibler et al., 2006), is thought to play a role in the function of the kinetic chain (Kibler et al., 2006). More particularly, the stabilized core is thought to contribute to the function of a closed kinetic chain (CKC) (Karandikar & Vargas, 2011), and thus CKC activities such as rugby scrums, football tackles, and free weight exercises (Baechle & Earle, 2008). A CKC consists of fixed distal segments such as the feet that transmit kinetic energy through the segments of the body until it becomes outputted (Karandikar & Vargas, 2011).

The purpose of the kinetic chain in the context of core stabilization is to allow for optimal sequencing and activation of all body segments involved in the specified task such as carrying, throwing or actively resisting (Kibler et al., 2006). The muscles within the core are said to stiffen the spine, thus reducing its mobility in order to enhance stability (McGill, 2001; Willardson, 2007). Due to the wide range of degrees of freedom within a spinal vertebra, poor coordination (a single muscle failing to apply the correct amount of tension) can lead to instability (McGill, 2001). A lack of instability within the spine will cause the aforementioned inefficiency in transferring force along the kinetic chain as well as potential injury (Fredericson & Moore, 2005).

2.3 Unstable training

In reference to the SAID principle, exercise selection is made with the intent to warrant a specific adaptation based on the needs of the exerciser (Baechle & Earle, 2008). Common resistance exercises for upper and lower body strengthening have been modified through implementation of instability (Willardson, 2007). Training of core muscles can generally be achieved through usage of heavy, ground-based, free-weight exercises, but UT is recommended as a supplement to a training program as opposed to
being the primary focus (Behm, Drinkwater, Willardson, & Cowley, 2010b). Usage of
unstable training may be more appealing to non-athletic and rehabilitative populations as
they are less likely to comply with heavy, ground-based, free weight exercises (Behm et
al., 2010b). Similar muscle activation magnitudes can be achieved with a lower force
output through usage of unstable training (K. G. Anderson & Behm, 2004). Lower force
outputs during training may appeal to non-athletic and rehabilitative populations where
high impact is either deliberately avoided, as with the non-athletic populations, or
contraindicated for rehabilitation to occur within injured populations (Willardson, 2007).

In the literature, unstable training has been approached through two distinct
means. The first of which is unstable surface training (UST), which puts the body’s
posture into disequilibrium and shifts the center of mass more unpredictably than a
traditional ground-based exercise (Behm et al., 2011). Unstable load training (ULT) by
comparison utilizes implements that are either uncoupled, as is the case with dumbbells
(Campbell et al., 2014), or are designed to be dynamic and unstable (Lawrence, Leib,
Ostrowski, & Carlson, Publish ahead of print; Ostrowski et al., 2016). Besides utilizing
specifically unstable equipment, a traditional resistance implement such as a barbell can
be outfitted with elastic bands to produce instability (Lawrence & Carlson, 2015).

2.3.1 Unstable surface training

Anderson & Behm (2004) analyzed upper body resistance exercise on a stable
bench and a stability ball. EMG was reported to not differ significantly at the level of
prime mover muscles, limb stabilizers and core stabilizer (specifically the rectus
abdominis) while force output, quantified with a strain gauge, was significantly lower in
executed a similar experiment with free weight bench pressing. Results were similar, as total force output (quantified by 6-repetition maximum strength) was lower in the stability ball condition. The unstable condition enhanced EMG of the rectus abdominis (Saeterbakken & Fimland, 2013b), thus verifying the practicality of using an unstable surface in upper body resistance training protocols.

Goodman et al (2008) had found that EMG and force output were maintained between a stable and unstable bench press during 1-RM strength testing (Goodman et al., 2008). This finding provides a contradiction to the findings of Anderson & Behm (2004), whom found a decrease in force output in a similarly unstable condition but with maintained EMG amplitudes across all muscle groups.

Marshall & Murphy (2006) utilized loads equating to 60% of maximum force output on a Swiss ball dumbbell press and stable dumbbell press. Anterior deltoid muscle activity (a prime mover of chest press exercises) and abdominal muscles were both recruited to a higher magnitude when using the unstable surface (Marshall & Murphy, 2006). In contrast to the findings of Anderson & Behm (2004) and Saeterbakken & Fimland (2013), this study utilized a consistent load between the two stability conditions and showed an augmentation of core muscle activity.

With regards to lower body exercise, McBride et al (2006) reported on isometric squats. Prime mover EMG had either not differentiated (gastrocnemius and biceps femoris) or were decreased (vasti). The study had not examined core musculature, but did find a loss of peak force (McBride, Cormie, & Deane, 2006) similar to the upper body studies. Anderson & Behm (2005) examined the squat exercise with a variety of stability requirements (Smith squat, free range squat, balance disc squat) and found that
abdominal and erector activity was significantly higher with more surface instability. Interestingly, prime movers of the squat had either been increased with instability (soleus) unchanged (biceps femoris) or slightly decreased (vasti) (K. Anderson & Behm, 2005).

While there are mixed results on limb activity in response to UST, research has more clearly suggested that UST is effective for core stability training (Willardson, 2007). Norwood et al (2007) analyzed muscles of the core (rectus abdominis, internal oblique, erector spinae) during a bench press while implementing instability at the feet, torso, or both. A significant increase was seen within the internal oblique while utilizing instability vs. stability, but did not differ between levels of instability (Norwood, Anderson, Gaetz, & Twist, 2007). This finding would indicate that if increased activity in core muscles is desired, it is only necessary to implement instability at the feet or at the torso (Norwood et al., 2007). Behm et al (2005) found instability to have a significant effect on lower-abdominal activation relative to a stable surface, particularly when performing the side bridge exercise. A variety of exercises were performed on either a Swiss ball or a stable surface, and usage of the unstable Swiss ball resulted in 27.9% more activation of the abdominal stabilizers (Behm, Leonard, Young, Bonsey, & MacKinnon, 2005). Further, the side bridge resulted in significantly more activation compared to the other exercises, which produced anywhere from 13.9-48.2% of the side bridge amplitude (Behm et al., 2005). Vera-Garcia et al (2000) observed double the amplitude of rectus abdominis activity during a curl-up performed on a Swiss ball compared to a stable bench, and fourfold increases in external oblique activity to keep the body from laterally sliding off of the ball (Vera-Garcia, Grenier, & McGill, 2000). The
findings of Vera-Garcia et al (2000) and Behm et al (2005) indicate the practicality of implementing progressively more challenging methods of traditional core exercises to enhance stability and motor control.

Implementing UST can be particularly helpful for formerly sedentary and rehabilitation populations. Vera-Garcia et al (2000) had highlighted the importance of being able to tolerate spinal compression, which occurs during the core stabilization process (Vera-Garcia et al., 2000). In a research review by Behm et al (2011), it was stated that lower impact exercises with lower external resistance may be necessary for individuals with low back pain and lack of muscular coordination. Neuromuscular control and “intermuscle coordination” are considered necessary for ground-based, heavy free-weight resistance exercises (ie. Squatting, pressing). Furthermore, sufferers of low back pain exhibit impairments with intermuscle coordination and thus, UST may be a healthy alternative (Behm et al., 2011).

A limitation to UST is in the ability to implement progression and progressive overload. Marshall and Desai (2010) had claimed that due to the lack of sufficient external resistance (as seen in free-weight training), the primary modality for progression in UST is through increasing repetitions. While higher repetition ranges can enhance muscular endurance (Marshall & Desai, 2010), it may be necessary to utilize ground-based free weight exercises to address core strength and power aspects during certain program phases (Willardson, 2007). In addition, there is ongoing discussion in the strength & conditioning community in regards to how safe it is to execute conventional free-weight exercises on an unstable surface and if the risk is worth the benefits (Behm et al., 2011; Marshall & Desai, 2010).
2.3.2 Unstable load training

Kohler (2010) reported on the seated overhead press as it pertains to training with unstable loads. The study approached ULT from an uncoupled perspective (using dumbbells) while being compared to a stable load training (SLT) control group. By uncoupling left and right hand movements, each arm executes their resisted range of motion independent of each other. In Kohler’s (2010) study, a relative resistance for each lifting condition was determined through a 10-repetition max strength test. The ULT condition had a lighter resistance relative to the SLT condition, in which a barbell was used. Prime movers either significantly loss activation (triceps) or sustained activation (anterior deltoid, trapezius) in the ULT condition, when compared to SLT. The same was found in regards to core stabilizers, where EMG was either significantly lost (erector spinae) or sustained (external oblique, rectus abdominis) (Kohler et al., 2010).

The usage of a relative resistance within each condition yielded a significantly lighter resistance for the ULT condition compared to the SLT condition. Kohler (2010) attributed the loss of strength in the ULT method to the added instability, suggesting that there is an inverse relationship between force output and instability of implement. The resulting loss of triceps EMG is proposed to be due to a loss of neural drive and concomitant antagonist activity (biceps) to accommodate the instability (Kohler et al., 2010). Maintenance of EMG at the trapezius and anterior deltoid was thought to be due to their function as stabilizers in the glenohumeral joint and scapula (Kohler et al., 2010). Finally, the SLT positioning was said to increase the external torque against which the erector spinae had to overcome, explaining why ULT resulted in a loss of activity within that muscle group (Kohler et al., 2010).
Saeterbakken (2013) investigated the overhead press with two levels of instability, one at the resistance implement (bilateral or unilateral dumbbell) and one at the positioning of body (seated vs. standing) and found a regression of 1 repetition maximum (1-RM) strength as instability increased. While the standing unilateral overhead press (most unstable) had the lowest 1-RM strength, it also resulted in the greatest magnitude of activation for the anterior deltoid despite the loss of strength (Saeterbakken & Fimland, 2013a). Higher biceps activity was observed in the more unstable conditions, which supports the aforementioned proposition of antagonist accommodation for unstable loads (Saeterbakken & Fimland, 2013a).

2.4 Dynamic Instability

In current research, a common approach to ULT is through creating DI, in which executing a movement pattern results in destabilization of some or all of the resistance. The term “DI” has not appeared in research as a formally defined term. Dunnick examined the bench press and created DI by suspending a 16kg kettle bell from each side of a traditional bar. This form of ULT was compared to SLT to confirm or reject the effectiveness of ULT on the bench press. Prime movers (pectoralis major, anterior deltoid, triceps) and limb stabilizers (biceps, latisimus dorsi) were examined, but their EMGs did not differ between SLT and ULT even though resistance was constant between conditions. These findings are contradicted by Ostrowski (2016) whom created a greater “magnitude of DI” in the bench press, by implementing a flexible Earthquake bar™ and suspension of all resistance with elastic bands. Limb stabilizers (biceps, medial deltoid) had significantly higher activation during the ULT protocol, even though resistance was lower compared to SLT (60% 1-RM vs 75% 1-RM) (Ostrowski et al., 2016).
Lawrence (2015) investigated lower body exercise (squat) as it pertains to DI, and approached it through suspension of all resistance from a traditional bar. With total resistance being held constant between the stable and unstable condition, prime mover activity (soleus) as well as core muscle activity (rectus abdominis, external oblique, erector spinae) was increased in the unstable condition (Lawrence & Carlson, 2015). These findings are similar to what was seen with lower body exercises that utilize UST, i.e. Anderson and Behm (2005).

Besides showing increase in limb stabilizer activity, ULT also makes exercises more sensitive to perturbations, as explained by Lawrence (Publish ahead of print). Lyapunov exponent of a ULT bench press (using VDI similar to that of Ostrowski [2016]) was found to be higher than that of an SLT bench press, which indicated the bar moved with more degrees of freedom and less predictably. In addition, Lyapunov exponent was applied to muscle activation data, and lower exponents were found in the ULT condition. This indicated the muscles had less control over the bar and more constraint in how they controlled perturbations (Lawrence et al., Publish ahead of print). More degrees of freedom in a movement requires more control on the part of the exerciser, which may explain the anecdotal perception that ULT is more challenging than a similar SLT exercise (Lawrence et al., Publish ahead of print).

Behm et al (2005) investigated bilateral and unilateral chest press exercises and found when performing unilateral movement, the contralateral erector spinae and abdominal muscles had significantly higher activation compared to performing bilateral movement. This finding would suggest that if weight is horizontally distributed on one side, the external torque placed on the spine becomes increased on the contralateral side.
and thus a higher demand for spinal stabilization (Behm et al., 2005). Findings by Andersen et al (2016) show a similar conclusion. Erector spinae muscles contralateral to the arm producing a unilateral kettlebell swing are significantly more active compared to the ipsilateral side (Andersen et al., 2016). The findings of Andersen et al (2016) and Behm et al (2005) indicate that core activity can be increased in a resistance exercise if some or all of the resistance is concentrated on one side in a mediolateral direction. This indication is what contrives HDI as a potentially effective training method.

To date, research has not officially defined DI and branched it into VDI and HDI subsections. Currently, all forms of DI in research were created through what the present study defined as VDI. In future consideration of the present research concept, it may be beneficial to not only define the different methods of ULT and DI, but to compare their effects on muscles of the limbs and core pertaining to a variety of exercises.

2.5 – Electromyography

Electromyography (EMG) is utilized in studying neuromuscular activity, ranging from activity in the face and jaw (Al-Saleh, Armijo-Olivo, Flores-Mir, & Thie, 2012) to the ankle and foot (Soma, Murata, Kai, Nakae, & Satou, 2013). Previously referenced studies have investigated EMG activity in the prime movers and limb stabilizers of the bench press (Dunnick et al., 2015; Ostrowski et al., 2016), the squat (Lawrence & Carlson, 2015), and the overhead press (Kohler et al., 2010), all in comparison between stable and unstable load conditions. Further, the core has been analyzed in addition to the prime movers during the squat (Lawrence & Carlson, 2015) and the overhead press (Kohler et al., 2010).
In studies of the core muscles’ activity during unstable resistance exercises, the superficial muscles (rectus abdominis, external obliques, erector spinae) have been selected for analysis (Kohler et al., 2010; Lawrence & Carlson, 2015).

2.5.1 – Electrode Placement

Lauver (2015) had detailed a specific methodology for placement of the anterior deltoid and triceps brachii electrodes. The anterior deltoid electrode was said to be placed approximately 4 cm below the lateral end of the clavicle and the triceps electrode was placed midway between the olecranon process and the acromion process (Lauver et al., 2015). Both of these electrodes were placed upon the middle of the muscle belly (Lauver et al., 2015). This procedure is in agreement with Kasman and Wolf (2002) who depicted the aforementioned electrode placements with pictures (Kasman & Wolf, 2002).

Ekstrom et al (2003) had subjects perform 90 degrees of shoulder abduction to identify the placement region for upper trapezius electrodes. The electrodes ran in a direction parallel to the muscle fibers, and was physically located 2 cm lateral to one-half the distance between the 7th cervical vertebra and the acromion process (Ekstrom, Donatelli, & Soderberg, 2003). This recommendation is also in accordance with the pictorial depiction referenced earlier (Kasman & Wolf, 2002).

Regarding global muscles, Souza (2001) described erector spinae electrode placement as 3 cm lateral from the 3rd lumbar vertebra (L3) vertebral process. Oblique muscles were outfitted with electrodes midway between iliac crest and inferior ribcage and in a direction parallel to the anterosuperior iliac spine (ASIS) (Souza et al., 2001). This is slightly different from Escamilla’s (2010) recommendation in which the
electrodes are oriented in a 45 degree direction. More specifically, a theoretical line was drawn between the inferior ribcage and contralateral pubic tubercle and the electrode was oriented in that direction above the ASIS (Escamilla et al., 2010).
Chapter Three

Methods

3.1 Subjects

The present study was limited to healthy, physically active volunteer subjects (male or female) between the ages of 18-40 years. The physically active qualification was determined through a physical activity questionnaire (Appendix B). Subjects who had recent surgeries, any orthopedic conditions that could be aggravated through intense resistance training, or any neurological injury or disorder were excluded from the study. The healthy qualification was determined through a health history questionnaire (Appendix C). Absence of any contraindicative measure within the questionnaires was required to qualify the volunteers as subjects. All subjects had to be at minimum 1 year experienced in resistance training with exposure to overhead pressing tasks within the last three months prior to participation. Subjects were recruited from a convenience sample at The University of Toledo and participation was voluntary and limited to those who met the aforementioned criteria.

Before beginning the experimental intervention, all subjects gave their informed consent to participate in the present study. Consent was acquired through an informed consent document approved by The University of Toledo Institutional Review Board (Appendix A). Subjects were given a chance to read over the protocol and ask any questions before completing the physical activity questionnaire (Appendix B) and the
health history questionnaire (Appendix C). The subjects were made aware that there would be no compensation for participation, that their participation could be withdrawn at any time without consequence, and that there were foreseeable risks involved with the study including but not limited to soreness, physical injury, dehydration, and light headedness.

3.2 Experimental Design

The present study had a repeated measures design, consisted of one group, and had three assignments at the level of “condition.” Subjects participated in all three conditions in a counter balanced order. The protocol was administered over two separate visits to the Strength & Conditioning Lab at The University of Toledo. Subjects were asked to abstain from upper body resistance training exercise 48 hours prior to each visit to control for the influence of fatigue on muscle activity. By virtue of this request, a minimum of 48 hours was also selected for between lab visits. The first visit to the lab was intended to acquire anthropometric measurements as well as the 5 repetition maximum (5-RM) strength for overhead press, and to familiarize subjects with the three exercise conditions, which was said to last 45 minutes at most. The second visit was intended to acquire the voltage of 8 muscle regions during performance of each muscle’s MVIC and the exercise conditions, which was said to last 1 hour and 15 minutes at most.

During the first visit to the lab, subjects’ height, weight and age were recorded. Biacromial width was measured to quantify each subject’s standardized thumb-to-thumb grip width for the exercises. Subjects were asked to mount a cycle leg ergometer to determine the proper seat height, which was to be held constant between visits. The seat height was determined by acquiring a 150-degree knee angle on the extended leg while
mounted. Subjects performed a warm-up progression consisting of non-specific cycling at a steady state for 5 minutes, followed by a specific warm-up consisting of overhead presses with self-selected weight, tempo, repetition selection within a 6-8 repetition range, and interset rest periods within a 2-3 minute window. Four warm-up sets were performed. 5-RM strength was acquired with a minimum of one and a maximum of three attempts at a set of self-selected weight and tempo for 5 repetitions with interset rest periods of 2-4 minutes.

During the second lab visit, surface EMG (sEMG) electrodes were attached to subjects at the dominant side’s long head of triceps, upper trapezius, anterior deltid, and upper erector spinae muscle as well as bilaterally at the rectus abdominis and external oblique. Two maximum voluntary isometric contractions (MVICs) were performed on each muscle to establish a maximum amplitude of activation (µV). Upon MVIC completion, the aforementioned warm-up protocol was utilized before administering the conditions. In a randomized order, subjects performed a set of five repetitions with a barbell, a pair of dumbbells, and a hollowed out barbell with wheel bearings placed inside. The sets were performed to a 1:1:1:1 tempo (Dietz & Peterson, 2012) while utilizing a weight equal to 50% of their 5-RM, rounded up to multiples of 10. During the testing processes, if subjects had failed to maintain the tempo, the trial was disqualified and retried. Interset rest was maintained at 2-3 minutes to control for fatigue. Each trial yielded µV for the eight muscle sites along a time domain. Video data were recorded to align muscle activation patterns with muscle action (ie. Concentric, eccentric).
3.2.1 Anthropometrics & Exercise Setup

Height was measured in centimeters (cm) and mass was measured in kilograms (kg) using a physician’s scale (Detecto, Webb City, MO). Biacromial width was chosen in the present study to standardize grip width between subjects. Research on grip width in regards to overhead press is limited, but bench press grip variations have been shown to either not influence (Clemons & Aaron, 1997) or have a greater influence with biacromial width (Barnett, Kippers, & Turner, 1995) in regards to the pectoralis major muscle. Biacromial grip width had demonstrated increased triceps activity in the bench press as well (Lehman, 2005). The standardized grip width for the overhead press in the present study placed the subjects in a biomechanically advantageous position in which the moment arms between shoulder and palm were reduced. Forearm, elbow and palm were vertically aligned.

In addition to standardization of grip, the setup positions for the overhead press were constant between each visit for the subjects. The presses were performed within a power rack (Body-Solid, inc., Forest Park, IL) in which the pin height was set at or slightly below standing clavicle height. Subjects unracked the bar themselves and performed all presses seated; in a self-selected orientation that allowed maximal exertion of strength. Safety pins were set at a height aligned with or slightly below the xiphoid process during the seated position. Safety spotting was performed in accordance to the National Strength & Conditioning Association (NSCA) (Baechle & Earle, 2008) and executed by a certified strength & conditioning specialist (CSCS).
3.2.2 Warm Up Protocol

Warm up was performed prior to both the 5-RM test and the resistance exercise conditions. The non-specific warm up was administered for a 5-minute period and consisted of cycling on a stationary bike (Ergomedic 828E, Monark, Vansbro, Sweden). Subjects were instructed to cycle at a self-selected low intensity tempo. The resistance on the bike was kept constant between all subjects at 1 kilopond. The seat was adjusted to a height that allowed approximately 150-160 degrees of knee extension at the bottom portion of the bike with the ball of the foot on the pedal (Alvar, Sell, & Deuster, 2017). Knee angle was quantified with a goniometer.

The specific warm-up occurred immediately after the 5-minute cycling period, and consisted of 4 sets of seated, unsupported barbell overhead presses with self-selected repetitions in the 6-8 range as well as a self-selected tempo. All repetitions had to consist of bar contact with the upper chest/clavicular region and a lock out at the elbow’s end range of motion. Subjects were encouraged to increase resistance after each set. Interset rest was limited to 2-3 minutes (Baechle & Earle, 2008).

3.2.3 5-RM Strength on the Overhead Press

5-RM strength was assessed for the overhead press while seated and without back support. The back support serves as a point of contact to stabilize the back in a press activity (Baechle & Earle, 2008) and was thus removed to require trunk and spine stabilization regardless of the condition being analyzed. Five repetitions were chosen over one repetition for maximum strength assessment. Compound and structural movements that utilize multiple body segments and large muscle masses can be
accurately assessed with 1-RM testing (Baechle & Earle, 2008). In considering the seated overhead press, only a few body segments and smaller muscle groups are utilized, thus a 1-RM test was assumed to be insufficient in truly testing maximum strength. A second consideration in the repetition choice for the test was in safety of the subjects. Due to the inherent and apparent risks of resistance exercise testing, a repetition amount of five was selected to reduce total resisted weight in the testing setting. A weight that is relatively lower than a 1-RM load is also more manageable for the safety spotter in the event of failure strength being reached.

Three attempts were selected as the maximum allotment based on a three-subject pilot test performed previously. Subjects tended to approach volitional fatigue by the third attempt and preferred not to take more than three attempts. A minimum of one and a maximum of three attempts at the 5-RM test were thus allotted in the present study. The resistance for each attempt was selected ad libitum. All five repetitions in the test had to be completed (contact with upper chest, full extension of elbow) in order to affirm the selected weight as the subject’s 5-RM strength. Subjects were allowed to re-attempt a selected weight if they failed the test previously, as long as they were still within their 3-attempt allotment. In the event that the third attempt was failed, the previously completed weight was indicated for the subject’s 5-RM strength. In the event that all three attempts had been failed, subjects were permitted to retry the protocol, provided a 48 hour minimum recovery.

The test was administered in accordance to the NSCA’s guidelines on strength testing. 2-4 minutes were provided between attempts and a spotter was available in the event that fail strength was approached (Baechle & Earle, 2008). The present strength test
differed in that weight was selected ad libitum, given that only three attempts were allotted.

3.2.4 EMG and sEMG Electrode Placement

Surface electromyography (sEMG) has been utilized to investigate core muscle activity during the overhead press (Kohler et al., 2010). In the present study, a wireless 8-channel transmitter system was utilized to record EMG signal to a desktop receiver (8 Channel DDTS, Noraxon, Scottsdale AZ). Silver-silver chloride electrodes with 1.75 cm of fixed inter-electrode space were used to detect amplitudes within the muscle (#272, Noraxon, Scottsdale, AZ). Skin was shaved, debrided and cleansed of impurities with isopropyl alcohol swabs. All electrodes were placed parallel to the theoretical direction of the specified muscle bellies.

The prime movers of the seated overhead press as well as superficial core stabilizing muscles were selected for analysis in the present study. The dominant side was analyzed unilaterally at the level of the triceps brachii, upper trapezius, anterior deltoid and erector spinae. Bilateral EMG analysis was performed on the rectus abdominis and external obliques. The present study was limited to eight channels of muscle site analysis, thus bilateral examination could not be performed beyond the rectus abdominis and the external obliques.

The electrode for the triceps muscle (TRI) was placed midway between the acromion process and the olecranon process on the lateral head (Lauver et al., 2015) (Figure 3.1). The electrode for the anterior deltoid (AD) was placed approximately 4 cm below the lateral end of the clavicle (Lauver et al., 2015) (Figure 3.2). The trapezius
(TRAP) electrode was placed midway between the 7th cervical spinous process (C7) and the acromion process while the arm is in 90 degrees of shoulder abduction (Ekstrom et al., 2003) (Figure 3.2). The electrode for the erector spinae (ES) was placed 3 cm laterally from the L3 process (Kasman & Wolf, 2002), (Souza et al., 2001) (Figure 3.3). The electrodes for the rectus abdominis were placed midway between umbilicus and xiphoid process, and 2 cm lateral from the midline (Escamilla et al., 2010). External oblique electrodes were placed superiorly to the anterior superior iliac spine (ASIS), and horizontal to the umbilicus (Kasman & Wolf, 2002) (Figure 3.4).

3.2.5 MVIC

All MVICs were performed twice with a five-second hold and rest period of one minute between efforts. Subjects were trained on the movements and were permitted to observe the computer screen to encourage maximization of the voltage reading. During all MVICs, the examiner(s) verbally encouraged the subject to maintain constant high effort while also providing biofeedback as needed. The training was administered to control for lack of familiarity with the MVIC movement while biofeedback was offered during the MVIC to improve upon any decrements immediately observable.

The administration of the MVICs were purposively administered in a non-randomized fashion. During pilot testing, MVIC administration was seen to be erroneous if all electrodes were outfitted beforehand. The subjects were put into a variety of positions during MVIC collection, and some MVICs had resulted in compression or contorting of the body surface to which an electrode was attached. The body positioning had resulted in disconnecting of the electrode or wireless transducer, which would render the reading of said electrode invalid.
The order in which the MVICs were administered were in a multi-stage format, with randomized selection within each stage. The stages were 1.) Left RA, Right RA, Left EO, Right EO, 2.) ES and 3.) AD, TRI, TRAP. Before each stage, the skin was properly prepared as discussed previously. After placing the electrodes, the examiner(s) wrapped flexible athletic tape (item #28236, Andover Healthcare, Salisbury, MA) around the segment to keep the electrode(s) and transducer(s) from displacing during activity.

For the left and right RA, subjects lied on a cushioned bench in supine position with knees and hips flexed to 90 degrees and 45 degrees, respectively. Subjects crossed their arms while performing an abdominal curl-up with manual resistance placed on the shoulders (Escamilla et al., 2010). Restraint was applied to the lower body to reduce its contribution to the movement. For the left and right EO, subjects were positioned supine on a cushioned bench with 90 degrees of lateral trunk rotation, placing one leg on top of the other. Hips and knees were still in 45 and 90 degrees of flexion, respectively. The examiner applied resistance to the shoulder and restraint to the lower body. The subject attempted an oblique curl-up in which they brought the resisted shoulder to the contralateral knee (Souza et al., 2001).

The ES MVIC was acquired with the subjects lying in prone position with shoulder flexion putting the arms in front of the head. The examiner restrained the lower body and applied maximum manual resistance to the upper back while the subject elevated the chest and arms through lower back extension (Souza et al., 2001).

For the AD, subjects were seated on a cushioned bench with a neutral shoulder, 90 degrees elbow flexion, and a closed supine fist. The untested hand remained in the lap, so as not to contribute to the movement. The examiner manually resisted the fist with
maximal exertion while the subject performed shoulder flexion (Lauver et al., 2015). For the TRI, subjects assumed the same position, but rotated the closed fist to face the palm toward the midline, assuming a neutral grip. Maximum elbow extension was performed against the examiner’s manual resistance (Lauver et al., 2015). For the TRAP muscle, the subject was seated on a cushioned bench with both hands placed in their lap, with their neck bent to the tested TRAP side, rotated in the opposite direction, and extended. The scapula was brought into elevation maximally against the examiners manual resistance. Manual resistance was placed directly above the TRAP during elevation and against the head during extension (Ekstrom et al., 2003).

3.2.6 Resistance Exercise Conditions

The resistance exercise conditions were administered after a warm-up protocol on the 2nd visit to the lab in a counterbalanced order. Standardized grip width and pin heights were utilized as they were in the 5-RM test. Five repetitions were performed for each of the conditions at a total resistance of 50% 5-RM. The 50% 5-RM resistance was selected due to an equipment limitation. The maximum amount of weight that could be accommodated at the level of ULT was 100 pounds (two 50-pound dumbbells). Due to this equipment limitation, the maximum amount of weight that could be accommodated for the 5-RM strength test was 200 pounds. It was assumed that 200 pound 5-RM strength for the seated, unsupported overhead press would be beyond reach of the volunteer subjects. In the event that a subject reached beyond 200 pounds, they would be excluded from the study.

3.2.6.1 Barbell Exercise – SLT
A stable, traditional 45-lb Olympic barbell (Body-Solid, Forest Park, IL) was utilized as the SLT implement. The weight was added to the bar as needed to equate 50% of the subject’s 5-RM, rounded up to a multiple of 10. The standardized grip and pin heights were utilized during the data collection.

In the present experiment, an SLT condition was needed to serve as a control group. The subjects’ muscle activities in the SLT condition were compared to ULT and HDI.

3.2.6.2 Dumbbell Exercise – ULT

A pair of dumbbells (Body-Solid, Forest Park, IL) was utilized for ULT. The weight selection was available in increments of 5 pounds. Resulting from the weight availability, the 50% of subject’s 5-RM was rounded up to a multiple of 10. Since a dumbbell was placed in each hand during the ULT condition, total resistance increased by 10 with each 5 pound increase in dumbbell weight. The weight for the dumbbell selection available at the time of the study increased by 5 pound increments, thus 50% 5-RM strength could not be expressed in a dumbbell format if it was any number other than a multiple of 10.

In testing the hypothesis regarding HDI’s effectiveness, it must be compared to a more traditionally utilized method of instability.

3.2.6.3 HDI Exercise – HDI

No research to date has examined ULT by way of implementing DI in a horizontal direction. In the present study, HDI was implemented with a hollowed-out axle bar with the addition of wheel bearings inside (Club 4 bar, Fitness Stability Dynamics,
Displacement of the wheel bearings created variability in the effective “perceived” mass of the resistance. As a resistance becomes more concentrated to one side, it will place more destabilizing external torque on the trunk (Andersen et al., 2016). More torque on the trunk requires more demand from core stabilizing muscles contralateral to the load (Andersen et al., 2016) and thus higher activation in said muscles should occur in comparison to a stable exercise.

A standardized amount of wheel bearings were placed inside the bar to make the total weight of the implement 20 pounds (9kg).

### 3.2.7 Exercise Tempo

Exercise tempo was selected to allow qualification of the different muscle actions. Eccentric, isometric, and concentric as well as a locked out hold at the end of the concentric were all performed in a one-second period. The resultant tempo is thus reported in a 1:1:1:1 fashion, in accordance to the methodological tempo-reporting format by Dietz (2012).

Subjects were granted a practice period after the 5-RM strength test to familiarize themselves with the tempo on each implement. A metronome App (ProMetronome, EUMLab, Hangzhou, China) was used to administer a 60 beats per minute tempo to signify the 1:1:1:1 tempo. Each beat signified the subsequent muscle action in the task, during both practice and data collection.

Failure to follow the tempo during data collection disqualified the attempt. One successful attempt at each of the three resistance exercises during data collection was required. 2-3 minutes of rest were taken after every attempt.
3.2.8 Videography

A commercially available web camera (Microsoft LifeCam, Microsoft, Redmond, WA) was mounted on a tripod to record the resistance exercise conditions in the frontal plane. The camera was oriented to view the anterior frontal plane of the subject. The videography served the purpose of quantifying the periods at which eccentric, isometric, concentric and lockout of each repetition occurred.

3.3 Data Collection, Processing, and Analysis

Analyses were performed on all MVIC trials and the resistance exercise conditions that occurred in the second visit to the lab. Raw data were recorded at a sampling frequency of 1,000 Hertz (Hz) and stored on a laptop. EMG interpretation software (Myoresearch XP 1.08 Master Edition, Noraxon, Scottsdale, AZ) was used for digital signal processing. Root means square smoothing was performed with a 50-millisecond moving window and a band-pass filter was applied at 10-500 Hz (Merletti & Di Torino, 1999) for all MVIC and condition trials. The better of the two MVIC trials for each muscle was utilized for normalization. The signal for each condition trial was time aligned with frontal plane video footage to quantify concentric and eccentric muscle actions. Concentric and eccentric action times were collected for all five repetitions of each condition and averaged. The RMS values were taken for concentric and eccentric actions of every repetition for each condition. The five RMS values were averaged for each muscle action (concentric, eccentric) within each condition (SLT, ULT, HDI). The RMS value was normalized to MVIC and multiplied by 100 to generated a percentage.

3.4 Statistical Analysis
All data in the present study were reported as mean ± standard deviation. RMS activation data were derived from the middle three seconds for both trials on each muscle, the higher of which was reported and utilized in %MVIC calculations. A 2-way repeated measures ANOVA was used to determine differences in muscle activation (%MVIC) across the conditions (BB, ULT, HDI) and muscle action (concentric, eccentric) for each of the eight muscles (AD, TRI, TRAP, ES, LRA, RRA, LEO, REO). All significant differences were followed through with Tukey post hoc tests. Significance was set a priori at an α level of 0.05. Statistical analyses were performed with commercially available software (SigmaPlot 13.0.0, Systat Software Inc., San Jose, CA).

Figure 3.1 – Triceps brachii electrode placement.
Figure 3.2 – Upper trapezius and anterior deltoid electrode placement

Figure 3.3 – Erector spinae electrode placement.
Figure 3.4 – Rectus abdominis and external oblique electrode placement.
Chapter Four

Results

4.1 – Subject Anthropometrics and 5-RM Strength

Thirteen subjects (n=13, 13M, 0F) were retained from the initial pool of fifteen volunteers for the present study. Two subjects discontinued the study for reasons not specific to the study. The mean mass was 84.1 ± 9.7 kg (range 69.8-101.8 kg), mean height was 178 ± 7.2 cm (range 164-191 cm), mean age was 24.1 ± 2.4 years (range 22-30 years), and biacromial width was 43.2 ± 2.6 cm (range 38-46 cm). The mean 5-RM strength was 58.3 ± 12.7 kg (Table 4.1).

4.2 – Muscle Activation

The F scores for all statistical tests (main effects and interactions) are reported in table 4.2. Repetition times for all conditions were significantly different between concentric and eccentric (SLT concentric 1.2 ± 0.1 s, eccentric 1.4 ± 0.1 s; ULT concentric 1.2 ± 0.1 s, eccentric 1.4 ± 0.1; HDI concentric 1.2 ± 0.1, eccentric 1.4 ± 0.2 sec).

4.2.1 – Prime Movers of the Seated Overhead Press

For the anterior deltoid’s concentric action, the ULT condition yielded the highest amplitude of activity (103.3 ± 31.0 %), which was significantly greater than SLT (79.9 ± 30.46 %, d = 0.76) and HDI (90.1 ± 29.9 %, d = 0.43). HDI and SLT did not differ
significantly. Across all conditions, the concentric action was significantly higher than the eccentric action (SLT eccentric: 57.6 ± 17.0, \( d = 0.91 \); ULT eccentric: 66.8 ± 26.1, \( d = 1.27 \); HDI eccentric: 57.6 ± 17.5, \( d = 1.33 \% \)) (Figure 4.1). For the triceps brachii, none of the conditions produced a significant difference in muscle activation. Within the ULT condition, the concentric action was significantly greater (33.52 ± 28.9 %) than the eccentric action (26.9 ± 20.8 %) (Figure 4.2).

For the upper trapezius muscle, the concentric action of the ULT condition yielded a significantly higher amplitude of activity (89.1 ± 61.4 %) relative to SLT and HDI (71.7 ± 46.6, 77.7 ± 58.7 %, respectively). The eccentric action resulted in significantly higher activity for ULT (70.8 ± 52.1 %) relative to SLT (57.1 ± 35.3 %) and HDI (57.5 ± 41.4 %) conditions as well. The SLT and HDI conditions did not differ significantly from one to another. All three conditions resulted in a significantly higher activation during concentric compared to eccentric muscle action (Figure 4.3).

4.2.2 – Core Muscles

For the erector spinae muscle, the concentric action within HDI (17.4 ± 6.8 %) and SLT (16.8 ± 8.2 %) conditions yielded significantly higher amplitudes of muscle activity compared to ULT (12.0 ± 4.1 %). HDI and SLT did not differ from one another during the concentric action. Regarding eccentric actions, only SLT (17.6 ± 8.8 %) produced a significantly higher magnitude of activation relative to ULT (13.3 ± 5.6 %). HDI eccentric was not significantly higher than ULT eccentric nor was it significantly lower than SLT eccentric. There were no differences within any condition between muscle action (Figure 4.4).
For the right and left sides of the rectus abdominis, there were no significant differences between conditions or between muscle action (Figure 4.5).

The right external oblique resulted in a significant difference between ULT eccentric (61.5 ± 43.5 %) and concentric actions (43.7 ± 28.7 %). No differences were seen between the concentric and eccentric actions for SLT or HDI, nor were there differences between the two conditions. Further, the eccentric action of ULT resulted in significantly higher muscle activation relative to the eccentric action of SLT (41.7 ± 36.2 %). Similar results were found with the left external oblique. ULT eccentric action resulted in significantly higher activation (45.5 ± 30.0 %) compared to the concentric action (32.8 ± 17.6 %). The ULT eccentric action was also significantly greater than the HDI eccentric action (33.6 ± 14.1 %MVIC) as well as the SLT eccentric action (30.4 ± 11.4 %) (Figure 4.6).

Table 4.1 - Subject Demographics and 5-RM Strength

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<tbody>
<tr>
<td>Mean ± SD</td>
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<tr>
<td>Mass (kg)</td>
<td>84.1 ± 9.7</td>
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<td>Height (cm)</td>
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<tr>
<td>Age (years)</td>
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<td>Biacromial Width (cm)</td>
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<td>5-RM Strength (kg)</td>
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<td>Muscle</td>
<td>Source of Variation</td>
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<tr>
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<td>Action</td>
</tr>
<tr>
<td></td>
<td>Condition x Action</td>
</tr>
<tr>
<td>Right Rectus Abdominis</td>
<td>Condition</td>
</tr>
<tr>
<td></td>
<td>Action</td>
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<td>Condition x Action</td>
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<tr>
<td>Left Rectus Abdominis</td>
<td>Condition</td>
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<td></td>
<td>Action</td>
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<td>Condition x Action</td>
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<tr>
<td>Right External Oblique</td>
<td>Condition</td>
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<td></td>
<td>Action</td>
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<td>Condition x Action</td>
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<tr>
<td>Left External Oblique</td>
<td>Condition</td>
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<td></td>
<td>Action</td>
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<td></td>
<td>Condition x Action</td>
</tr>
</tbody>
</table>
Table 4.3 - Repetition times, \( n = 13 \)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Action</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLT</td>
<td>concentric</td>
<td>1.2 ± 0.1*</td>
</tr>
<tr>
<td></td>
<td>eccentric</td>
<td>1.4 ± 0.1</td>
</tr>
<tr>
<td>ULT</td>
<td>concentric</td>
<td>1.2 ± 0.1*</td>
</tr>
<tr>
<td></td>
<td>eccentric</td>
<td>1.4 ± 0.1</td>
</tr>
<tr>
<td>HDI</td>
<td>concentric</td>
<td>1.2 ± 0.1*</td>
</tr>
<tr>
<td></td>
<td>eccentric</td>
<td>1.4 ± 0.2</td>
</tr>
</tbody>
</table>

* = significant difference between concentric and eccentric action, within group (\( p < 0.05 \))

Figure 4.1 – Muscle activation of the anterior deltoid. SLT = stable load training; ULT = unstable load training; HDI = horizontal dynamic instability; dark gray = concentric; light gray = eccentric; * = significant difference between concentric and eccentric action (\( p < 0.05 \)); # = significantly higher concentric activation compared to all other conditions (\( p < 0.05 \)). \( n = 13 \).
Figure 4.2 – Muscle activation of the triceps brachii. SLT = stable load training; ULT = unstable load training; HDI = horizontal dynamic instability; dark gray = concentric; light gray = eccentric; *= significant difference between concentric and eccentric action ($p<0.05$). $n=13$.

Figure 4.3 – Muscle activation of the upper trapezius. SLT = stable load training; ULT = unstable load training; HDI = horizontal dynamic instability; dark gray = concentric; light gray = eccentric; *= significant difference between concentric and eccentric action ($p<0.05$); #= significantly higher concentric activation compared to all other conditions ($p<0.05$). $n=13$. 
Figure 4.4 – Muscle activation of the erector spinae. SLT = stable load training; ULT = unstable load training; HDI = horizontal dynamic instability; dark gray = concentric; light gray = eccentric; * = significantly higher eccentric activation compared to ULT ($p<0.05$); # = significantly higher concentric activation compared to ULT ($p<0.05$). $n=13$.

Figure 4.5 – Muscle activation of right and left rectus abdominis. SLT = stable load training; ULT = unstable load training; HDI = horizontal dynamic instability. $n=13$. 
Figure 4.6 – Muscle activation of right and left external obliques. SLT = stable load training; ULT = unstable load training; HDI = horizontal dynamic instability; *= significant difference between concentric and eccentric action (p<0.05); # = significantly higher eccentric activation compared to SLT (p<0.05). †= significantly higher eccentric activation compared to HDI. (p<0.05). n=13
Chapter Five

Discussion

The purpose of the present study was to use an EMG to measure the muscle activation of the core stabilizers and prime movers of the seated overhead press when using HDI and to compare the amplitudes to a traditional form of ULT and SLT. The primary hypothesis was that HDI, SLT and ULT would all result in similar amplitudes of activity for the triceps brachii, anterior deltoid, and trapezius, while HDI and ULT would result in similar differences for rectus abdominis, external oblique, and erector spinae activity relative to SLT. The secondary focus pertained to concentric and eccentric actions, and it was hypothesized that there would be a significant difference between the actions for all muscles across all conditions. The results are mixed, with some portions of each hypothesis being rejected or verified.

The results indicated that performing the overhead press while seated with no back support requires significantly more activation within the anterior deltoid and trapezius muscles when using traditional ULT relative to SLT and HDI. These findings applied only to the concentric action of the exercise. In addition, triceps activity was maintained throughout the three conditions. Core activity had only differentiated at the external oblique, in that ULT required more stabilization than SLT on the right side and more stabilization than both SLT and HDI on the left, all during the eccentric action. The erector spinae muscle was more active during the SLT compared to ULT, but HDI was
only more active during concentric actions compared to ULT. This study had implemented a constant load between the three exercise conditions, and 50% of subjects’ 5-RM strength were utilized, rounded up to a multiple of 10 pounds (4.5 kg).

Research has previously shown that usage of ULT during the seated overhead press decreased activity in the triceps muscle (Kohler et al., 2010). Kohler (2010) research protocol required that ULT and SLT acquire their own 10-RM strengths. Because ULT is a less stable modality compared to SLT, the load was approximately 85% of the SLT load. The load reduction between conditions in Kohler’s (2010) study can explain the resultant reduction of triceps activity, and thus load maintenance in the present study can explain resultant triceps activity maintenance.

Anterior deltoid and trapezius activity increases do not follow the same rationale as the triceps activity maintenance. Previous research observed a similar 1-RM strength between seated ULT and unilateral overhead press, but higher amplitude of activity within the anterior deltoid for the ULT method (Saeterbakken & Fimland, 2013a). Another study reported no difference between ULT and SLT during the seated overhead press (Kohler et al., 2010). As explained earlier, Kohler (2010) utilized a relative load between the conditions, but made the case for anterior deltoid and trapezius activity maintenance due to their secondary roles as stabilizers within and around the scapula. Thus, the findings in the present study indicate that while maintaining load between conditions, the seated overhead press becomes a relatively more challenging task when the left and right hands act in an uncoupled manner.

The present study normalized the three conditions to a 5-RM strength that was achieved with the most stable implement. Other studies have recommended each exercise
condition being tested for its own RM strength (Saeterbakken & Finland, 2013a, 2013b). Saeterbakken (2013) argued that it is not possible to differentiate the contributions of a higher relative load when examining different stability requirements. Since ULT requires more stability compared to SLT, absolute load should result in higher muscle activity for all prime movers (Saeterbakken & Finland, 2013a). The findings in the present study only verify this argument to the extent that anterior deltoid and trapezius muscle activity were significantly higher in the concentric actions of ULT. Eccentric activity had not significantly differed between conditions within prime movers.

Rectus abdominis activity had not differentiated between conditions. These findings contradict the original hypothesis. Previous research analyzed the core during seated overhead press and found that standing or performing unilaterally can significantly increase the demands of the rectus abdominis (Saeterbakken & Finland, 2012). While seated, the core experiences much less destabilizing torque and thus less demand is placed on the muscles such as the rectus abdominis and erector spinae (Saeterbakken & Finland, 2012). The lack of back support was intended to enhance the instability inherent to the exercise, but feet positioning was ad libitum for the intent to maximize force output during the 5-RM strength test. It is theorized that because of foot positioning, the magnitude of destabilizing torque was not sufficient enough to demand high rectus abdominis activation.

Additionally, Campbell et al. (2014) analyzed the rectus abdominis during chest press exercises utilizing SLT and ULT. Rectus abdominis activity was augmented through usage of the ULT modality, but this increase was seen while also performing on a Swiss ball (Campbell et al., 2014). Other studies have confirmed that using an unstable
surface augments activity of the rectus abdominis (Marshall & Murphy, 2006; Saeterbakken & Finland, 2013b), and it may thus be reasoned that UST is superior for amplifying rectus abdominis activity with certain populations (Behm et al., 2011).

The current study resulted in higher activation of the erector spinae during SLT (concentric and eccentric) and HDI (concentric) relative to ULT. Kohler (2010), who analyzed both the upper and lower erector spinae muscles, similarly observed this. Activity was significantly lowered with ULT compared to SLT (Kohler et al., 2010). The results of this study show that even when controlling for absolute load, lack of stability reduces erector spinae activity. This theory would need further research to verify the connection. In the present study, the bar utilized in SLT was more anterior to the spine, loaded above the sternum as opposed to the clavicles with ULT. The SLT condition would have lengthened the external moment arm between resistance implement and spine. Additionally, eccentric activity did not differ between conditions. In the concentric action, the initial external torque that the erector spinae muscles have to overcome to stabilize the spine would certainly be higher than in the eccentric action, where the resistance starts in the same line of action as the muscle.

The external oblique was significantly more active during eccentric ULT compared to eccentric SLT regardless of the side (left or right). Only the left external oblique differed significantly between eccentric ULT and HDI, with higher activation in the ULT condition. ULT and HDI did not differ significantly on the right oblique. This could possibly be explained by the horizontal displacement of the dynamic resistance within the HDI implement. Previous research has reported on the external oblique’s role as a mediolateral stabilizer (Souza et al., 2001). More activity on the right oblique could
likely be caused by a contralateral shift of external torque generation, i.e. to the left side (Andersen et al., 2016; Behm et al., 2005; Saeterbakken & Finland, 2012). A general observation that occurred during kinematic data interpretation was that the HDI bar would visibly shift to the left for many of the subjects, usually by the fourth or fifth repetition. During the recording process, if the spotter could audibly hear the wheel bearings move within the bar, he would point in which direction the shift occurred. The purpose of the pointing was to aid in the kinematic observations if the visible bar deviation was not sufficient. 12 of the 13 subjects in the present study were right handed, which may possibly contribute to a preference to shift the dynamic resistance to the left during the set.

Activity within the external oblique muscles during overhead pressing has been augmented when transitioning from seated to standing (Saeterbakken & Finland, 2012). The increase in activity presently observed occurred when transitioning from SLT to ULT, and this may have occurred due to the increased instability and complexity of the task (Kohler et al., 2010; Saeterbakken & Finland, 2013a). Even with implementation of relative loads, Kohler (2010) observed maintenance of the external oblique during seated overhead press. The increase was noted at the level of eccentric action, within the ULT condition. The external oblique is thought to be active in preventing lateral-flexion of the core (Saeterbakken & Finland, 2012). Contrary to the findings within the erector spinae, the eccentric action necessitates more activity even though the external moment arm is reduced relative to starting in the concentric action. This indicates that external oblique activity may be influenced by more than external torque alone. It has been recommended recently that external oblique activity is most significantly increased with unilateral
implementation in the overhead press (Saeterbakken & Finland, 2012). This is indicative not only of increased external torque, but a lack of counterbalancing torque on the contralateral side, as seen in bilaterally executed movements.

5.1 – Limitations

One limitation pertains to the MVIC protocol. Due to the complication of administering all MVICs in a randomized order, electrode placement and MVIC administration were performed in a multi-stage format. Counter balancing could thus not be achieved and fatigue may have possibly contributed to third stage (anterior deltoid, triceps brachii, trapezius). The second limitation is related in that wrapping of the core electrodes did not occur until all five were placed (both sides of rectus abdominis and external oblique muscles and erector spinae). Thus, the wraps were not present during the first stage of MVICs, and the application of pressure from the wraps may have failed to reduce artifact (Cömert, Honkala, & Hyttinen, 2013). The last limitation pertains to the intensity selection. At the time of the study, the strength & conditioning lab was limited in dumbbell selection and thus loading intensities had to be selected to accommodate a maximum of 100 pounds (45.4 kg) (two 50 pound dumbbells [22.7 kg]) for all conditions.

5.2 – Conclusions

HDI, as a concept, was researched for the first time in the present study. The concept fits into the category of DI, a subcategory of ULT. Traditionally, ULT is implemented through uncoupling of left and right hand movement (Campbell et al., 2014; Kohler et al., 2010; Saeterbakken & Finland, 2012). DI, as a subcategory, has recently
been researched through implementing a vertical path for the dynamic resistance to displace (Dunnick et al., 2015; M. A. Lawrence & Carlson, 2015; M.A. Lawrence et al., Publish ahead of print; Ostrowski et al., 2016). The present study has defined this concept as VDI. The purpose of this study was to reject or verify HDI as having similar effects on muscle activity as ULT. Further, the purpose was to evaluate HDI’s impact on core stabilization, an objective that has become the focus of practitioners, therapists, and coaches in the strength and conditioning profession (Behm et al., 2011; Willardson, 2007). HDI was compared to ULT, a more traditional way of inducing instability at the level of resistance and SLT, a control group in which no instability was induced. Based on the results of the experiment, it can be concluded that HDI is potentially more effective in placing mediolateral stabilization demands on the core relative to SLT. Souza et al (2001) described the external oblique muscle as contributing to the stabilization process when mediolateral rotation occurs. The seated overhead press may not be sufficient for putting the exerciser in a position in which core stability is necessitated (Saeterbakken & Fimland, 2012). It is thus theorized that HDI may possibly amplify the activity of the external oblique muscle activity. That is to say, a highly stabilized exercise (seated) will only be slightly less stable when using HDI, but a highly destabilized exercise (standing) may be more challenging when an extra stabilizing task is added. Lastly, in considering the goals of the exerciser, other options for increasing demands of the external oblique should be considered depending on varying levels of experience and strength. Unilateral resistance training may be significantly more effective than HDI (Saeterbakken & Fimland, 2012), but research needs to be conducted to confirm or verify.
Further analysis should be considered for HDI in the future. The squat has been analyzed regarding the effect of VDI on core and prime mover activity (M. A. Lawrence & Carlson, 2015). In addition, relatively heavier loads were utilized in the study by Lawrence & Carlson (2015) totaling 60% of 1-RM, whereas the present study’s 50% of 5-RM would equate to approximately 40-45% of 1-RM (Baechle & Earle, 2008). At the time of publication, other options exist for HDI, implementing different lengths of bar (Pro 7 Reaction Bar, Fitness Stability Dynamics LLC, Toledo, OH) which could cause more aforementioned mediolateral destabilization. Research should also focus on the magnitude of mediolateral shifting and destabilization. The present study only quantified this concept visually and audibly. Future analysis could possibly be performed using two-dimensional video analysis or by performing bar path Lyapunov exponent, as seen in previous studies on the bench press (M. A. Lawrence et al., Publish ahead of print).
References


Appendix A: Informed Consent Form
IRB Approval

TO: Suzanne Wambold, M.D.
UT Department of Kinesiology

FROM: Roland Skeel, M.D., Chair
Boyd Koffman, M.D., Ph.D., Vice Chair
Susan Pocotte, Ph.D., Vice Chair
Steven Peseckis, Ph.D., Vice Chair
Rachel Rarus, PharmD, Chair Designee
UT Biomedical Institutional Review Board

SIGNED: R[illegible]

DATE: 1/MA/2016

SUBJECT: IRB # 201363
Protocol Title: Muscle activation in prime movers and stabilizers when performing seated overhead press with followed-out barbell with wheel bearings inside

The above project was reviewed and approved by the Chair and Chair Designee of the University of Toledo Institutional Review Board as an expedited review (category #4 & #7). The requirement to obtain a informed consent/authorization for use and disclosure of protected health information form is required prior to any research activities taking place. This research is approved for a period of up to one year from the date of this review and approval. This action will be reported to the committee at its meeting on 05/19/16.

Items Available for Review:
- IRB Application Requesting Initial Expedited Review of Research
  - Risk-benefit assessment
- Adult consent/authorization version date 03/21/2016
- Protocol dated 3/14/2016

This research is approved until the expiration date listed below, unless the IRB notifies you otherwise.

You are approved to enroll up to 15 subjects

APPROVAL DATE: 04/21/2016
EXPIRATION DATE: 04/20/2017

Please read the following attachment detailing Principal Investigator responsibilities.
Muscle Activation in prime movers and stabilizers when performing seated overhead press with hollowed-out barbell with wheel bearings inside.

Principal Investigator: Suzanne Wambold, Ph.D.

Other Staff (identified by role): Travis Reynolds, BS (co-investigator)
Tyler Falor, BS (co-investigator)

Contact Phone number(s): (419) 530-2692 Office
(419) 530-2058 Lab

What you should know about this research study:

- We give you this consent/authorization form so that you may read about the purpose, risks, and benefits of this research study. All information in this form will be communicated to you verbally by the research staff as well.

- Routine clinical care is based upon the best-known treatment and is provided with the main goal of helping the individual patient. The main goal of research studies is to gain knowledge that may help future patients.

- We cannot promise that this research will benefit you. Just like routine care, this research can have side effects that can be serious or minor.

- You have the right to refuse to take part in this research, or agree to take part now and change your mind later.

- If you decide to take part in this research or not, or if you decide to take part now but change your mind later, your decision will not affect your routine care.

- Please review this form carefully. Ask any questions before you make a decision about whether or not you want to take part in this research. If you decide to take part in this research, you may ask any additional questions at any time.

- Your participation in this research is voluntary.

Purpose (Why this research is being done)
You are being asked to take part in a research study that will observe muscle activation of primary and stabilizer muscles in response to performing a seated overhead press with a hollowed-out barbell with wheel bearings inside, a barbell, and dumbbells. The purpose of the study is to compare muscle activity across each method of exercise.
You were selected as someone who may want to take part in this study because you indicated an interest in this study by either contacting Dr. Suzanne Wambold and/or Travis Reynolds and/or Tyler Falor and you meet the criteria outlined below. This study will include 15 subjects recruited from the University of Toledo Community.

In order to participate in this study, you must be in good health and between the ages of 18-40 years and be free of any known cardiovascular, pulmonary, neuromuscular, and/or metabolic diseases such as heart attack, stroke, any heart surgery, asthma, COPD, hypertension (high blood pressure, ≥ 140/90 mmHg), or diabetes as assessed by a medical history questionnaire and an activity level questionnaire. You will also need to be free of orthopedic related injuries including but not limited to any bone fractures, tendon tears, and carpal tunnel syndrome, which will also be assessed by using a medical history questionnaire. In addition, you must not be a smoker and have not smoked in the previous 6 months. Also, you will need to not be currently taking prescription medication and/or over-the-counter supplements that affect your blood pressure or blood flow. If you do not meet these criteria, we greatly appreciate your willingness to volunteer but unfortunately, you will not be able to participate in this study.

**DESCRIPTION OF THE RESEARCH PROCEDURES AND DURATION OF YOUR INVOLVEMENT**

If you decide to take part in this study, you will be asked to visit the Biomechanics Research Laboratory (room 1416, Health and Human Service Building, University of Toledo) on 2 separate occasions; each session will last approximately 1.5 hours.

**Initial Visit (Visit 1)**

During the first visit, the investigator will explain the procedures to you and you will be given an informed consent form. You will be encouraged to ask the investigator(s) any questions regarding the research study. Also, please remember that you can take as much time as you need to make an informed decision regarding your participation in the study. You are volunteering to participate in the research study and you can stop your participation during the research study at any time, for any reason, without any consequence. Once you feel comfortable with the research procedures and you would like to participate in the research study, you will be asked to provide written informed consent by signing this document.

Next, you will be asked to complete a medical history questionnaire and an activity level questionnaire that will help to determine if you meet the criteria defined above for participation within the research study. After the completion of the medical history
questionnaire, health and activity level questionnaire and giving consent, a few measurements will be made.

During visit 1, you will first undergo pre-exercise measurements including:

- **Anthropometric Measurements**: Your height and weight will be assessed using a basic scale. Your age will be recorded as well.
- **Hand Placement Width**: Your hand placement upon the barbells in the present study will be determined and held constant. The length between your left and right acromian process will be measured with measuring tape.

After the pre-exercise measurements have been made, you will be familiarized with the exercise protocol. Before onset of exercise, you will warm up on a cycle ergometer at a resistance of 1kp and a speed of under 70 revolutions per minute.

Once warmed up, you will proceed with three warm up sets with your own selected weight and repetition range. During the initial sets, you will want to familiarize yourself with the movement and cadence set by a metronome. Following the initial sets, you will perform as many as three-5 repetition sets with as much weight as you can comfortably manage. You will have a 10-minute rest period to recover and return to a preexercise state following the initial protocol.

**Visit 2**

During the second visit to the Biomechanics Lab, you will be outfitted with surface EMG electrodes. The locations for electrode placement will be prepared by shaving any hairs and cleansing/abrating of skin to reduce inter-electrode resistance. You will proceed with the same warm up protocol from the first visit.

Once warmed up, you will be prompted to perform a series of maximum voluntary isometric contractions (MVICs) to set a baseline for EMG collection. The order in which you perform each contraction will be randomized. All contractions will be performed three times, from which average peak activation will be acquired. Instruction will be provided prior to each contraction, and 1 minute of rest will be allotted after each contraction to control for fatigue.
Once the MVIC data is collected, you will be assigned to each treatment group (barbell, dumbbells, hollowed out barbell with wheel bearings inside) in a randomized fashion. Before proceeding with the pre-determined weight and repetition range, you will be granted as many as two sets to familiarize yourself with each piece of equipment. Data collection will occur during the 5-repetition sets with the pre-determined weight. After each data collection set, you will be allotted a 5 minute interval for rest to control for fatigue. After the third and final data collection set, the electrodes will be removed from your attachment sites and a 10-minute interval will be granted for post-exercise recovery.

RISKS AND DISCOMFORTS YOU MAY EXPERIENCE IF YOU TAKE PART IN THIS RESEARCH
Immediate risks may include muscle cramping, strain, and/or soreness during exercise. Exercise induced muscle soreness can take effect 1-2 days following any strenuous activity. Physical injury can be caused through resistance training movements if executed improperly on the part of the subject.

POSSIBLE BENEFIT TO YOU IF YOU DECIDE TO TAKE PART IN THIS RESEARCH
We cannot and do not guarantee or promise that you will receive any benefits from this research study. The benefit of participating in this study is to help further research regarding activation of primary and stabilizer muscles in resistance training activities.

COST TO YOU FOR TAKING PART IN THIS STUDY
You are not directly responsible for making any type of payment to take part in this research study. However, you are responsible for providing your own means of transportation to and from the Biomechanics Research Laboratory at The University of Toledo’s main campus in the Health and Human Services Building (room 1416). You will not be compensated for gas, travel, or any other expenses to participate in this research study.

PAYMENT OR OTHER COMPENSATION TO YOU FOR TAKING PART IN THIS RESEARCH
If you decide to take part in this research you will receive no compensation. No money, free treatment, free medications, or free transportation will be provided for this study. No extra credit will be provided to students.

ALTERNATIVE(S) TO TAKING PART IN THIS RESEARCH
The only alternative is to not participate.
CONFIDENTIALITY - (USE AND DISCLOSURE OF YOUR PROTECTED HEALTH INFORMATION)
The researchers will make every effort to prevent anyone who is not on the research team from knowing that you provided this information, or what that information is. The consent forms with signatures will be kept separate from the information we collect, which will not include names and which will be presented to others only when combined with other responses. In addition, all electronic data will be stored on the hard drive of a password protected desktop computer located in the Biomechanics Research Laboratory and all hardcopy/paper copies of data will be kept in a locked cabinet in the Biomechanics Research Laboratory. Although we will make every effort to protect your confidentiality, there is a low risk that this might be breached.

IN THE EVENT OF A RESEARCH-RELATED INJURY
In the event of injury resulting from your taking part in this study, treatment can be obtained at a health care facility of your choice. You should understand that the costs of such treatment will be your responsibility. Financial compensation is not available through The University of Toledo or The University of Toledo Medical Center. In the event of an injury, contact Sue Wambold, PhD at (419) 913-6905 or Travis Reynolds at (330) 696-6905.

VOLUNTARY PARTICIPATION
Taking part in this study is voluntary. You may refuse to participate or discontinue participation at any time without penalty or a loss of benefits to which you are otherwise entitled. If you decide not to participate or to discontinue participation, your decision will not affect your future relations with the University of Toledo or The University of Toledo Medical Center.

NEW FINDINGS: You will be notified of new information that might change your decision to be in this study if any becomes available.

OFFER TO ANSWER QUESTIONS
Before you sign this form, please ask any questions on any aspect of this study that is unclear to you. You may take as much time as necessary to think it over. If you have questions regarding the research at any time before, during or after the study, you may contact Sue Wambold, PhD at (419) 913-6905 or Travis Reynolds at (330) 696-6905.

If you have questions beyond those answered by the research team or your rights as a research subject or research-related injuries, please feel free to contact the Chairperson of the University of Toledo Biomedical Institutional Review Board at 419-383-6796.

SIGNATURE SECTION (Please read carefully)

YOU ARE MAKING A DECISION WHETHER OR NOT TO PARTICIPATE IN THIS RESEARCH STUDY. YOUR SIGNATURE INDICATES THAT YOU HAVE READ THE INFORMATION PROVIDED ABOVE, YOU HAVE HAD ALL YOUR QUESTIONS ANSWERED, AND YOU HAVE DECIDED TO TAKE PART IN THIS RESEARCH.
BY SIGNING THIS DOCUMENT YOU AUTHORIZE US TO USE OR DISCLOSE YOUR PROTECTED HEALTH INFORMATION AS DESCRIBED IN THIS FORM.

The date you sign this document to enroll in this study, that is, today's date, MUST fall between the dates indicated on the approval stamp affixed to the bottom of each page. These dates indicate that this form is valid when you enroll in the study but do not reflect how long you may participate in the study. Each page of this Consent/Authorization Form is stamped to indicate the form’s validity as approved by the UT Biomedical Institutional Review Board (IRB).

Name of Subject (please print) ____________________________________________________________________________  Signature of Subject or Person Authorized to Consent ____________________________________________________________________________  Date ____________________________________________________________________________

Relationship to the Subject (Healthcare Power of Attorney authority or Legal Guardian) ____________________________________________________________________________  Time __________ a.m. p.m.

Name of Person Obtaining Consent (please print) ____________________________________________________________________________  Signature of Person Obtaining Consent ____________________________________________________________________________  Date ____________________________________________________________________________

Name of Witness to Consent Process (when required by ICH Guidelines) (please print) ____________________________________________________________________________  Signature of Witness to Consent Process (when required by ICH Guidelines) ____________________________________________________________________________  Date ____________________________________________________________________________

YOU WILL BE GIVEN A SIGNED COPY OF THIS FORM TO KEEP.
Appendix B: Health History Questionnaire
Age: _______  Gender: M/F  Subject ID #: _______

Weight (lbs): _______ (kg): _______  Height (in): _______ (cm): _______

<table>
<thead>
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<tbody>
<tr>
<td>Family history of heart disease</td>
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<tr>
<td>i.e. Heart attack, bypass, stroke, or sudden death before age 55 in 1st degree male relative (father, brother, son) or before age 65 in 1st degree female relative (mother, sister, daughter)</td>
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<td>Smoking habit</td>
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<td>i.e. Current cigarette smoker or one who has quit within the previous 6 months</td>
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<td>High blood pressure</td>
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<td>i.e. ≥140/90 on two separate occasions or currently on antihypertensive medication</td>
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<td>Abnormal cholesterol levels</td>
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<td>i.e. Total cholesterol &gt;200 mg/dL, or LDL &gt;130 mg/dL, or HDL &lt;35 mg/dL, or currently on lipid lowering medication</td>
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<td>High fasting glucose</td>
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<td>i.e. Fasting blood glucose ≥110 on two separate occasions</td>
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<tr>
<td>Are you inactive?</td>
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</tr>
<tr>
<td>i.e. Accumulate ≤30 minutes of moderate physical activity on most days of the week</td>
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</tbody>
</table>

If you can answer yes to 2 or more above, please obtain medical clearance for exercise from your personal physician.

<table>
<thead>
<tr>
<th>Health Conditions</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain in the chest, neck, jaw, or arms?</td>
<td></td>
<td></td>
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<tr>
<td>Shortness of breath at rest or with mild exertion?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dizziness or fainting?</td>
<td></td>
<td></td>
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<tr>
<td>Awakened by a shortness of breath?</td>
<td></td>
<td></td>
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<tr>
<td>Swelling in your ankles?</td>
<td></td>
<td></td>
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<tr>
<td>Rapid heart rate while at rest?</td>
<td></td>
<td></td>
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<tr>
<td>Leg pain or cramping while walking; stops with rest?</td>
<td></td>
<td></td>
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<tr>
<td>Heart murmur?</td>
<td></td>
<td></td>
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<tr>
<td>Unusual fatigue or shortness of breath with usual activities?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If you can answer yes to any of the above please obtain medical clearance for exercise from your personal physician.

<table>
<thead>
<tr>
<th>Health Conditions</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart attack or stroke?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart surgery (CABG, angioplasty, other)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metabolic disorder (diabetes, kidney, thyroid)?</td>
<td></td>
<td></td>
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<tr>
<td>Respiratory problems (asthma, COPD)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospitalization or surgery within the last 6 months?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If you can answer yes to any of the above please obtain medical clearance for exercise from your personal physician.

Contact Information

- Street: ____________________________
- City: ____________________________
- Zip: ____________________________
- Home Phone: ______________________
- Work Phone: ______________________
- Cell Phone: ______________________
- E-mail: __________________________
- Preferred contact method: __________________________

Emergency Contact Information

- Name: ____________________________
- Relationship: ______________________
- Home Phone: ______________________
- Work Phone: ______________________
- Cell Phone: ______________________

Other Health Related Questions:

- Prescription Medications: __________________________
- Allergies: __________________________
- Do you have any orthopedic conditions/arthritis that may limit your activities? __________________________
- Are you pregnant? If yes, how many weeks? __________________________
- Do you have any other problems or medical conditions not addressed on this form including any disorders that might affect the ability of your blood to clot normally? __________________________
- How long have you had your medical condition(s)? __________________________

Signature: ____________________________  Date: ____________________________

Appendix C: Physical Activity Questionnaire
Health & Physical Activity Level Questionnaire

Subject ID: ____________ Date: __________

1. Do you currently perform regular exercise on 2 or more days of the week for 1 hour or more and have done so for the last 6 months (please circle)?

   YES           NO

   If you answered no to this question, this survey will be concluded

2. If you answered "yes" to question 1, how many days per week on average do you perform exercise?

3. If you answered "yes" to question 1, what type of exercise do you regularly perform (please state all forms of exercise)?
4. If you answered "yes" to question 1, how long does a typical exercise session last?

5. If you answered "yes" to question 1, in the last 12 months what is the longest duration that you have NOT participated in any regular exercise?

6. If you answered "yes" to question 1, during the past 12 months have you participated in, or prepared to participate in, a power-lifting and/or bodybuilding competition (please circle)?

   YES
   NO

7. If you answered "yes" to question 1, during the past 12 months have you participated in, or prepared to participate in, a marathon (26.2 miles) competition (please circle)?

   YES
   NO

8. Do you, or have you had, a bone or joint problem in the past 12 months? Please list your current injury and/or joint problem?
9. Do you, or have you had, a bone or joint problem in the past 12 months that could be made worse by a change in your physical activity?

YES    NO

10. Do you, or have you had, a concussion or any other neurological disorder in the past 12 months?

YES    NO

11. Do you lose, or have you ever lost, your balance because of dizziness?

YES    NO

12. If you answered "yes" to question 11, please indicate approximately how long it has been since you lost your balance because of dizziness.

13. Do you lose, or have you ever lost consciousness?

YES    NO

14. If you answered "yes" to question 13, please indicate approximately how long it has been since you lost your consciousness and indicate the cause if known (i.e. collision during sports, car accident...).
15. Do you have any orthopedic issues such as scoliosis, arthritis, ACL reconstruction, PCL reconstruction, torn meniscus, any bone fractures, patellofemoral syndrome, herniated disc, muscle tears, or tendon tears?

YES  NO

16. If you answered “yes” to question 15, please list your orthopedic injury or condition.

17. Do you know of any other reason(s) why you should not perform physical activity?

YES  NO