TRUNCK MUSCLE ACTIVATION DURING DYNAMIC WEIGHT LIFTING EXERCISES AND ISOMETRIC INSTABILITY ACTIVITIES

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**A Masters Thesis submitted
to the School of Graduate Studies and
The School of Human Kinetics
and Recreation in partial fulfillments
of the Degree of Masters of Science
in Kinesiology**

St. John's **August 25, 2006**

Your file Votre référence
ISBN: 978-0-494-30470-9
Our file Notre référence
ISBN: 978-0-494-30470-9

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ABSTRACT

The experience of low back pain is a common medical occurrence that often interferes with one's routine activities and has been associated with poor physical conditioning. Adequate strength and endurance of the trunk muscles is necessary for various activities of daily living, numerous athletic endeavors and manual labor environments. However, there are many ways to train the trunk muscles which raises the question of which one is the most appropriate. Traditionally, most training programs have involved dynamic resistance training exercises in order to battle muscle fatigue. Moreover, in recent years there has been more of a demand to incorporate methods of instability exercises such as Swiss balls, Dyna discs and wobble boards in order to provide a greater challenge to the trunk musculature. Thus, the objective of this study is to investigate the extent of activation in various muscles of the trunk region during dynamic weight-lifting exercises and isometric instability activities.

Acknowledgements

First and foremost, I would like to extend my sincerest appreciation to my family. My parents, Doreen and Carl have instilled in me a strong work ethic and the opportunity for the best education. Along with constant support, my parents have provided me with incredible motivation that has allowed me to pursue my goals in education and life. From my parents I have learned that the most important thing is to never stop learning and to never give up on your dreams, two qualities that I will carry with me forever.

To my supervisor Dr. Behm, who has had guided me through the long and tedious process of a Masters Thesis. In addition to the vast amount of resources and information, I am truly grateful for the time and patience that has been provided to me during this time. I have learned an enormous amount from conducting this research with Dr. Behm and will continue to build upon the knowledge that I have acquired. Finally, I would like to extend a special thank you to Glen Rowsell who has been there for me during every step of my thesis and has provided me with endless assistance and encouragement.

CO-AUTHORSHIP STATEMENT

Dr. Behm has been a significant contributor to a number of aspects during this research. This includes the initial research idea, formulating the methods to carry out the experimental procedure, interpreting and analyzing the data and finally reviewing the text.

1 INTRODUCTION

1.0 Overview

Back pain is amongst the most common complaints seen by physicians (second only to the common cold). It's estimated that 80% of the population will experience at least one episode of low back pain (LBP) in their lifetime and as many as 50% of those cases will have a recurrence within 3 years (Shiple & DiNuble, 1997).

In recent years, the focus of rehabilitating back injuries has undergone many changes. Previously, LBP was treated by the use of bed rest and medication which only advanced the deconditioned state of the trunk musculature allowing further loss of strength and endurance. Bed rest, it appears, has no advantage in most cases and can, in fact, compromise recovery (Shiple & DiNuble, 1997). Considering the previous statement it does seem reasonable to assume that exercise is the intervention of choice in order to help rehabilitate patients and prevent low back disorders. However, at the present time it still remains unclear as to what method of training will provide the most beneficial results for conditioning the trunk muscles.

New research has focused on training in unstable conditions as compared to training with traditional strength training methods. Many strength training methods typically attempt to isolate specific muscle groups while keeping the body unloaded on a stable surface (i.e. bench) (Goldenberg & Twist, 2002). However, this type of training has little relation to activities of daily living. Whereas incorporating an unstable surface such as a Swiss ball into a training program provides an unpredictable environment in which one must involve multiple joints and muscles to maintain balance. This type of training is then able to transfer to unpredictable daily activities or athletic settings, such as walking on an icy surface, reaching to catch a falling object or withstanding a body check in hockey (Goldenberg & Twist, 2002).

Recent studies have indicated that incorporating an unstable base does lead to greater activation of the muscles in comparison to stable surfaces (Marshall & Murphy, 2005, Behm et al., 2005, Anderson & Behm, 2005). However, these studies typically employ exercises lying down on a Swiss ball which do not mimic daily activities.

Thus, the proposed study will investigate the extent of activation in various muscles of the trunk region during dynamic weight-lifting exercises and isometric instability activities. Based on the literature review, it was hypothesized that the isometric activities on instability devices would produce greater EMG activity of the trunk stabilizers. The study may have direct implications on exercises that are prescribed in rehabilitative settings as well as athletic training programs.

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2 REVIEW OF LITERATURE

2.0 Introduction

Trunk or core stabilizer muscles play an integral part in carrying out simple day to day activities. This often includes obvious activities such as walking or sitting but can also include more vigorous activities such as athletic competitions and heavy lifting during work or leisure. To ensure that these activities are carried out with minimal risk of injury or muscle soreness (i.e. low back pain), the trunk stabilizer muscles must be conditioned to endure the activities at hand. Whereas increasing the strength of trunk stabilizers can aid in injury prevention, fatigue can lower the tissue safety threshold increasing the possibility for injury. Fatigue has many definitions, including the transient loss of work capacity that results from an increase in work load (Asmussen, 1979); a failure to maintain a required force output during a sustained contraction and an increased effort while trying to maintain the contraction (Kirkendall, 1990). The deficit in work capacity or force output can refer to either external production or internal (muscle and connective tissue) capacity. A fatigue-induced loss of internal capacity for workers or athletes can not only cause a decrease in motor performance but also increase the risk of musculoskeletal injury.

Adequate endurance of trunk muscles is necessary for good health and is often taken for granted until the first incidence of LBP, which is estimated to affect 80% of the population at some time in their lives (Moffroid, 1997). As of 1998, it was estimated that over 24 billion dollars is required each year to cover the medical costs in order to manage low back pain (LBP) and at least a quarter of the working population have reported an episode of lower back pain (Sparto & Parnianpour, 1998). The development of most low back disorders, come as a result of a lack of strength and endurance of the trunk muscles. Numerous studies have demonstrated lower incidence of LBP episodes following training (Moffroid et al., 1993). While causes and mechanisms of chronic LBP have been well investigated, the most effective training for the prevention of LBP requires more attention.

The purpose of this review is to investigate the effect of fatigue on trunk and spinal stabilization. Furthermore, the effectiveness of implementing instability training programs for the prevention of back injury will also be reviewed.

2.1 Functioning of Trunk Stabilizers

When considering the dynamic functions of muscles, there are two main classifications consisting of stabilizer muscles and mobility muscles (Gibbons & Comerford, 2001). The stabilizer muscles help to support the muscles that are producing the movement while at the same time maintaining the integrity of the bones and joints. Stabilizer muscles are deep, mono-articular or segmental that work on an eccentric basis to control the movement while also having static holding capacities (Gibbons & Comerford, 2001). In contrast, mobility muscles are known as the prime movers of the body. They initiate and allow various movements and activities to take place, such as flexion and extension. Mobility muscles are more superficial than the stabilizers and are bi-articular or multi-segmental that work to allow force or power producing movements and acceleration (Gibbons & Comerford, 2001).

The stabilizer muscles can be categorized into local and global muscle systems. The local system includes deep muscles which all have their origin or insertion on the lumbar vertebrae (Richardson et al., 1999). These muscles help to control the stiffness during a contraction which will obtain mechanical stability and posture of the lumbar spine while also controlling lumbar curvature (Gibbons & Comerford, 2001). Common muscles included in the local system are the lumbar multifidus and the transverse abdominus. During movement activities, local muscles are subjected to minimal length change and producing little range of motion (Gibbons & Comerford, 2001).

The global muscle system is not only responsible for movement of the spine, but also for transferring load between the thoracic cage and the pelvis (Richardson et al., 1999). Primarily, the global muscles function to balance the external loads that are being applied to the trunk region. The residual forces are then transferred to the lumbar spine where the local muscles can help to minimize the forces (Richardson et al., 1997). Muscles included in the global system are the rectus abdominus and the obliqous abdominus (internal and external) (Emerson, 2001). These muscles help to generate force by working eccentrically in order to control range of motion (Gibbons & Comerford, 2001).

The global mobilizers are a subdivision of the global system and include the iliocostalis and piriformis muscles. The mobilizers are ideally recruited for stability function when under load or high-speed movements (Gibbons & Comerford, 2001). Generally, these muscles will produce power and speed by working concentrically and can work eccentrically when loads must be decelerated (Gibbons & Comerford, 2001).

2.2 Spinal Stabilization

Due to considerable debate concerning the terms and conditions surrounding spinal stability and instability, Panjabi (1992) developed an innovative model to provide insight in understanding these terms. The model consists of three subsystems that are associated with spinal stability: the passive subsystem, the active subsystem and the neural control subsystem (Richardson et al., 1999). The passive subsystem includes the osseous and articular structures, along with the connective spinal ligaments. The active subsystem refers to the musculotendinous unit that has force-generating capacities which provides the ability to support the spinal segment. The neural control subsystem relates to the nervous system by recognizing that muscles require programming from feedback in order to adjust and activate the appropriate muscles at the appropriate level (Richardson et al., 1992).

Panjabi (1992) suggests that all three of the subsystems are interdependent components of the whole stabilization system. This will allow one subsystem to compensate for deficits that may appear as a result of abnormally large segmental motions. Expansive movement can compress or stretch the neural structures as a consequence of abnormal deformation of ligaments and the regions that consist of pain-sensitive structures (Panjabi, 1992).

Instability at the segmental level has many different definitions including a loss of joint stiffness and/or an increase in mobility and abnormal spinal motion (Richardson et al., 1999). Since there is such a broad definition, instability may also possibly occur due to an insufficiency of the muscle system. Spinal instability may result from fatigue, degenerative diseases or injury, which can all further lead to a decrease in muscle stiffness. Muscle stiffness can be referred to as a quality reflecting the ratio of force change to length change in a muscle to describe the spring-like qualities of a muscle (Richardson et al., 1999). Thus, a lack of muscle stiffness can leave the spine and core region of the body unsupported and less stable, allowing pain and/or injury to occur.

2.3 Mechanisms of Low Back Pain

It has already been established that LBP is one of the most common and costly medical problems in modern societies (Graves & Franklin, 2001). However, one major problem in the area of treatment and prevention is that the etiology of LBP is very widespread and that there is not just one specific cause. The development of LBP has been associated with poor physical conditioning. Evidence indicates that individuals with fatigue resistant back muscles and good general physical conditioning have fewer incidences of back problems than their deconditioned counterparts (Roy et al., 1988). The lack of endurance of the trunk muscles has been identified as a precursor of low back trouble and a discriminating factor in those individuals with and without a history of LBP (Moffroid, 1997).

Epidemiological research has also identified several biomechanical factors in those individuals with a prevalence of LBP. These include heavy physical work, static work postures, frequent bending and twisting, lifting and forceful movements, repetitive movements and exposure to whole body vibration (Sparto & Parnianpour, 1998). While a single exposure to theses factors may not result in LBP injuries, the probability of injury is likely increased with weak or fatigued trunk muscles.

The endurance capacity of a muscle is an expression of its fatigability. Mechanically, it can be defined as either the point of isometric fatigue, where the exertion can no longer be maintained, or as the point of dynamic fatigue where repetitive work can no longer be sustained at a certain force level (Moffroid, 1997). It has been demonstrated that those individuals in good physical condition have a lower incidence of back pain than those who are less conditioned. Furthermore, the isometric endurance of the trunk muscles rather than trunk strength has a greater association with the occurrence of LBP (Sparto & Parnianpour, 1998). An interesting counterpoint is the high incidence of LBP in rowers.

It is suggested that people with fatigue resistant back muscles and good physical fitness have fewer reported back problems, yet back injuries and LBP are the most common complaints among competitive rowers (Roy et al., 1990). Rowing at a competitive level requires dedicating many hours of intense training both on and off the water. The rowing stroke has many biomechanical demands and due to the rigorous nature of the training, repeated forces of high magnitude are placed upon the muscles (especially those of the trunk region) on a daily basis. The excessive forces placed upon the trunk muscles can potentially cause LBP especially when fatigue impairs the contractile ability of the muscle (Roy et al., 1990).

One potential reason for a high incidence of LBP amongst rowers involves the repetitive asymmetric activity which also includes loading the back in a rotated and flexed position (McGregor et al., 2002). When an asymmetric activity is repeated continually as in rowing, it can lead to muscle imbalances and eventually the potential of injury. These imbalances have been seen to occur between agonist and antagonist muscles. Noted motion changes have been seen in the pelvis of rowers with LBP while engaging in the rowing motion (McGregor et al., 2002). This may potentially be caused by an imbalance of the back flexors and extensors.

The asymmetrical activity mentioned previously, primarily occurs when rowers are set to row on one side or the other (port or starboard) for extended amounts of time. Port rowers will typically use the left side of their backs to execute the rowing stroke, while starboard rowers will use the right side. This is consistent with the finding from Roy et al. (1990), showing that there is a greater percent recovery on the right for starboard rowers and left for port rowers. Rowing consistently on one side or the other may eventually lead to the trunk extensors developing asymmetrically.

Many studies that have investigated low back concerns among rowers have found that in rowers with LBP, the muscles of the back are larger and can exert more force than the rowers without incidence of LBP (Roy et al., 1990). Perhaps, the enlarged muscles found in the LBP group could be caused as a consequence of poor technique. Often rowers can develop the habit of generating the force-producing drive mainly with their back instead of initiating the stroke with their legs. More research must be done in order to determine whether this observation is a cause or an effect of LBP. In summary, highly conditioned athletes (strong and endurant backs) can still develop LBP with the adoption of improper mechanics (i.e. asymmetry, excessive range of motion) and physiology (i.e. inadequate recovery between training sessions).

Without adequate recovery time, an occupational setting where lifting is performed many times a day can increase the risk of low back disorders. In a study by Mooney et al. (Graves & Franklin, 2001), 80% of workers who volunteered in a once a week training program had previously reported back pain. Following the program, both the back pain and non-back pain groups of workers improved their functional capacity to the same level. During a one year follow-up, the incidence of back injury was reduced in relation to an untrained control group.

The trunk muscles are physiologically well suited to provide low levels of activity for long periods of time. The trunk flexors and extensors are active throughout most daily activities. These normal daily activities may often present an opportunity for an "unguarded movement" (Graves & Franklin, 2001). This movement may include a sudden position change or the impact of an unexpected force. Therefore, the muscles of the trunk act as a protective mechanism in maintaining the position of the spine. When the trunk muscles are weak or fatigued, they are left vulnerable and susceptible to back injury.

Another important factor of the spine is to provide a stable support for the variety of movements carried out by the upper and lower limbs. The transverse abdominus and the multifidus are good examples of these supporting muscles. In all trunk movements, the transverse abdominus is activated slightly before other abdominal muscles and is in coordination with the multifidus (Graves & Franklin, 2001).When investigating muscle activity during unexpected movements, the transverse abdominus is also activated prior to arm muscles activity (Cresswell et al., 1994). The activity of these muscles in individuals with LBP is of utmost importance. When the LBP subject flexes, extends or abducts the spine, there is a delay in the firing of the transverse abdominus and multifidus associated with shoulder motion compared to healthy individuals (Hodges & Richardson, 1996). The inhibition of the transverse abdominus results in a vulnerability of the spine in relation to physical stress during unexpected movements.

It is clear that there is a relationship between back extensor strength and LBP. In a study conducted by Biering-Sorensen (Moffroid et al., 1993), lumbar strength and range of motion were investigated during an extensive physical examination. Results indicated that there was a direct correlation between the incidence of LBP and isometric back extensor weakness. In an additional study, the Biering-Sorenson muscular endurance test was used to detect fatigue of the low back muscles. This test is performed as a timed test in which a subject holds a horizontal unsupported position for as long as possible (Moffoid et al., 1993). After performing the test, results indicated that individuals who exhibited poor endurance times on the test were three times more likely to experience back pain than their counterparts (Graves & Franklin, 2001). Furthermore, in comparison to normal subjects, fatigue is greater in those who have LBP.

Individuals who suffer from LBP are shown to have significantly less endurance and therefore greater fatigability in comparison to those without LBP (Richardson et al., 1999). The reduction in trunk muscle strength that produces fatigability may be a characteristic of the individual's level of physical activity as well as their work and leisure environment. Thus, it is plausible to assume that with proper conditioning and training many cases of LBP attributed to decreased endurance can be rectified or possibly avoided.

2.4 Fatigue of Trunk Muscles

When an individual exhibits weakness or a decreased endurance of the trunk muscles, the muscles are continuously placed under postural stress that leads to incorrect loading of the spine and eventually LBP (Nicolaisen & Jorgensen, 1985). Physiologically, the trunk muscles are well-suited to provide the strength required to maintain activity for long periods of time. This is due primarily because of the physiological make-up of these muscles, which are rich in type I fibers. Interestingly type II muscle fibers in human trunk extensor muscles have a smaller mean diameter than that of type I (Roy et al., 1989). This finding is a departure from the norm with almost all other muscle fibers in humans. Even though the trunk flexor and extensor muscles are primarily thought of as postural muscles, they are actually active throughout most activities (Moffroid, 1997).

As fatigue develops, the force generated by these muscles deteriorates. One consequence of the decline in force that is seen in the primary trunk extensors is the increased reliance on the passive tissue subsystems (Sparto & Parnianpour, 1998). It is hypothesized that when muscles are required to respond to an unexpected load or demand that is greater than the muscles capability, most of the load is placed onto the passive tissues (Sparto & Parnianpour, 1998). At this point, injury may occur due to the lack of support and stiffness from the passive tissues.

A study conducted by Zetterberg et al. (1987) investigated the trunk muscle activity involved with exertion movements made in flexion and extension activities. Results indicated that during flexion movements all of the erector spinae muscles were almost silent. Whereas during extension movements, the erector spinae muscles in addition to the abdominal muscles were activated. It is suggested that during the attempted extension, the abdominal muscles were activated to raise the intra-abdominal pressure or were activated to stabilize the trunk for the movement (Zetterberg et al., 1987).

In a study conducted by Moffroid et al. (1993), the effects of an endurance exercise training program on an isometric holding time of the trunk extensor muscles were measured. Twenty-eight subjects were assigned to either an exercise or control group and were tested before the experiment, after three weeks and again after six weeks. In the exercise group, a mean increase in holding time of 17% was found after three weeks and an increase of 22% was found after six weeks. Whereas there was only an increase of 1% after six weeks in the control group (Moffroid et al., 1993). Throughout this particular study, the multifidus and erector spinae muscles were more active.

In order to make the trunk muscles become more endurant, there needs to be an increase in static loading exercises as well as graded activity programs (Moffroid, 1997). In a study conducted by Salminen et al. (1992), 15-year-olds with and without LBP indicated that those who participated in regular physical activity had increased spinal mobility, greater endurance of back muscles and more dynamic strength (Moffroid, 1997). A study has also shown that with a training program that includes graduated mobility and general fitness over a one year period there are improved return-to-work rates, as well as trunk muscle endurance (Moffroid, 1997).

As a result of gradual increases in strength, endurance and range of motion, qualitative changes in posture and movement may be expected. Often, specific postural exercises can also help to improve the endurance of the trunk muscles. However, it may be necessary to perform these exercises more vigorously and/or for longer periods of time. In most cases, training has been shown to increase the strength and endurance capacities of the trunk muscles. These training programs must be implemented properly and are most often successful over extended periods of time.

2.5 Specificity of Training

The vast majority of activities of daily living are dynamic. Based on the concept of training specificity, training the trunk musculature should attempt to replicate the activity mode, type and speed of contractions, and range of motion (Morrissey et al., 1995). Training specificity suggests that an individual will experience the greatest adaptation by performing similar movement and recruiting similar muscle groups that are used in their specific activity (McLaughin, 2001). These training specific adaptations are believed to occur in the nervous system, for example, improved technique, the increased recruitment of motor units, and possibly the synchronization of motor units (McLaughin, 2001).

A good resistance training program for the trunk musculature should include exercises for all major muscle groups which can also be modified to target the unique demands of a particular activity (ACSM, 1998). The extent to which these factors are incorporated into a specific training program remains a popular topic of research.

A study conducted by Duchateau and Hainaut (1984) compared both isometric and dynamic training of the adductor pollicis muscle. After 3 months of training, the maximal isometric muscle force for those that trained isometrically increased by 20%, while those who trained by dynamic contractions only increased their force by 11%. However, a greater increase in the speed of contraction was seen following dynamic as opposed to isometric training. It can be seen that the specific pattern of neuromuscular activation required by a particular exercise or training program can stimulate systems in such a way as to provoke a particular response or adaptation (Graves & Franklin, 2001).

Morphological and functional deficits of the lumbar spine muscles, for example, atrophy, weakness and low levels of endurance have clearly been associated with an incidence of LBP (Verna et al., 2002). Thus training of the trunk muscles has shown to successfully increase strength and endurance and therefore decrease pain and improve functional capacity (Pollock et al., 1998). Many exercises and/or rehabilitative programs have focused on developing lumbar strength through dynamic progressive exercise by incorporating highly specialized equipment. One study that examined healthy subjects and patients with LBP, reported large strength gains in lumbar extension torque production after twelve weeks of training on a lumbar extension dynamometer (Verna et al., 2002). A study conducted by Graves et al. (1989) compared strength gains in 114 subjects during isometric and dynamic training using a lumbar extension machine. This study also investigated different training frequencies in the development of lumbar extension strength. The subjects were randomly assigned to one of five training groups. One group trained isometrically once a week, while the others trained dynamically with different frequencies. Frequencies included, once every two weeks, once a week, twice a week and three times a week. After 12 weeks of training, results indicated that all groups did improve lumbar extension strength to some extent. Isometric training resulted in 11.5 to 18.6% increases during 72 degrees of flexion and 53.7 to 129.7% in full extension. Improvements in dynamic strength were 26.6 to 41.1%. Results also determined that training once every two weeks was not as effective as more frequent training. Due to the potential risk of overtraining with training two and three times a week, it was determined that a frequency of once a week is the safest and most effective way to train (Graves et al., 1989).

Despite many noted improvements by using specific back extension machines, these devices have been questioned due to their high cost and availability (Verna et al., 2002). For this reason, many rehabilitation specialists have resorted to more simplified alternatives in order to condition and strengthen the lumbar muscles. Examples of these alternatives include progressive floor exercises and prone back extension exercises. Although these methods provide a cheaper and easier way to perform exercises, there are still many limitations. For example, performing prone back extension exercises on tables or the conventional Roman chair exercise may not be able to provide enough resistance necessary for patients with LBP (Verna et al., 2002). In addition, the amount of resistance achieved on these devices depends on torso mass. For many individuals, this can be greater then their initial capability. With regards to many floor exercises, most do not allow for exercise over a full range of motion and may not provide the overload stimulus needed to elicit physiological changes in the lumbar muscles (Verna et al., 2002).

It has been a common belief in the past that training the trunk flexors or the abdominals should be the highest priority in order to decrease back pain. It has been hypothesized that strengthening the abdominal muscles will increase the intra-abdominal pressure and help to maintain a balance between the abdominal muscles and the back extensors (Graves & Franklin, 2001). By increasing the intra-abdominal pressure, there is a decrease in compressive forces on the spine. However, evidence suggests that during contraction of the abdominals, the intra-abdominal pressure is not increased and furthermore not increased following an abdominal strength training program (Hemborg et al., 1985). This reiterates the idea that training the lumbar muscles is of utmost importance in the treatment and prevention of low back disorders.

During traditional training and rehabilitation of the low back, it has been suggested that isolating the lumbar area through pelvic stabilization eliminates the contribution of both the gluteal and hamstring muscle groups during training (Graves & Franklin, 2001). Thus, this allows the lumbar extensors to receive the appropriate stimulus to increase strength. In attempt to refute this theory, many studies have investigated the difference between training with stabilization and without. For example, a study conducted by Mayer et al. (1998) compared a group that used pelvic stabilization to train on a lumbar extension dynamometer to a group that didn't use pelvic stabilization. Results indicated that lumbar extension torque values were similar during the stabilization test for both groups. However, only the non-stabilization group increased torque output during the unstabilized test. The investigators concluded that training with pelvic stabilization is not necessary to increase lumbar extension strength. In addition, training without pelvic stabilization may be more closely related to normal daily activities (Graves & Franklin, 2001). Therefore, training without pelvic stabilization may be more realistic and versatile for real world activities.

2.6 Instability Training

Unstable environments provide greater challenges to the musculature and thus greater possibility for injuries. Performing activities of daily living on an icy surface, while standing on uneven ground or when a load places the center of gravity outside the base of support, all place the back in a jeopardizing position. Hence, based on the concept of specificity, should not core or trunk training use unstable bases?

Training the abdominals has traditionally been designed around exercises such as sit-ups, crunches or leg raises (Baker, 1999). However, in recent years, certain devices have been incorporated into the training regimen in order to place a greater emphasis on instability training for the core stabilizing muscles. The term core stability is used to generally describe training the abdominals and lumbopelvic region (Marshall & Murphy, 2005). There are many different instability devices that can be incorporated into a training program, for example Swiss balls, wobble boards, dyna discs and other equipment.

Originally, the Swiss ball was used in the early 1960's in Europe to treat children with neurological impairments. Thereafter, physiotherapists began to use them for posture retraining and back pain rehabilitation (Spalding et al., 1999). It wasn't until the mid-1970's that Swiss balls could be purchased in North America.

Incorporating a Swiss ball into strength and conditioning programs claims to more effectively train the musculoskeletal system on the belief that a labile surface will provide a greater challenge to the trunk musculature (Lehman et al., 2005). Whether the Swiss ball has a greater effect on the core stabilizers than other methods of training is inconclusive.

It is essential that the spine and all other joints maintain flexibility, not only for the health of the tissues but also in order to have good balance reactions while carrying out daily activities and sports (Spalding et al., 1999). Thus the use of a Swiss ball has been established on the idea that they challenge balance and proprioception (Baker, 2000). They are used in most training regimens to replace traditional stable benches or the floor. It is proposed that there will be a greater stress placed on the neuromuscular system in comparison to traditional resistance training methods while training under unstable conditions (i.e. using a Swiss ball) (Anderson & Behm, 2005b). While just sitting on a Swiss ball, more muscles are activated around the spine for postural support while the feet, legs and hips have to work to maintain balance. With more muscles activated there is increased circulation to the spine, making sitting more like standing (Spalding et al., 1999). Thus while sitting on a Swiss ball, numerous muscles are activated in a similar manner as they would be while standing.

Since there are opposing views and a lack of research on the topic, it is not clear if using a Swiss ball provides a greater benefit than using traditional methods. However, the research on the topic is becoming more prevalent. For example, a study conducted by Marshall and Murphy (2005), compared activation patterns of muscles associated with the global and local stability systems during different core stability exercises on and off a Swiss ball. The research results indicated that there were greater activation patterns in the muscles of the lumbopelvic region during the exercises that were performed on the Swiss ball.

Anderson and Behm (2005a) reported increased EMG activity of the soleus, abdominal stabilizers, upper-lumbar and lumbo-sacral erector spinae (ULES & LSES) during an unstable squat movement in comparison to a stable movement. The squat movement was altered by performing three different movements: a free squat, a Smith machine squat, and standing on two balance discs. The increased EMG activity was attributed to the postural and stabilization role of the muscles.

Behm et al. (2005) compared EMG activity in the trunk muscles during popular resistance exercises and trunk strengthening exercises with stable and unstable bases. In addition, they compared the activation of the trunk muscles with modifications (unilateral and bilateral) of the resistance exercises in order to determine if the trunk activity could be increased. Results indicated that there was an overall increase in lower abdominal muscle activation (EMG) levels during the unstable exercises. In addition, there was greater trunk activation during unilateral dumbbell press of the contralateral arm than compared to ipsilateral arm or bilateral press (Behm et al., 2005). Thus, the use of free weights in a training program does benefit the individual by requiring them to balance and stabilize the weight.

Instability training has also been shown to increase the activation levels of other muscles besides those of the trunk region. Evidence shows that introducing balance training can produce increases in strength and a reduction in muscle imbalances in recreationally active females (Kean et al., 2006). A study by Kean et al., (2006) examined the effects of fixed foot (wobble board) and functionally directed balance training (jump and landing) on muscle activation and co-contraction during jump landings. Furthermore, they examined the effects of these factors on measures of jump height, sprint time and static balance. Results indicated there was a 33% improvement in static balance and a 9% improvement in jump height in the fixed foot balance training group. This group also showed a 33% increase in EMG activity upon landing in rectus femoris activity as measured by EMG. It should be noted that the fixed foot balance training group used a wobble board to induce an instability training effect. Therefore, the authors concluded that fixed foot balance training for recreational active women may provide greater rectus femoris activity when landing from jumps and increased countermovement jump height (Kean et al., 2006).

However, while comparing the EMG activity during a stable and unstable bench press Anderson and Behm (2004) found no significant difference of the pectoralis major, anterior deltoid, triceps brachii, latissimus dorsi and rectus abdominus. Since forces were depressed when performed under unstable conditions, the authors suggested the muscles had maintained similar activation levels by providing greater stabilization rather than movement functions. In comparison, a study by Behm et al., (2002) reported that performing leg extension and plantar flexion under unstable conditions produced 44.3% and 2.9% less activation respectively than compared to stable conditions. It was suggested that under conditions of great instability (leg extension), the increased stabilization function of the muscles was not enough to maintain balance and therefore decreased the overall activation (Behm et al., 2002).

Optimal control of balance in upright posture as well as postural stability are essential requirements for daily activities, high level sports, in addition to the prevention of musculoskeletal injury, including LBP (Kollmitzer et al., 2000). Although many questions concerning instability training remain unanswered, it is evident that combining both stability/balance exercises with traditional methods is beneficial. In particular, high level athletes who compete in an environment that is relatively unstable need to focus on having a very sport specific training program that incorporates both stable and unstable conditions (Anderson & Behm, 2005).

2.7 Conclusion

Many of the aforementioned studies have shown that fatigue decreases motor performance, while placing individuals at an increased potential for musculotendinous injury. There are many factors that contribute to these deficits, including decreased proprioception within the joints and the possibility of joint laxity. When considering the trunk muscles, evidence has been presented showing that a lack of endurance is a predictor of LBP. Even during normal limb activity (i.e. walking), trunk muscles play a significant role. Therefore, in order to prevent chronic low back pain, there is a definite necessity for general physical fitness and a trunk stabilization training program not only for elite level athletes but the general population as well. Training has been shown to improve endurance characteristics and increase spinal mobility (Moffoid, 1997). At this particular point in time it is clear that trunk stability is essential, it is uncertain however which type of training will be the most beneficial.

Thus, it is important to determine the goal of the particular individual. Given the plasticity of the neuromuscular system and large range of adaptability, a variety of specific training programs can be devised (Graves & Franklin, 2001). Whether these programs should definitely contain use of instability devices has yet to be seen, however it is recommended that a program reflect the requirements of a particular sport or movement. For that reason, it is plausible that instability devices are good tools in some aspects of training however it should not be overused at the expense of traditional resistance training methods.

When considering future research, investigation should concentrate on whether performing prone or supine isometric exercises help to prevent low back pain during upright posture. In summary, it can be concluded that a conditioning program for the core stabilizing muscles serves as a valuable part of a physical training program and as a preventative method of chronic LBP.

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TRUNK MUSCLE ACTIVATION DURING DYNAMIC WEIGHT LIFTING EXERCISES AND ISOMETRIC INSTABILITY ACTIVITIES

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3 TRUNK MUSCLE ACTIVATION DURING DYNAMIC WEIGHT LIFTING EXERCISES AND ISOMETRIC INSTABILITY ACTIVITIES

3.0 Abstract

The purpose of this study was to compare the extent of activation and fatigue in various muscles of the trunk region during dynamic weight-lifting exercises and isometric instability activities. Sixteen subjects (8 males and 8 females) were tested while performing squats and deadlifts for 2 sets of 6 repetitions. The first set was performed at 45% of the 1RM and the second set at 80% of 1 RM. The subjects also performed 2 unstable Swiss ball exercises (superman and sidebridge) for a duration of 30 seconds. Electromyographic (EMG) activity was measured from the lower abdominal stabilizers (LAS), the external obliques (EO), upper lumbar (ULES) and lumbar-sacral erector spinae (LSES) muscle groups. Results indicated that the LSES EMG activity during the squat significantly exceeded deadlift LSES EMG activity by 34.5%. The LSES EMG activity of the squat also exceeded the superman and sidebridge LSES EMG activity by 65.5% and 53.1% respectively. In addition, the deadlift ULES EMG activity significantly exceeded the squat exercise by 12.9%. Tthe ULES EMG activity during the deadlift also exceeded the superman and sidebridge exercises by 69.3% and 68.6% respectively. There were no significant changes in the external obliques or the LAS. Therefore, the augmented activity of the LSES and ULES during dynamic resistance training exercises such as the squat and deadlift respectively exceeded the activation levels achieved with typical instability exercises.

Key Words: instability, dynamic exercise, muscle activation, trunk muscles

3.1 Introduction

Training the muscles surrounding the trunk region, otherwise known as the core stabilizer muscles has gained greater emphasis in recent years. Developing core strength has been emphasized as a valuable component in general and sports conditioning programs in addition to active rehabilitation programs for individuals with low back pain (LBP). These muscles play an integral role in carrying out simple day to day activities. To ensure that these activities are carried out without risk of injury or muscle soreness (i.e. low back pain), the core stabilizer muscles must be conditioned to endure the activities at hand.

LBP is one of the most common and costly medical problems in modern society. Even though it is not a life threatening condition like heart disease or cancer, LBP is the most common cause of musculoskeletal afflictions in North America for persons under the age of 45 years (Graves & Franklin, 2001). As of 1998, it was estimated that over 24 billion dollars is required each year to cover the medical costs in order to manage LBP and at least a quarter of the working population have reported an episode of LBP (Sparto & Parnianpour, 1998). The development of many low back disorders, arise as a result of a lack of strength and endurance of the trunk muscles. Numerous studies have placed individuals on trunk exercise programs and in turn resulted in a greater increase in endurance and decline in reports of LBP episodes (Moffroid et al., 1993).

Since LBP has been associated with poor physical conditioning, it is apparent that active exercise has been identified as an effective approach for both the prevention and rehabilitation of low back injuries (Graves & Franklin, 2001). However, it still remains unclear as to the most efficient method of training the trunk muscles. It is apparent that training while under unstable conditions does increase the activity of these muscles. According to Anderson and Behm (2005), the electromyographical (EMG) activity of the soleus, abdominal stabilizers, upper lumbar erector spinae (ULES) and lumbo-sacral erector spinae (LSES) all significantly increased during an unstable squat movement when compared to the stable movement. In addition, Behm et al., (2005) had subjects perform various trunk stabilizing exercises with stable and unstable (Swiss ball) conditions. Results indicated that the abdominal stabilizers, LSES and ULES exhibited significantly greater activity with the unstable condition. A study by Marshall & Murphy (2005) found that performing tasks on a Swiss ball led to greater activation of the external obliques, transverse abdominus, internal obliques, erector spinae and rectus abdominus levels when compared to stable surfaces.

A common sight in many fitness and rehabilitation centers are the various devices used in order to establish unstable conditions, for example, Swiss balls, dyna discs and wobble boards. Swiss balls have been incorporated into strength training programs on the belief that a labile surface will provide a greater challenge to the trunk muscles, increase the dynamic balance of the user and possibly help to stabilize the spine in order to prevent injuries (Lehman et al., 2005).

It is important to recognize that for an individual to experience optimal performance, one must ensure that their training regimen incorporates training specificity (Sale, 1988). Thus, it is imperative for a training program to emulate the specific muscular actions and velocities that will be encountered in the particular sport or task at hand. The practical application of training the trunk stabilizers from a supine or prone position may not transfer effectively to the predominately erect activities of daily living.

Dynamic resistance training exercises with free weights provide a modicum of instability. Perhaps a combination of relatively high intensity resistance using free weights (light to moderate instability) can provide greater activation than the very popular instability exercises commonly used today.

No other studies were found to have attempted to compare trunk EMG activity between dynamic weight lifting activities and isometric instability activities. Therefore, the objective of this study was to compare the extent of activation in various muscles of the trunk region during dynamic weight-lifting exercises and isometric instability activities. Based on previous research it was hypothesized that the isometric activities on instability devices would produce greater EMG activity of the trunk stabilizers.

3.2 Methodology

Experimental Design

The purpose of this experiment was to compare the activation and fatigue of various muscles in the trunk region with weight lifting activities and typical rehabilitation type exercises for the trunk with an unstable base. For the dynamic weight-lifting exercises, the estimated 1 Repetition Maximum (1RM) for each subject was first determined. On a separate day, subjects first performed a warm up set (approximately 45% of 1RM) for a barbell squat (see Figure 1, Appendix A), which was followed by a set at 80% of 1RM. The same format was followed for a barbell deadlift (see Figure 2, Appendix A). In addition, subjects were required to perform two trunk-specific isometric activities using a Swiss ball. The chosen activities included the superman (Behm, Young et al., 2005) and the side bridge (see Figures 3 & 4, Appendix A) (Behm, Young et al., 2005 & Carter et al., 2006). These particular exercises were chosen since previous studies indicated that they provided the highest trunk EMG activation amongst a wide variety of exercises (Behm, Young et al., 2005 & Carter et al., 2006). The subjects were required to maintain each contraction for 30 seconds. The activation was monitored by examining changes in the mean Root Mean Square (RMS) amplitude of the electromyographic (EMG) activity of selected trunk muscles.

Subjects

In total, 16 physically active participants including 8 males and 8 females (24.1 years ± 6.8, 175.6 cm ± 5.9, 74.9 kg ± 12.4) were chosen to take part in the experiment. All participants were chosen from a healthy population and had previous experience with weight training and Swiss ball exercises. All participants were from a university population and completed a Physical Activity Readiness Questionnaire (PAR-Q) form (Canadian Society for Exercise Physiology, 2003) to identify any significant health problems. Exclusion criteria included any individual with known acute or chronic back pain. Each subject was required to read and sign a consent form prior to participating in the study. The University's Human Investigations Committee approved the study.

Measurements

Surface electromyographic (EMG) electrodes were used to measure signals from the lower abdominal muscles (LA), the external obliques, upper lumbar (ULES) and lumbar-sacral erector spinae (LSES) muscle groups. In preparation for the electrodes, the placement area was shaved, abraded and cleansed with alcohol in order to improve the conductivity of the EMG signal. Due to opposing reports that indicate the use of intra-muscular electrodes are necessary to measure the deep lumbar stabilizers accurately, electrodes were placed on the area referred to as the LSES muscles (Stokes et al. 2003, Behm et al. 2005, Anderson & Behm 2005). Electrodes (Kendall * Medi-trace 100 series, Chikopee, MA) were placed 2 cm lateral to the L5-S1 spinous processes for the LSES muscles and 6 cm lateral to the L1-L2 spinous processes for the ULES muscles. The muscles of the back can be categorized into local and global stabilizing groups (Richardson et al., 1999). Deep muscles such as the multifidus are categorized as local, whereas more superficial muscles for instance the longissimus are categorized as global stabilizers. The positioning of the ULES EMG electrodes was placed more lateral in order to decrease the activity of the deep multifidus and emphasize the activity of the longissimus (Behm et al., 2005, Anderson & Behm, 2005). Therefore, positioning for the LSES muscles attempts to represent activity of the local stabilizer group. Electrodes to represent the LA were placed superior to the inguinal ligament and medial to the anterior superior iliac spine (ASIS). Based on reports from McGill et al., (1996), the surface electrodes can adequately represent the EMG activity from the deep abdominal muscles. In contrast Ng et al., (1998) indicated that if the electrodes are placed to close to the ASIS, there may be competing signals from the transverse abdominus and the internal obliques. Therefore, the EMG activity for the lower abdominal stabilizers received EMG signals from both the internal obliques and the transverse abdominus.

The EMG signals were monitored, amplified (Biopac Systems MEC 100 amplifier, Santa Barbara, CA) and directed through an analog-digital converter (Biopac MP100) and stored on a computer (Sona, St. John's, NL). Signals were collected at 2000 Hz and amplified at 1000x. AcqKnowledge software (AcqKnowledge III, Biopac System Inc., Holliston, MA) was used to filter the signal (10-500Hz). EMG activity was sampled at 2000 Hz, with a Blackman -61 dB band-pass filter between 10-500 Hz, amplified

(Biopac Systems MEC bi-polar differential 100 amplifier, Santa Barbara, CA., input impedance = 2M, common mode rejection ratio > 110 dB min (50/60), gain x 1000, noise > 5: V), and analog-to-digitally converted (12 bit) and stored on a personal computer (Sona, St. John's NL) for further analysis. The EMG signal was rectified and smoothed (10 samples) and the amplitude of the root mean square (RMS) EMG signal was calculated.

Measurements were taken for 1 sec during the eccentric (down phase) and 1 sec during the concentric (up phase) portions of the squat and deadlift during the middle portion of the exercises (i.e. repetition 3, 4 and 5) and 5-7, 10-12 and 20-22 sec of the superman and side bridge exercises. These repetitions and times were chosen in order to reduce any instability at the beginning of the exercise and fatigue at the end. Although one normally should not directly compare dynamic contractions to isometric contractions, the trunk muscles would be contracted isometrically during the squat and the deadlift exercises.

Exercise Protocol

Following an adequate warm-up (10 repetitions that did not elicit failure), a resistance was estimated through trial and error that would force the participant to fail to complete more than 3-5 repetitions. Participants 1 repetition maximums (1RM) were calculated from NSCA tables based on the resistance and number of repetitions completed (National Strength and Conditioning Association, 2000). From the estimation, 45% and 80% of 1RM's were calculated for both exercises (see Appendix B). A 1RM was not used so as to decrease the possibility of injury and to allow multiple repetitions for analysis.

On a separate day, each subject first underwent a normalization procedure. This was achieved by performing a maximum voluntary contraction (MVC) for the various muscle groups that were measured for EMG activity. This included a prone MVC back extension following the Bierning-Sorensen testing procedure (Moffroid et al, 1993) to measure the ULES and LSES muscles. In addition a MVC abdominal crunch was used as the reference for the LA. Both MVC's were held for 5 seconds.

Each subject then proceeded to perform the following activities in random order with 10 minute rest periods between exercises to ensure complete recovery: (a) one set of 6 repetitions (at 45%) for the Olympic bar free squat followed by one set of 6 repetitions (at 80%). The squat movement descended until the thighs were parallel to the floor. Each repetition of the squat and deadlift was performed with a 2-1-2 tempo (2s eccentric, 1s pause and 2s concentric) as determined by a metronome. A 2-1-2 tempo of 6 repetitions provided 30 seconds of contractile activity equivalent to the unstable superman and sidebridge exercises (b) one set of 6 repetitions (at 45% of 1 RM) for the Olympic bar deadlift followed by on set of 6 repetitions (at 80% of 1 RM). (c) Swiss ball superman (Behm, Young et al., 2005) maintained for 30 seconds and (d) Swiss ball side bridge (Behm, Young et al., 2005) also maintained for 30 seconds.

Statistics

Analysis was conducted with GB Stat: Dynamic Microsystems, Silver Springs Maryland. Analysis was completed using a 2 way ANOVA with repeated measures (4 x 3). Levels for analysis included 4 exercises and 3 test times (beginning, middle and end of the exercises). A Tukey/Kramer post hoc test was used to determine significant differences.

3.3 Results

Since the repeated measures ANOVA indicated there was no main effect for gender, all data reported in the following sections will be reported with the data collapsed over gender.

LSES

The squat exercise exhibited significantly ($p = 0.0002$) greater LSES EMG activity than all other exercises (See Figure 1). Squat LSES EMG activity significantly exceeded the deadlift exercise by 34.5%. The squat EMG activity also exceeded the superman and sidebridge exercises by 65.5% and 53.1% respectively. There were no significant LSES EMG differences between the deadlift, superman and sidebridge exercises.

ULES

The deadlift exercise exhibited significantly ($p = 0.001$) greater ULES EMG activity than all other exercises (See Figure 2). The deadlift ULES EMG activity significantly exceeded the squat exercise by 12.9%. In addition, the ULES EMG activity of the deadlift also exceeded the superman and sidebridge exercises by 69.3% and 68.6% respectively. There were no significant ULES EMG differences between the squat, superman and sidebridge exercises.

External Obliques and LA

From the four exercises performed, no single exercise showed significant differences in the external oblique and LA EMG activity (See Figure 3 & 4).

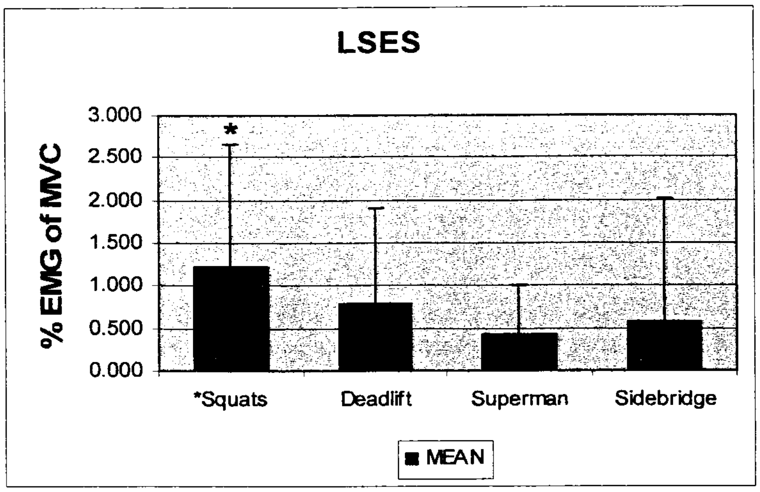

FIGURE 1: The graph depicts the mean electromyographic (EMG) activity of the LSES muscles during the performance of weight-lifting exercises and isometric instability exercises. With data collapsed over sets and repetitions, bars depict the mean data of the individual exercises. Asterisks indicate that the exercise was significantly differently from all other exercises. Vertical bars represent *SD*.

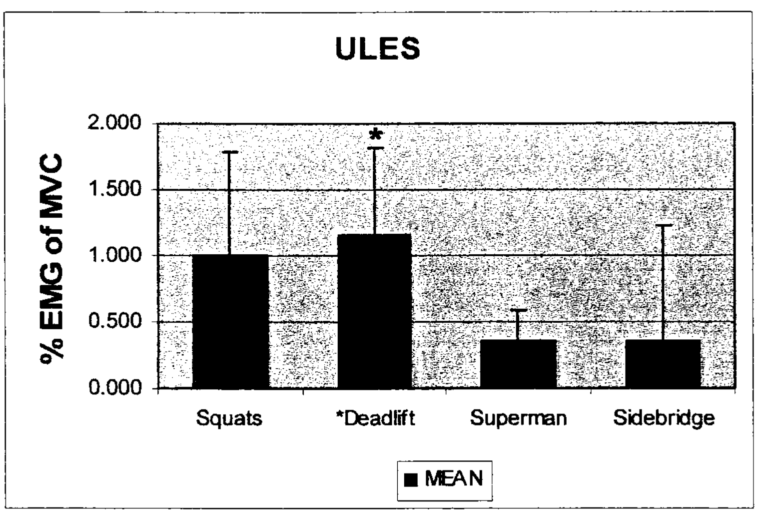

FIGURE 2: The graph depicts the mean electromyographic (EMG) activity of the ULES muscles during the performance of weight-lifting exercises and isometric instability exercises. Bars depict the mean combined data of the individual exercises. Asterisks indicate that the exercise was significantly differently from all other exercises. Vertical bars represent *SD*.

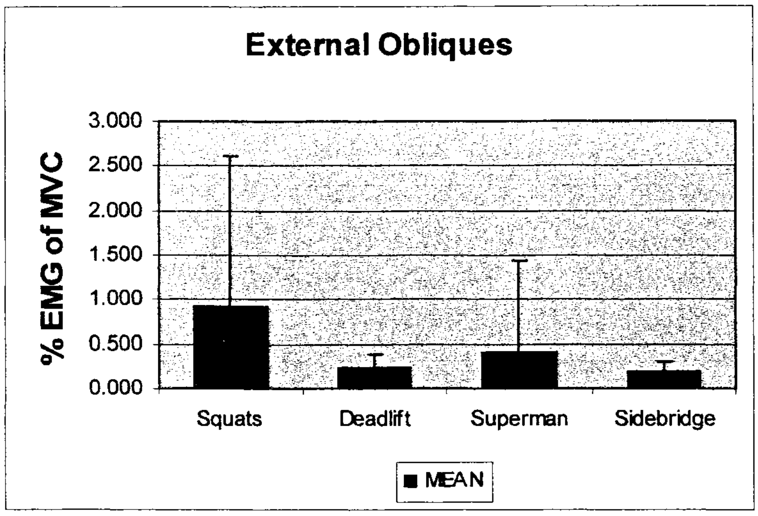

FIGURE 3: The graph depicts the mean electromyographic (EMG) activity of the external oblique muscles during the performance of weight-lifting exercises and isometric instability exercises. Bars depict the mean combined data of the individual exercises. Vertical bars represent *SD*.

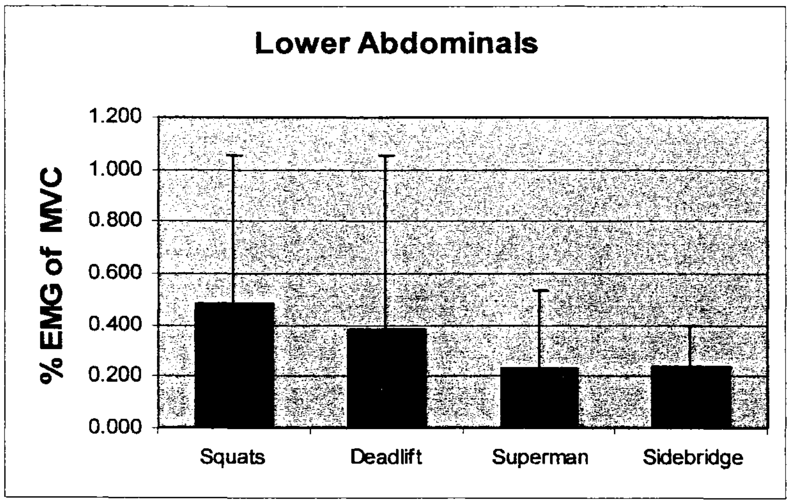

FIGURE 4: The graph depicts the mean electromyographic (EMG) activity of the lower abdominal muscles during the performance of weight-lifting exercises and isometric instability exercises. Bars depict the mean combined data of the individual exercises. Vertical bars represent *SD*.

3.4 Discussion

The most important findings of this study indicated that there was significantly greater EMG activity in the LSES and ULES muscle groups during the squat and deadlift exercises respectively compared to unstable superman and sidebridge exercises. Conversely, neither forms of exercise were able to produce significantly greater changes in the external obliques nor the LA. Previous instability training studies have shown greater, similar and lesser muscle activation when comparing exercises performed with unstable bases compared to stable bases.

Instability-Induced Increases in Muscular Activation

Training of the trunk muscles has been identified as an important consideration in order to provide an individual with a strong foundation and to prevent LBP. Somewhat contrary to the present findings, a number of studies proposed that the use of instability devices provide higher activation of trunk musculature. Marshall and Murphy (2005) compared the activation patterns of muscles associated with the global and local stability systems during different core stability tasks on and off a Swiss ball. Their results indicated that the performance of tasks on the Swiss ball did lead to greater activation levels when compared to a stable surface. Additionally, a study by Cosio-Lima et al. (2004) demonstrated that after five weeks of training with a Swiss ball there were greater gains in torso balance and trunk EMG activity when compared to traditional floor exercises. Behm et al. (2003) had subjects perform various trunk stabilizing exercises with stable and unstable (Swiss ball) conditions. Results indicated that the abdominal stabilizers, LSES and ULES exhibited significantly greater activity with the unstable condition.

Instability training has also been shown to increase the activation levels of other muscles besides those of the trunk region. A study by Kean et al. (2006) examined the effects of fixed foot (wobble board) and functionally directed balance training (jumps and landings) on muscle activation and co-contraction during jump landings. There was a 33% increase in rectus femoris EMG activity upon landing from a jump in the fixed foot balance training group.

In many exercise regimens, instability training is incorporated into the program as a variation or modification from traditional resistance training exercises. With this in mind, it is important to establish which method will produce the greatest amount of activation within the muscles. Anderson and Behm (2005) investigated the differences in EMG activity in six muscle groups including, the abdominal stabilizers (AS), the ULES group and the LSES group, while performing squats of different stability and resistance. The squat movement was performed on a Smith machine, a free squat and while standing on two balancing discs. Results indicated that the AS, ULES, LSES and soleus were all activated to a greater extent while performing the movement under unstable conditions. The authors attributed this finding to the stabilizing roles of these muscles.

However, most daily activities also involve the use of the upper and lower limbs. Therefore, how does the addition of limb movements change the activation of the trunk muscles? Behm et al. (2005) compared EMG activity in the trunk muscles during popular resistance exercises and trunk strengthening exercises with stable and unstable bases. In addition, they compared the activation of the trunk muscles with modifications (unilateral and bilateral) of the resistance exercises in order to determine if the activity could be increased. Results indicated that there was an overall increase in lower abdominal muscle activation (EMG) levels during the unstable exercises. In addition, there was greater trunk activation during unilateral dumbbell press of the contralateral arm than compared to ipsilateral arm or bilateral press (Behm et al., 2003).

Maintenance of Muscle Activation with Instability

Not all instability studies have provided evidence of greater muscle activity. A study conducted by Anderson and Behm (2004) had subjects perform chest press exercises under stable and unstable conditions. EMG activity was measured from various muscles including the pectoralis major, anterior deltoid, triceps brachii, latissimus dorsi and the rectus abdominus. Results showed that there were no significant differences in EMG activity between the stable and unstable chest presses. In addition, the unstable base elicited a 60% decrease in maximal isometric chest press forces. The researchers suggested that even though external forces are impaired by instability, the activation of muscles is still maintained due to the greater reliance of the limb muscles on joint stabilization (Anderson & Behm, 2004).

Instability-Induced Decreases in Muscle Activation

On the contrary, a study by Behm et al. (2002) showed that there was a decrease in quadriceps and plantar flexors muscle activity under unstable conditions. The study had subjects perform leg extensor and plantar flexion under stable and unstable conditions. Activation averaged 44.3% and 2.9% less respectively in comparison to the stable conditions. In addition, leg extensor force was 70.5% less under unstable conditions while plantar flexor force decreased by 20.2%. It was suggested that under conditions of great instability, the increased stabilization function of the muscles was not enough to maintain balance and therefore decreased the overall activation (Behm et al., 2002).

Trunk Muscle Activation with Dynamic Exercise

Typically, unstable isometric-type exercises are performed while in a supine or prone position. However, these activities do not mimic many of the movements of daily life (i.e. lifting) whereas other traditional dynamic resistance training exercises such as squats and deadlifts do more closely resemble these actions. In addition, the use of free weights does incorporate a degree of instability into the squat and deadlift exercises (Stone et al., 1998). However proponents of instability devices suggest that instability training device exercises are necessary additions to the traditional resistance training program to ensure training adaptations for the trunk musculature (Goldenberg and Twist 2002). Hence, does the stress associated with stabilizing the trunk with dynamic exercises such as the squat and deadlift result in greater, similar or lesser activation than isometric-type exercises performed on a Swiss ball?

The results of the present study indicate that the use of moderately high (80% of 1RM) intensity resistance while performing dynamic exercises such as the squat and deadlift can provide greater dorsal trunk activation than isometric style instability activities. It is plausible that the increased EMG activity of the LSES during the squat may be due to the participant attempting to counterbalance themselves during the movement. The LSES muscle group has been shown to be very active as a stabilizer during the squat movement (Anderson & Behm, 2005). As the body acts as an inverted pendulum there is a tendency for the center of gravity to sway (Roberson, Kamen & Whittlesey, 2004). Balance is maintained by controlling the extent of sway. Placing a bar above the center of gravity as with squat exercise increases the motive movements producing greater body sway. This study demonstrates the substantial activity of the LSES needed to counterbalance the destabilizing torques of the swaying body and suspended resistance. Although the local stability muscles of the spine have a role in maintaining segmental stability, they often need the aid of the large global muscles during certain movements such as the squat exercise. The global muscles help to provide the bulk of stiffness to the spine, in addition to generating force to control range of motion (Gibbons & Comerford, 2001). Thus, while performing a movement such as a squat or deadlift, the local stabilizers help to maintain mechanical ability and posture of the lumbar spine while the global muscles function to balance the external load that is being applied to the trunk region and generate force in order to maintain the range of motion for the exercise (Gibbons & Comerford, 2001).

In addition to the counterbalancing action of the torso during the squat movement, it involves handling compressive forces. These forces occur when the spine is loaded (i.e. during a squat) and cause the vertebrae to be pushed directly downward. High compressive loads can exacerbate the possibility of serious injuries such as slipped discs. It is the responsibility of the local stabilizers, such as the deep lumbar multifidus to maintain inter-segmental stability. The local stabilizers have their origin or insertion at the vertebrae, which provides stiffness to maintain mechanical stability of the lumbar spine, in addition to controlling the curvature of the lumbar spine (Gibbons & Comerford, 2001).

With the deadlift exercise, it is plausible that the greater activation of the ULES was evoked due to the recruitment of the upper back muscles in order to both dynamically lift the weight off the floor as well as stabilize the thoracic and lumbar verebrae. In the current study, subjects used a ¼ squat position in order to lift the weight off the floor. In the ¼ squat position, the hips are placed in a higher position during the initial pull of the weight. Compared to a ½ squat position where the hips are lower thus putting the initial load of the pull onto the quadriceps muscles with less stress on the lower lumbar region of the spine (Groves, 2000). Similar to many activities of daily living, the deadlift necessitates the integration of vertebral muscles for mobilization and stabilization.

While Figure 4 illustrates graphically a slightly greater LA activation with squats and deadlifts, the variability associated with this activation strategy was very high between individuals in the study. The lack of significant differences in LA activation between the squat and deadlift compared to instability exercises indicates that either form of exercises are similarly suitable for ventral trunk activation.

In conclusion, while there are a number of studies that have demonstrated greater trunk muscle activation when comparing similar unstable to stable exercises (Marshall and Murphy, 2005 & Behm et al., 2003) the present study illustrates the high trunk muscle activation needed to stabilize external resistance during traditional weight training exercises such as the squat and deadlift. The common notion regarding the necessity to add instability device exercises to a traditional resistance training program to accentuate trunk activation has been shown to be unnecessary if exercises such as the squat and deadlift are included in the program. Individuals who do not incorporate such compound muscle actions in their training or those who wish to provide activation over a greater range of motion (Siff 1991) may wish to add instability device exercises.

In consideration for future research, it may prove applicable to carry out a similar study but to apply similar loads between all exercises. For example, use additional weight with the superman and sidebridge or conduct the squat and deadlift with no real weight load (i.e. broomstick). Thus the EMG activity from the two different types of exercises would be produced from similar load conditions.

3.5 Conclusion

The current study indicates that dynamic exercises such as the squat and deadlift incorporating moderate to high intensity resistance paired with moderate instability can increase the muscle activity of the trunk region to a greater degree than typical isometric instability exercises. Thus, it may be unnecessary to add isometric-type instability exercises to a training program to promote core stability if full body dynamic erect exercises are implemented in the program.

3.6 References

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3.7 Appendices

Appendix A

Figure 1 - Squat

Figure 2 - Deadlift

Figure 3 - Superman

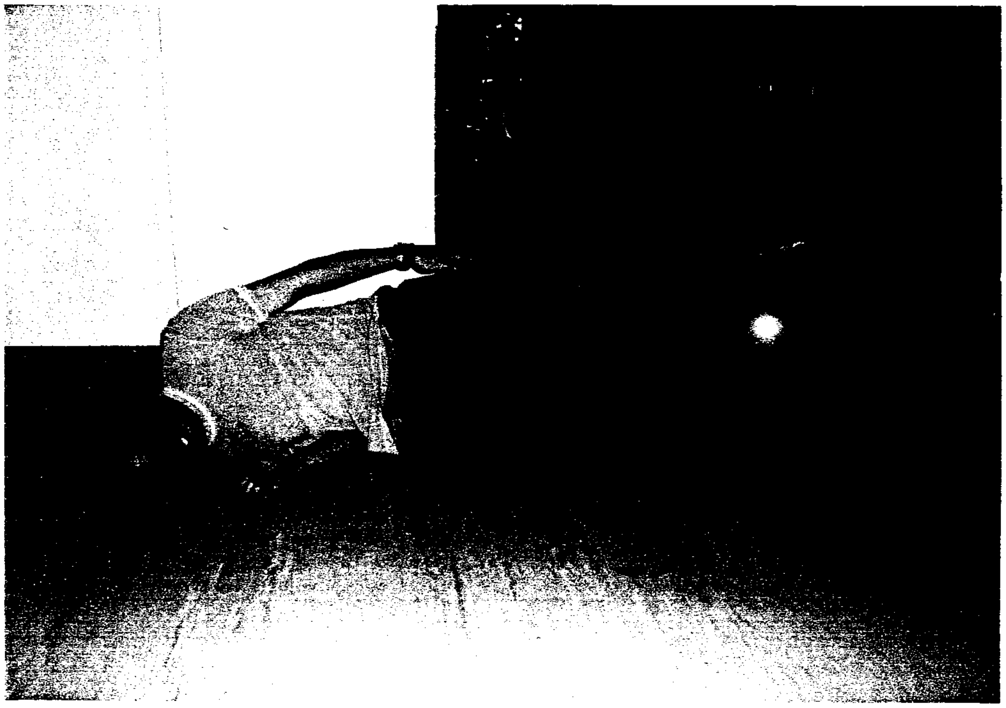

Figure 4 - Sidebridge

Appendix B

Subject's Data Table

Subject	Age (Yrs)	Height (Cm)	Weight (Kg)	Squat 45% (lbs)	Squat 80% (lbs)	Deadlift 45% (lbs)	Deadlift 80% (lbs)
#1	31	175.26	68.04	80	142	54	96
#2	23	162.36	72.58	80	142	54	96
#3	20	167.64	66.23	74	132	78	138
#4	19	172.72	63.96	78	140	35	63
#5	20	172.72	57.15	50	90	60	107
#6	19	175.26	64.86	68	121	65	115
#7	20	170.72	68.49	68	121	65	115
#8	20	170.18	61.24	68	121	70	124
#9	24	177.80	73.48	145	259	94	167
#10	24	180.34	82.10	126	224	116	206
#11	21	186.97	92.53	114	203	94	167
#12	23	175.26	71.67	108	192	91	162
#13	30	177.80	95.26	163	290	163	290
#14	20	175.26	78.47	101	180	101	180
#15	26	177.80	84.82	135	240	124	220
#16	45	182.88	97.52	145	257	132	235