Utah State University
DigitalCommons@USU

All Graduate Plan B and other Reports | Graduate Studies

5-2012

Functional Rehabilitation of Low Back Pain With Core Stabilization Exercises: Suggestions for Exercises and Progressions in Athletes

Joshua Johnson
Utah State University

Follow this and additional works at: https://digitalcommons.usu.edu/gradreports

Part of the Physical Therapy Commons

Recommended Citation

Johnson, Joshua, "Functional Rehabilitation of Low Back Pain With Core Stabilization Exercises: Suggestions for Exercises and Progressions in Athletes" (2012). *All Graduate Plan B and other Reports*. 159.
https://digitalcommons.usu.edu/gradreports/159

This Report is brought to you for free and open access by the Graduate Studies at DigitalCommons@USU. It has been accepted for inclusion in All Graduate Plan B and other Reports by an authorized administrator of DigitalCommons@USU. For more information, please contact digitalcommons@usu.edu.

FUNCTIONAL REHABILITATION OF LOW BACK PAIN WITH CORE STABILIZATION EXERCISES: SUGGESTIONS FOR EXERCISES AND PROGRESSIONS IN ATHETES

by

Joshua Johnson

A Plan B manuscript proposal submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

HEALTH AND HUMAN MOVEMENT

Approved:

Major Professor Dennis Dolny	**Committee Member** Cameron Peterson
Committee Member Eadric Bressel	**Committee Member** Lori Olsen

Utah State University
Logan, UT

Spring 2012

Abstract

Introduction: Low back pain is very common in the adult population and accounts for more time lost from work than other diagnoses. It also affects athlete's at all different levels of competition and results in missed practice and game time. Diagnosing and treating a specific pathology is often difficult because clinical evaluation and radiologic studies are often unable to find a root cause. A popular treatment approach with a high volume of anecdotal evidence is the use of core stabilization exercise in the treatment of low back pain.

Purpose: To evaluate exercise as a treatment for low back pain with a specific emphasis on core stabilization and provide an outline of exercises and progression to help guide clinicians in treating the athlete with low back pain.

Methods: A search of electronic databases was performed including; PubMed, SPORTDiscus, Google Scholar, and Cochrane Databased. Key Words used: Lumbar stabilization, core stabilization, low back pain, athletes, exercise, and core strengthening and any combination of these words.

Exercises and Progressions: Based on the search of electronic databases their does appear to be some efficacy established in the general population of core stabilization exercises. However, at this time does not appear to be superior to other exercise interventions. There are no specific studies involving athletes so evidence based treatment of athletes using core stabilization is limited. The literature seems to establish a need for total core muscle recruitment to stabilize the spine and does not identify one specific muscle as being critical for spinal stability. The program designed is based on firing of the entire core muscular to stabilize the spine with an emphasis to functional movements that imitate sport-like situations. The exercises chosen were based on how effectively they challenge the muscle groups without causing loads that may be detrimental to recovery and pain free movement.

Conclusion: Due to the demands placed on the athlete's lumbar vertebrae, spinal instability may be a significant source of pain in athlete not diagnosed with other pathologies. While at this time there is insufficient evidence to support or refute the use of stabilization exercise in the treatment of low back pain in athlete's, this paper hopefully gives insight into some exercises that may be used to reestablish core muscle strength and endurance.

Introduction

Low back pain is presumed to occur in 85-90% of the adult population at least once throughout an individual's lifespan (Bono, 2004). It accounts for more time lost from work and is one of the most costly health problems among work related incidences. It also occurs in athletes at all different levels of competition and can result in significant time-lost from participation in their respective sporting activity. In an article published by Bono (2004) rates of low back pain in athletes range from 1% to greater than 30 % depending on factors such as sport, gender, training intensity, training frequency, and technique. The success of rehabilitation of low back pain depends more on symptoms and function than determining a definitive anatomical cause (Heck & Sparano, 2000). While it is a source of significant lost practice and playing time it can be incredibly difficult and frustrating for the clinician to treat when the goal is to decrease pain, restore function, and return to activity. These goals are particularly problematic due to the fact that clinical evaluation and imaging studies are often unable to identify a specific pain generator responsible for the disability and dysfunction experienced by the athlete (Bono, 2004). This lack of a specific pain generator can make designing rehabilitation programs difficult for clinicians because the tissue level (ie, muscle, tendon, ligament, facet, vertebrae) is not specified so targeting the root of the cause is nearly impossible.

Though low back pain can be difficult to treat there are many clinicians who report positive patient outcomes with various treatment and rehabilitation protocols. One of the most recent concepts in the management of low back pain in athletes is the utilization of core stability exercises to improve spinal stability and function while eliminating pain. It has been shown that low back pain can cause muscle atrophy and inhibit muscle firing which leads to altered spinal mechanics which may exacerbate the pain-spasm-pain cycle leading to increased dysfunction, decreased muscle endurance and delayed return to play (Krabak & Kennedy, 2008, McGill 1998). Strengthening and neuromuscular reeducation of the core musculature is thought to play a significant role in restoring stability to the spinal column and in turn minimizing pain associated instability (Kibler, Press, & Sciascia, 2006). The main emphasis of core strengthening is focused on muscular stabilization of abdominal, paraspinal and gluteal musculature (Nadler, Malanga, Bartoli, Feinberg, Prybicien, & DePrince, 2002.) The specific role of individual muscles in relation to spinal stability is still widely unknown, but optimal firing and synchronization of all core muscles is proposed to be necessary for the greatest amount of spinal stability.

Purpose

The purpose of this project is to perform a comprehensive review of literature regarding rehabilitation programs for the treatment of low back pain, with a specific focus on core stabilization exercises. With the information gathered a rehabilitation program will be proposed with emphasis on specific exercises and progressions that can be used to help guide rehabilitative clinicians in their treatment of the athlete with low back pain. It is not the intent of this project to create an all-encompassing approach to treating every athlete, but to give some insight into the best strategies and progressions to receive the best outcomes possible.

Review of Literature

What is the Core?

The core as described by Akuthota et al (2008) is a muscular box with the abdominals in the front, paraspinals and gluteals in the rear, the diaphragm at the top, and the pelvic floor and hip girdle musculature at the bottom. Within the "box" multiple muscles help to stabilize the spine and pelvis as well as transmit forces through the kinetic chain. Without the stability provided by the core musculature the spine would become unstable with forces less the 90 N when loaded anteriorly, which is considerably less than the weight of the torso (Akuthota, Ferreiro, Moore & Fredericson, 2008). The muscles and joints of the hip, pelvis, and spine are located centrally to maintain stability necessary for the limbs to function properly, thus providing the proximal stability required for distal mobility of the kinetic chain (Kibler. Press, & Sciascia, 2006)

What is the definition of core stability?

The article published by Panjabi (1992a) may give the first theoretical perspective to what is meant when clinicians use the term core stability. In his article he describes the core through three subsystems, the passive subsystem, active subsystem, and the neural control subsystem. It was proposed that these subsystems were highly integrated and optimization of all three were necessary for normal biomechanics of the spine. If any one of these subsystems became impaired it could lead to instability of the spinal column predisposing an individual to injury, dysfunction, and pain. This injury, pain, and dysfunction could develop over time with the gradual degeneration of joints and soft tissue from repetitive microtrauma, caused by poor control of spinal structures (Barr, Griggs, & Cadby, 2005)

As described by Panjabi (1992 a/b) the components of the passive subsystem mainly involve the spinal ligaments that provide stability in the end ranges of motion. The active subsystem involves the spinal muscles and tendons that produce forces required to maintain stability of the spine. Finally the neural control subsystem receives information from the active subsystem and determines the forces required to maintain spinal stability and adjusts the force production of the musculature accordingly.

In an article by Kibler, Press, and Sciascia (2006) a more functional definition of core stabilization was described as the ability to control the position and motion of the trunk over the pelvis and leg to allow for optimum production, transfer, and control of force and motion to the terminal segment in integrated kinetic chain activities. The second definition may be more applicable for clinicians when trying to communicate the goals of a specific rehabilitation for a patient, but understanding of the principles proposed by Panjabi (1992a) is important when designing a program.

Anatomy of the Core

The core is comprised of a complex system of muscle, ligament, and fascial layers that assist in providing spinal stability necessary for activities of daily living. The scope of this paper will mainly focus on the musculature involved in providing spinal stability. This is the tissue level that is targeted through the use of core stability exercises. This is not to say that the other tissues are not important, but that they are considered to be passive in that they do not respond to exercise in the same way an active tissue such as muscle does. The muscles that are relevant to spinal stability as described by Bergmark (1989) can be grouped into local stabilizers and global stabilizers. The local stabilizers can be thought of as small position sensing muscles that do not produce high amounts of force, but are responsible for maintaining intersegmental stability between 2-3 vertebrae. The global stabilizers can be thought of as the larger force producing muscles crossing multiple vertebrae and developing tension across the joints to illicit gross spinal motions such as flexion and extension.

The core musculature can be described as a “box” with the abdominals in the front; transverse abdominis , rectus abdominis, internal obliques, and external obliques. The muscle that has received the most attention recently is the transverse abdominis because of its ability to provide stiffness to the segments of the spine during functional posture and movements (Richardson et al, 2002).It has been demonstrated that transversus abdominis is selectively activated prior to limb movement at different speeds, but activation is inhibited in patients with a history of low back pain (Hodges & Richardson, 1999) It is thought to play a major role in spinal stability as it increases intra-abdominal pressure and places tension on thoracolumbar fascia when contracted (Kibler, Press, & Sciascia, 2006). There is little evidence however that clearly identifies it's function in providing lumbar stability as research has been inconclusive to date regarding transverse abdominis' capacity to provide segmental stabilization .The remaining abdominal muscles are considered global in that they produce mass spinal movements such as flexion and rotation of the torso, but they also contract to maintain the intra-abdominal pressure needed for a stable lumbar spine.

The posterior or back of the “box” is comprised of global stabilizers such as the erector spinae and quadratus lumborum , as well as local stabilizers including the mutifidi and deep transversospinalis. The multifidi has received attention as a primary stabilizer, due to its attachment directly to the spine and its ability to control intersegmental spinal motions. Its specific role is still unproven by research at this time and in article published by Van Dieen, Cholewicki, and Radebold (2003) it has been reported that no single core muscle is greatest in achieving spinal stability. They propose that coordinated sequencing and firing of all the core muscles is necessary for proper mechanics and stability of the lumbar spine. The quadratus lumborum, considered to be a global stabilizing muscle through the paradigm presented by Panajbi (1992a/b) and Bergmark (1989) is thought to play a significant role in stabilization due to its orientation. Though it is considered to provide stability in frontal plane movements such as flexion and extension its insertion on the transverse processes of the spine to the iliac crests provide stabilization against shearing forces on the spine outside of the frontal plane movements (Kibler, Press, & Sciascia, 2006). It is clear that the core muscles can provide multidirectional lumbar stability based on their anatomical orientation within the musculoskeletal system.

The diaphragm and the pelvic floor, respectively make up the last two sides of the “box” that has been used to describe the core. Their primary contribution to lumbar stability is through cocontraction with the abdominals to increase intra- abdominal pressure, thus creating a rigid cylinder or an anatomical back brace to decrease the load on the spine (Kibler, Press, & Sciascia, 2006).

Though the musculature associated with the spine contributes greatly to its functional stability, it would be inept without passive stabilizing structures like ligaments. The anterior and posterior longitudinal ligaments run continuously from the cervical vertebrae to the sacrum. The anterior longitudinal ligament is a strong broad ligament that attaches to the front of the vertebrae and disc and is resistant to hyperextension of the spinal column. The posterior longitudinal ligament is thin and relatively weak compared to its anterior counterpart and only attaches to the posterior element of intervertebral discs, its primary purpose is resistance to hyperflexion. The ligamentum flavum connecting the lamina of individual vertebrae however is very strong as it contains elastic connective tissue that stretches and recoils during flexion activities (Marieb, 2004).

Table 1. Local and Global Stabilizers

Local Stabilizers	**Global Stabilizers**
Multifidi	Rectus abdominis
Transverse abdominis	Internal obliques
Deep Transversospinalis	External obliques
Pelvic floor musculature	Latissimus Dorsi
Diaphragmatic musculature	Quadratus Lumborum
	Erector Spinae

Trunk muscle activation and low back pain/injury

In the three sub-system theory of spinal stability presented by Panjabi (1992a) optimal function of each system is required for ideal level of stability for functional movement. Any level of dysfunction within any of three systems is proposed to lead to instability, which in turn may lead to pain and biomechanical changes to normal spinal motion. The passive subsystem appears to be the culprit responsible for failure within the multidimensional support structure of the spine, but there is belief that changes in activation and firing of the muscular component may be able to counteract the stability lost through dysfunction of the ligamentous supports. However, altered recruiting patterns can significantly affect the magnitude and direction of loading on the intervertebral joints, as well as the spine (Reeves, Cholewicki, & Silfies, 2006).

It has been shown in multiple studies that muscle recruitment patterns are different in individuals with low back pain when compared to control subjects not experiencing low back pain (Van Dieen, Cholewicki, & Radebold, 2003; Ershad, Kahrizi, Abadi, & Zadeh, 2009; Reeves et al, 2006). In a study by Reeves et al. (2006) of an athletic population they addressed 3 questions concerning low back pain and injury with respect to muscle activation: (1) Is muscle activation imbalance associated with injury? (2) Does muscle activation imbalance cause injury? (3) Is muscle activation imbalance an impairment or adaptation? The results relating to the first research question did not indicate any muscle activation imbalance between sides being associated with low back injury. The results however, did support the idea that activation between spinal levels is associated with low back injury. The data relating to the second question suggest that activation imbalance between levels did not cause low back injury, but that progression of imbalance may occur over time after the initial insult. Finally the data does not lend credence to the idea of alternate muscle activation patterns contributing to impairment because imbalance was not associated with extended episodes of low back pain or recurrence of low back injury. The findings of the study overall suggest that changes in muscle activation patterns do not lead to low back pain or low back injury and that the neuromuscular adaptations are in fact beneficial in restoring the stability of the spine.

In another study relating to neuromuscular imbalances Renkawitz, Boluki, and Grifka (2006) used tennis players to assess the relationship between low back pain, extension strength, and muscle imbalance. The results indicate a difference in activation of the right and left erector spinae in tennis players with and without low back pain. This difference, however, could be related to the fact that tennis players inherently play with either the left or the right hand, which could in fact lead to muscle imbalances purely due to the amount of work that one side gets over the other. This begs the questions are neuromuscular activation changes a cause of low back pain or are they an adaptation to structural deficiencies that cause low back pain? At this time it is still unclear whether muscle activation is the culprit or bystander trying to alleviate the condition.

Van Dieen et al. (2003) focused on specific muscle recruitment patterns with patients experiencing low back pain as opposed to level of muscle activation. Based on the three system model presented by Panjabi (1992a) the authors formulated multiple hypotheses regarding muscle activation in the patients. The authors believed that patients would show higher levels of co-contraction then controls, thus leading them to hypothesize that ratios of antagonist to agonist activation are higher in patients. Second based on the paradigm presented by Bergmark (1989) and Panjabi (1992a) in which intersegmental muscles appreciate spinal stability more readily than muscles with broad multisegmental attachment to the thorax and pelvis, they hypothesize that lumbar erector spinae will show higher activation levels compared to thoracic erector spinae. In both cases the data suggest that the results of the study support the author's hypotheses regarding antagonist versus agonist activation and lumbar erector spinae versus thoracic eretcor spinae activation. According to the authors the differences found between groups appear to reflect a trunk muscle recruitment strategy that serves to enhance spinal stability. They also state that even though the proposed changes to muscle recruitment have a positive impact, negative consequences may occur with sustained alteration of muscle recruitment patterns. The increased co-contraction of muscle may themselves be a source of pain thus perpetuating the pain-spasm-pain cycle. It is also possible that altered recruitment remain present after the biological source of pain has resolved leading to continued spinal dysfunction.

Pain Models and Low Back Pain

Pain is often a difficult phenomenon for people to explain yet everyone knows what is meant when someone states they are experiencing pain. Though pain is difficult to describe as everyone experiences pain differently, it is often the goal in therapeutic rehabilitation to identify the source of pain and treat the source appropriately. In the case of patients with low back, the source of their pain can be perplexing for rehabilitative clinician's when radiographic studies are often inconclusive. In relation to pain two paradigms have developed to explain the possible physiologic events that occur when pain is experienced.

The first paradigm states that a pain-spasm-pain cycle is likely responsible for dysfunction and disability related to musculoskeletal conditions. This theory proposes that when an injury occurs there is a reflexive response from the surrounding musculature to become hypertonic to essentially brace the injured structure preventing further injury. However, if the contracture of the musculature is maintained for an extended period of time a deleterious effect occurs in which the muscles themselves become a source of pain, therefore propagating the pain-spasm-pain effect. This pain model appears to have a significant relationship to Panjabi's (1992a) theory of spinal stability, thus when the passive structures sustain damage, the active structures adjust through altered neuromuscular firing patterns.

The second paradigm proposed by Lund, Donga, Widmer, and Stohler (1991) came about when their comprehensive review of literature demonstrated inconsistent evidence to support the idea of hyperactivity in muscles with different musculoskeletal conditions. In respect to low back pain they identified only one study that demonstrated higher muscle activity in the paraspinals of patients compared to control subjects. They did, however, find a relationship that suggests decreased force output of flexor and extensor muscles of the spine when acting as agonists during movement. Conversely studies have shown increased hyperactivity of the erector spinae when acting as an antagonist to movement patterns.

The findings of their study led them to conclude that the pain-spasm-pain cycle does not adequately explain pain associated to musculoskeletal injury. The model they propose, called the pain adaptation model suggests decreased motor neuron activity occurs in muscle acting as an agonist and increased motor neuron activity in response to antagonist muscle action. They explain the changes in agonist-antagonist activity through nociceptive interneurons acting in a reciprocal fashion on motor neuron firing. These interneurons supply the alpha motor neuron through excitatory and inhibitory pathways creating a polysynaptic connection to the central nervous system. To account for decreased force output during agonist movement in the presence of pain, excitation of the inhibitory group occurs and a converse inhibition of the excitatory group supplying the agonist motor neuron. The increase of antagonist muscle activity can be explained through the same pathway, with an increase in facilitation of the excitatory pathway and a decrease in transmission through the inhibitory interneurons. These changes in agonist-antagonist activation according to the authors are a protective mechanism to reduce further injury to the involved tissue. This can basically be explained as the muscle firing shutting down during agonist movement that will increase pain and likely cause more tissue damage.

There is still much debate over the model that most accurately reflects how pain effects changes to the musculoskeletal system surrounding an injury. That being said it is important to recognize that a complete understanding of the why underlying low back pain has not been achieved to this point and will continue to grow. Understanding of these models and the pros and cons of each may be more beneficial to rehabilitative clinicians than narrowing their view to a single model.

Evaluation of Core Stability

Evaluating core stability can be difficult for a clinician and there is no universally accepted testing to objectively quantify an individual's core strength and endurance. Clinicians with a sound understanding of the biomechanics of spinal motion and the muscles acting about the spine can be creative in their evaluations. Kibler et al. (2006) suggest that any test that is used to evaluate core stability should be performed, if possible, in a functional position. One option for assessing core strength is presented in the same article by Kibler et al.(2006) using a progressive battery of three tests; single leg balance ability, single leg squat, and what they call a three plane core test. It begins with evaluation of single leg balance for postural deviations such as Trendelenburg's sign. This indicates gluteus medius weakness on the contralateral side of the standing leg or limb deviations such as internal and external rotation of the limb on the standing side. These findings may indicate a deficit in proximal core stability and if assessed as being very poor would discontinue further testing. If single leg balance is performed well enough the next maneuver would be performance of bilateral single leg squat maneuver recognizing once again any postural deviations such as a large valgus moment at the knee indicating weak abductors of the lower extremity.

The three plane core test is a battery of tests that progress from a closed chain double leg stance, to partial weight bearing, and finally to single leg stance in all planes of motion. The initial sagittal plane evaluation is done with the patient about 8cm from a wall facing away from it. The patient is instructed to lean backwards, keeping both feet on the ground, to touch their head just barely to the wall. Leaning back causes eccentric loading of the abdominals, hip flexors, and quadriceps group with concentric activation of the spine and hip extensors. Next frontal plane testing is done at the same distance from the wall with one side or the other toward the wall, the patient is then asked to touch their inside shoulder just barely to the wall. This test assesses eccentric capabilities of quadratus lumborum, hip abductors, and some spinal muscles that work in the frontal plane. Finally transverse plane motion is assessed similarly to sagittal plane motion with the patient facing away from the wall; the patient is then instructed to barely touch one shoulder to the wall and then the other. In all tests quality and speed of motion can be assessed. The inability to maintain single leg stance or touch the wall barely may indicate core weakness in that plane and therapy can be initiated to improve e strength and endurance in that plane. Another clinical test described in the literature that may help identify which patients will respond to stabilization exercises is called the prone instability test. The prone instability test is done with the patient's lower extremities hanging off the end of the table with toes touching the groun; the lumbar vertebrae are palpated with an anterior posterior force noting pain at any vertebral level. Then while the clinician maintains an anterior posterior force at the painful vertebrae the patient is instructed to lift their feet off the ground activating the lumbar extensors, any decrease in pain at the painful vertebrae is considered a positive test. The underlying belief is that as the lumbar extensors are activated the painful spinal segment is stabilized and symptoms decrease, indicating stabilization exercises may be useful as treatment (McGill, 1998). It is important again to recognize that reliability and validity studies have not been done regarding the aforementioned evaluation techniques. However, as they are the only set of published guidelines I have found in my review of literature to this point they appear to be an appropriate set of evaluation techniques to help guide rehabilitation programs focused on core strengthening.

Core Stability and its Relationship to Injury

The physical demand of athletic endeavors has led researches to evaluate the effects of core stability on not only low back injury, but also lower extremity injury. The fact that most athletic events occur in a closed kinetic chain means that evaluation of the joints proximal and distal to the injury must be included in rehabilitation. With this is mind it is abvious that athletes must possess sufficient strength and endurance of the hip and trunk muscles to sufficiently stablilize the spine and pelvis in all planes of motion (Leetun, Ireland, Willson, Ballantyne, & Davis, 2004). Core stability measures between males and females have been shown to be different in multiple studies. McGill, Childs, and Lieberman (2003) found that males demonstrated greater quadratus lumborum endurance the primary lateral stabilizer of the spine compared to females. They additionally found no differences between trunk flexor endurance between the sexes, but females demonstrated greater trunk extensor endurance In a prospective study of young female gymnasts specific segmental stabilizing exercises were prescribed to athletes with and without low back pain. Interestingly 8 out of 15 gymnasts who were prescribed stabilizing exercises became symptom free and overall reported less pain than those in the control group (Harringe, Nordgren, Arvidsson,& Werner, 2007) In a study by Leetun et al. isometric strength of core musculature was measured to identify which muscles contribute to lower extremity injury in athletes including the back. The major finding of the study indicates that athletes who had higher peak levels of force with abduction and external rotation had lower injury rates. This is an interesting finding that may indicate the importance of the hip musculature in core stability programs, specifically gluteus medius and the external rotators of the hip.

Therapeutic Exercise as Treatment of LBP: Athletes Vs. Non-Athletes

Core stabilization exercises and other exercise programs fall within in a paradigm of therapeutic exercises used in treatment of low back pain. This exercise approach has become very popular recently as opposed to passive modalities such as; ultrasound, electrical stimulation, short-wave diathermy, and massage that only aim to reduce symptoms. The major premise of restoration in these treatment programs is no different than the way various orthopedic injuries have been treated for years. Whether you believe the pain-spasm-pain cycle or the pain adaptation model is responsible for the changes in muscle recruitment, the idea behind spinal rehabilitation programs is to restore normal function of the surrounding tissue to improve functional movement patterns in the patient.

It is fairly easy to ascertain the demands on the stabilizing structures of the spine differ greatly between an athletic population and a non-athletic population (Kumar, Sharma, & Negi, 2009). Imagine an offensive lineman setting up for pass protection and being impacted by a 300 pound defensive lineman or a gymnast performing a tumbling pass on floor and the forces that are transmitted through the spine. However, the detriment to the patient may be similar in that a non-athletic patient may miss an extended period of work leading to socioeconomic distress and the athlete could possibly miss extensive practice and game time. So whether the goal is to return to work or to return to the playing field the ultimate goal of exercise is to allow that as quickly and safely as possible. Though the outcome goal is very similar in treating athletes vs non-athletes the approach should differ in regards to the patient's needs.

In a non-athletic population many studies promoting early physical activity in low back pain patients have demonstrated positive results in the resolution of symptoms. (Hayden et al.

2005; Maher, Latimer, & Refshauge, 1999; Koumantakis, Watson, & Oldham 2005). This is one area athletes may differ significantly, athletes are often highly conditioned and physically active most days of the week, so continuing the same levels of physical activity may be detrimental to long term prognosis. Activity modification (ie frequency, duration, intensity) paired with an individualized exercise program would probably lead to better prognosis and outcome in this population. A recent Cochrane Databased meta-analysis evaluated the efficacy of exercise therapy in the treatment of chronic low back pain patients. The findings of which indicate that an individualized exercise programs with supervision may improve pain and function in these patients when compared to home based programs or group therapy (Hayden, Van Tulder, & Tomlinson 2005).

Aquatic Therapy as a Treatment for Low Back Pain

Aquatic based therapies have been used in the treatment of musculoskeletal injuries and have gained popularity in recent years when early exercise is indicated, but is too difficult or painful to perform on land. They have also gained popularity in the treatment of low back pain as the properties of water immersion decrease axial loading of the spine and through the effects of buoyancy, allow the performance of movements that cannot be performed in a normal weight bearing position (Cole & Becker, 2004).

In a meta-analysis by Waller, Lambeck, and Daly (2009) aquatic therapies in the treatment of LBP were evaluated to ascertain the efficacy of this treatment program. In their search of online databases 7 studies were identified as relevant to their research question based on their inclusion/exclusion criteria. The primary finding suggests that this type of exercise intervention appears to be safe and effective, but is not superior to other exercise interventions.

The studies evaluated in this meta-analysis with exception of 1 were not deemed to be of high quality and this is probably indicative that more research is necessary to define the role of aquatic therapy in the treatment of low back pain.

In a recent study by Bressel, Dolny, Vandenburg, and Cronin (2011) trunk muscle activation was measured during specific stabilization exercises in an aquatic environment. Their results indicate lower maximal voluntary contraction of core musculature in the water when compared to results of similar studies using exercises performed on land. This finding is interesting in relation to rehabilitating patients with low back pain who are unable to perform exercises under normal conditions because of fear-avoidance behavior or lack of motor control. The aquatic environment may allow patients to perform exercises to reestablish motor control without exacerbating symptoms and could be a key component to progressing athletes to more functional positions under normal weight bearing conditions (Bressel, Dolny, & Gibbons, 2011). Another interesting finding in this study was that abdominal bracing and Swiss Ball exercises produced the highest overall trunk muscle activity and an exercise like abdominal hollowing was effective in targeting the lower abdominals. This also gives insight into rehabilitation as there are two schools of thought regarding stabilization exercises, one says to target specific local stabilizers and the other takes the perspective of global neuromuscular reeducation. Whatever the goal of the rehabilitative clinician this finding gives an idea as to which exercises will be most beneficial.

It is important to recognize that to this point there have not been any studies evaluating the effect of aquatic based therapies in an athletic population. This type of intervention in theory should be very effective in treating athletes because it will allow them to maintain high activity levels while retraining the core musculature. The properties of water immersion and the concept of maintaining activity may prove to be beneficial in treating athletes. It may also serve a critical role in retraining the core musculature when land based interventions are not possible due to pain and dysfunction. This however, is an area where research is needed to complete our understanding of treating low back pain in athletes.

METHODS

The goal of this research project is to design a rehabilitation program to guide clinicians in the treatment of low back pain, with an emphasis on core stabilization for an athletic population. The use of core stabilization as a treatment for low back pain has gained popularity in recent years and a substantial amount of anecdotal reports from clinicians has lent credence to its efficacy in treating low back disorders.

Resources were gathered using the Utah State University Electronic Resources and Databases, Cochrane Database Collaboration, PubMed, and the online search engine Google Scholar. The primary reason for the use of Google Scholar was to make sure articles relevant to the topic were not being overlooked because they were not available on the Utah State University database. Secondarily if an article was not immediately available on the Utah State database, a search was done on Google Scholar to check availability.

A preliminary search using SPORTDiscus , Google Scholar, PubMed and Cochrane Database was initiated with the following key words: lumbar stabilization, core stabilization, low back pain, athletes, functional rehabilitation, exercise, core strengthening and any combination of the key words. Articles were deemed relevant by the following criteria:

- Meta-Analyses evaluating Core/Lumbar stabilization exercises in treating low back pain
- Core/ lumbar stabilization review articles

- Core/lumbar stabilization in athletes
- Functional rehabilitation of low back pain in athletes
- Other peer reviewed exercise programs that may not directly involve core stabilization.

It is clear from the electronic database search the efficacy of core stabilization exercises in the treatment of LBP is largely unproven. However, there is a database of research building that indicates it is a safe and effective treatment.

Developing a core stability program will help to guide clinicians in their decision making of when and how to progress athletes with LBP. While there may not be a preponderance of evidence-based research to support core stability programs, there is a solid theoretical foundation that suggests it has a role in the treatment of LBP.

Efficacy of Core Stabilization Exercise

It is clear from the research that muscle activation is impaired in patients with chronic low back pain and is thought to contribute to spinal instability, which may be causing the patients symptoms to persist. The aim of core stabilization exercises is to restore normal function of the muscles and enhance spinal stability to decrease pain and dysfunction. In a recent meta-analysis lumbar stabilization exercises were evaluated in treating chronic low back pain patients. The authors found 24 articles deemed relevant for evaluation, but of those only 3 were chosen and only 2 of those 3 were considered to be High quality randomly controlled trials. The overall conclusion from this meta-analysis was that lumbar stabilization exercises are effective in treating chronic low back pain, but at this time does not appear to be more effective than other exercise programs. It is clear from the available research that there is a lack of high quality evidence available to support or refute the use of core stabilization programs (Standaert, Weinstein, &

Rumpeltes, 2008).

Inclusion Criteria	Exclusion Criteria
1. RCT with stabilization included in the intervention group and no specific stabilization in the control group.	1. Duplicate Reports.
2.Chronic low back pain defined as at least 3 mo or 12 wk.	2. Abstract only.
3. English Language.	3. Combined treatments where effect of stabilization exercise cannot be determined.
4. Outcomes to include pain, disability, quality of life, satisfaction, and/or functional measures.	4. No clinical outcome data.
5. Follow-up of 6 mo minimum	

Table 2. Study eligibility requirements from meta-analysis (Standaert, Weinstein, & Rumpeltes, 2008).

Contraindications to Stabilization Exercises

It is important in your initial evaluation of the patient to rule out any medical conditions or “red flags” that would contraindicate the use of this type of exercise. Particular attention should be paid to certain parts of the patient’s history to assess whether core stabilization exercises would be helpful. Those parts of the patients history that indicate a serious underlying pathology such as tumor, fracture or progressive neurological deficit indicate further medical evaluation is necessary (Barr, Griggs, & Cadby, 2006).

Table3. Red Flags for Spinal Conditions (Heck & Sparano, 2000).

Cancer History of cancer Unexplained weight loss Night pain Duration greater than 1 month Failure of conservative treatment **Spinal Infection** Fever, chils Night pain IV drug use History of infection elsewhere **Ankylosing Spondylitis** Male less than 40 years old Morning stiffness Night pain Activity reduces pain Gradual onset Duration longer than 3 months **Cauda Equina Syndrome** Bladder dysfunction Saddle anesthesia Bilateral pain Bilateral weakness

Which core stabilization exercises are the best?

This question cannot be explicitly answered as it depends highly on the individual presentation of the patient and the findings of the clinician’s evaluation. One approach used by clinicians is to focus on activating specific “local stabilizers” such as transverse abdominis and lumbar multifidi that are thought to play a large role in stabilization during dynamic movement and loading of the spinal column (Jull & Richardson, 2000). The research however, indicates that activation of all stabilizing muscles are important for increasing stability in the lumbar region and no one muscle can be identified as contributing greatest to stability. (Kavcic, Grenier, & McGill 2004; Vera-Garcia, Elvira, Brown, & McGill 2007). It is well documented in the literature that activation of core musculature for stabilization comes with a compressive penalty to the spinal column that has been suggested may be a cause of injury. So it would be intuitive that the most appropriate lumbar stabilization exercises should challenge the muscles at a high enough level to enhance strength and endurance gains, but should minimize compressive forces. (McGill 1998; Vera-Garcia et al 2007;, Kavcic, Grenier & McGill 2004). In a general population studies have shown that during normal daily activities 10-15% of MVC of the core musculature is sufficient in providing stability to the lumbar spine (Cholewicki & McGill 1996). In an athletic population performing dynamic movement at high speed and under high load it can be postulated that the core stabilizers must function at a higher level to provide stiffness to the spine. This is an important concept to recognize as a clinician working with athletes because it important to find ways to challenge the core stabilizers in sports specific manner while minimizing the compressive load on the spine.

Exercises and Progression

The prevalence of low back pain in athletes according to the literature is not as common as the general population and in most cases is self- limiting. Many athletes continue to participate while experiencing symptoms and more or less may perform at a level adequate to function in their respective athletic event. If full participation or specific activities exacerbate their symptoms it is more than likely necessary that participation needs to be modified (Ie... frequency, intensity, specific drills) for core stabilization exercises to be effective. This is important to emphasize as a clinician because the no pain no gain idea that accompanies strength training does not seem to apply to low back rehabilitation, if an athlete is unwilling to modify their activity during the competitive season core stability exercises are unlikely to alleviate symptoms as long as the aggravating stimulus is still present. This leads me to believe that core stabilization as a rehabilitative strategy to treat chronic low back pain would be best achieved during the off season when the aggravation is lowest or in conjunction with activity modification to alleviate aggravating circumstances.

Core Stabilization Initial Exercises & Progression

The Neutral Spine

The initial stage of core stability exercise is to instruct the athlete to find his or her neutral spine position as this position places the lowest amount of strain on the passive structures of the spine (Panjabi 1992b; McGill, 1998). This position is also the position that all subsequent exercises should be performed in. This can simply be done by having the athlete in an upright position and instruct them to rock their lumbar spine through the end ranges of flexion and extension, telling them to feel for the strain it places on the spine. Then instruct them to find the position between the flexed and extended position that feels the most comfortable. It may be necessary to assist them by placing your hand on the iliac crests and working them through the motions to find their position of comfort. (See Appendix A Figure 1.)

Abdominal Bracing

It is well documented in the literature that total muscle activation is necessary to efficiently stabilize the spine and the no single muscle contributes greatest to lumbar stability (Cholewicki & Van Vliet 2002; Vera-Garcia et al 2007; Kavcic, Grenier, &

McGill, 2004). Because of this fact this rehabilitative program will focus on reestablishing complete motor control of the core musculature as opposed to focusing on specific muscles like transverse abdominis or the lumbar multifidi. Multiple studies have shown that abdominal bracing is a highly effective technique that activates all of the core musculature with a low to moderate cost to lumbar spinal compression (McGill, 1998). This maneuver will also be a basic building block that should be maintained during most of the exercises that follow. This maneuver can simply be instructed by having the athlete contract their abdominals isometrically.

Aquatic Therapy Vs. On Land

It is clear from the literature that the use of aquatic therapy in the treatment of chronic low back pain can neither be supported nor refuted. I postulate however, that it may have a great benefit to athletes who are unable to perform traditional core stabilization exercises under normal weight bearing circumstances. Prescript of aquatic therapy in the initial phase is highly dependent on your examination findings and the tolerance of the individual that you are working with. If the athlete is too painful during the initial phase the hydrostatic properties of water may provide enough of a supportive cylinder to the spine to allow pain free movement and exercise. It may not be possible to perform all core stabilization exercises in the water, but with a little bit of creativity and the concepts of neutral spine and abdominal bracing in mind much can be accomplished in the water if available to the clinician. (See Bressel, Dolny, and Vandenberg for exercises, 2011). If the athlete is able to tolerate on land activities early in the treatment this may be more beneficial to returning them to competition as quickly and safely as possible due to the fact higher muscle activation levels have been found during on land core stabilization exercises.

The Partial Curl-Up

The sit-up has been done by athletes for years to build strength in the anterior abdominal muscles, specifically the rectus abdominis. This exercise may very well cause more pain in the athlete with low back pain because of the stress it places on the posterior structures of the spine and the significant compressive forces that occur during performance. In a study by Axler and McGill (1997) he found that well over 3,000 N compress the spine during straight leg and bent knee sit-ups. So we must find a way to effectively challenge the anterior abdominal muscles to build strength and endurance without placing high compressive loads on the spine. A great exercise to activate the rectus abdominis without compressive loading is the partial curl up. It has been measured to compress the spine between 2000-2500 N (Axler & McGill, 1997; Kavcic, Grenier, & McGill, 2004). This maneuver is performed by instructing the athlete to perform an abdominal brace then to curl up slowly lifting only their shoulders and neck off of the ground while maintaining a neutral spine. It may be beneficial to instruct them to have their axis of rotation just above the breast line. (See Appendix B Figure 2.)

The Side Bridge

The primary lateral stabilizer of the spine is quadratus lumborum and has been shown to greatly contribute to spinal stability (McGill, 1998). This muscle is often neglected in the athlete so retraining to build strength and endurance is crucial. This exercise can be done in one of two ways; in an upright position with the weight of the body supported on the elbow against the wall or it can be done from the table with the body weight supported by the elbow and knees and the hips off the ground. This exercise has also been shown to activate the lateral oblique musculature that also contributes to spinal stability. (See Appendix B Figure 3.)

The Quadraped Exercise

The first three exercises have focused on the anterior and lateral core musculature, but it is important to remember the posterior or the “back” of the muscular box is important for spinal stability as well. A great exercise to activate the posterior musculature with a low to moderate compressive cost is the quadraped exercise or four-point kneeling. (Kavcic, Grenier, & McGill, 2004) It is important to emphasize the abdominal brace maneuver and the maintenance of a neutral spine for the duration of the exercise. In the initial stages performance of a single arm raise or a single leg raise during the exercise will challenge the athlete and increase muscle activity. If the athlete is unable to maintain a neutral spine during the limb movements regress with the exercise as it may likely be detrimental to train poor motor patterns. (See Appendix B Figure 4.)

Progression

The initial exercises should be challenging enough to provide the athlete with a solid foundation to progress to intermediate and eventually advanced exercises in a functional more sport-specific capacity. Before progression to an intermediate phase of exercise I think it is important to evaluate the athlete's changes in symptoms that may indicate that they are ready to be challenged further. If there is any increase in symptoms during the foundational exercises, progression to more challenging activities is likely contraindicated. It is also important to recognize when the athlete becomes proficient at the exercises and is able to do high level of repetitions with low load while maintaining a neutral spine which indicates more challenging exercises are necessary to increase strength and endurance.

Intermediate Exercises and Progression

The goal of this stage is to effectively increase the challenge to the core musculature to prepare the athlete to perform more advanced exercises that simulate functional positions that occur during sporting activity. Many of the exercises will build on the foundational work done during the initial phase of the core stabilization program while adding some new exercises to further enhance strength and endurance.

The Intermediate Curl-Up

To increase the challenge to the anterior abdominal muscles with the curl-up the clinician can make a simple adjustment. Instruct the athlete to place their hands with their palms down to the floor underneath their lumbar spine. Then instruct them to elevate their arms slightly off of the floor and perform the curl up maneuver just as before while maintaining a neutral spine. Instruct the athlete to hold at the top for and take 5 quick breaths in and out. (See Appendix C Figure 5.)

The Intermediate Side Bridge

The intermediate side bridge can be utilized to further challenge the lateral musculature specifically quadratus lumborum and the oblique group. It is performed by instructing the athlete to support themselves at the elbow and feet with the hips and knees elevated off of the ground, neutral spine should be maintained throughout the exercise. The side bridge has a moderate compressive cost to the spine of 2726 N according to research by Kavcic, Grenier, and McGill (2004). This is important to keep in mind if the athlete experiences pain during this exercise, which may indicate the lateral musculature is not able to stabilize in this position. (See Appendix C Figure 6.)

The Intermediate Quadraped Exercise

This exercise can be advanced by instructing the athlete to simultaneously move the arm into flexion while extending the contralateral leg. If they are unable to maintain a neutral spine at any point during the exercise, it may be necessary to provide them with verbal or sensory cues to help maintain the correct spinal position. This exercise also comes with a moderate compressive cost of 2740 N to the lumbar region at the L4-L5 level.(Kavcic, Grenier, & McGill, 2004). It was also found that the erector spinae were activated greatest during this exercise. (See Appendix C Figure 7.)

Supine Bridging

In the study by Kavcic, Grenier, and McGill (2004) the bridging exercise produced the highest muscle activity in the lumbar multifidi. This exercise thus can be used to target strength and endurance increases in the aforementioned muscle group, however it does activate the other extensors in the group to lesser values of MVC. This exercise can be used in conjunction with quadraped exercises or as a substitute to target the extensor musculature because the compressive load placed on the spine is amongst the lowest of core stability exercises. It is important to instruct the athlete to maintain activation of the hamstrings and gluteals during the motion to help maintain the neutral spine position. (See Appendix C Figure 8.)

Prone Bridge

This exercise can be used to activate all of the core musculature when done with the abdominal brace maneuver. It is important to emphasize the neutral spine position and activation of the gluteal muscles to assist in maintaining the neutral spine position. There is no data to date that I can find that would contraindicate this exercise being used in an individual with low back pain and have found it effective in challenging patients that I have treated. (See Appendix C Figure 9.)

Progression to Advanced Exercise and Functional Activities

As all clinicians know who provide medical services and rehabilitation to athletes there is no specific time frame for when they can progress to more advanced exercises. It is highly dependent on the athlete and how they respond to the treatment with core stabilization exercises. It is important to evaluate the athlete for sufficient strength and endurance gains that will allow them to perform progressively more difficult exercises without breaking form and compromising spinal stability.

Advanced Core Stabilization Exercises

Advanced partial curl-up

The advanced curl- up can be performed by having the athlete complete the movement as described before, and at the top have them perform five quick shallow breaths. This maneuver should be challenging for even the toughest athletes, but is not nearly as compromising to the posterior elements of the spinal column as a full sit-up would be. This exercise can also be advanced to a labile surface such as a swiss ball to further enhance the activity of the core musculature.

The Advanced Side Bridge

This is done by having the athlete rotate from a left side bridge to a right side bride. It is important stress that they maintain a neutral spine and that their lumbar spine and pelvis rotate in unison to prevent excessive rotational stress on the vertebrae. It may be necessary to assist the lumbo-pelvic rhythm by placing your hand on their iliac crests to support simultaneous movement of the neutral spine and pelvis. (See Appendix D

Figure 10)

The Advanced Quadraped Exercise

To increase the challenge of the quadraped exercise perform the maneuver exactly the same as the intermediate exercise, but with the arm and leg extended have the athlete draw a small square. Just as before cue the athlete to maintain a neutral spine throughout the performance of the exercise. To challenge the athlete further progress by having them progressively larger squares.

The Advanced Supine Bridge

This exercise can be advanced by supporting the feet on a swiss ball or bosu ball challenging the core musculature on an unstable object. Another advanced progression that may be used is to place a resistance band between the knees and to perform abduction of the knees during the bridge. This seems to be safer than alternating leg extension while performing a bridge as it causes high levels of lumbar compression (McGill, 1998). (See Appendix D Figure 11 and 12.)

The Advanced Prone Bridge

This exercise can be made more difficult by adding an unstable surface such as a Bosu ball or swiss ball to increase the challenge. To increase the difficulty even more using a swiss ball have the athlete make small circular motions with the ball while maintaining a neutral spine. (See Appendix D Figure 13.)

Functional Exercises

These exercises should only be initiated when an athlete demonstrates the strength and endurance to control spinal motion during the advanced exercises. The primary goal of rehabilitation is to restore functional movement and treating chronic low back pain in an athlete is no different. The end goal is to retrain the muscles to adapt to the dynamic loading situations that occur during sporting activity in order maintain the spine in a neutral stable position. The exercises that are done in the phase will vary depending on the sport in which the athlete participates. When performing these exercises it is important to cue the athlete to maintain a neutral spine and the abdominal bracing maneuver throughout the performance of the exercise to ensure spinal stability and core muscle activation. Any exercise that is done to treat other musculoskeletal injuries can be adapted to illicit trunk muscle activation and postures that encourage pain free movement. It is important to always be creative and think of new ways to challenge an athlete; this can be accomplished through the use of different labile surfaces to challenge balance and proprioception. This teaches the athlete to adjust to a dynamically unstable situation without compromising spinal stability and creating a painful movement pattern. A progression from single plane movements such as an upright row to multi-planar activities such as D1 & D2 PNF patterns with gradual increase in resistance will help improve core strength and endurance.

Table 4. Example Functional Exercise Progression
Upright Rows- Low/ Mid/High
Lateral rotation
Double leg balance w/ eyes closed & perturbations
Double leg Squat on unstable surface
Double leg Squat w/ rotation
Upper extremity PNF D1/D2 patterns
Wood Chop Low/High
Wood Chop High/Low
Lunges
Lateral Lunges
Single leg Squat
Single leg Squat w/ Rotation
Lunges w/ unstable surface
Lateral Lunge w/ Rotation
Single leg Balance w/perturbations

Table 4. All exercises should be performed with the abdominal brace to stabilize the spine and neutral spine should be emphasized by instructing the athlete to move at the hip as opposed to the spine.

Conclusion

These exercises are not intended to be used to treat all athletes with low back pain as this is dependent on clinical evaluation findings. There is a solid theoretical foundation that indicates core stabilization exercises should be effective in treating back pain due to spinal instability and other clinical diagnoses. With the high demands placed on the lumbar spine during athletic competition and practices these individuals are presumably susceptible to experience pain due to instability or spinal injury. Hopefully this information will give clinicians ideas as to the most safe and effective exercises to challenge the core musculature and restore function and pain free movement in athletes with low back pain.

References

Akuthota, V., Ferreiro, A., Moore, T., & Fredericson, M. (2008). Core stability exercise principles. *Current Sports Medicine Reports*, 7(1), 39-44.

Axler, C.T.,& McGill S.M. (1997) Low back loads over a variety of abdominal exercises: searching for the safest abdominal challenge. *Medicine Science in Sports & Exercise*,29, 804-811.

Barr, K., Griggs, M., & Cadby, T. (2005) Lumbar Stabilization: A review of core concepts and current literature part 1. *American Journal of Physical Medicine & Rehabilitation*, 84 (6), 473-480.

Barr, K., Griggs, M., & Cadby, T. (2006) Lumbar Stabilization: A review of core concepts and current literature part 2. *American Journal of Physical Medicine and Rehabilitation,* 86 (1), 72-80.

Bono, B. M. (2004). Low back pain in athletes. *The Journal of Bone and Joint Surgery,* 86 (2), 382-396.

Bergmark, A. (1989). Stability of the lumbar spine: A study in mechanical engineering. *Acta Orthopaedica Scandinavica Supplementum,* 230 (60), 1-53

Bressel, E., Dolny, D,. & Gibbons M. (2011). Trunk muscle activity during exercises performed on land and in water. *Medicine & Science in Sport & Exercise*, 43 (10), 1927-1933

Bressel, E., Dolny, D., Vandenberg, C., & Cronin J.B. (2011) Trunk muscle activity during spine stabilization exercises performed in a pool. *Physical Therapy in Sport,* 1-6

Chloewick, J., & McGill, S.M. (1996) Mechanical stability of the in vivo lumbar spine: implications for injury and chronic low back pain. *Clinical Biomechanics,* 11(1), 1-15.

Cholewicki, J., & Van Vliet, J.J. (2002). Relative contribution of trunk muscles to the stability of the lumbar spine during isometric exertions. *Clinical Biomechanics,* 17, 99-105.

Cole M.D., & Becker, B.E. (2004) Comprehensive aquatic therapy. Butterworth-Heinemann

Ershad, N., Kahrizi, K., Abadi, M., & Zadeh, S. (2009) Evaluation of trunk muscle activity in chronic low back pain patients and healthy individuals during holding loads. *Journal of Back and Musculoskeletal Rehabilitation*, 22, 165-172

Heck, J.F., & Sparano, J.M. (2000) A classification system for the assessment of lumbar pain in athletes. *Journal of Athletic Training,* 35(2), 204-211

Haringe, M.L., Nordgren, J.S., Arvidsson I., & Werner, S. (2007) Low back pain in young female gymnast and the effect of specific segmental muscle control exercises of the lumbar spine: a prospective controlled intervention study. *Knee surgery, Sports Traumatology, Arthroscopy,* 15, 1264-1271

Hodges, P.W., & Richardson, C.A. (1999). Altered trunk muscle recruitment in people with low back pain with upper limb movement at different speeds. *Archives of Physical Medicine and Rehabilitation,* 80, 1005-1012.

Hayden, J.A., van Tulder, M.W.,& Tomlinson, G. (2005) Systematic review: Strategies for using exercise therapy to improve outcomes in chronic low back pain. *Annals of Internal Medicine,* 142(9), 776-785.

Jull, G.A., & Richardson, C.A. (2000). Motor control problems in patients with spinal pain: a new direction for therapeutic exercise. *Journal of Manipulative Physiological Therapeutics,* 23(2), 115-117

Kavcic, N., Grenier, S.,& McGill, S.M. (2004) Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises, *Spine*, 29(20), 2319-2329.

Kibler, B.W., Press, J., & Sciascia, A. (2006). The role of core stability in athletic function. *Sports Medicine,* 36 (3), 189-198.

Krabak, B., & Kennedy, D. J. (2008). Functional rehabilitation of lumbar spine injuries in the athlete. *Sports Medicine Arthroscopic Review,* 16 (1), 47-54.

Koumantakis, G., Watson, P., Oldham, J. (2005) Trunk muscle stabilization training plus general exercise versus general exercise only: Randomized control trial of patients with recurrent low back pain. *Physical Therapy,* 85(3), 209-225.

Kumar, S., Sharma, V., & Negi, M. (2009) Efficacy of dynamic muscular stabilization techniques over conventional techniques in rehabilitation of chronic low back pain. *Journal of Strength and Conditioning Research*, 23(9), 2651-2658.

Leetun, D., Ireland, M., Willson, J., Ballantyne, & B., Davis, I (2004) Core stability measures as risk factors for lower extremity injury in athletes. *Medicine & Science in Sport & Exercise,* 926 - 934

Lund, J. P., Donga, R., Widmer, C. G.,& Stohler, C. S. (1991). The pain adaptation model: a discussion of the relationship between chronic musculoskeletal pain and motor activity. *Canadian Journal of Physiology and Pharmacology,*69, 683-694.

Maher, C., Latimer, J., Refshauge K. (1999) Prescription of activity for low back pain: What works? *Australian journal of Physiotherapy,* 45, 121-132.

McGill, S.M. (1998). Low back exercises: Evidence for improving exercise regimens. *Physical Therapy,* 78 (7) 754-765.

McGill, S.M., Childs, & A., Lieberman, C., (1999) Endurance times for low back stabilization exercises: Clinical targets for testing and training from a normal database. *Archives of Physical Medcicine and Rehabilitation,* 80, 941-944

Marieb, E. N. (2004). Human Anatomy & Physiology (p.220). San Francisco: Pearson Publishing Press.

Nadler, S.F., Malanga, G.A., Bartoli, L.A., Feinberg, J.H., Prybicien, M.,& DePrince, M. (2002) Hip muscle imbalance and low back pain in athletes: Influence of core strengthening. *Medicine & Science in Sports & Exercise*, 34(1), 9-16

Panajbi, M. (1992a). The stabilizing system of the spine. Part I. Function, dysfunction, adaptation, and enhancement. *Journal of Spinal Disorders & Techniques*, 5 (4), 383-389.

Panjabi, M. (1992b). The stabilizing system of the spine. Part II. Neutral zone and instability hypothesis. *Journal of Spinal Disorders & Techniques* 5 (4), 390-397.

Reeves, P. N., Cholewicki, J., & Silfies, S. P. (2006). Muscle activation imbalance and low back injury in varsity athletes. *Journal of Electromyography and Kinesiology*, 16, 264-272.

Renkawitz, T., Boluki, D.,& Grifka, J. (2006). The association of low back pain, neuromuscular imbalance, and trunk extension strength in athletes. *The Spine Journal*, 6, 673-683.

Richardson, C.A., Snijders, C.J., Hides, J.A., Damen, L., Pas, M.S., & Storm, J. (2002). The Relation between transversus abdominis muscles, sacroiliac joint mechanics, and low back pain. *Spine*, 27 (4), 399-405.

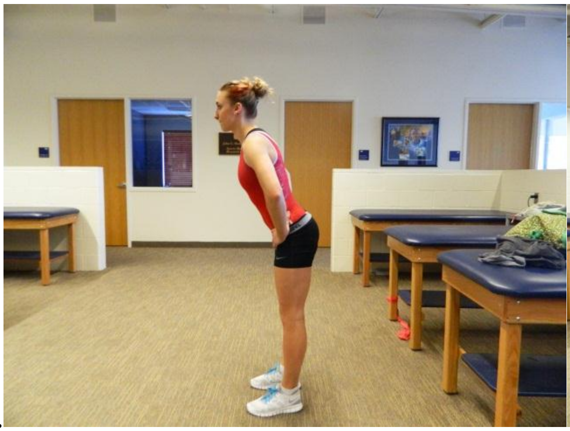
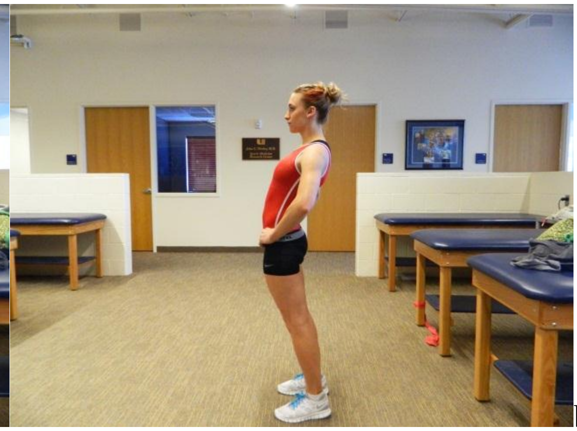
Standaert, C.J., Weinstein, S.M.,& Rumpeltes, J. (2008). Evidence-informed management of chronic low back pain with lumbar stabilization exercises. *The Spine Journal*, 114-120

Van Dieen, J.H., Cholewicki, J., & Radebold, A. (2003). Trunk muscle recruitment patterns in patients with low back pain enhance the stability of the lumbar spine. *Spine*, 28(8), 834-841.

Vera-Garcia, J.F., Elvira, J.J., Brown, S,& McGill, S.M. (2007). Effects of abdominal stabilization maneuvers on the control of spine motion and stability against sudden trunk perrturbations. *Journal of Electromyography and Kinesiology*, 17, 556-567.

Waller, B., Lambeck, J., & Daly, D. (2009). Therapeutic aquatic exercise in the treatment of low back pain: a systematic review. *Clinical Rehabilitation*, 23, 3-14

Appendix A

.b.

a) b)

 Figure 1 Demonstration of neutral spine: a) posture

c)

demonstrating hyper flexion. b) posture demonstrating hyperextension. c) neutral spine position

Appendix B

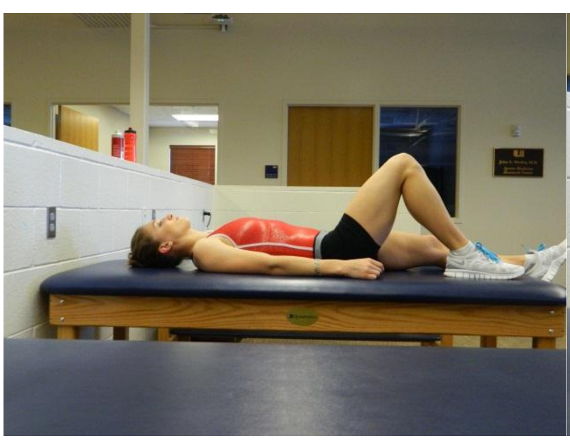
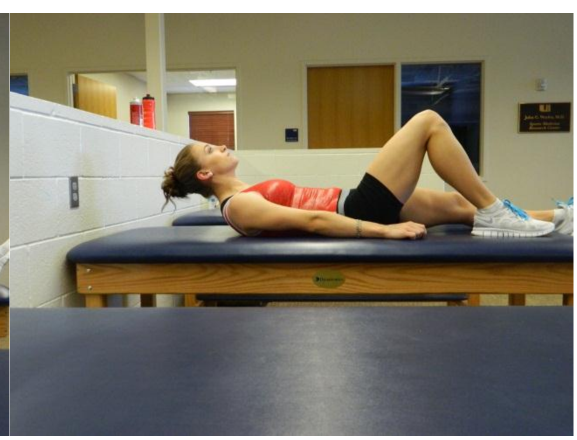


Figure 2 Demonstration of the beginning curl up

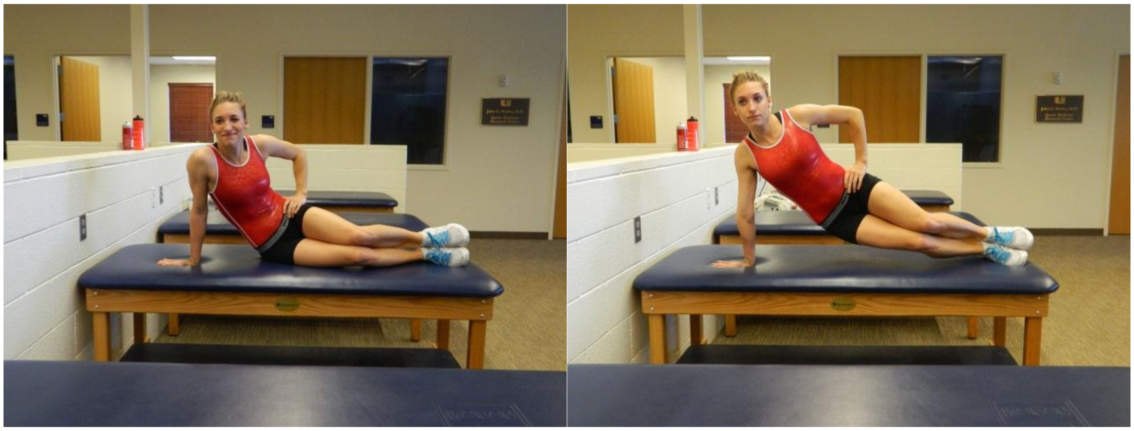
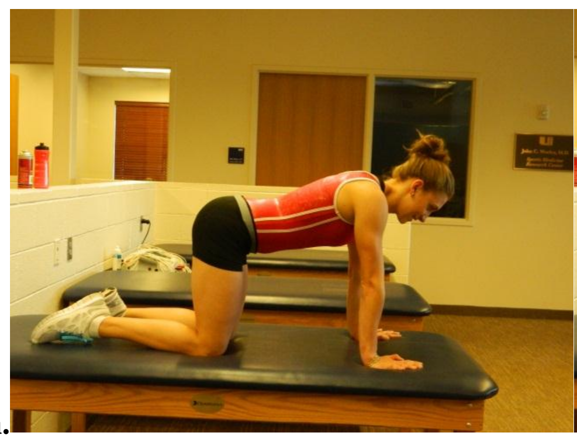
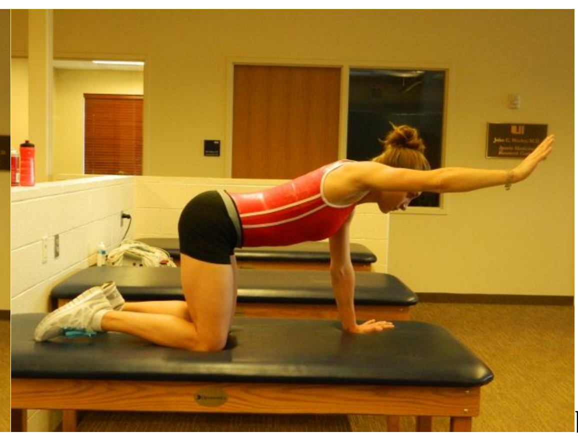


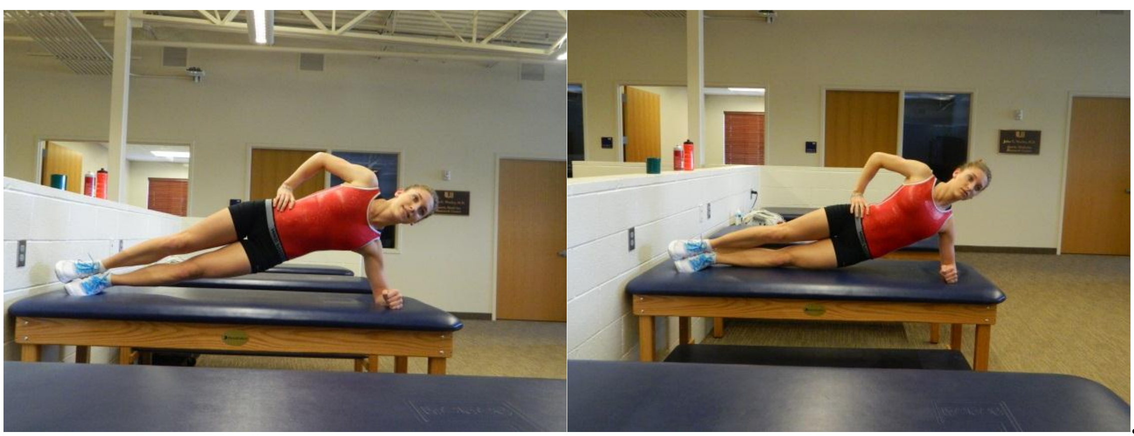
Figure 3 Demonstration of the beginning side bridge

a.**b.**

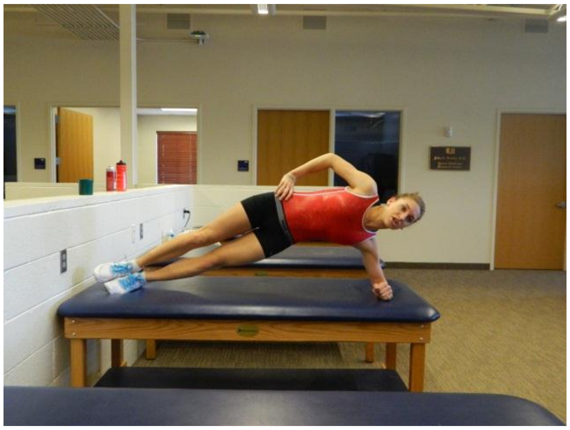
c. Figure 4 Demonstration of the beginning qudraped exercise: a) beginning position. b) single arm flexion while maintaining neutral spine and abdominal brace. c) single leg extension while maintaining neutral spine and abdominal brace.

Appendix C

Figure 5 Intermediate Curl up- Arms placed under lumbar vertebrae to help maintain lumbar spine in neutral and elevated slightly off table to increase difficulty. Advanced exercise performed by holding at top and taking in five short shallow breaths or performing exercise on a swiss or BOSU ball.



a. **b.**



c.

Figure 6 a. Intermediate side bridge with correct neutral spine position. b. Intermediate side bridge with lower iliac crest dropped. c. Intermediate side bridge with upper iliac crest elevated.

Figure 7 Intermediate quadraped exercise with alternating opposite limb movement. Progress to an advanced exercise by having the athlete draw squares with the contralateral limbs.

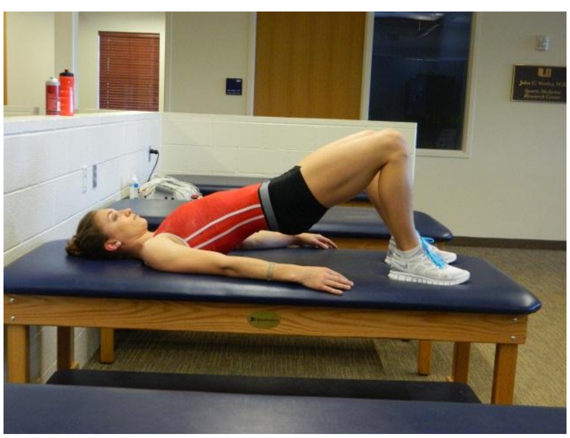


Figure 8. Supine Bridge

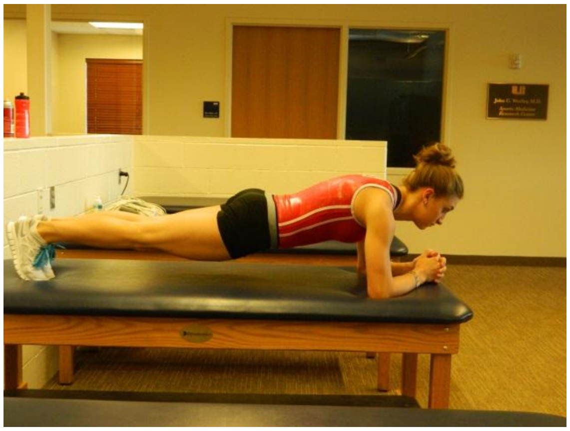


Figure 9 Prone Bridge

Appendix D

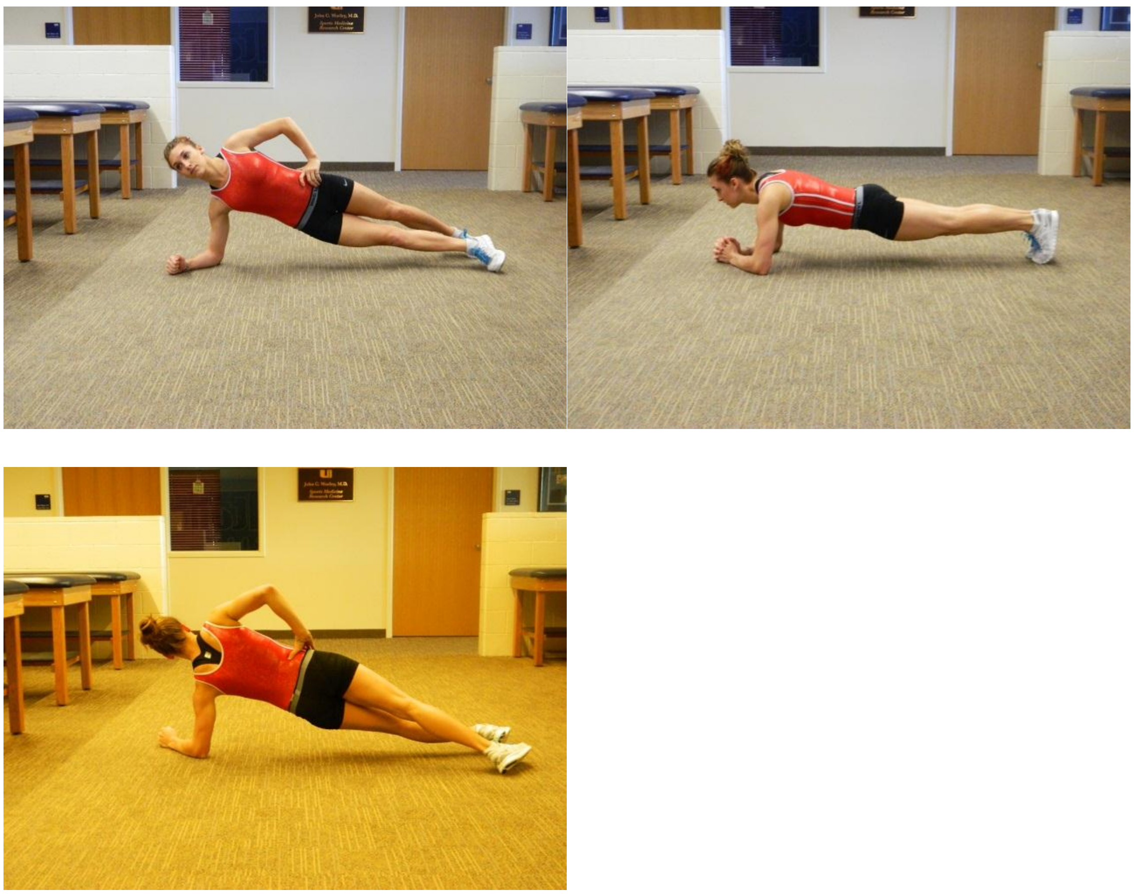


Figure 10 Advanced Side Bridge- Athlete rotates from a right side bridge, then to a prone bridge and completes the repetition by rotating to a left side bridge. Note: Make sure the pelvis and spine move simultaneously.

Figure 11 Advanced Supine Bridge with BOSU Ball

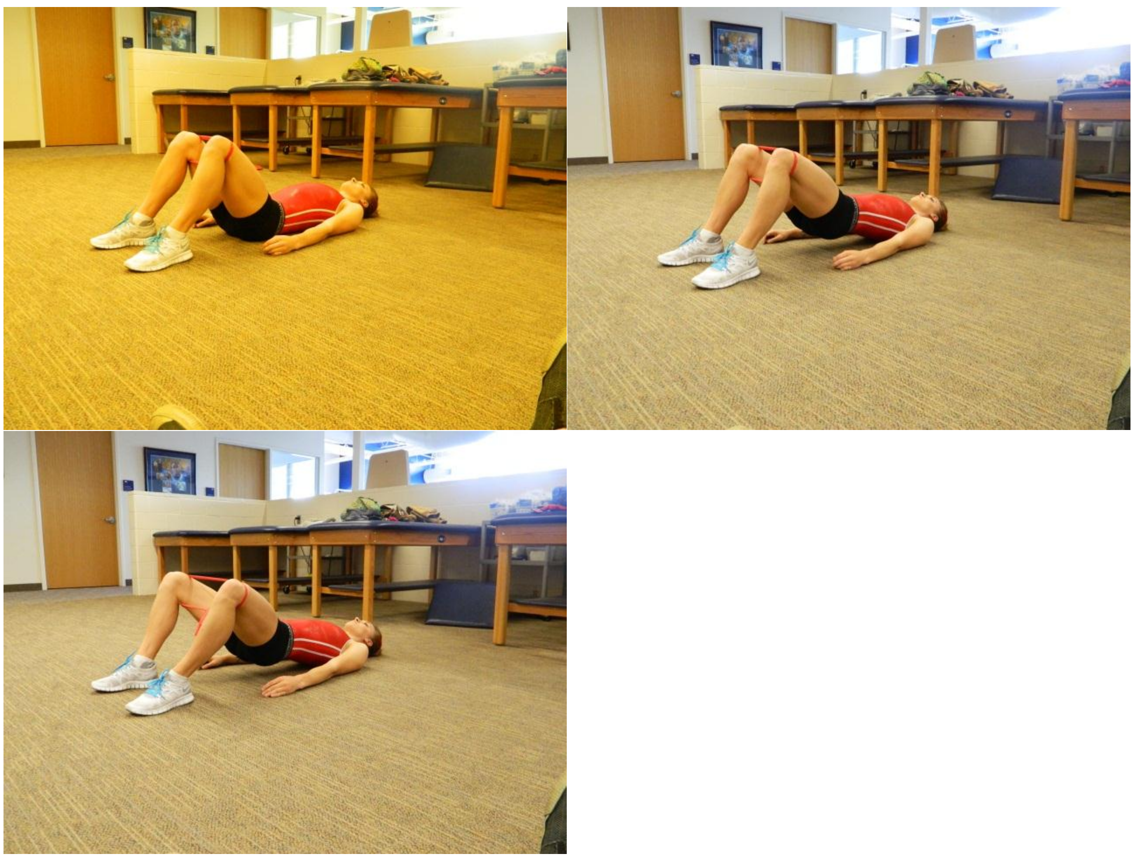


Figure 12 Advanced Supine Bridge with Theraband abduction

Figure 13 Advanced Prone Bridge with Swiss Ball. Advance this exercise by having the athlete draw circles with the swiss ball.