Effects of Unstable Versus Stable Free Weights on Surface EMG of Shoulder Musculature in Males

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Abstract

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Background: There are injury risks involved in not correctly activating stabilizing musculature while training. Researchers have created, designer, and implemented equipment to improve activating shoulder stabilizers. **Purpose:** The purpose of this study was to examine shoulder muscle activation between stable and unstable loads across the bench press and seated overhead press. **Methods:** Subjects (n = 12, males) randomly performed two sets of five repetitions at 50% 1RM for both exercises and modalities. Surface EMG was collected, and the average amplitude was analyzed for the three middle repetitions. **Results:** The Earthquake Bar™ (EQ bar) produced significantly ($p < 0.05$) higher activation in all muscle groups except the lateral triceps brachii during the bench press ($p > 0.05$). There was also a significantly more optimal co-contraction with the EQ bar ($p < 0.05$). **Conclusion:** The study suggests the EQ bar produced greater activation and co-contraction and may provide an improved method of training shoulder stabilizing musculature.

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Chapter 1: Introduction

When performing resistance-training exercises involving the shoulder joint, stabilization of the shoulder can be of concern depending on the population. If the goal of training is to translate an increase in strength to performance, the ability to stabilize the shoulder during training and performance is pivotal (Behm, Drinkwater, Willardson, & Cowley, 2010; Cacchio et al., 2008; Hibberd, Oyama, Spang, Prentice, & Myers, 2012; Kolber Beekhuizen, Cheng, & Hellman, 2010). Assuming that maximal activation of all complimenting musculature of a given joint would yield the best performance, correct sequencing/timing of activation of the stabilizing musculature of the shoulder would then be vital for achieving these goals and producing maximal force output. These stabilizers consist of the serratus anterior (SA), latissimus dorsi (LD), the upper, middle, and lower trapezius (UT, MT, LT), biceps brachii long head (BB), supraspinatus (SS), infraspinatus (IS), subscapularis (SSc), and teres minor (TM). There are many injury risks involved in not correctly activating stabilizing musculature while training, thus researchers have attempted to create, design, and implement various training tools to enhance the activation of shoulder stabilizers (Cronin, McNair, & Marshall, 2003; García-López et al., 2014; Iorgio, Amozino, & Enoi, 2009; Joy, Lowery, Oliveira de Souza, & Wilson, 2013). Such tools used have consisted of suspension straps, flexible barbells, stability balls, chains, and elastic bands. Each of the previously mentioned tools is a form of variable resistance that produces instability.

As an individual becomes more trained one might assume that by continuing to train the shoulder and surrounding musculature, that the stabilizers increase in strength just as the primary movers (pectoralis major, anterior deltoid, triceps brachii) do. This isn't always the case (Joy et al., 2013; Park & Yoo, 2011; Lee, Lee, & Park, 2013). As a simple motor pattern such as the bench press and/or overhead press gets refined through repetition, the need for the body to activate stabilizing musculature decreases. The body now understands this movement and can better utilize primary movers, not wasting energy on stabilizers (Sampson, McAndrew, Donohoe, Jenkins, & Groeller, 2013). This decrease in stabilizer activity could be cause for a possible future injury (Kolber et al., 2010). The lack of training stimulus for the shoulder stabilizers creates a lack of neuromuscular control necessary to utilize these stabilizers optimally during all movements involving the upper extremity. Activation of stabilizing musculature provides increased support to the working joint. The purpose of utilizing variable resistance apparatuses is to force the body to increase muscle activation by decreasing joint and/or core stability, thus increasing the stress perceived by the body (Campbell, Kutz, Morgan, Fullenkamp, & Ballenger, 2013; Park, Nho, Chang, & Kim, 2012). Benefits of increasing proprioceptor function include but are not limited to; increase in co-contraction, decreased risk of injury, and improved joint stability.

Therefore, the purpose of this study was to examine the difference in shoulder muscle activation between the use of a 5-pound bar, made with composite material, using elastic bands and kettle bells as the resistance (Earthquake bar ™, abbreviated EQ), and conventional equipment, across the bench press and seated overhead press exercises.

Hypothesis

The hypotheses for this investigation were:

1. The use of the EQ bar would increase shoulder stabilizer activity more than conventional equipment including a 45-pound barbell.
2. The EQ bar would cause greater co-contraction between agonist and antagonist musculature of the shoulder than would the conventional barbell.

Assumptions

This investigation had the following assumptions:

1. All electrode placements remained consistent between the two testing sessions to ensure accuracy. Subjects were marked at each electrode location and asked to keep marks clear and visible until completion of the second session.
2. Diet was held constant prior to each session, as requested, to prevent any discomfort that may affect the study.
3. Subjects did not take any supplements that alter performance affecting the results of the study.
4. Subjects would not perform any exercise related to the tested muscle groups between the first and second testing session.

Delimitations

The parameters of this investigation were delimited by the following factors:

1. Participants were apparently healthy males between the ages of 18 and 30.
2. The tempo at which each subject performed the “up” and “down” phase of each repetition. A metronome was provided to give athletes a verbal que as researchers required a 2-s “up” phase and a 2-s “down” phase with a 1-s pause between phases. Relative loads, according to each subject’s one repetition maximum

determined on the first session, were used for the testing weight.

3. All subjects have had previous weight training experience as determined by the fitness history questionnaire taken prior to all testing.
4. Participants completed a health history questionnaire to determine their relative level of risk, according to the American College of Sports Medicine (ACSM). Only those individuals who were considered to be at low-risk of a cardiovascular event or musculoskeletal event were included in this study.
5. Participants read and signed a consent form prior to participation.

Limitations

The following are potential limitations of this investigation:

1. Subject motivation could vary but was controlled by giving the subjects the same amount of encouragement in each session.
2. The study consisted of only males and that there was no direct control of diet or supplement use.

Definitions

Agonist. A contracting muscle that is resisted or counteracted by another muscle, the antagonist.

Antagonist. A muscle that opposes the action of another muscle.

Bandbell Earthquake Bar. A bamboo bar weighing 5 pounds that allows for elastic bands to be placed over the ends to suspend weights from. This bar can perform many of the same functions that a normal barbell can.

Co-contraction. A muscular contraction of both the agonist and antagonist muscle of the same joint.

Co-contraction index. Ratio between agonist and antagonist musculature of a single joint.

Co-contraction index distance from optimal. The distance between the co-contraction index and 1.0 (optimal).

Electromyograph. A device that detects and records electrical potential of a muscle.

Multiple repetition maximum. The maximal amount of weight that can be moved for a specific number of repetitions.

One repetition maximum. The maximal amount of weight that can be correctly lifted only one time.

Optimal co-contraction. Is 1.0, being a ratio of 1:1 (agonist EMG amplitude:antagonist EMG amplitude).

Overhead athlete. An amateur or professional athlete who participates in an overhead sport putting them at risk of traumatic or degenerative injuries to the shoulder girdle.

Surface electromyogram. A myoelectric signal recorded from the surface of the body to indicate the functional state of skeletal muscle fibers.

Chapter 2: Review of Literature

Electromyography

Much of the current research being done involving resistance training exercises and equipment is done with the use of electromyography. Electromyography (EMG) allows one to view the electrical activity of muscle fibers. More specifically it gives insight into the firing patterns and activities of muscle groups (Naik, Arjunan, & Kumar, 2011). This study utilizes surface EMG to assess the amplitude of electrical activity (representing motor unit recruitment and firing rate) in the working skeletal muscle. This myoelectric signal from the skeletal muscle is relayed to the surface of the skin and detected by small electrodes placed on the surface of the skin. The detected signal shows the functional state of the muscle. Changes in these characteristics can be insightful when looking for underlying neuromuscular adaptations in response to stress placed on a muscle group (Naik et al., 2011).

Researchers choose EMG when studying muscle responses to exercise to help them understand the complexity of different motor patterns. Motor patterns are so complex at times that the human body must develop muscle activation strategies in the brain to accomplish specific movements (Von Werder, Kleiber, & Disselhorst-Klug, 2015). EMG helps to identify muscle activation patterns during a specific movement and the contribution of a particular muscle group to the overall performance (Von Werder et al., 2015). With that information researchers can better identify what exercises would be most beneficial in helping to strengthen or rehabilitate an individual lacking in those movements. Surface EMG also has some added difficulties that can be of concern when dealing with dynamic movements. Surface EMG is affected by: shape/thickness of muscle and surrounding tissue, electrode placement and/or the distance between electrode and muscle, cross talk from nearby muscles, fiber membrane and/or motor unit properties, and skin (Von Werder et al., 2015).

Force Production During Dynamic Actions

The human capacity for force production has both a neural and contractile component (Folland, Buckthorpe, & Hannah, 2014). Using surface EMG, Folland et al. (2014) examined the variability of force production between individuals and compared the components responsible for the change in force. They determined that several factors played a role in explosive force; maximal voluntary force, muscle fiber type, muscle tendon unit stiffness, neural drive, and the contractile response to the evoked muscle twitch (Folland et al., 2014). Between the 40 untrained subjects the inter-individual variability for explosive force production showed the greatest amount of variability in the early stages of contraction than in the later stage of maximal voluntary force (Folland et al., 2014). This is a noteworthy finding given that explosive force production has great importance as a functional component of joint stabilization. For example, to quickly stabilize the joint to stop oneself from falling or to stabilize a joint upon impact, the body's neuromuscular system must have rapid force production.

One way of testing a person's ability to produce force is an isometric maximal voluntary contraction (MVC). Tillin, Pain, and Folland (2012) investigated the relationship between athletic performance and force-time curves during explosive-isometric-squats in a trained athletic group. This type of force time curve displays the amount of force produced over time. The study used 18 elite male rugby players and determined that there is a clear relationship between explosive force during isometric squats and athletic performance (Tillin et al., 2012). This was confirmed by comparing the results of the men's squat force production to both sprinting and jumping force production (Tillin et al., 2012). The sprint measurements used a photocell timing system, the countermovement jump used a portable force plate, and the isometric squat used an in-ground force plate.

In the world of college athletics, strength and stability are both important components of athlete development, but to what degree depends on the athlete. How would a strength and conditioning coach know if an athlete has too much or not enough of either component? This led to the development of the Dynamic Strength Index (DSI). The DSI is a ratio of maximal and isometric force production of the musculature of a single joint (Murphy & Wilson, 1996; Thomas, Jones, & Comfort, 2015). This ratio allowed researchers to know whether an athlete should focus more on absolute strength training or explosive plyometric training in order to reduce joint muscle imbalances (Murphy & Wilson, 1996; Thomas et al., 2015). Thomas et al. (2015) examined the reliability of the DSI and determined it to be a reliable source. Strength and conditioning coaches as well as researchers can make better assessments of athletes to meet the specific needs of their sport as well as the athletes themselves using DSI (Thomas et al., 2015).

Neural Adaptations to Resistance Training

The first 6 weeks of resistance training, training progress is generally attributed to neuromuscular adaptations (Narici, Roi, Landoni, Minetti, & Cerretelli, 1989; Rutherford & Jones, 1986). This is often noticed as the individual will see increases in strength gain and relatively little to no increases in lean body mass (Kristiansen, Madeleine, Hansen, & Samani, 2015). This can include increases in joint stabilization and neuromuscular coordination, which are very important to the development of strength (reference). EMG studies have provided the most direct assessment of neural adaptation to training focusing mainly on the primary movers of the joint (Sale, 1988). Trained individuals rely more on the primary movers and less on the stabilizers of the active joint as they have developed the joint stability and neuromuscular coordination that the untrained individuals do not yet possess (Sale, 1988). The primary movers are the larger muscle groups that produce the greatest amount of force while the joint stabilizers are smaller muscle groups that keep the joint in a safe, stable position in order to handle the load being placed on it. This is done most often by joint stabilizers pulling in the opposite direction of the primary movers to keep the joint tightly in place. This is known as the co-contraction of agonists and also hinders the amount of force that can be exerted (Sale, 1988). As an individual becomes more trained they inhibit the antagonist force and can produce a larger agonistic force, but have less joint stability which may or may not be beneficial (Sale, 1988). Someone who does not have the stability and coordination to perform an exercise under increased load is at a much higher risk of failure and injuring themselves (Rutherford & Jones, 1986).

A study examining the role of learning and coordination of strength training attempted to determine the most efficient way to train the quadriceps. By using surface EMG the study determined that an increase in electrical activity in a working muscle may account for increase in performance (Rutherford & Jones, 1986). Also, performance increases come from the ability synchronize muscle groups to accomplish a common task, not solely the intrinsic strength of the quadriceps (Rutherford & Jones, 1986). The specificity of training is very important as researchers also established that the neuromuscular connections trained during the knee extension exercise may not transfer to activities involving the quadriceps such as jumping, running, and cycling (Rutherford & Jones, 1986). Transferability of the exercise to the task should be the main focus as only 40% of increases in force production are attributed to increased cross-sectional area, while the remaining is related to increased neural drive (Narici et al., 1989).

As mentioned previously the rate at which a person can develop force can be the difference between falling or being able to quickly stabilize and prevent falling (Folland et al., 2014). Some researchers have inferred that strength training may even be able to have an effect on reflex responsiveness (Häkkinen et al., 1998; Sale, 1988). Hakkinen et al. (1998) suggests that heavy resistance training allows for a greater amount of muscle fiber activation, therefore bringing about a greater response in more fibers. This type of training has shown adaptations such as increased activation of primary movers, improved co-contraction of synergists, and an increased inhibition of antagonist muscle groups (Häkkinen et al., 1998; Sale, 1988).

Aagaard, Simonsen, Anderson, Magnusson, & Dyhre-Poulsen (2010) examined the effect of resistance training on contractile rate of force development and neural drive during maximal muscle contractions. The study took 15 males and placed them on a 14-week heavy resistance training program of 38 sessions in total (Aagaard et al., 2010). Researchers used EMG to track the amplitude and the rate of the muscle contractions. The results of this study explained that the increases in explosive muscular strength after a 14-week heavy-resistance-training program could be due to increased neural drive (Aagaard et al., 2010). This can be explained by the marked increase in EMG amplitude and rate at which amplitude increased in the early stage of muscle contraction (Aagaard et al., 2010).

Seeing that strength training has an impact on force production led researchers Amarantini & Bru (2008) to investigate whether strength training influences motor control as well. They compared five trained and five untrained males using EMG-moments during isometric knee flexion and extension contractions. The results showed that strength training increased maximal force production and decreased co-contraction of antagonists (Amarantini & Bru, 2008). Although the trained men had greater force production, the difference between groups was attributed to increased motor unit recruitment and synchronicity in the trained group giving them better motor control than the untrained group (Amarantini & Bru, 2008). This study, as well as the previous studies mentioned are examples of how EMG can be used to measure and detect changes in muscle activation and force.

Muscular Stability

The shoulder joint has more mobility than any other joint in the body, which decreases the amount of stability. Stability of the shoulder joint is dependent upon the joint capsule, the glenoid labrum, the glenohumeral/coracohumeral ligaments, and the muscles of the rotator cuff (Culham & Peat, 1993). Of those four factors the muscles of the rotator cuff are arguably the only trainable feature. Culham and Peat (1993) explain that poor scapular positioning can be due to poor postural positions. This is attributed to excessive scapular protraction, causing elongation and stretch weakness of the rhomboid and lower trapezius muscles (Culham & Peat, 1993).

The ratio of muscular strength and stability is an important assessment made during an athlete's training as seen by Thomas et al. (2015). The popularity of an athlete's strength can sometimes overshadow the importance of maintaining the proper ratio of strength and stability. If the shoulder joint is used as an example, sports like the NFL and Powerlifting use lifts such as the bench press as a measure of upper body strength. Cibulka, Enders, Jackson, Maines, Von der Haar, and Bennett (2015) examined how a person's shoulder range of motion, specifically internal and external rotation, affect their shoulder joint stability. The research showed that subjects, both males and females, who showed excessive glenohumeral rotation had reduced force output of the external and internal rotators of that joint (Cibulka et al., 2015). Decreased strength of the rotator cuff usually leads to a forward shift of the shoulders and protraction of the scapula (Cibulka et al., 2015; Kolber et al., 2010). This position can put a person at an increased risk for separation and/or dislocation of the glenohumeral joint if the rotator cuff isn't incorporated in a weight-training program (Kolber et al., 2010).

Expanding past just poor posture, Seitz & McClelland (2015) studied scapular kinematics during weighted and unweighted activity in adults with and without scapular dyskinesis. Scapular dyskinesis is common in overhead athletes and is an abnormal movement of the scapula (Seitz & McClelland, 2015). Scapular dyskinesis may be related to muscle weakness and contribute to a lack of shoulder stability, which would continue to amplify instability once placed under load (Seitz & McClelland, 2015). Athletes with scapular dyskinesis showed less upward rotation and a 40% lower force generation from the lower trapezius (Seitz & McClelland, 2015).

Overhead athletes are required to perform skilled movements that rely on flexibility, muscular strength, coordination, synchronicity, and neuromuscular control at the shoulder joint (Radwan et al., 2014). Improvements in functional stability are achieved by increased muscular strength and endurance of the assisting joints and musculature (Radwan et al., 2014). The foundation of musculature that links the upper and lower extremities is often referred to as the body's core. Further insight into the relationship between overhead athletes and shoulder dysfunction found that there is a correlation between the amount of shoulder dysfunction and the amount core instability or balance (Radwan et al., 2014). A decrease in balance is due to a neuromuscular imbalance between synergist and antagonist musculature (Radwan et al., 2014). Results support the implementation of balance and core stability training for overhead athletes.

Variable Resistance

Over the past decade exercises designed to increase the efficiency of training such as variable resistance have gained popularity. Variable resistance exercises typically use some form of instability, such as chains or elastic bands, causing variations in velocity of load and the magnitude of force (Soria-Gila, Chirosa, Bautista, Baena, & Chirosa, 2015). Soria-Gila et al. (2015) compared the effects of variable resistance training on maximal strength via a meta-analysis. They compared data from seven training studies of >7 weeks using either chains or elastic bands added to a standard barbell (Soria-Gila et al., 2015). The subjects were both trained and untrained individuals. The researchers claimed that variable resistance is an effective way to overcome the mechanical disadvantages of sticking points, or the joint angle at which there is a loss of velocity through a range of motion (Soria-Gila et al., 2015). They also claimed that since variable resistance training required a lower percentage of the one repetition maximum (1RM) to achieve the same level of muscle activation as conventional free weights, joint overloading may be reduced during a range of athletic motion when compared to conventional free weights (Soria-Gila et al., 2015). The authors concluded that variable resistance training showed significantly greater gains in mean strength than conventional strength training methods (Soria-Gila et al., 2015).

Behm and Anderson (2006) studied the role of instability with resistance training on force output, trunk and limb muscle activation, co-contractions, coordination, and what role it may have in rehabilitation applications (Behm & Anderson, 2006). With neural adaptations being the first factors contributing to gains in strength in the untrained individual it would make sense that the researchers concluded both stable and unstable training should take place in order to emphasize high force and balance stressors to the neuromuscular system (Behm & Anderson, 2006). It has been known for years that the overload training stimulus produces gains in strength, but now adding another, more sport specific stress to training that also has rehabilitation implications may not be a bad idea. Incorporating instability training or variable resistance training into the later stages of a training program may allow for continued neurological stress, leading to further increased neurologic adaptations similar to those in the first 6 weeks of training (Behm & Anderson, 2006).

Another added benefit of incorporating variable resistance into training is the substantial amount of core muscle activation as a result of instability on the distal portion of a limb (Behm & Anderson, 2006). This is noteworthy, as variable resistance is not just advocated for athletes, but general health as well. This could be beneficial in preventing falls in older populations (Behm & Anderson, 2006). Behm et al. (2010) provided recommendations for the use of instability as a mode of training and suggested that the shoulder girdle be considered a component of the core stabilizers as it connects the upper limb to the core, and serves as a means to stabilize the body. With that being said, it would seem apparent that training the stabilizers of the shoulder would be as important as training a core stabilizer. The kinetic chain of the body is much like that of a real chain. The weakest link in the chain will likely be the point of injury when placed under stress (Kolber et al., 2010). As a strength coach if you would be able to prevent any weak point in the chain of your athlete, then they may be at a lower risk of future injury. Resistance training programs should be structured so that athletes are prepared for a wide range of body positions and postures potentially encountered in their sport (Behm et al., 2010).

Behm, Drinkwater, Willardson, and Cowley (2010) continued research on the link between variable resistance and core musculature. Although the researchers don't advocate variable resistance as a primary mode of training they do acknowledge the place it has in a periodized training plan, rehabilitation, and untrained individuals (Behm et al., 2010). In an athletic population it is not prescribed as a primary source of training as it has shown decreased maximal force output, velocity, and power (Behm et al., 2010). However, it is advised as an accessory mode of training that more closely mimics the demands of the sport by activating more total musculature (Behm et al., 2010). Since no one muscle can be labeled a stabilizer, it is a combination of single muscle and muscle groups that is the stabilizing force of the body (Behm et al., 2010; Behm, Leonard, Young, Bonsey, & MacKinnon, 2005). Unstable exercises demand that these combinations of musculature work together, preparing individuals for real-life events (Behm et al., 2010, 2005).

The combination of force producing and joint stabilizing muscular contractions transfer to the demands of sport, much better than either alone (Anderson & Behm, 2004). Equipment such as Swiss balls, Bosu balls, chains, and elastic bands increase the reliance on stabilizing functions (Anderson & Behm, 2004). When examining the maintenance of EMG activity and loss of force output with instability, Anderson & Behm (2004) concluded that the decrease in balance as a result of an unstable surface might force limb musculature to take on a bigger role in joint stability. Consistent with other research involving unstable surface and unstable loads, Anderson and Behm (2004) recommend a comprehensive training program that incorporates stable as well as unstable conditions.

Athletes Training with Variable Resistance

Variable resistance has shown some promise with athletes that already have a strong training background. Anderson, Sforzo, and Sigg (2008) attempted to determine whether combining elastic resistance and free weight resistance would provide different strength and power adaptations than traditional free weight training. The authors had 44 college-aged athletes train using elastic bands combined with free weight resistance, or traditional free weights alone (Anderson et al., 2008). The results of this study demonstrated that combined elastic and free weight resistance might be better than traditional free weights alone at developing strength in the upper and lower extremities (Anderson et al., 2008). It also showed superior improvement in the development of power in the lower extremities (Anderson et al., 2008). The researchers claim that the disadvantageous nature of the human body and its lever system create sticking points which are the weak link in a joint's full range of motion (Anderson et al., 2008). When this one point in the entire joint range of motion is trained, average acceleration and force are compromised (Anderson et al., 2008). If sticking points could be minimized, then the potential strength gains would no longer be limited by the weak link Researchers claimed that adaptations from combined resistance training seen in experienced athletes, in the short-term, had an effect on athletic performance, noting that further research is needed to establish what impact adaptations will have over a longer period of time (Anderson et al., 2008).

Kibele and Behm (2009) compared the results of stable and unstable training over a seven-week training period looking at the effects on strength, balance, and functional performance. Forty physically active university students participated in either the stable or unstable training group. The two groups performed very similar exercises with the main difference being the percentage of weight lifted. The stable group used 70% of their 1RM whereas the unstable group trained at 50% of their 1RM (Kibele & Behm, 2009). The results of the study showed no significant difference between the two groups in any of the variables tested (Kibele & Behm, 2009). This data could be misleading due to the fact that both groups had the same outcome with a 20% difference in the amount of weight lifted. The unstable group used wobble boards, dyna-disks, and BOSU balls as the unstable variable (Kibele & Behm, 2009). They attribute the unstable training adaptations to a greater total amount of muscle activation due to the increased need for stabilizing musculature, the same theory brought about from Anderson & Behm (2004) (Kibele & Behm, 2009). Practical applications advocated by the researchers were the increased balance and trunk activation caused by the instability (Kibele & Behm, 2009). This agrees with much of the previous research on this topic (Behm et al., 2005; Jones, 2014; Kibele & Behm, 2009; McBride, Larkin, Dayne, Haines, & Kirby, 2010; Radwan et al., 2014).

Similar to Kibele's research is that of Shoepe, Ramirez, Rovetti, Kohler, and Almstedt (2011) by assessing the effects of 24 weeks of resistance training with simultaneous elastic and free weight tension using college aged males and females. Twenty novice lifters were split into one of three groups: traditional free weights, elastic bands with traditional free weights, and a normally active control group (Shoepe et al., 2011). The program used identical lifts during training with the traditional free weight group using 65-95% 1RM and 20-35% 1RM (Shoepe et al., 2011). The conclusion from this study is much like the previous in that no significant difference was found between the two experimental groups (Shoepe et al., 2011). Although there is no significant difference in the result there is reasonable difference between the amount of weight lifted (Shoepe et al., 2011). Variable resistance, which often utilizes a lighter load, was shown to be effective at increasing strength and power similar to free weights alone (Shoepe et al., 2011). It was also noted that the addition of bands allowed for higher forces and velocities translating to increased power from the athlete (Shoepe et al., 2011).

Elastic resistance can be used in a number of ways. Hibberd et al. (2012) used bands as part of a 6-week shoulder and scapular-stabilizing and strengthening program for 44 division-1 college swimmers. The bands were attached to the ground or placed under the feet of an athlete and held in each hand (Hibberd et al., 2012). The bands were used as a means of strengthening and stretching the musculature of the shoulder and scapula. One of the goals of this program was to try to eliminate the muscle imbalances presented by the nature of swimming (Hibberd et al., 2012). The study was not found to significantly affect strength or scapular kinematics but may serve as a framework for future programs (Hibberd et al., 2012). Changes to the program should include adding more stretches, eliminating exercises that overlap with weight training and swim training, and the timing of the implementation (Hibberd et al., 2012). Although like other studies, the significance of the study does not depend on the significance of the data. It was purported that non-significant trends in the data supported increased shoulder flexion and abduction strength as a result of the program (Hibberd et al., 2012).

Specificity is an important aspect that coaches must consider when developing a strength and conditioning program for athletes. Since the transferability of training adaptations made in the weight room to the field of play is such a crucial component to developing athletes, the program design should mimic the demands of the sport. Much research that has been conducted changes the stability of the lifting surface (Anderson & Behm, 2004; Beach, Howarth, & Callaghan, 2008; Campbell et al., 2013; De Mev et al., 2014; Goodman, Pearce, Nicholes, Gatt, & Fairweather, 2008; Park & Yoo, 2011; Uribe et al., 2010). Other ways to decrease stability is to reduce the stability of the load. One way to accomplish this is to hang elastic bands from a traditional barbell and suspend weights from the elastic bands (Dunnick, Brown, Coburn, Lynn, & Barillas, 2015). This is different from attaching bands to a stable object on the floor and the barbell as the suspended weights can move in all directions making the load more unstable (Dunnick et al., 2015). This technique has been used in several studies performing squatting exercises (McBride et al., 2010), but Dunnick et al. (2010) have used this method in conjunction with the bench press. Dunnick et al. (2015) suspended kettlebells from a traditional barbell and performed the bench press exercise. He compared the amount of muscle activation between the variable resistance bench press to that of the traditional bench press, using the same relative loads, and saw no significant difference between the two methods (Dunnick et al., 2015). Most variable resistance studies have the unstable group at a lower load compared to the stable group (Dunnick et al., 2015). With the results showing no significant difference between groups, researchers urged coaches to use their preference when designing programs (Dunnick et al., 2015). However, given previous findings that found benefit of instability training with lighter loads (Anderson & Behm, 2004; Behm et al., 2005; Soria-Gila et al., 2015), one must question whether the instability of the traditional barbell with suspended weights is enough stimulus to produce an effect (Dunnick et al., 2015).

Co-contraction

Co-contraction is the simultaneous activation of various muscles surrounding a joint (Kellis, Arabatzi, & Papadopoulos, 2003). It is component in examining joint stability and is related to the inefficiency of human movement (Baratta et al., 1988; Emily, 2015; Kellis et al., 2003). As stated previously, the reduction of this co-contraction is an early adaptation of resistance training (Sale, 1988). Co-contractions play a very important part is sport specific movements (Kellis et al., 2003). For example, a drop jump can produce tibiofemoral forces up to 24 times bodyweight, which is far more than conventional back squatting or other common stable resistance training exercises (Kellis et al., 2003). Such high forces require joint stability in order to avoid injury. Stability of the shoulder when an athlete falls, takes a hit, and/or delivers a hit is of concern. If increasing joint stability is a determinant of decreasing injury, and muscle weakness is a determinant of joint stability, one could infer how import strengthening joint stabilizers and training sport specific actions like co-contraction would be of benefit.

Injury Prevention

Too often resistance training programs are focused on performance rather than prevention (Kolber et al., 2010). Coaches and individuals base performance off of what the large muscle groups are able to do separately instead of how the body works as a whole. Narrowing the focus to upper extremities, the most commonly injured muscles are the biceps, rotator cuff, and pectoralis major (Kolber et al., 2010). These injuries are attributed to muscle imbalances, joint imbalances, overloading/overuse, and improper lifting technique (Kolber et al., 2010). This combination of repetitive loading, unfavorable positioning, and biased exercise selection may be able to be minimized by incorporating variable resistance into a training program (Hibberd et al., 2012; Kolber et al., 2010; Shoepe et al., 2011). Strengthening rotator cuff musculature will balance the strength ratios within the shoulder and provide more stability while lifting weights and on the field of play (Kolber et al., 2010). Stabilizers not only help the joint under load but also help in preventing falls and or sudden occurrences of instability (Anderson et al., 2008; Behm et al., 2010; Kibele & Behm, 2009). The key points illustrated by the researchers are to incorporate rotator cuff musculature, increase flexibility to minimize joint imbalances, and to avoid loading the joint in unfavorable positions by enforcing proper lifting technique (Kolber et al., 2010).

Developing rehabilitation strategies for the shoulder complex is also another growing area of research. Anderson et al. (2010) investigated muscle activation and perceived loading during upper body extremity resistance training using dumbbells or elastic tubing. A key component to resistance training is the training intensity, being the percentage of voluntary force produced (Anderson et al., 2010). The same exercises were performed in each group, with one using dumbbells and the other using elastic tubing. The amount of muscle activation was comparable between the two groups and researchers suggested that the low cost and practicality of using bands may make them a preferable choice (Anderson et al., 2010; Hibberd et al., 2012). Both groups were able to sufficiently activate the stabilizers of the shoulder as the study was targeting the trapezius muscles which are often the cause of neck and shoulder pain (Anderson et al., 2010). Another added benefit to using the elastic bands was the linear increase in tension as the band stretched, whereas the dumbbells provided an isotonic resistance (Anderson et al., 2010). Variable resistance could play a major role in rehabilitating and preventing injuries of the shoulder complex by increasing activation of stabilizing musculature, reducing joint overloading, and offering a larger variety in exercise selection.

In summary, the data surrounding the topic of variable resistance and its impact on upper body resistance training programs is gaining popularity and demands further research. It shows many signs of improving the current sport-specific prehabilitation measures currently used both in athletics and recreationally. It allows for the ability to train with a decreased load while receiving the same overload benefits, evoking greater amounts of muscle activation by decreasing stability, and training the shoulder joint similar to what overhead athlete would experience during gameplay. With the many benefits seen from the implementation of variable resistance it would suggest that exploring more ways to incorporate this mode of training would only benefit the athletic and recreational community.

Chapter 3: Methods

Subjects

Subjects were recruited through a mass email to undergraduate exercise physiology students at Ohio University. The inclusion criteria was as follows: subjects were between 18 and 30 years of age and in good health as determined by a health history questionnaire; subjects have had no complaints of shoulder pain or instability in the past 12 months; subjects had no history of orthopedic surgery to the shoulders or surrounding areas; and subjects were currently participating in a recreational resistance-training program for longer than 6 months previous to this study. Subjects were also asked to keep diet constant and refrain from taking any supplements that would alter physical performance. Any supplement usage would eliminate them from the study. All participants read and signed informed consent forms upon their first visit and were allowed to ask questions to be answered.

Testing

All research took place on the Ohio University campus (Grover Center room E226). Subjects were asked to attend 2 sessions no more than 7 days apart. During the first session, a one repetition maximum (1RM) of the bench press first and then seated overhead press using a standard barbell was determined by having subjects perform repetitions of: 10 at 60%-70%, 5 at 70%-80%, 3 at 80%-90%, 1 at 100% of estimated 1RM. Three to 5 min of rest was given between each set. The amount of weight that allows the completion of 1 repetition only was the 1RM. If the subjects failed a set without completing one full repetition, weight was reduced after a 2-min rest was taken and the subject made another attempt. The 1RM was considered a reference voluntary contraction and was utilized to set the loads for the second training session, and to normalize EMG amplitude between subjects. During the 1RM testing, subject maintained a five-point body contact position with the bench (head, both shoulder blades, and buttocks on the bench, with left and right foot on the floor). After the 1RM testing had taken place subjects practiced using the BandBell Earthquake Bar (Bandbell Inc., Columbus, OH, USA) to become familiar with the equipment. Spotters were present at all times while subjects were performing the exercises.

During the second session, the subjects returned and randomly performed the two exercises with both the EQ bar and a standard barbell (BB) at 50% of their 1RM on each exercise which was determined during the first session. For the bench press each subject was instructed to keep the upper arm 45 degrees abducted from the midline of the body, and the forearm perpendicular to the floor. The duration for each phase of each repetition was controlled using a metronome (60 beats per min). The tempo of the metronome allowed each subject to perform the “up” and “down” phase of each repetition which gave subjects a verbal que as researchers required a 2-s “up” phase and a 2-s “down” phase with a 1-s pause between phases. Verbal encouragement was given by researchers to encourage subjects and to correct performance. Subjects performed two sets of five repetitions on each piece of equipment on each exercise. There was a rest interval of 2 min between each set and each exercise. Each exercise consisted of a 2 s eccentric and concentric phase separated by a 1 s isometric phase. There was one beat of the metronome for every 1 s elapsed during the repetition. The bar was to touch the subjects’ chest and remain there isometrically for one second before beginning the concentric phase of the lift. The same timing occurred at the top of the lift before beginning the eccentric phase. Grip was overhand and width was self-selected. Grip and timing were the same for the seated overhead press while the bottom of the lift was determined by the bar returning to the top of the subjects' chest, and the top of the lift is total elbow extension directly above the subjects' head. Subjects maintained five-point body contact position with the bench at all times; head, shoulders, buttocks, left foot, and right foot.

Procedures

The Noraxon DTS system with 8 channels of wireless EMG system and the Noraxon MR3 MyoMuscle software (Noraxon USA Inc., Scottsdale, AZ, USA) was used in acquiring all electrical muscle activation. In all subjects the dominant side was prepared by shaving and cleansing the surface of the skin to reduce impedance (<k). Noraxon disposable, self-adhesive Ag/Ag-Cl snap electrode for surface EMG were placed over the muscles being tested, with a reference electrode placed over the clavicle on the same side if the body. EMG signals were inspected to assure that the placement was correct and repeatable. The EMG amplitude for each muscle and each subject was analyzed and compared between mode, set, and exercise for the three intermediate repetitions for each of the two sets of five, as the first and last repetitions will be dismissed to avoid fatigue and the fluctuations during the initial lift off. The signal was selected from the entirety of the middle three repetitions for each set. The EMG signal was rectified and smoothed with a 150 ms temporal resolution to minimize noise and artifact in the data. The EMG analysis of the co-contraction index was calculated as a

ratio of the mean EMG amplitude of the agonist divided by the mean EMG amplitude of the antagonist, using pectoralis major/latissimus dorsi, anterior deltoid/posterior deltoid, and lateral triceps brachii/bicep brachii.

Electrode Placement

When placing the electrodes, each subject had the skin prepped before actual electrode placement. The first step was removing body hair from the area if necessary, then cleaning the skin with an abrasive towel and alcohol pad to remove body oils/sweat/dirt and dead skin. The exact location of each electrode placement was determined by the Noraxon manual (USA, n.d.). The placements were marked with a permanent marker and subjects were asked to keep markings clear and visible until both sessions were completed to ensure the electrodes were placed back in the same location. Electrode placements were:

- Pectoralis Major (Clavicular Placement): diagonally placed 2 cm below the clavicle medial to the axillary fold parallel to the muscle fibers.
- Anterior Deltoid: 4 cm below the acromioclavicular joint (AC Joint) on the anterior aspect of the shoulder parallel to the muscle fibers.
- Posterior Deltoid: 2 cm below the lateral aspect of the scapular spine, parallel to the muscle fibers.
- Latissimus Dorsi: 4 cm below the inferior angle of the scapula, centered between the spine and lateral border of the body, parallel to the muscle fibers.

- Triceps: one-third of the distance between the olecranon and acromion, on the belly of the muscle, running parallel with the muscle fibers.
- Biceps: the distance between the radius and the acromion, on the belly of the muscle, running parallel with the muscle fibers.

Statistics

Two separate, 2 (sets) x 2 (mode) repeated measures ANOVAs were performed to analyze the EMG amplitude of the bench press and the shoulder press (SPSS v.21, IBM, Inc., Chicago, IL USA). One examining the bench press and one examining the overhead press. If a significant interaction was found, paired *t*-tests were utilized to determine if the EQ bar differed from the standard barbell during set one, and set two. The alpha level was set at $p < 0.05$.

The co-contraction index and co-contraction index distance from optimal were analyzed by a paired *t*-test. The alpha level was set at $p < 0.05$.

Chapter 4: Results

Bench Press

The normalized EMG amplitude for each muscle group and mode was analyzed with a 2 x 2 repeated measures ANOVA (mode x sets). There were no significant ($p > 0.05$) interactions found for any of these analyses, however, some of the main effects were significant ($p < 0.05$).

For the bench press, the normalized EMG amplitude showed no significant main effect for sets in any muscle group. There was however a significant main effect for the mode in all muscle groups, except for the triceps brachii ($p > 0.05$). When assessing this main effect, it was determined that the EQ bar demonstrated significantly higher normalized amplitude (see Table 1) than the traditional barbell.

Table 1

Normalized EMG Amplitude of the Muscles During the Bench Press (*Mean* ± *SD*)

Muscle (%)	Sets	Traditional barbell	EQ
Pectoralis major	1	41.0 ± 14.5	69.0 ± 34.4*
	2	37.8 ± 15.9	72.3 ± 37.6*
Anterior deltoid	1	40.3 ± 20.5	60.2 ± 34.2*
	2	38.8 ± 20.2	56.1 ± 31.3*
Lateral triceps brachii	1	51.6 ± 22.6	62.3 ± 27.3
	2	49.8 ± 26.4	63.3 ± 27.0
Latissimus dorsi	1	34.5 ± 31.4	88.4 ± 71.5*
	2	33.3 ± 23.7	96.8 ± 80.4*
Posterior deltoid	1	26.3 ± 20.0	104.4 ± 68.8*
	2	28.3 ± 30.6	108.7 ± 69.9*
Biceps brachii	1	37.2 ± 21.8	178.0 ± 149.5*
	2	37.7 ± 29.8	191.6 ± 164.0*

*Significant mode effects $p < 0.05$.

For the co-contraction index of the bench press, the paired t-test demonstrated a significant difference ($p <.001$) between the traditional barbell and the EQ bar in pectoralis major/latissimus dorsi, anterior deltoid/posterior deltoid, and the lateral triceps brachii/bicep brachii (see Table 2). The distance of the co-contractions to optimal was also measured by subtracting one from the original co-contraction index, and these two were found to be significant ($p < .001$) in all three pairings of muscle groups (see Table 3).

Table 2

C-ocontraction Index of the Muscle Groups for the Bench Press (Mean ± SD)

Muscle groups	Traditional barbell	EQ bar
Pectoralis major / Latissimus dorsi	2.72 ± 7.34	2.35 ± 6.90*
Anterior deltoid / Posterior deltoid	1.58 ± 1.02	.702 ± .559*
Lateral triceps brachii / Bicep brachii	1.80 ± 1.13	.682 ± 1.06*

*Significant mode effect $p < 0.001$.

Table 3

Co-contraction Index Distance from Optimal of the Muscle Groups for the Bench Press (Mean ± SD)

Muscle groups	*Traditional barbell*	*EQ bar*
Pectoralis major / Latissimus dorsi	-1.72 ± 7.34	-1.36 ± 6.90*
Anterior deltoid / posterior deltoid	-.578 ± 1.02	.098 ± .559*
Lateral triceps brachii / Bicep brachii	-.799 ± 1.13	.318 ± 1.06*

*Significant mode effect $p < 0.001$.

Seated Overhead Press

The normalized EMG amplitude for each muscle group and mode was analyzed with a 2 x 2 repeated measures ANOVA (mode x sets). There were no significant ($p >$ 0.05) interactions found for any of these analyses, however, some of the main effects were significant ($p < 0.05$).

For the overhead press, the normalized EMG amplitude showed no significant main effect for sets in any muscle group. There was however a significant main effect for the mode in all muscle groups. When assessing this main effect, it was determined that the EQ bar demonstrated significantly higher normalized amplitude than the traditional barbell (see Table 4).

Table 4

Normalized EMG Amplitude of the Muscles for the Seated Overhead Press (Mean ± SD)

Muscle	Sets	Traditional barbell	EQ bar
Pectoralis major	1	36.7 ± 23.4	68.6 ± 46.3*
	2	34.1 ± 23.1	62.3 ± 46.9*
Anterior deltoid	1	52.8 ± 26.7	64.2 ± 35.5*
	2	50.4 ± 27.1	64.1 ± 35.5*
Lateral triceps brachii	1	45.1 ± 21.2	56.0 ± 27.8*
	2	42.9 ± 23.6	57.2 ± 26.4*
Latissimus dorsi	1	49.1 ± 25.1	78.7 ± 34.0*
	2	53.4 ± 23.3	73.5 ± 35.3*
Posterior deltoid	1	46.1 ± 25.9	84.2 ± 57.4*
	2	48.1 ± 26.8	77.1 ± 49.1*

*Significant mode effect $p < 0.05$.

For the co-contraction index of the bench press, the paired t-test demonstrated a significant difference between the traditional barbell and the EQ bar in pectoralis major/latissimus dorsi, anterior deltoid/posterior deltoid, and the lateral triceps brachii/biceps brachii (see Table 5). The distance of the co-contractions to optimal was also measured by subtracting one from the original co-contraction index, and these two were found to be significantly different ($p < 0.001$) in all three pairings of muscle groups (see Table 6).

Table 5

Co-contraction Index of the Muscle Groups for the Seated Overhead Press (Mean ± SD)

Muscle groups	Traditional barbell	EQ bar
Pectoralis major / Latissimus dorsi	.713 ± .479	.803 ± .329*
Anterior deltoid / Posterior deltoid	2.29 ± 4.44	1.27 ± 1.67*
Lateral triceps brachii / Bicep brachii	1.26 ± .819	.766 ± .403*

*Significant mode effect $p < 0.001$.

Table 6

Co-contraction Index Distance from Optimal of the Muscle Groups for the Seated Overhead Press (Mean ± SD)

Muscle groups	Traditional barbell	EQ bar
Pectoralis major / Latissimus dorsi	.287 ± .479	.197 ± .329*
Anterior deltoid / Posterior deltoid	-1.19 ± 4.44	-.287 ± 1.67*
Lateral triceps brachii / Bicep brachii	-.258 ± .818	.234 ± .403*

*Significant mode effect $p < 0.001$.

Chapter 5: Discussion

The purpose of this study was to examine the difference in shoulder muscle activation between the use of a 5-pound bar, made with composite material, using elastic bands and kettle bells as the resistance EQ bar, and conventional equipment, across the bench press and overhead press exercises. The main finding was that the EQ bar produced significantly more muscle activation than did the conventional barbell. This result agrees with the first hypothesis; the use of the EQ bar would increase shoulder stabilizer activity more than the conventional 45-pound barbell. Apart from the triceps brachii during the bench press, all muscle groups in both exercises had significantly higher amount mean amplitude when using the EQ bar compared to the conventional barbell.

Muscle Activation and Stability

Previous research has shown that during the same exercise, as load increases so does muscle activation (Aagaard et al., 2010; Häkkinen et al., 1998). This is required when planning a resistance training program in order meet the specific dose response for an individual to achieve an overload stimulus, thus stimulating muscle growth (Häkkinen et al., 1998) . What has been seen with unstable surfaces and unstable loads has shown something quite different (Cronin et al., 2003; Park et al., 2012; Park & Yoo, 2011; Saeterbakken & Fimland, 2013). There have been various ways to reduce the stability of a pushup by changing the surface such as BOSU balls, wobble boards, suspension straps, and Swiss balls (De Mev et al., 2014; Park et al., 2012; Park & Yoo, 2011; Lee et al., 2013). When stability is decreased muscle activation increases, while the load stays the same (Dunnick et al., 2015; Iorgio et al., 2009; Kibele & Behm, 2009). Even changing the surface during the bench press has been shown to increase muscle activation in prime movers of the shoulder as well as trunk musculature while the load remained constant (Behm & Anderson, 2006).

As the location of the instability is changed from the surface of the exercise to the load being moved the results are exaggerated (Bellar et al., 2011; Dunnick et al., 2015; Saeterbakken & Fimland, 2013). When comparing a stable and an unstable load across the bench press, research has shown significantly increased muscle activation of the shoulder musculature as well as the trunk stabilizers (Anderson & Behm, 2004; Behm & Colado, 2012; Behm & Anderson, 2006; Behm et al., 2010, 2005; Campbell et al., 2013; Halperin, Copithorne, & Behm, 2014; Sakamoto, Sinclair, & Moritani, 2012). Researchers have also shown that unstable loads produce the same or greater muscle activation at decreased loads compared to conventional equipment (McBride et al., 2010; Park & Yoo, 2011; Pinto et al., 2013). This redefines conventional methods of progressive overload as increased intensity is not the only way to increase muscle activation.

Reasons for the increased muscle activation found in the current study during the bench press and overhead press can be explained by the constant need for the body to stabilize the load (Emily, 2015; Kellis et al., 2003). The bouncing weights suspended from the EQ bar change the direction of force needed to complete the lift. Traditionally, bench press is a linear force with a constant line of force, while the EQ bar presents increased degrees of freedom during which the lifter cannot easily predict direction of movement (Behm et al., 2005; Dunnick et al., 2015; Kellis et al., 2003; McBride et al., 2010; Nairn, Sutherland, & Drake, 2015). The unpredictable nature of the EQ bar required the lifter to remain stable throughout the exercise by activating not only the prime movers but antagonists as well, to help stabilize the changing force. This contradicts the training adaptation normally seen with experienced lifters. The neural adaptation of reducing antagonist contractions during resistance training allows the lifter to produce a larger agonist contraction thus greater force production (Pinto et al., 2013). Much of the muscle activation seen in a novice lifter is attributed to stabilizing musculature, much like what is seen with unstable loads seen in experienced lifters (Folland et al., 2014; Sampson et al., 2013). Although currently the EQ Bar would fall into the category of variable resistance, a more accurate operational definition may be variable vector as the resistance loaded on the bar doesn’t change but the plane in which the force acting does. This changes the force vector placed on the lifter constantly.

The question arises as to whether or not these agonist-antagonist contractions, also known as co-contractions, are of benefit to the lifter (Anderson & Behm, 2004; Behm & Colado, 2012; Behm & Anderson, 2006; Behm et al., 2010, 2005; Emily, 2015; Kellis et al., 2003; Kibele & Behm, 2009) Research has determined that a potential cause of injury at the shoulder joint is lack of stability caused by muscle weakness (Anderson et al., 2010; Kibele & Behm, 2009; Kolber et al., 2010). If a muscle is too weak to respond quickly and efficiently to unexpected forces, such as falling or contact during sport, the joint structures may be at a higher risk of injury. The extremities of the body should be identified as stabilizers of the core. Arms and legs are used to help maintain balance when the body's center of gravity falls outside the base of support. Unstable loading may be a way to prepare the body for such events and prevent future injuries by activating both the joint stabilizers and joint antagonists acting as a stabilizing force instead of furthering the adaptation of decreasing activation when using a stable load.

The only nonsignificant variable was the lateral triceps during the bench press. This is believed to be because the extension of the elbow joint was relatively unaffected by the instability and variability of the load. Being that the lateral head of the triceps was the only muscle being analyzed, it may be possible the long head of the triceps would have seen greater activation acting as a shoulder extensor.

Co-contraction

Another finding in this study was that the EQ bar produced a more ideal co-contraction than the conventional barbell in both exercises, which is in support of the second hypothesis. The ideal co-contraction index is a ratio of 1.0, agonist EMG amplitude:antagonist EMG amplitude (Baratta et al., 1988; Emily, 2015; Kellis et al., 2003). The EQ bar co-contraction was significantly more ideal. Reasons for this are similar to what has been previously stated about EMG amplitude.

While the degrees of freedom for the EQ bar are increased, the need to stabilize many unpredictable forces requires the musculature of the shoulder joint to be constantly working. Since there is no time to "relax" during the entirety of the lift, the mean amplitude stays increased in both agonist and antagonists compared to the conventional barbell, leading to significantly more ideal co-contraction ratios. Other studies using unstable loads differ from our study due to the amount of unstable weight compared to stable weight (Dunnick et al., 2015). The use of the EQ bar allows all but the 5-pounds of the bar to be unstable. Many studies use a conventional barbell and simply suspend a standard amount of weight from the 45-pound barbell (Dunnick et al., 2015). The use of the EQ bar allows more of the weight to be unstable increasing the intensity of the unpredictable force. This increased percentage of unstable load is what separates the EQ bar from other methods of instability.

Studies examining the co-contraction index of the quadriceps femoris and hamstrings, have provided an index to identify muscle imbalance and predict the risk of injury (Emily, 2015; Kellis et al., 2003). This information has provided strength and conditioning professionals with a comprehensive understanding of how to prepare their athletes to best avoid injury (Anderson et al., 2010; Kolber et al., 2010). Equipment used to train dynamic stability such as the bosu ball, dyna disk, and Swiss ball have become increasingly popular while methods to decrease the stability of the load are less mainstream (Campbell et al., 2013; De Mev et al., 2014; Dunnick et al., 2015; Iorgio et al., 2009; Joy et al., 2013; McBride et al., 2010; Nairn et al., 2015; Uribe et al., 2010). In sport is it often the object or load that is unstable, not the surface, which may prove to increase the popularity of equipment like the EQ bar. The EQ bar prepares the shoulder musculature for quick and unexpected changes in force. Another benefit is that the intensity of the load doesn’t need to be as high to receive the same amount of muscle activation which allows athletes to train at a lower intensity which could be beneficial, depending on the season (Anderson & Behm, 2004; Behm & Anderson, 2006; Behm et al., 2010; Hibberd et al., 2012; Soria-Gila et al., 2015).

Lastly, the use of instability training may be able to prolong the training effects seen in novice lifters that attribute to the majority of their strength gain seen in the first 6 weeks of training (Pinto et al., 2013). The greater mean amplitude over the acute bout provides a greater neural stimulus. Several studies have shown benefits of chronic training with unstable loads (Anderson et al., 2008; Behm et al., 2010; Joy et al., 2013; Kibele & Behm, 2009; McBride et al., 2010; Stevenson, Dietz, Giveans, Erdman, & Warpeha, 2010). More research is needed using specifically the EQ bar, as the percentage of unstable weight differs as compared to much of the current research.

In conclusion, the Earthquake bar was shown to elicit significantly greater muscle activation at the same intensity as a conventional barbell in the bench press and seated overhead press. The use of unstable loading may have various benefits and should be considered when creating a resistance training program. The instability of the Earthquake bar resulted in a more ideal and sport specific co-contraction that may benefit coaches wanting to train athletes to improve their body control. More research is needed to determine how the amount of unstable weight effects the amount of muscle activation as there has been conflicting research.

References

Aagaard, P., Simonsen, E. B., Andersen, J. L., Magnusson, P., & Dyhre-Poulsen, P. (2010). Increased rate of force development and neural drive of human skeletal muscle following resistance training. *Journal of Applied Physiology (Bethesda, MD: 1985)*, *93*(4), 1318–1326. http://dx.doi.org/10.1152/japplphysiol.00283.2002

Amarantini, D., & Bru, B. (2008). Training-related changes in the emg-moment relationship during isometric contractions: Further evidence of improved control of muscle activation in strength-trained men *Journal of Electromyography and Kinesiology*, *25*(4), 697–702. http://dx.doi.org/10.1016/j.jelekin.2015.04.002

Anderson, C. E., Sforzo, G. A., & Sigg, J. A. (2008). The effects of combining elastic and free weight resistance on strength and power in athletes. *Journal of Strength and Conditioning Research*, *22*(2), 567–574. http://dx.doi.org/10.1519/JSC.0b013e3181634d1e

Anderson, K. G., & Behm, D. G. (2004). Maintenance of emg activity and loss of force output with instability. *Journal of Strength and Conditioning Research, 18*(3), 637–640. http://dx.doi.org/10.1519/1533-4287(2004)18<637:MOEAAL>2.0.CO;2

Anderson, L., Anderson, C., Mortensen, O., Poulsen, O., Bjornlund, I., & Zebis, M. (2010). Muscle activation and perceived loading during rehabilitation exercises: Comparison of dumbells and eleastic resistance. *Physical Therapy, 90*(4), 538-549. http://dx.doi.org/10.2522/ptj.20090167

Baratta, R., Solomonow, M., Zhou, B. H., Letson, D., Chuinard, R., & D’Ambrosia, R. (1988). Muscular coactivation. The role of the antagonist musculature in maintaining knee stability. *American Journal of Sports Medicine*, *16*(2), 113–122. http://dx.doi.org/10.1177/036354658801600205

Beach, T. A. C., Howarth, S. J., & Callaghan, J. P. (2008). Muscular contribution to low-back loading and stiffness during standard and suspended push-ups. *Human Movement Science*, *27*(3), 457–472. http://dx.doi.org/10.1016/j.humov.2007.12.002

Behm, D., & Colado, J. C. (2012). The effectiveness of resistance training using unstable surfaces and devices for rehabilitation. *International Journal of Sports Physical Therapy*, *7*(2), 226–241. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3325639&tool=pmcentrez&rendertype=abstract

Behm, D. G., & Anderson, K. G. (2006). The role of instability with resistance training. *Journal of Strength and Conditioning Research*, *20*(3), 716–722. http://dx.doi.org/10.1519/R-18475.1

Behm, D. G., Drinkwater, E. J., Willardson, J. M., & Cowley, P. M. (2010). The use of instability to train the core musculature. *Applied Physiology, Nutrition, and Metabolism*, *35*(1), 91–108. http://dx.doi.org/10.1139/H09-127

Behm, D. G., Leonard, A. M., Young, W. B., Bonsey, A. C., & MacKinnon, S. N. (2005). Trunk muscle electromyographic activity with unstable and unilateral exercises. *Journal of Strength and Conditioning*, *19*(1), 193–201.

Bellar, D. M., Muller, M. D., Barkley, J. E., Kim, C.-H., Ida, K., Ryan, E. J., . . . Glickman, E. L. (2011). The effects of combined elastic and free-weight tension vs. free-weight tension on one-repetition maximum strength in the bench press. *Journal* *of Strength and Conditioning Research*, *25*(2), 459–463. http://dx.doi.org/10.1519/JSC.0b013e3181c1f8b6

Cacchio, A., Don, R., Ranavolo, A., Guerra, E., McCaw, S. T., Procaccianti, R., . . . Santilli, V. (2008). Effects of 8-week strength training with two models of chest press machines on muscular activity pattern and strength. *Journal of Electromyography and Kinesiology*, *18*(4), 618–627. http://dx.doi.org/10.1016/j.jelekin.2006.12.007

Campbell, B. M., Kutz, M. R., Morgan, A. L., Fullenkamp, A. M., & Ballenger, R. (2013). An evaluation of upper-body muscle activation during coupled and uncoupled instability resistance training. *Journal of Strength and Conditioning Research*, *28*(7), 1833–1838. http://dx.doi.org/10.1519/JSC.0000000000000350

Cibulka, M. T., Enders, G., Jackson, A., Maines, S., Von der Haar, J., & Bennett, J. (2015). The relationship between passive glenohumeral total rotation and the strength of the internal and external corresponding author. *International Journal of Sports Physical Therapy*, *10*(4), 434–440.

Cronin, J., McNair, P. J., & Marshall, R. N. (2003). The effects of bungy weight training on muscle function and functional performance. *Journal of Sports Sciences*. http://dx.doi.org/10.1080/0264041031000071001

Culham, E., & Peat, M. (1993). Functional anatomy of the shoulder complex. *Journal of Orthoaedic & Sports Performance*, *18*(1), 342–251. http://dx.doi.org/10.2519/jospt.1993.18.1.342

De Mev, K., Danneels, L., Cagnie, B., Borms, D., T'Jonick, Z., Van Damme, E., &

Cools, A. M. (2014). Shoulder muscle activation levels during four closed kinetic chain exercises with and without redcord slings. *Journal of Strength and Conditioning Research*, *28*(6), 1626–1635.

Dunnick, D. D., Brown, L. E., Coburn, J. W., Lynn, S. K., & Barillas, S. R. (2015). Bench press upper-body muscle activation between stable and unstable loads. *Journal of Strength and Conditioning Research*, *29*(12), 3279–3283. http://dx.doi.org/10.1519/JSC.0000000000001198

Emily, G. (2015). The relationship between muscular co-contraction and dynamic knee stiffness in acl-deficient non-copers. *PhD Proposal*, *1*. http://dx.doi.org/10.1017/CBO9781107415324.004

Folland, J. P., Buckthorpe, M. W., & Hannah, R. (2014). Human capacity for explosive force production: Neural and contractile determinants. *Scandinavian Journal of Medicine and Science in Sports*, *24*(6), 894–906. http://dx.doi.org/10.1111/sms.12131

García-López, D., Hernández-Sánchez, S., Martín, E., Marín, P. J., Zarzosa, F., & Herrero, A. J. (2014). Free-weight augmentation with elastic bands improves bench-press kinematics in professional rugby players. *Journal of Strength and Conditioning Research*. http://dx.doi.org/10.1519/JSC.0000000000000374

Goodman, C. A., Pearce, A. J., Nicholes, C. J., Gatt, B. M., & Fairweather, I. H. (2008). No difference in 1rm strength and muscle activation during the barbell chest press on a stable and unstable surface. *Journal of Strength and Conditioning Research*, *22*(1), 88–94. http://dx.doi.org/10.1519/JSC.0b013e31815ef6b3

Häkkinen, K., Newton, R. U., Gordon, S. E., McCormick, M., Volek, J. S., Nindl, B. C., . . . Kraemer, W. J. (1998). Changes in muscle morphology, electromyographic activity, and force production characteristics during progressive strength training in young and older men. *Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, *53*(6), B415–B423. Retrieved from http://biomedgerontology.oxfordjournals.org/content/53A/6/B415.full.pdf

Halperin, I., Copithorne, D., & Behm, D. G. (2014). Unilateral isometric muscle fatigue decreases force production and activation of contralateral knee extensors but not elbow flexors. *Applied Physiology, Nutrition, and Metabolism*, *104*(6), 919–929. http://dx.doi.org/10.1139/apnm-2014-0109

Hibberd, E. E., Oyama, S., Spang, J. T., Prentice, W., & Myers, J. B. (2012). Effect of a 6-week strengthening program on shoulder and scapular-stabilizer strength and scapular kinematics in division 1 collegiate swimmers. *Journal of Sport Rehabilitation*, *21*(3), 253–65. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/22387875

Iorgio, P. I. G., Amozino, P. I. S., & Enoi, J. E. A. N. (2009). Multigrip flexible device: Electromyographical analysis and comparison with the bench press exercise. *Journal of Strength and Conditioning Research*, *23*(2), 652–659.

Jones, M. T. (2014). Effect of compensatory acceleration training in combination with accommodating resistance on upper body strength in collegiate athletes. *Open Access Journal of Sports Medicine*, *5*, 183–189. http://dx.doi.org/10.2147/OAJSM.S65877

Joy, J. M., Lowery, R. P., Oliveira de Souza, E., & Wilson, J. M. (2013). Elastic bands as a component of periodized resistance training. *Journal of Strength and Conditioning Research*, (July 2015). http://dx.doi.org/10.1519/JSC.0b013e3182986bef

Kellis, E., Arabatzi, F., & Papadopoulos, C. (2003). Muscle co-activation around the knee in drop jumping using the co-contraction index. *Journal of Electromyography and Kinesiology*, *13*(3), 229–238. http://dx.doi.org/10.1016/S1050-6411(03)00020-8

Kibele, A., & Behm, D. G. (2009). Seven weeks of instability and traditional resistance training effects on strength, balance and functional performance. *Journal of Strength and Conditioning Research*, *23*(9), 2443–50. http://dx.doi.org/10.1519/JSC.0b013e3181bf0489

Kolber, M. J., Beekhuizen, K. S., Cheng, M.-S. S., & Hellman, M. A. (2010). Shoulder injuries attributed to resistance training: A brief review. *Journal of Strength and Conditioning Research*, *24*(6), 1696–1704.

Kristiansen, M., Madeleine, P., Hansen, E. A., & Samani, A. (2015). Inter-subject variability of muscle synergies during bench press in power lifters and untrained individuals. *Scandinavian Journal of Medicine and Science in Sports*, *25*(1), 89–97. http://dx.doi.org/10.1111/sms.12167

McBride, J. M., Larkin, T. R., Dayne, A. M., Haines, T. L., & Kirby, T. J. (2010). Effect of absolute and relative loading on muscle activity during stable and unstable squatting. *International Journal of Sports Physiology and Performance*, *5*(2), 177–183. http://dx.doi.org/10.1097/01.JSC.0000367168.56347.0a.

Murphy, A. J., & Wilson, G. J. (1996). Poor correlations between isometric tests and dynamic performance: Relationship to muscle activation. *European Journal of Applied Physiology and Occupational Physiology*, *73*(3–4), 353–357. http://dx.doi.org/10.1007/BF02425498

Naik, G. R., Arjunan, S., & Kumar, D. (2011). Applications of ica and fractal dimension in semg signal processing for subtle movement analysis: A review. *Australasian Physical and Engineering Sciences in Medicine*, *34*(2), 179–193. http://dx.doi.org/10.1007/s13246-011-0066-4

Nairn, B. C., Sutherland, C. A., & Drake, J. D. M. (2015). Location of instability during a bench press alters movement patterns and electromyographical activity. *Journal of Strength and Conditioning Research*, *29*(11), 3162–3170. http://dx.doi.org/10.1519/JSC.0000000000000973

Narici, M. V., Roi, G. S., Landoni, L., Minetti, A. E., & Cerretelli, P. (1989). Changes in force, cross-sectional area and neural activation during strength training and detraining of the human quadriceps. *European Journal of Applied Physiology and Occupational Physiology*, *59*(4), 310–319. http://dx.doi.org/10.1007/BF02388334

Park, S., Nho, H., Chang, M.-J., & Kim, J.-K. (2012). Electromyography activities for shoulder muscles over various movements on different torque changes. *European Journal of Sport Science*, *12*(9), 408–417. http://dx.doi.org/10.1080/17461391.2011.566375

Park, S. Y., & Yoo, W. G. (2011). Differential activation of parts of the serratus anterior muscle during push-up variations on stable and unstable bases of support. *Journal of Electromyography Kinesiology*, *21*(5), 861–867.

http://dx.doi.org/10.1016/j.jelekin.2011.07.001

Pinto, R., Cadore, E., Correa, C., Gonçalves Cordeiro da Silva, B., Alberton, C., Lima, C., & de Moraes, A. (2013). Relationship between workload and neuromuscular activity in the bench press exercise. *Medicina Sportiva*, *17*(1), 1–6. http://dx.doi.org/10.5604/17342260.1041876

Radwan, A., Francis, J., Green, A., Kahl, E., Maciurzynski, D., Quartulli, A., . . . Strang, R. (2014). Is there a relation between shoulder dysfunction and core instability? *International Journal of Sports Physical Therapy*, *9*(1), 8–13.

Rutherford, O. M., & Jones, D. A. (1986). The role of learning and coordination in strength training. *European Journal of Applied Physiology and Occupational Physiology*, *55*, 100–105. http://dx.doi.org/10.1007/BF00422902

Saeterbakken, A. H., & Fimland, M. S. (2013). Electromyographic activity and 6RM strength in bench press on stable and unstable surfaces. *Journal of Strength and Conditioning Research*, *27*(4), 1101–1107.

Sakamoto, A., Sinclair, P. J., & Moritani, T. (2012). Muscle activations under varying lifting speeds and intensities during bench press. *European Journal of Applied Physiology*, *112*(3), 1015–1025. http://dx.doi.org/10.1007/s00421-011-2059-0

Sale, D. G. (1988). Neural adaptation to resistance training. *Medicine and Science in Sports and Exercise*. http://dx.doi.org/10.1152/japplphysiol.01185.2001

Sampson, J. A., McAndrew, D., Donohoe, A., Jenkins, A., & Groeller, H. (2013). The effect of a familiarisation period on subsequent strength gain. *Journal of Sports Sciences*, *31*(2), 204–11. http://dx.doi.org/10.1080/02640414.2012.725134

Lee, S., Lee, D., & Park, J., (2013). The effect of hand position changes on electromyographic activity of shoulder stabilizers during push-up plus exercise on stable and unstable surfaces. *Journal of Physical Therapy Science*, *25*, 981–984.

Seitz, A. L., & McClelland, R. I. (2015). A comparison of change in 3D scapular kinematics with maximal contractions and force production with scapular muscle tests between asymptomatic overhead athletes with and without scapular dyskinesis. *International Journal of Sports Physical Therapy*, *10*(3), 309–318.

Shoepe, T. C., Ramirez, D. A., Rovetti, R. J., Kohler, D. R., & Almstedt, H. C. (2011). The effects of 24 weeks of resistance training with simultaneous elastic and free weight loading on muscular performance of novice lifters. *Journal of Human Kinetics*, *29*(9), 93–106. http://dx.doi.org/10.2478/v10078-011-0043-8

Soria-Gila, M. A., Chirosa, I. J., Bautista, I. J., Baena, S., & Chirosa, L. J. (2015). Effects of variable resistance training on maximal strength: A meta-analysis. *Journal of Strength and Conditioning Research*, *29*(11), 3260–3270.

Stevenson, M. W., Dietz, C. C., Giveans, R. M., Erdman, A. G., & Warpeha, J. M. (2010). Acute effects of elastic bands during the free-weight barbell back squat exercise on velocity, power, and force production. *Journal of Strength and Conditioning Research*, *24*(11), 2944–2954.

Thomas, C., Jones, P. A., & Comfort, P. (2015). Reliability of the dynamic strength index in collegiate athletes. *International Journal of Sports Physiology and Performance*, *10*(5), 542–545. http://dx.doi.org/10.1123/ijspp.2014-0255

Tillin, N. A., Pain, M. T. G., & Folland, J. (2012). Explosive force production during isometric squats correlates with athletic performance in rugby union players. *Journal of Sports Sciences*, *31*(July 2015), 1–11. http://dx.doi.org/10.1080/02640414.2012.720704

Uribe, B. P., Coburn, J. W., Brown, L. E., Judelson, D. A., Khamoui, A. V., & Nguyen, D. (2010). Muscle activation when performing the chest press and shoulder press on a stable bench vs. a swiss ball. *Journal of Strength and Conditioning Research*, *24*(4), 1028–1033.

Von Werder, S. C. F. A., Kleiber, T., & Disselhorst-Klug, C. (2015). A method for a categorized and probabilistic analysis of the surface electromyogram in dynamic contractions. *Frontiers in Physiology*, *6*(February), 1–8. http://dx.doi.org/10.3389/fphys.2015.00030