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EFFECT OF SURFACE STABILITY ON CORE MUSCLE ACTIVITY DURING DYNAMIC RESISTANCE EXERCISES

by

Brennan J. Thompson

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Health, Physical Education and Recreation

Approved:

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UTAH STATE UNIVERSITY
Logan, Utah

2008

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ABSTRACT

Effect of Surface Stability on Core Muscle Activity

During Dynamic Resistance Exercises

by

Brennan J. Thompson, Master of Science

Utah State University, 2008

Major Professor: Eadric Bressel, Ed.D.
Department: Health, Physical Education and Recreation

The purpose of this study was to compare core muscle activity during resistance exercises performed on stable ground versus an unstable surface and to examine whether lifting at different relative intensities affects core muscle activity levels. Twelve trained men performed four different movements including the deadlift, back squat, military press, and curl. Surface electromyography (EMG) was utilized to assess the activity of the rectus abdominis, external oblique, transversus abdominis, and erector spinae muscles. Participants performed each movement under three separate conditions including standing on stable ground with 50% of their one repetition maximum (1-RM), standing on a BOSU balance trainer with 50% of their 1-RM and, standing on stable ground with 75% of their 1-RM. The following muscles exhibited greater activity during the 75% 1-RM condition than all other conditions: the transversus abdominis (TA) and external oblique (EO) muscles during the deadlift; the rectus abdominis (RA) during the squat; the TA, RA, and EO during the press, and TA and erector spinae (ES) during the

curl. The ES muscle during the press movement and EO during the squat movement were more active during the BOSU 50% 1-RM condition than the stable 50% 1-RM condition. Healthy individuals might consider performing the military press, curl, squat and deadlift movements with higher intensity resistances while standing on stable ground to incur higher widespread muscle activity of the core region.

(61 pages)

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I would like to thank my family; my parents for their support and good example, by living the life the way that most would say life should be lived, but few have the capacity or courage to actually achieve; to my brothers for many priceless memories and adventures; to my sister, brother-in-law, and nephews whom give encouragement, hope, joy, and substance to a wandering nomad.

A personal and uncompromising thanks is expressed to my grandparents. Educational pursuit and achievement are the best thanks I can render to Harold and Elda Thompson; who had the patience, courage, foresight, and love to support and believe in a stubborn young man that had all but given up on graduating from high school.

Brennan J. Thompson

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CHAPTER I

INTRODUCTION

Recently, there has been a significant increase in core stability training for both sports conditioning programs and the general population as a result of fitness professionals emphasizing training the core region of the body. Prior to this, core training exercises were reserved mainly for individuals with low back problems in physical therapy clinics (Check, 1999; McGill, 2001; Saal, 1990). The term core has been defined as the 29 pairs of muscles that support the lumbo-pelvic-hip complex. Core muscles such as the rectus abdominis and erector spinae may stabilize the spine and pelvis, and increase power transfer during functional movements (Fredericson & Moore, 2005). Core strength and endurance are important both for athletic performance and overall general health, including prevention and treatment of low back pain (Biering-Sorensen, 1983). Researchers suggest that strong and endurable core muscles stabilize the spine favorably by providing greater passive support with effective mechanical integrity and enhanced neurological recruitment patterns; including timely activation of these muscles when exposed to forces and loads (Cholewicki, Simons, & Radebold, 2000; Hodges & Richardson, 1996; McGill, Grenier, Kavcic, & Cholewicki, 2003).

Researchers have examined different methods to strengthen the core. A common and popular method used to train the core is unstable surface training. Examples of unstable apparatus' may include but are not limited to stability balls, wobble boards, foam pads, and balance discs. The believed advantage of training on unstable surfaces is based on the importance of neuromuscular adaptations and the association with increases

in strength (Anderson & Behm, 2005; Behm, 1995; Sale, 1988). It has been suggested that an increase in instability of the surface to human body interface will stress the neuromuscular system to a greater degree than stable resistance training methods performed on solid ground (Behm, Anderson, & Curnew, 2002).

Several studies have demonstrated that performing exercises on an unstable surface elicits a greater effect on increasing the muscular activity of the core region, including the rectus abdominis, erector spinae, and internal and external oblique muscles (Arokoski, Valta, Airaksinen, & Kankaanpaa, 2001; Behm et al., 2005; Marshall, & Murphy, 2005; Marshall & Murphy, 2006; Norwood, Anderson, Gaetz, & Twist, 2007). Norwood et al. (2007) compared core muscle activity during four bench-press movements with varying degrees of instability. The results demonstrated that there was a greater increase in electromyographic (EMG) activity of all but the rectus abdominis muscles during the dual instability bench-press condition. Similarly, Marshall and Murphy (2006) also found that performing the bench press on a swiss ball resulted in increased EMG activity of the abdominal muscles compared to the same exercise performed on a stable bench.

Much of the research on unstable surface training has examined the effects of EMG activity of the core region while performing exercises lying on a swiss ball. Cressey et al. (2007) proposed that standing unstable strength training exercises may stress the core differently than trunk-specific exercises (e.g., curl-ups) performed on a swiss ball because the overall stability challenge is less difficult while lying on the ball.

To date, little research has evaluated the EMG activity of core muscles during conventional free weight exercises on an unstable surface. Anderson and Behm (2005)

conducted one such study in which they compared core muscle activity during three squat movements with varying levels of instability: (a) an unstable squat performed while standing on balance discs, (b) a stable squat performed with a free weight bar while standing on stable ground, and (c) a very stable squat performed on a Smith machine while standing on stable ground. Each squat movement was performed at three levels of resistance (i.e., body mass, 29.5 kg, & 60% of body mass). The results indicated that EMG activity of all muscles examined increased progressively from the very stable to the unstable squat condition. A limitation of their study was that a low percentage of relative strength was used.

Because healthy individuals might be capable of lifting at higher intensities when standing on stable ground versus an unstable surface, there is a need for research to compare differences in core muscle activity with loads that are typical and safe for each condition. This may allow for meaningful comparisons that could be applied in training settings.

Therefore, the purpose of this study was to compare differences in the activity of four selected core muscles when resistance exercises were performed while standing on stable ground versus standing on a BOSU balance trainer. A dual purpose was to examine the effects of lifting at different relative intensities on core muscle activity as measured by EMG. The researcher hypothesized that standing on stable ground would result in increased levels of core muscle activity due to the ability to use greater resistance.

CHAPTER II

LITERATURE REVIEW

Recently, there has been a substantial increase in core stability training for both sports conditioning programs and healthy individuals as a result of fitness professionals emphasizing training the *core* region of the body. Prior to this new training fad, core training exercises were reserved mainly for individuals with low back problems in physical therapy clinics (Check, 1999; McGill, 2001; Saal, 1990).

In 1989, the San Francisco Spine Institute published a manual entitled *Dynamic Lumber Stabilization Program*, within which a concept of the neutral spine was stressed (Saal, 1990; San Francisco Spine Institute, 1989). It was likely this concept that may be largely responsible for the popularizing of core training exercises to a more commercialized setting (Liemohn, Baumgartner, & Gagnon, 2005). The concept and application of core training can now be found among physical therapists, personal trainers, strength and conditioning professionals and the like. Many of the ideas and rational behind this newfound exercise frenzy are propagated by the media. Core training has become the newest 'buzz' word in the fitness and conditioning fields. Magazine articles, seminars and work-shops, research articles, and even newspapers are teaming with information related to this training topic (Boyle, 2004; Chek, 1999; Gambetta & Clark, 1999; Johnson, 2002; Morris & Morris, 2001).

This literature review will discuss several aspects pertaining to core stabilization training. The following sections will be included in this review: (a) definition of the core

region, (b) purpose and rationale of core training, (c) unstable surface training, and (d) summary.

Definition of the Core Region

As the term core implies, it is the central portion of the body, or torso, where stabilization of the abdominal, paraspinal, and gluteal muscles are critical for optimal performance (Nadler et al., 2002). The core is much more than the abdominal muscles. In addition to the abdominal muscles (rectus abdominis, external oblique, internal oblique, & transversus abdominis), the core consists of four general muscle groups: (a) hip musculature, (b) lumbar spine musculature, (c) thoracic spine musculature, and (d) cervical spine musculature (Hedrick, 2000). Fredericson and Moore (2005) provided a more absolute definition that states: "The core musculature can be defined generally as the 29 pairs of muscles that support the lumbo-pelvic-hip complex in order to stabilize the spine, pelvis, and kinetic chain during functional movements" (p. 26).

A further distinction categorizing the core muscles into local and global subgroups has been developed. The local muscles are primarily responsible for generating sufficient force for segmental stability of the spine. These muscles are shorter in length and attach directly to the vertebrae offering spinal support by both passive and active mechanisms (Briggs, Greig, Wark, Fazzalari, & Bennell, 2004). The muscles primarily in charge of producing movement and torque of the spine are collectively described as the global muscles. These muscles possess long levers and large moment arms, which allows them the capability of producing high outputs of torque, with an emphasis on speed and power while countering external loads for transfer to the local

musculature (Fredericson & Moore, 2005). The global muscles are generally the larger muscles of the trunk region, responsible for eliciting movement in a wider range of motions. It is important to note that both the global and local subsystems are involved in both movement and stability. It has been proposed that one group is merely emphasized more in regards to the aforementioned designation of the proposed function for each. Both systems theoretically work in synergism (Cholewicki & Van Vliet, 2002).

Purpose and Rationale of Core Training

Many health professionals emphasize core training in a variety of settings. Strength and conditioning coaches recognize the benefits of a strong core in enhancing sport performance. Fitness professionals convey to the general population the benefits of core training or core health and the effects on activities of daily living, injury prevention, and aesthetic benefits. Rehabilitation professionals are known to have pioneered the training of the trunk muscles both for treatment of injury and prevention of re-occurrence of injuries related to poor trunk muscle development.

Trunk strength is critical for performance because all movements either originate in or are coupled through the trunk (Brittenham & Brittenham, 1997). Therefore, to develop an athlete's full potential, the core strength must be at least equal, if not greater, to that of the rest of the body. As the old saying goes, 'a chain is only as strong as its weakest link.' For many people and athletes this weak link is the core region of the body.

The core allows for an improved force output when adequate strength is attained. The trunk connects movements of the lower body to the upper body and vise versa. Force vectors are continuously being transmitted up and down the body when performing

movements. Ground reaction forces as well as those generated by the lower body muscles are transferred up the body to the upper extremities when used in an activity (Hedrick, 2000). Also, the weight and forces applied at the upper extremities move through the body down to the ground. In either case, the forces all must traverse through the core. The core musculature is also responsible for generating a variety of movements of the trunk in many planes of motion.

A poorly developed core may also contribute to poor posture. Because force is transferred most efficiently through a straight line, poor posture can lead to less efficient movements and decreased force output (Brittenham & Brittenham, 1997). This may reduce the power output of the upper extremities, as well as lead to jerky, uncoordinated movements. These principles apply to sport performance as well as any functional activity that may be performed by a human being. The results of a strong core may lead to an increase in power transfer involved in a variety of activities such as throwing, jumping, running, lifting, striking, and just about any other movement that humans use to develop forces in an almost infinite number of movement patterns.

Studies have shown that a poorly developed core may be correlated with low back pain. It has been well established that core muscles provide an important role in stabilizing the spine (Cholewicki & McGill, 1996; Crisco & Panjabi, 1991). Because the spine is inherently unstable, a critical role of the musculature is to stiffen the spine during movements that elicit instability (McGill, Grenier, Kavcic, & Cholewicki, 2003). McGill, et al. (2003) found that it is likely that spine stability results from highly coordinated muscle activation patterns that involve many muscles and that recruitment patterns must continually change, depending on the task. It has also been observed that a

deficiency in the timing of muscle activation in response to sudden trunk loading is documented in patients with low back pain (Hodges & Richardson, 1999; Magnusson et al., 1996). Implications as a result of these findings apply to both the prevention and treatment of patients susceptible of sustaining unstable events. This is based on the fundamental principle that load bearing tissue will result in stiffness losses and an increased risk of unstable behavior when the mechanical integrity of these tissues is lost or diminished (McGill et al., 2003). Instability of the spine can be associated with both the cause and result of injury.

It has been suggested that it only takes one muscle with inappropriate activation amplitude to produce instability. Furthermore, Stuart McGill (2003) who is a leading expert on the subject of muscle coordination and activation patterns has said: "The relative contributions of each muscle continually changes throughout a task, such that discussion of the most important stabilizing muscle is restricted to a transient in time" (p. 355). This would support the theory that to have a stable and thus healthy spine, all muscles of the trunk must possess a minimum muscular strength or endurance level that apparently needs to be above a certain threshold.

Several studies suggest that endurable muscles in the core region reduce the risk of low back troubles (Biering-Sorenson, 1983; Luoto, Helioraara, Hurri, & Alaranta, 1995). In a study conducted by Biering-Sorenson (1983), participants were tested for trunk muscle strength and endurance. The results of the study after a 1-year period were that good isometric endurance of the low back muscle was a significant predictor of reducing low back trouble in men. They also found that men with hyper-mobile backs were more likely to contract low back trouble.

The research suggests that a relationship exists between healthy, endurable, and strong core muscles and reduction of risk for low back pain. This is likely due to several factors: (a) abnormal muscle recruitment and activation patterns, (b) poor/weak muscle endurance and strength measures, and (c) lack of mechanical integrity of both the muscles as well as the passive structures that are responsible for stabilizing the spine. Many professionals concur that a strong, endurable, and healthy core are important for overall health, performance, and injury prevention and treatment. There is however, much more discrepancy involved in the programming methods by which this is achieved, which encompasses a wide variety of variables and little empirical support for an absolute concrete and superior training method.

Unstable Surface Training

Training on an unstable surface is a common method used to train the core region of the body. Free weight exercises that used to be traditionally performed on stable ground are now performed on unstable apparatus'. For example, it is not uncommon to observe squats or chest presses being executed on balance discs or swiss balls in gyms and sporting facilities. There are almost an infinite number of ways or apparatus' that could be used to elicit an unstable training environment. The most common unstable training tools on the market today however, are wobble boards, foam pads, swiss balls, balance discs, and BOSU balance trainers.

The main purpose or goal of training on an unstable surface is to decrease the points of contact the body has with a solid surface. This can potentially be done at any interface between the human body and a surface it contacts. The believed advantage of

training on unstable surfaces is based on the importance of neuromuscular adaptations and the association with increases in strength. It is believed that increasing the instability of the surface and human body interface will stress the neuromuscular system to a greater degree than stable resistance training methods performed on solid ground (Behm, Anderson, & Curnew, 2002). This increased challenge on the neuromuscular system may provide an overload stimulus above the current threshold and thereby elicit a positive training adaptation. Unstable surface training has the potential to be a time efficient and cost effective mode to improve several health and performance parameters simultaneously. If proven to be effective, this form of training may increase strength and torque production, increase core muscle strength and endurance, decrease risk for low back injury and improve coordination and balance all at the same time. As with any new concept each of these claims must be validated with sound empirical data to prove or disprove the effectiveness of each.

The remainder of this literature review will focus on giving a brief overview of the current research on unstable surface training and its effectiveness on core activation. Several studies have investigated the performance of exercises on unstable surfaces and the effects conferred upon the local muscles. The common outcome measure for assessing these effects has been muscle activation measured by EMG. A summary of these findings is provided in Table 1.

Table 1

Muscle Activation for Stable vs. Unstable Surfaces

Authors	Purpose	Methods	Movements	Muscles	Summary of results
Anderson and Behm (2005)	Evaluate differences in EMG activity of various muscles while performing squats of varied stability and resistance	14 healthy men Stability was altered by performing squats under 3 conditions with varied loads	1. SMS 2. FS 3. SBD	SOL VL BF AS ULES LSES	Activities of the SOL, AS, ULES, and LSES were highest during SBD and lowest with SMS
Behm and co-Leagues (2005)	Evaluate the effect of unstable and unilateral ex-ercises on trunk muscle activation	11 healthy men and women Unilateral and bilateral exercises on stable or unstable bases	1. Bridge 2. Pelvic tilt 3. AALE 4. PH 5. SB 6. Superman 7. CP 8. SP	ULES LSES LA	Instability generated greater activation of the LA with the trunk exercises and all trunk stabilizers with the chest press Unilateral shoulder press produced greater activation of back

(table continues)

Authors	Purpose	Methods	Movement	Muscles	Summary of results
					stabilizers and unilateral chest press resulted in higher activation of ES
Norwood and Colleagues (2007)	Investigate the effectiveness of instability training in recruitment of core stabilizing muscles during varying degrees of instability	15 healthy men and women EMG measured while subjects performed bench press exercise on stable or unstable surfaces	1. SSSF 2. UBI 3. LBI 4. DI	LD RA IO ES SOL	Significant increases in EMG with increasing instability DI resulted in greatest mean muscle activation of 3 conditions. Single instability conditions significantly greater than stable condition
Marshall and Murphy (2006)	Investigate muscle activity using EMG of upper body and abdominal muscles during bench press on and off a swiss ball	14 healthy trained men and women Performed eccentric and concentric bench press reps on swiss ball or stable bench	Bench Press stable or unstable at 60% 1 – RM	AD BB TB PM RA TA	AD, RA, and TA activity was increased for repetitions performed using the swiss ball compared with the stable bench

EMG = electromyography; SMS = Smith machine squat; FS = freeweight Squat; SBD = squat on balance discs; SOL = soleus; VL = vastus lateralis; BF = biceps femoris; AS = abdominal stabilizers; ULES = upper lumbar erector spinae; LSES = lumbo-sacral erector spinae; AALE = alternate arm and leg extension; PH = parallel hold; SB = side bridge; CP = chest press; SP = shoulder press; LA = lower abdominals; SSSF = stable surface for shoulders and feet; UBI = upper body instability; LBI = lower body instability; DI = dual instability; LD = latissimus dorsi; RA = rectus abdominis; IO = internal oblique; ES = erector spinae; AD = anterior deltoid; BB = biceps brachii; TB = triceps brachii; PM = pectoralis major; RA = rectus abdominis; TA = transversus abdominis

Behm et al. (2005), Marshall and Murphy (2006), and Norwood et al. (2007) all examined the effects of performing repetitions on the bench press under stable and unstable conditions. Their results demonstrated that the unstable bench press condition increased core muscle activity more than the stable condition. These studies suggest that there appears to be an association between the level of instability that an exercise is performed on and muscle activity levels. This association appears to move in a somewhat linear fashion, as instability increases muscle activation also increases, as demonstrated by Norwood et al. (2007).

Of the studies described in Table 1, only one study evaluated the effects of muscular activity levels while doing a standing, dynamic, multi-joint, free weight exercise. This was the study conducted by Anderson and Behm (2005), in which the squat was used on three conditions of varying stability. The condition in which the squat was performed on balance discs (greatest instability of all conditions) invoked the greatest degree of activity from the four muscles that were evaluated.

One aspect of this study evaluated the effect of different levels of resistance on the activity levels of the muscles of interest. Participants in the study performed each movement at three different intensities: (a) no external resistance (body mass), (b) 29.5

kg, and (c) 60% of body mass. There was a significant increase in EMG activity for all muscles except the biceps femoris and abdominal stabilizers as resistance increased. Perhaps there is a threshold point that must be achieved for the abdominal stabilizers to increase in activation levels as the remainder of the muscles exhibited.

It appears that more research is warranted on both instability and multi-joint exercises as well as amount of resistance used during the movement. It would seem logical to perform exercises on an unstable surface while in a standing position, because this is the way most sports and daily activities are performed. It would also seem advantageous to perform multi-joint, dynamic movements because these are the foundation exercises for most strength and power developments in most weight lifters and power athletes. To date, only one study has evaluated one exercise in this manner on an unstable surface that is known to the author. Clearly more research is warranted to evaluate the effects of performing other standing, dynamic movements on an unstable surface on muscle activation of the core region.

Another area that needs more research is the amount of resistance and the effects on muscular activation. The Anderson and Behm (2005) study reported a relationship between the amount of resistance and muscle activation. Interestingly the amount of resistance even in the highest resistance condition was relatively light (60% body mass) considering the squat exercise has a high potential for force output. Most athletes and weight lifters perform the squat on stable ground at a percentage equal or greater to 70% 1 RM. One repetition maximum (& related percentages) would also appear to be a more valid measure of relative strength than loads based on body weight percentage. External load or intensity is a critical component in strength training as muscular adaptations have

been shown to result from overload at a minimum level of 60% 1 RM (McDonagh & Davies, 1984). Therefore, performing strength training exercises below 60% intensity may prove to be counter-productive on stable ground. It may be noted that this 60% threshold for a training stimulus was only validated on stable surfaces. Less is known about the effects of intensity on invoking a training stimulus while on an unstable surface. In theory, a given percentage of stable 1 RM on an unstable surface would be relatively higher. For example, 50% of stable 1 RM would be relatively higher than 50% unstable 1 RM due to the decreased capacity for force production on the unstable surface. Research is needed to examine the effects of varying intensities from stable to unstable surfaces and the effects each has on muscle activation patterns.

Summary

After examining the research on the subject of unstable surface training, it is evident that more research is needed to evaluate the effects of multi-joint, dynamic movements performed standing on an unstable surface. It is also evident that more studies need to examine the effects of different relative intensities, including a relatively high intensity (one that is commonly used by weight lifters, i.e., > 70% 1 RM). These variables need to be evaluated on a more extensive region of the core muscles, to give the strength and conditioning field a better understanding of the effects of this modality of training, whether they be positive or negative; time efficient or inefficient; and ultimately effective or ineffective in regards to what it is believed this form of training is used for.

CHAPTER III

METHODS

Participants

Twelve male subjects volunteered from a university community to participate in the study (age, 21.50 ± 1.31 year; height, 179.08 ± 5.62 cm; weight, 83.17 ± 9.25 kg). Qualification criteria for the study were that the participants were required to be trained lifters, with a minimum of 4 years of consistent performance of all exercises tested. All participants were currently training in a program for the purpose of strength and hypertrophy with a frequency of 3 to 5 sessions per week. One repetition maximums were taken on two occasions (squat, 132.45 ± 23.25 kg; deadlift, 154.12 ± 10.98 kg; military press, 67.12 ± 9.55 kg; barbell curl, 55.21 ± 6.45 kg) and the mean was used for computing percentage of load to be lifted for the conditions.

Participants were screened using a PAR-Q to rule out pre-existing health contraindications and risk factors to exercise. None of the participants had any low back, knee, or ankle injuries during the previous year. Each participant signed an informed consent prior to participating in the study, which was approved by the institutional review board at Eastern Illinois University. Participants were permitted to continue their current resistance training program throughout the study. However, they were restricted from lifting weight the same day prior to a testing session.

Procedures

All participants engaged in a 5-week familiarization protocol prior to EMG testing to become familiar with the unstable surface and to determine maximal strength.

Participants attended one training session per week. During Week 1, participants practiced the required movements while standing on the BOSU balance trainer. During this session, participants performed 2 sets of 15 repetitions of each movement while utilizing an unloaded Olympic barbell (20 kg). Maximal strength testing was assessed on stable ground for each movement during Weeks 2, 3, 4, and 5. Maximal strength testing was assessed twice for each movement; during Weeks 2 and 4 for the back squat and overhead press, and during Weeks 3 and 5 for the deadlift and curl. As a safety precaution, all testing sessions took place while standing inside a lifting cage, in which catch pins were set at the bottom point in the range of motion for each movement. Two experienced spotters were present for each testing session.

Maximal strength testing for all lifts proceeded as follows: for the first warm-up set, 5-10 repetitions were performed at 40-60% of the perceived maximum. Participants were allowed to rest for 1-min and perform light stretching, then 3 to 5 repetitions were performed at 60-80% of the perceived maximum. Resistance was then increased to the same level or a level that was 5-10 pounds higher than the perceived maximum, and a maximal repletion was attempted. If the repetition was successful, 5-10 more pounds were added to the bar, and following a 5 min rest, another maximal repetition was attempted. This process was repeated until a failed attempt occurred. The 1-RM (one-repetition maximum) was recorded as the last successfully completed attempt.

Following each of the maximal strength tests on stable ground, participants practiced the same lift while standing on the BOSU balance trainer for 2 sets of 15 repetitions with 50% of the maximal resistance. During Week 6, the muscle activity of

the selected trunk muscles was assessed using EMG. Both the order of exercise sequence and the mode of exercise were counterbalanced.

All 4 of the exercises were performed under 3 conditions: (a) 50% of 1 RM on a stable surface, (b) 50% of 1 RM on the BOSU, and (c) 75% of 1 RM on a stable surface. Cadence was controlled for by giving a verbal count to the subject while performing each repetition by an administrator using a stop watch. Cadence was set at a constant 4 s to lower the weight and 4 s to raise the weight. Each exercise was performed 3 times, except on a few participants where level of difficulty appeared to be in excess, in which case only 2 repetitions were used for EMG recording. All participants completed the study as originally prescribed, none of the participants failed to meet the requirements of the aforementioned protocols.

Skin impedance to the electrical signal was reduced by: (a) shaving the location at the site of the electrode placement, (b) wiping the skin with isopropyl alcohol swabs, and (c) gently abrading the skin with fine grade sandpaper. Medical grade adhesive was used to affix the electrodes to the skin. Electromyographic (EMG) signals were recorded using Delsys DE-2.1 differential surface electrodes, which contained preamplifiers (10 x) potted in polycarbonate enclosures (Delsys Inc. Boston, MA, USA). The electrode configuration included 2 silver bars each 10 mm long x 1 mm in diameter. The inter-electrode distance was 10 mm with a typical common-mode rejection ratio of 92 dB, with a minimum at 84 dB. The surface electrodes were positioned on the skin over muscles rectus abdominis (RA), external oblique (EO), transversus abdominis (TA), and erector spinae (ES). A common reference electrode was placed on the skin over the anterior superior iliac spine. These muscles were selected as they can be observed with surface

EMG and because they are representative of the core muscle group. The guidelines for positioning the electrodes over muscle RA, EO, and ES were followed as described by Cram and Kasman (1998). Muscle TA location was determined using procedures described by Marshall et al. (2005). The TA location of 2 cm inferior and medial to the anterior superior iliac spine is where the TA blends with the internal oblique muscle, therefore, the activity of these 2 muscles can not be separated. EMG activity from the selected muscles of each participant was recorded on the right side only. A small fan was placed directly in front of the participants while they were performing the activities to help prevent sweating, which could possibly cause the electrodes to become unsecured.

Participants commenced their repetitions on the verbal command “go” at which time the EMG system was manually triggered to record 10 s of data between a bandwidth of 20 Hz and 450 Hz. EMG signals were amplified by a factor of 10000 using a Delsys Bagnoli-4 amplifier (Delsys Inc.). The amplified signals were sampled at 1000 Hz with a 16-bit A/D card and subsequently used for analytical procedures.

Upon completion of collecting the EMG data during the weight lifts, participants were asked to perform maximal voluntary isometric contractions (MVIC) for each muscle as reference data. For muscles RA and TA subjects lay supine with hips and knees flexed and feet secured by an assistant. Participants crossed their arms over their chest and on the command “go” attempted to maximally curl-up against resistance. For muscle EO the curl-up included a twist to the left. For muscle ES subjects lay prone with feet secured by an assistant. Participants placed their hands behind their head and on the command “go” they attempted to extend the trunk maximally against resistance. Each test was performed twice and each effort was held for 3 s with a 30 s rest in between

repetitions. Participants received verbal encouragement while performing MVIC contractions. Muscle EMG activity was recorded during all MVIC tests and used for post processing.

EMG Analysis

During post processing, the root mean square (RMS) over an 8 s window of the EMG data collected during each repetition for each weight lifting exercise was computed. The RMS over the middle 8 s of the 10 s window was chosen to correspond with the 8 s lifting cadence. An average RMS was then computed over the 3 repetitions of each exercise performed. The average RMS value was then normalized to the peak RMS value computed for each muscles MVIC test. Accordingly, the dependent measure was a normalized EMG (NEMG) value as a percent of MVIC.

Statistical Analysis

The NEMG of each muscle assessed was compared between each condition (50% 1-RM stable, 50% 1-RM unstable, and 75% 1-RM stable) using a repeated measure analysis of variance (ANOVA). Significance of a main effect was based on an alpha level of $p < 0.05$. In the event of significance, post hoc comparisons were made using the Bonferroni correction factor. All statistical comparisons were made using SPSS version 15.0 (SPSS Inc., Chicago, IL).

CHAPTER IV

RESULTS

The purpose of this study was to compare differences in activity of four core muscles when resistance exercises were performed on stable ground versus on a BOSU balance trainer. A dual purpose was to examine the effects of increasing the intensity (load) of each exercise on the muscle activation for the same core muscles. A total of four movements were performed under three conditions. The independent variables were the type of surface (stable and unstable) and amount of resistance (50% 1-RM and 75% 1-RM) for each movement. The *ANOVA* revealed a significant effect for each muscle (p = 0.001-0.002). The NEMG (%) values for each condition tested are presented in Table 2.

Table 2

Muscle Activity (NEMG;μ, SD) for Movements, Muscles, and Conditions

Movement	Condition	TA	RA	EO	ES
Deadlift	50Stable	10.5 ± 1.44	3.95 ± 0.41	10.1 ± 1.40	63.4 ± 5.90
	75Stable	14.7± 1.40*	4.39 ± 0.52*	14.2 ± 2.12*	62.8 ± 6.70
	50BOSU	9.44 ± 1.17**	4.27 ± 0.43	12.1 ± 2.30**	66.1 ± 8.30
Squat	50Stable	9.63 ± 1.23	3.89 ± 0.44	7.76 ± 0.82	46.2 ± 5.99
	75Stable	10.6 ± 1.34	4.69 ± 0.59*	9.42 ± 1.03	55.1 ± 3.85
	50BOSU	7.90 ± 1.10**	3.70 ± 0.30**	10.8 ± 1.27*	53.0 ± 5.07

(table continues)

Movement	Condition	TA	RA	EO	ES

Press	50Stable	31.7 ± 6.30	3.92 ± 0.31	14.7 ± 2.60	13.1 ± 1.47
	75Stable	42.4 ± 8.40*	9.93 ± 2.14*	25.4 ± 4.70*	16.8 ± 1.20*
	50BOSU	24.7 ± 3.30**	5.35 ± 0.71**	17.9 ± 3.27*	16.7 ± 2.24*
Curl	50Stable	24.1 ± 3.30	3.64 ± 0.48	7.38 ± 1.40	20.5 ± 1.56
	75Stable	45.9 ± 3.10*	3.75 ± 0.45	11.5 ± 1.37*	31.1 ± 2.45*
	50BOSU	19.6 ± 2.40**	3.50 ± 0.44	9.21 ± 1.99	23.0 ± 2.12**

Note. TA = transversus abdominis; RA = rectus abdominis; EO = external oblique; ES = erector spinae

*$p < 0.05$ significant difference from 50 Stable. ** $p < 0.05$ significant difference from 75 Stable

Deadlift

Post-hoc comparisons indicated the TA muscle was 29% and 36% more active during the 75% 1-RM condition than the 50% 1-RM and BOSU 50% 1-RM conditions respectively. The RA muscle was 10% more active during the 75% 1-RM condition than the stable 50% 1-RM ($p = .017$) condition. The EO exhibited significantly more activity during the 75% 1-RM condition compared to the stable 50% 1-RM (29% greater; $p = .008$) and BOSU 50% 1-RM (15% greater; $p = .022$; see Figure 1) conditions. There were no other significant differences for the deadlift (see Figure 2).

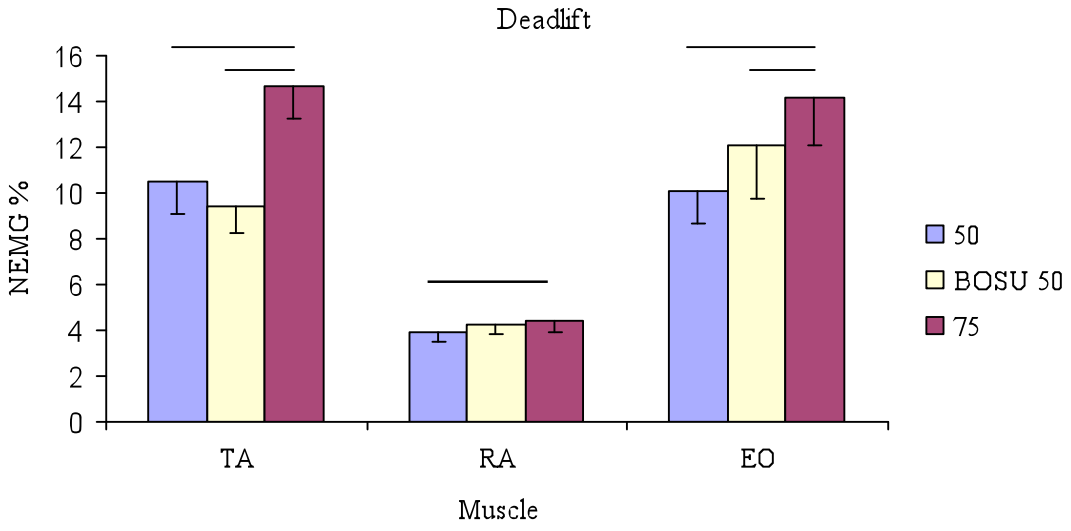

Figure 1. NEMG amplitude of core muscle activity expressed during the deadlift movement for three conditions: a) stable 50% 1-RM, b) BOSU 50% 1 –RM, and c) stable 75% 1 –RM. Horizontal bars indicate significance ($p < 0.05$) between conditions. TA and EO muscles exhibited significantly more activity during the 75% 1-RM condition than the stable 50% 1-RM and BOSU 50% 1-RM conditions. RA muscle activity was significantly greater during the 75% 1-RM condition than the stable 50% 1-RM condition. TA = transversus abdominis; RA = rectus abdominis; EO = erector spinae

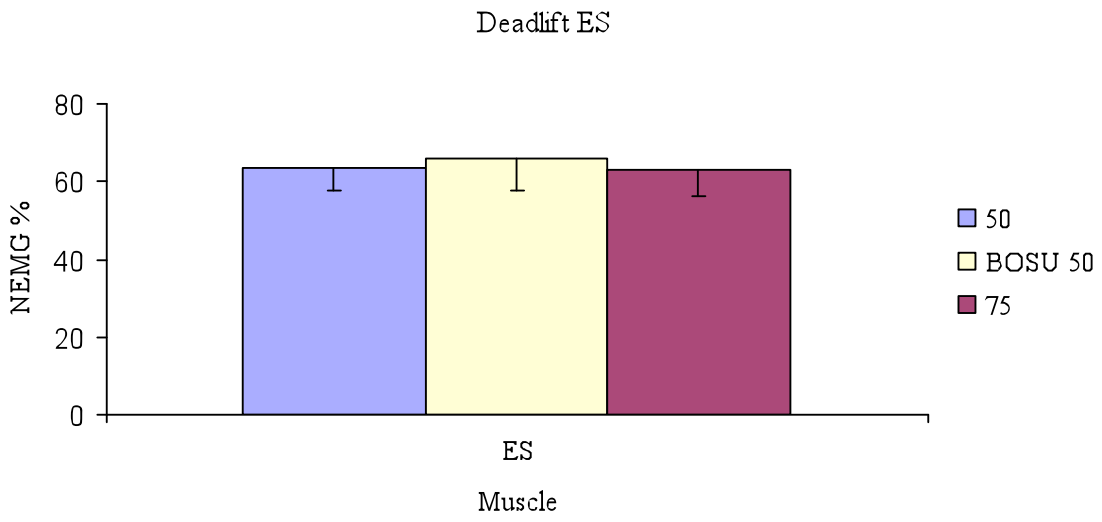

Figure 2. NEMG amplitude of ES muscle activity during the deadlift movement. No significant differences ($p > 0.05$) were found for ES muscle activity during the three conditions. ES = erector spinae

Squat

Post-hoc comparisons for the squat movement indicated the TA muscle was 25% more active during the 75% 1-RM condition than the BOSU 50% 1-RM ($p = .006$) condition. The RA muscle exhibited significantly greater activity for the 75% 1-RM condition than the stable 50% 1-RM (16% greater; $p = .039$) and BOSU 50% 1-RM (21% greater; $p = .042$) conditions. The EO muscle was 28% more active during the BOSU 50% 1-RM condition than the stable 50% 1-RM ($p = .003$; see Figure 3) condition. There were no other significant differences for the squat (see Figure 4).

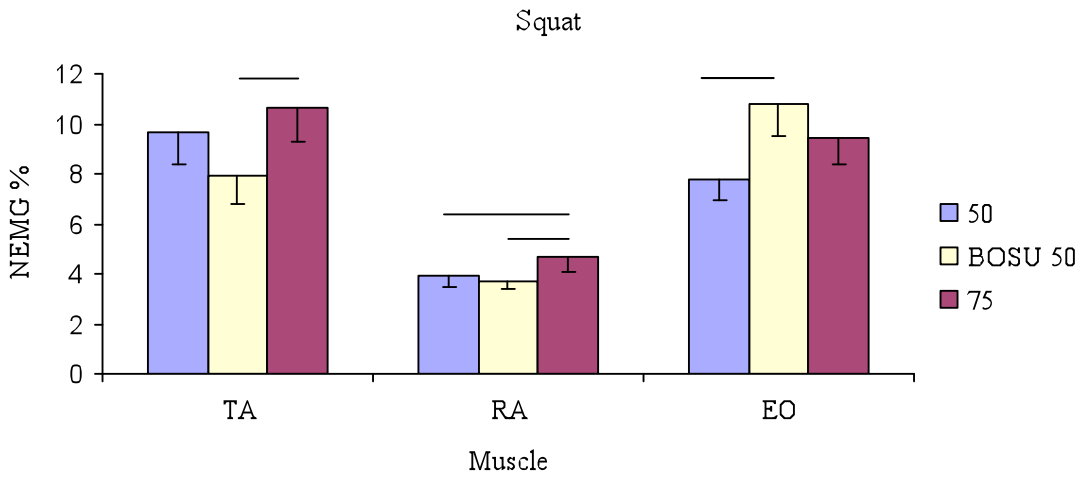

Figure 3. NEMG amplitude of core muscle activity during the squat movement. Horizontal bars indicate significance ($p < 0.05$) between conditions. The TA and RA muscles were significantly more active during the stable 75% 1-RM condition than the BOSU 50% 1-RM condition and RA muscle activity was greater during the 75% 1-RM condition than the stable 50% 1-RM condition. EO muscle activity was greater during the BOSU 50% 1-RM condition than the stable 50% 1-RM condition. TA = transversus abdominis; RA= rectus abdominis; EO = external oblique

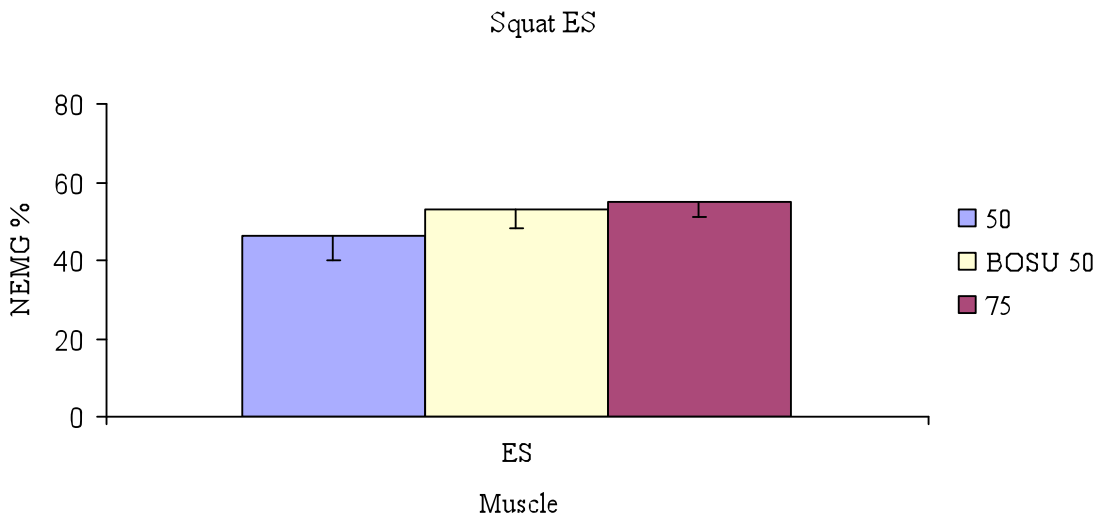

Figure 4. NEMG of ES muscle activity during the squat movement. No significant differences ($p > 0.05$) for ES muscle were observed between conditions . ES = erector spinae

Press

Post-hoc comparisons indicated the TA muscle was 25% more active during the 75% 1-RM condition compared to the stable 50% 1-RM ($p = .037$) and 42% more active than the BOSU 50% 1-RM ($p = .006$) conditions. Likewise, both the RA and EO muscles exhibited greater activity during the 75% 1-RM condition than both the stable 50% 1-RM (RA 60% greater, p = .013; EO 42% greater, $p = .001$) and the BOSU 50% 1-RM (RA 46% greater, $p = .038$; EO 30% greater, $p = .027$) conditions. The ES muscle was 22% more active during the 75% 1-RM condition than the stable 50% 1-RM ($p = .027$) condition and also 22% more active during the BOSU 50% 1-RM condition than the stable 50% 1-RM (p = .007; see Figure 5) condition.

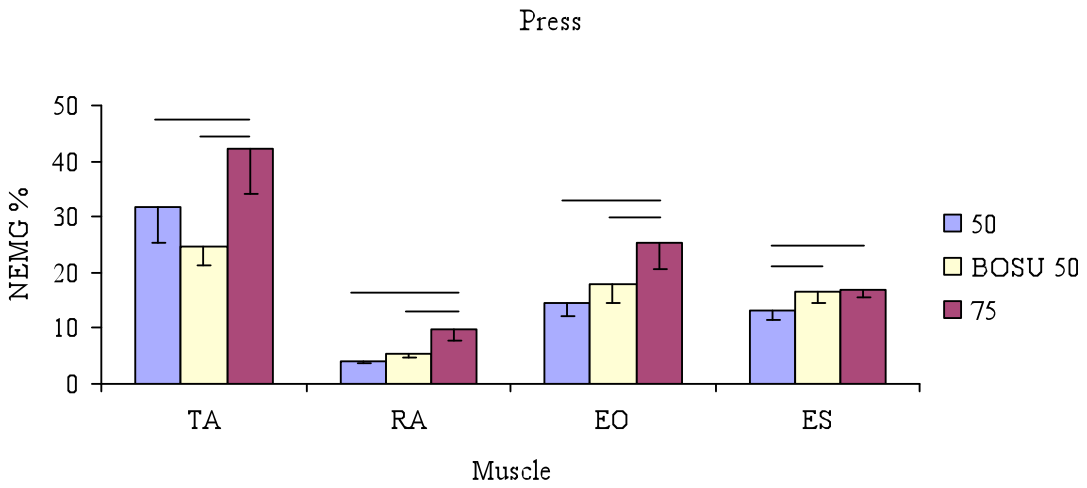

Figure 5. NEMG amplitude of core muscle activity during the press movement. Horizontal bars indicate significance ($p < 0.05$) between conditions. TA, RA, and EO muscles were more active during the stable 75% 1-RM condition than *both* the stable 50% 1-RM and BOSU 50% 1-RM conditions. The ES muscle was more active during both the stable 75% 1-RM and BOSU 50% 1-RM conditions than the stable 50% 1-RM condition. TA = transversus abdominis; RA = rectus abdominis; EO = external oblique; ES = erector spinae

Curl

Post-hoc comparisons indicated the TA muscle was 47% more active during the 75% 1-RM condition than the stable 50% 1-RM ($p < .0001$) and 57% more active than the BOSU 50% 1-RM ($p < .0001$) conditions. The EO muscle exhibited 36% more activity during the 75% 1-RM condition than the stable 50% 1-RM ($p = .001$) condition. The ES muscle was 34% more active during the 75% 1-RM condition than the stable 50% 1-RM ($p < .0001$) and 26% more active than the BOSU 50% 1-RM ($p = .001$; see Figure 6) conditions. There were no other significant differences for the curl.

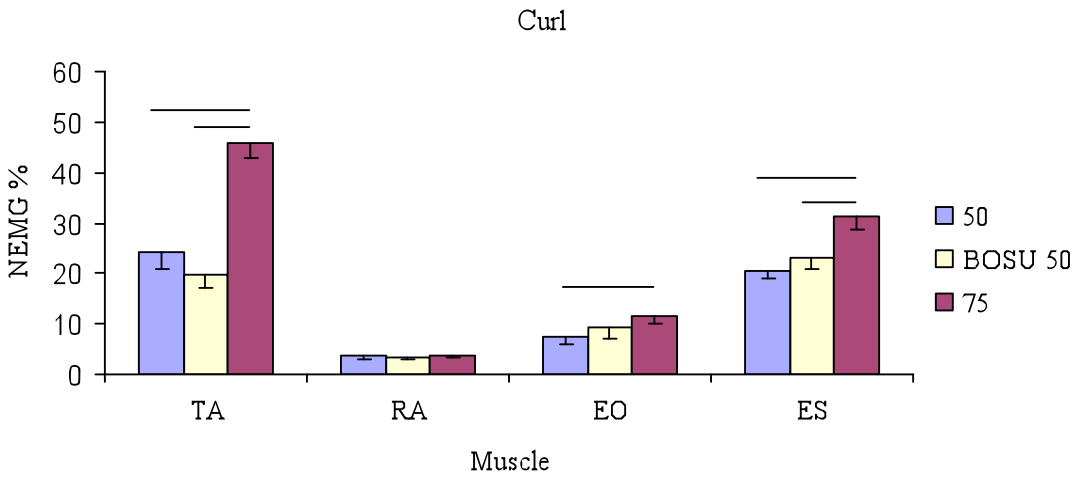

Figure 6. NEMG amplitude of core muscle activity during the curl movement. Horizontal bars indicate significance ($p < 0.05$) between conditions. TA and ES muscle activity was higher during the stable 75% 1-RM condition than *both* the stable 50% 1-RM and BOSU 50% 1-RM conditions. The EO muscle was more active during the stable 75% 1-RM than the stable 50% 1-RM. No significant difference was observed for the RA muscle between conditions.

CHAPTER V

DISCUSSION

The hypothesis of this study was that lifting at 75% 1-RM would elicit greater core muscle activity than lifting at either the stable 50% 1-RM or the BOSU 50% 1-RM conditions due to the greater absolute load. Several studies have demonstrated significant effects of varying loads on muscle activation recruitment and amplitude, likely due to the increased force requirements of the muscle to overcome the heavier loads (Anderson & Behm, 2005; Hamlyn, Behm, & Young, 2007). The hypothesis was supported in some cases and rejected in others.

Deadlift

The results of this study demonstrated that during the deadlift movement, the TA and EO muscles achieved the highest activation with the 75% 1-RM condition. The 75% 1-RM condition also evoked higher RA muscle activity than the stable 50% 1-RM condition. Therefore, it appears that performing the deadlift on stable ground at 75% 1-RM is more effective in activating the TA and EO muscles than the other two conditions. For the RA, it appears that either the BOSU 50% 1-RM or the 75% 1-RM may be equally as effective in recruitment of this muscle. There were no effects between conditions on the ES muscle, therefore, ES activation may be independent of level of instability or intensity.

These results differ from those of Hamlyn, Behm, and Young which found that 80% 1-RM loads on the deadlift resulted in greater ES muscle activation than performing this movement with only body weight. These conflicting results could be due to the

differences in the lower intensity levels evaluated between studies. The lowest resistance used in the present study was 50% 1-RM compared to the body weight resistance of Hamlyn, Behm, and Young. It is plausible that there is an intensity threshold in which the ES is activated at a high enough level that an increase in load intensity will have little or no effect on the ES muscle activation. This may be due to the recruitment of the upper back muscles in order to both dynamically lift the weight off the floor and stabilize the thoracic and lumbar vertebrae (Hamlyn, Behm, & Young, 2007).

Squat

During the squat movement, the 75% 1-RM condition elicited higher activation of the TA muscle than the BOSU 50% 1-RM condition. The RA muscle was more active during the 75% 1-RM condition being greater than the other two conditions. Interestingly, the EO muscle displayed greater activity with the BOSU 50% 1-RM condition being higher than the stable 50% 1-RM condition but not the 75% 1-RM condition, which does not support the hypothesis.

As with the deadlift movement, the ES was not found to be different among any of the conditions while performing the squat. This is contrary to the results of Anderson and Behm (2005) which found the unstable condition to have greater activation of the ES than the stable free weight squat condition. Their study also observed a relationship between load intensities, with the two higher load conditions eliciting a greater activation effect than the lower load condition.

It is likely that the differences observed between Anderson and Behm and the present study are due to differences in the load intensities used for the conditions. The

absolute loads used for the present study were larger than those used for the Anderson and Behm study. The lowest load condition for the present study was 50% 1-RM whereas Anderson and Behm used lighter resistances including: (a) body weight, (b) 29.5 kg, and (c) 60% of body mass. In their study, for the ES, the body mass level of resistance was significantly less than either of the other two resistances and all of the resistances used in the present study. Because the present study did not include a very low resistance level, the results are not directly comparable. It may be observed however, that the two higher load conditions (29.5 kg & 60% body mass) in the Anderson and Behm study were closer to the 50% 1-RM of the present study and elicited similar results.

Another difference between studies was the squat movement was performed on balance discs as opposed to the BOSU balance trainer used in the current study. Balance discs may incorporate a different degree of instability in that they are independent from each other at two points, as well as invoking a lower center of gravity and wider base of support on the body to surface interface (Anderson & Behm, 2005). It may be suggested based on the available research that the ES muscle for the squat movement maintains a threshold point whereupon above a given load, all conditions elicit similar activation effects. More research is warranted in evaluating various resistances to help achieve a greater understanding of the effects of load increments and the effects on ES muscle activation.

The results of this study indicate that there may be little if any benefit (as for the measured outcomes in this study) to performing the squat movement on a BOSU balance trainer for overall core muscle activation.

Press

The TA, RA, and EO muscles exhibited higher activity effects during the 75% 1-RM condition than both the other two conditions. The ES muscle was higher during both the 75% 1-RM and BOSU 50% 1-RM conditions compared to the stable 50% 1-RM condition. With the four movements examined in the present study, the press movement is the most extreme in the way it affects the center of gravity of the body. The press movement places the center of gravity higher than any of the other movements. The center of gravity moves superiorly throughout the concentric phase of the lift, and disruptive torques associated with postural sway may increase (Hamlyn, Behm, & Young, 2007). As the center of gravity moves superiorly, the less stable the body becomes because the center of gravity is a greater distance from the base of support. The effects may be that the core muscles are required to become more active with a higher center of gravity, to help prevent postural sway and maintain balance. This concurs with the findings of Hamlyn, Behm, and Young which observed the squat movement (also moves the center of gravity superiorly) elicited greater activation of the ES compared with isometric instability activities which do not alter the center of gravity.

The results of the present study demonstrated strong effects for increased load on all muscles examined with the exception of the ES muscle for the press movement. It may be more important to perform the military press on stable ground with an increased level of resistance than to increase the level of instability for a greater recruitment of the majority of the core muscles.

Curl

The TA and RA muscles exhibited higher activity effects during the 75% 1-RM condition than the other two conditions. It was observed that the EO muscle was more active during the 75% 1-RM condition than the stable 50% 1-RM condition but not the BOSU 50% 1-RM condition. There were no effects of load and instability on the RA muscle for the curl movement. For this movement it appears that increasing the intensity is more important than increasing instability for the TA and ES muscles. There were no differences observed for the RA and EO muscles between the 75% 1-RM and BOSU 50% 1-RM conditions. However, because the activity of the RA and EO muscles during the BOSU 50% 1-RM condition was no greater than the 75% 1-RM condition, there doesn't appear to be any benefit to increasing instability for the curl movement that exceeds the benefit of increasing the amount of resistance.

One of the difficulties in evaluating and comparing research studies regarding EMG data is the nature of which the data is analyzed, evaluated, and reported. One point of interest on the evaluation of the loads and levels of instability may be to compare magnitude of EMG activity between studies. Unfortunately, not all results are normalized and reported in the same manner. Anderson and Behm reported their results as RMS (mV) whereas the current study normalized values to % MVC. Hamlyn, Behm, and Young reported % MVC as normalized data for several stable and unstable movements. The reported values for both the squat and deadlift movements at stable 80% 1-RM for the ES muscle are of importance to the present investigation. The % MVC values from their study exceeded those of the present study for the deadlift and squat movements. Hamlyn, Behm, and Young report the stable 80% 1-RM squat and deadlift movements to

be at 100 % and 120 % MVC compared to the present study at 55 % and 63 % MVC respectably.

These observed differences are likely due to differences in testing protocols between studies. The present study maintained a slower tempo (4 s concentric and 4 s eccentric versus 1 s concentric and 1 s eccentric) than did Hamlyn, Behm and Young (2007). This may have had an effect on muscle activation levels between studies as momentum played a greater role in their study, whereas the slower tempo of the present study reduced momentum associated with the movements. Hamlyn, Behm, and Anderson also evaluated EMG over six repetitions versus three for the present study which may have resulted in a greater level of fatigue, possibly effecting EMG muscle activity readings. And finally, a slightly higher resistance was used (80% 1-RM for their study compared to 75% 1-RM for the present study) requiring more force production and consequently core muscle activation differences. Unfortunately, less data is available for the other muscles examined (i.e., TA, RA, and EO) for the squat and deadlift movements possibly because studies that examine these particular movements are more interested in the ES because it plays a more critical role in mobilizing and stabilizing the spine.

With all the movements and conditions being evaluated, there was not one instance in which the BOSU 50% 1-RM condition or the stable 50% 1-RM condition invoked higher core muscle activity than the 75% 1-RM condition. For the majority of the conditions the muscle activity during the 75% 1-RM condition was higher than either or both of the other two conditions. The findings of the current study do not support those from Norwood et al. (2007) which reported a linear relationship between increased instability and muscle activation. The differences of these results could be due to the

different nature of the movements between studies as the present study examined standing dynamic movements versus the lying bench press movement examined by Norwood et al. It may be that the standing dynamic movements incorporate the core more to begin with (higher at baseline), even on a stable surface, resulting in higher baseline activity requirements of the muscles thus minimizing the potential for large activity differences with increased loads. For the measured outcomes of this study it appears that increasing the intensity is more important and effective in widespread activation for most of the core muscles. It is noteworthy to point out that higher intensities also are widely accepted in the strength and conditioning field to be more effective for increasing strength and hypertrophy in the agonist muscles involved for a given movement (Baechle & Earle, 2000).

Future Research

More research is warranted on the effects of load intensity and unstable surfaces on core muscle activity. This study used a BOSU balance ball to elicit an unstable surface, there are however, many other forms of unstable surface modes that are each a little different in form and function. The results of this study are only limited to the BOSU ball and must not be assumed for other modes of unstable surface training. Four common dynamic exercises were selected and evaluated for this study. There are however, other common dynamic exercises that may be performed while standing on an unstable surface (i.e. triceps extensions, push-press, hang cleans, lateral raises, etc.). Likewise, the results of each movement performed are only limited to that movement.

Future research may use NEMG to evaluate the effects of the conditions and movements used in this study on muscle activity levels using either low-back healthy or low-back unhealthy subjects. An evaluation of activity levels for standing, dynamic exercises may yield an effective method for treating and/or evaluating causation for low back troubles. Muscle activation patterns on both a stable and unstable surface while performing standing, dynamic exercises may perhaps give further insight on potential interventions and current standards for this important health parameter. This may be achieved by observing notable differences in muscle activation levels and patterns between low-back healthy and low-back unhealthy participants. Movements that require high levels of activation for support and mobility such as those evaluated in the current study may prove to be valuable in muscle activation analysis and exercise protocol reform for LBP.

Summary

The purpose of this study was to compare differences in the activity of four selected core muscles when resistance exercises were performed while standing on stable ground versus standing on a BOSU balance trainer. A dual purpose was to examine the effects of varying load resistance on core muscle activity. The dependant variable was NEMG for each of the four core muscles, while the independent variables were the level of instability and load intensities. Twelve healthy, weight trained college aged males were used as participants and were familiarized over a six week period on a BOSU balance trainer to minimize the effects of the learning curve. Maximal strength testing was performed to predict weights to be lifted for each participant on each condition. The

three conditions were: (a) stable 75% 1-RM, (b) stable 50% 1-RM and, (c) BOSU 50% 1-RM. Each condition was performed with four common standing, dynamic, resistance movements: (a) squat, (b) deadlift, (c) curl and (d) military press. Results for the deadlift indicated that the TA and EO muscles were more active during the stable 75% 1-RM condition than all other conditions; likewise for the RA during the squat; the TA, RA, and EO during the press and; TA and ES during the curl. The majority of the conditions (8 out of 12) examined resulted in the stable 75% 1-RM invoking higher core muscle activity than *both* the stable 50% 1-RM and BOSU 50% 1-RM conditions. There was a strong effect between levels of resistances with the higher loads demonstrating greater core muscle activity in the majority of the conditions. There was not strong effects observed between the unstable and stable surfaces at the same relative intensity. There were only two conditions (ES on the press movement and EO on the squat movement) of the twelve examined resulting in the given muscle being more active during the BOSU 50% 1-RM condition than the stable 50% 1-RM condition. From the results of the present study it appears that increasing the levels of resistance has a more widespread effect on increasing core muscle activity than increasing the level of instability.

Ultimately the purpose of unstable surface training (or any training) is to improve some performance or health outcome measure. This may be faster sprint times or a higher vertical jump, it also may be a health measure such as reduced low back pain. To date, little research has evaluated the effects of unstable surface training on core muscle activity. This study evaluated a basic element of an effect of training on muscle activation, other studies are needed to take this to a more performance based level. Before people spend a great deal of money, time, and effort, (including risk, unstable surfaces

are perceived to be a higher risk than stable surface training) more empirical results are needed to confirm that unstable surface training is worthwhile.

Limitations

The following limitations may have an effect on interpreting the results of the study:

- The cadence of this study was set at a 4-1-4 (4 s eccentric, 1 s pause at the bottom and 4 s concentric) to help control for the effects of momentum and the possible decrease in EMG activity that may result due to less force required of the muscles to overcome inertia. This cadence is an unnaturally slow tempo for performing resistance exercises. A particular difficulty with this tempo is overcoming inertia resulting from transitioning from the eccentric to concentric motion. An evaluation of more natural tempos and the effects on EMG activity is warranted in this area of research.
- The amount of resistance utilized for the BOSU 50% 1-RM was calculated from the stable 1-RM. A true 50% 1-RM on the BOSU would be different than compared to the stable surface because the unstable condition may elicit a decrease in total force production. The loads used for the BOSU 50% 1-RM condition would have likely been higher than 50% 1-RM for that condition. A 1-RM for the unstable surface would yield more accurate resistances, however due to the nature of unstable surface training, a 1-RM test increases the hazard and reduces the safety for the participants.

- One limitation of EMG collection is the amount of adipose tissue between the muscles and the surface electrodes. Body composition was not taken of the participants and therefore means and SDs are unavailable for assessing possible levels of error in EMG readings. This data would be valuable for this type of research in the future as it may give insight to outliers and magnitude of potential sources of error in EMG readings.
- All 12 participants were recruited from a university population and so the results may only be applicable to college-aged males.
- One limitation of EMG includes cross-talk (electrodes placed over one muscle picking up activity from other muscles). Preparations were made as to minimize the effects of this factor by using previously identified locations for placement of electrodes over the muscles, which fortunately for this study kept the electrodes an acceptable distance apart.
- Increased fatigue may have an effect on EMG readings. An attempt was made to reduce factors that effect fatigue including performing only three repetitions of each movement. Although the movements were counterbalanced, fatigue may have been a factor towards the end of the routine as many reps were required due to the multiple conditions and movements. A solution for this may be to divide the routine into a two day occurrence, thus, reducing the number of repetitions performed during each occasion.

Conclusions

Within the limitations of the study the following conclusions may be made:

- Intensity of load may be more important for recruitment of TA and EO muscles during the deadlift movement than increasing the level of instability. Activation of the RA during deadlift movement may be achieved by either increasing the level of intensity or increasing instability.
- Performing the squat movement at 75% 1-RM on a stable surface may be more effective at recruiting the RA and TA than increasing instability. If recruitment of the EO muscle is desired, the squat movement may be performed with either increased level of intensity or on an increased level of instability.
- The ES muscle may be equally activated independent of intensity of load (at a minimum level of 50% 1-RM) or level of instability for the squat and deadlift movements. Either the squat or deadlift movements may be performed on an unstable surface or with higher levels of resistance for recruitment of the ES muscle.
- The military press may be more effective for recruitment of the TA, RA, and EO muscles when performed with higher levels of resistance (at least 75% 1-RM) as opposed to increased levels of instability.
- When performing the curl movement, if ES and TA activation are desired then the level of resistance is more influential than the level of instability at increasing muscle activity. If EO activation is desired than the curl movement may be performed with either higher levels of resistance or increased level of instability.

RA activation is insignificantly changed independent of level of resistance or level of stability for the curl movement.

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APPENDICES

Appendix A

Informed Consent

CONSENT TO PARTICIPATE IN RESEARCH

Effect of Surface Stability on Trunk Muscle Activity and Muscular Endurance Performance for Common Resistance Exercise Movements

You are invited to participate in a research study conducted by Dr. Jeffrey M. Willardson, Professor in the Kinesiology and Sport Studies Department at Eastern Illinois University. You have been invited to participate in this study because you are an experienced male lifter between the ages of 18 and 30 and answered "NO" to all questions on the Physical Activity Readiness Questionnaire (PAR-Q).

PURPOSE OF THE STUDY
The purpose of this research project will be to compare differences in the activity of different trunk muscles when resistance exercises are performed while standing on stable ground versus standing on a BOSU balance trainer.

PROCEDURES
This study will be carried out over a period of 9 weeks with 1 exercise session per week. During weeks 1 and 2, familiarization sessions will take place to allow you to practice the required lifts while standing on stable ground versus standing on the BOSU balance trainer. During these sessions, a relatively light resistance will be utilized (i.e. 20-60 kg) to ensure your safety. During weeks 3 and 4, maximal strength testing will take place on stable ground only. This will involve gradually increasing the resistance for each exercise to a level that allows for only a single repetition. During weeks 5 and 6, pilot testing will occur that will mimic the procedures conducted during weeks 7, 8, and 9.

During week 5, you will practice the resistance exercises with a set percentage (i.e. 50% 1-RM) of your maximal strength on both surfaces. During Week 6, a single subject will be utilized to standardize the EMG data collection. During week 7, you will perform 1 set of 3 repetitions of each exercise while standing on stable ground or standing on the BOSU with 50% of your 1-RM. You will also perform 1 set of 3 repetitions of each exercise while standing on stable ground with 85% of your 1-RM. Therefore, a total of 12 conditions will be assessed. During weeks 8 and 9, you will be tested for the maximal number of repetitions that you can perform with 50% of your 1-RM for each of the four exercises while standing on stable ground versus standing on the BOSU.

POTENTIAL RISKS AND DISCOMFORTS
The possible risks include injury to the low back and knee joints. You may experience mild muscle soreness following the workouts. However, there will be minimal risk of

injury through close supervision of every repetition and a thorough warm-up prior to each testing or exercise session. If you feel unable to complete a repetition, or experience discomfort at any time, you will be instructed to give a verbal cue at which time the weight will be removed. In case of injury the participant may seek immediate medical care at their own expense at the EIU Student Health Center (581-3014).

POTENTIAL BENEFITS TO SUBJECTS

The benefits of participation in this research are a greater understanding of how standing on unstable surfaces increases trunk muscle tension.

CONFIDENTIALITY

The results of this research study may be published, but your name or identity will not be used. In order to maintain confidentiality, your records will be assigned a code number. Further, all data will be kept on a disk in a locked desk, accessible only to Dr. Jeffrey M. Willardson.

PARTICIPATION AND WITHDRAWL

Your participation in this study is entirely voluntary. Please ask questions about anything you do not understand, before deciding whether or not to participate. If you choose not to participate or to withdraw from the study at any time, there will be no penalty.

IDENTIFICATION OF INVESTIGATORS

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

Dr. Jeffrey M. Willardson
Eastern Illinois University
Kinesiology and Sport Studies Department
2506 Lantz Bldg
600 Lincoln Avenue
Charleston, Illinois 61920
217.581.7592

RIGHTS OF RESEARCH SUBJECTS

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

Institutional Review Board
Eastern Illinois University
600 Lincoln Ave.
Charleston, IL 61920
Telephone: (217) 581-8576
E-mail: eiuirb@www.eiu.edu

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

I voluntarily agree to participate in this study. I understand that I am free to withdraw my consent and discontinue my participation at any time. I have been given a copy of this form.

_____
Printed Name of Participant

_____ _____
Signature of Participant Date

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

_____ _____
Signature of Investigator Date

Appendix B

PAR-Q

PAR-Q & YOU

Physical Activity Readiness
Questionnaire - PAR-Q (revised 2002)

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES NO

1. **Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
2. **Do you feel pain in your chest when you do physical activity?**
3. **In the past month, have you had chest pain when you were not doing physical activity?**
4. **Do you lose your balance because of dizziness or do you ever lose consciousness?**
5. **Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
6. **Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
7. **Do you know of any other reason why you should not do physical activity?**

YES to one or more questions

If you answered

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME _____

SIGNATURE _____

DATE_____

SIGNATURE OF PARENT _____ WITNESS

_____

or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions. HealthCanadaSantéCanada

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