A Thesis

Entitled

The Effects of Core Stability Training on Star Excursion Balance Test and Global Core Muscular Endurance

By

Alex McCaskey

Submitted to the Graduate faculty as partial fulfillment of the requirements for the Masters of Science Degree in Exercise Science

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An Abstract of
The Effects of Core Stability Training on Star Excursion Balance Test and Global Core Muscular Endurance

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Deficits in core muscular control and endurance have been linked to possible lower extremity injury. Deficits dynamic stability increase the risk of lower extremity injury. The purpose of this study is to explore the ability to increase both dynamic stability and core muscular endurance 30 subjects were counter-balanced into two groups. Fifteen were placed in a control group and fifteen were placed in a group which performed core stability training. All subjects performed the Sahrmann Stability Test, the Star Excursion Balance Test and core muscular endurance tests. Both groups repeated the testing session after 5 weeks with the intervention group participating in a 4-week core stability training program. The difference from pre-post testing was evaluated for statistical significance using independent T-tests. The core stability training group showed statistically significant increases in the posteriolateral reach direction (p=.007), the posteriomedial reach direction (p=.042), the right side bridge (p=.021) and the left side bridge (p=.002). Core stability training program can positively affect dynamic stability and core muscular endurance.
For Mom, Dad, Jess, Luke and Bryan. Your encouragement and pride in me is so important and it is what keeps me striving to accomplish everything. Thank you so much for everything you guys have done for me and for believing in me.
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Chapter 1:

Introduction

Postural control is important to both athletic activity and activities of daily living (ADLs), balance, or postural control, can be described as either dynamic or static.[1] Static postural control is attempting to maintain a position with little or no movement. Dynamic postural control involves the completion of a functional task without compromising one’s base of support.[1] Importance therefore should be placed on the ability to balance dynamically as this is a key component in both athletic activity and ADLs. This ability to balance dynamically is very important in the prevention and rehabilitation of injury.[2]

The core is split into two different regions, the local and global musculature. The multifidus, transverse abdominus, internal oblique and quadrates lumborum constitute the local stabilizing system. The longissimus thoracis, rectus abdominus and external oblique make up the global system.[3] The local system is responsible for segmental spine stability while the global system is responsible for isometric and isotonic contraction in the spine. Both of these regions play a role not only in daily and athletic movement but also potentially in injury prevention. The strength, endurance and neuromuscular control of these muscles is important for stability of the spine.[4]
The core musculature “provides the proximal stability for the distal mobility and function of the limbs.”[5] Core musculature is important in the sense of dynamic stability. The core musculature allows for the stiffening of the segments of the spine and the gross trunk motion to allow for both a stable base for the limb musculature to push against and to allow for the transfer of energy throughout the kinetic chain of the body. Both of these components can play a role in the application of dynamic stability. This lack of dynamic stability in the core has been associated with potential for increased risk for lower extremity injury.[6] Along with the overall strength and neuromuscular control which contribute to spine stability, the endurance of core muscles has been thought to play a role in injury as well.[7]

Core stability training is a form of training meant to increase core musculature strength, endurance and neuromuscular control. Through core stability training, intersegmental control of the spine, control of intra-abdominal pressure and global muscular control of trunk movement can be improved.[8] These aspects of core stability can influence the ability for the body to balance in various dynamic movements and allow for proper force production and segmental control to help prevent injuries.

The Star Excursion Balance Test (SEBT) provides a quantifiable way to measure dynamic balance.[9] This single leg standing and contralateral reaching test can be used to determine the dynamic stability of an individual as they perform a functional movement task. SEBT requires a participant to maintain a base of support with one leg while maximally reaching in different directions with the opposite leg without losing balance or significantly altering the base of support in the stance leg.[9] This tests also mimics many motions of both ADL and athletics as it is performed in a variety of
functionally integrated movement planes. Improvement in this test could prove that an intervention does help increase dynamic stability. In relation to core musculature, the ability for the core muscles to stabilize the spine to provide a stable base for the lower extremity muscles to contract against could provide a method to improve dynamic stability. The ability for the core musculature to also resist motion and momentum in the sagittal plane may also increase the dynamic stability in this particular test.

As stated earlier the overall endurance of core musculature may also be important for the potential prevention of injury. McGill et al. devised four tests to test for the isometric endurance of the global musculature as well as the transverse abdominus and the quadrates lumborum.[10] The ability to measure core endurance can also provide important information as to the effectiveness of a core stability program at increasing function of the core muscles.

The increase in dynamic stability and core muscular endurance can be a useful tool in both rehabilitation as well as prevention of injury for both athletic and non-athletic populations.

1.1 Statement of Problem

The research surrounding core stability has been focused on the improvement in physical performance tasks or the electromyographic activation levels during exercise for core. The studies[11, 12] that have focused on using core stability training as a way to improve dynamic stability have not reported any significant effects when compared to a control group. This is possibly because the authors chose the wrong group of exercises to
enhance dynamic stability or may have selected outcome measures not sensitive enough to measure potential improvements from the intervention. Core muscular endurance has never shown to be increase through core stability training. The possibility for improving core endurance through only four weeks of core stability training may prove significant in possible injury prevention programs.

1.2 Statement of Purpose

The primary purpose of this study is to determine if dynamic postural stability may be improved through core stability training. The corollary purpose of this study is to determine if improvement in core muscular endurance and core stability can be achieved through four weeks of core stability training.

1.3 Hypothesis

H₁: There will be improvement in dynamic stability in the core stability group when compared to the control group.

H₂: There will be improvement in core muscular endurance in the core stability training group compared to the control group.

1.4 Limitations
1. Subjects adhering to core stability program.

2. Subjects may feel uncomfortable with core muscular endurance tests.

3. Subjects may become fatigued during the pre and post test.

4. Proper progressive overload may be difficult to achieve

1.5 Delimitations

1. Allowing plenty of rest between tests may help reduce fatigue.

2. Subjects will have to engage in only 4 weeks of core stability training and this may encourage adherence.

3. Using a 2-3 set progression over general advice may help achieve progressive overload.

1.6 Significance

If there is a significant difference between the core stability training group and the control group in the dynamic stability test and the core muscular endurance test then core stability training programs could be investigated as an effective way to rehabilitate or prevent injury.
Chapter 2:

Literature Review

2.1 Dynamic Stability

The concept of dynamic stability has been extensively studied. A definition of dynamic stability would be the ability to maintain balance and control of the torso and distal segments of the body through dynamic movement. Anderson and Behm[13] stated that much is known about how muscles maintain static equilibrium, but little is known about how they maintain dynamic balance when exerting an external force. Exerting external forces while attempting to maintain dynamic balance forms the base of success in the majority of sports and it is a necessity in the activities of daily living.[13] There have been many injuries and disorders that have shown to be able to adversely affect the body’s ability to stabilize it through both dynamic and static movement. The reason dynamic movement is very important for study is because most musculoskeletal injuries will occur in a form of dynamic movement. The ability for the body to be able to regain normal function and previous performance capabilities after an injury is also related it the ability to stabilize dynamically. Being able to return a patient to pre-existing level of dynamic stability and function after an injury that may compromise these qualities is of the up most importance to any clinician.
The body works to achieve dynamic stability to resist forces that act both externally and internally on it to prevent injury and falls. Despite the effectiveness of the body stability can still become compromised from both internal and external factors. Some of these disruptions in stability can be avoided (Muscle Imbalances) and some cannot (being pushed outside the base of stability by a foreign entity). Some of these disruptions in dynamic stability can be the result of an injury such as an anterior cruciate ligament tear or a concussion. These compromises to stability, both chronic and acute, can become factors in possible or further injury to the body. In the case of chronic instability such as that experience after an injury or resulting from a biomechanical factor the body can’t properly protect itself from further injury. This is where testing for dynamic stability can become important.

There have been different test used to quantify dynamic stability. In this way dynamic stability can be objectively measured and evaluated. It can then be used to rate the effectiveness of interventions and the possible consequences that injury can have on dynamic stability. Each of these tests has different levels of intensity and effectiveness. For this study the test that has been chosen is the Star Excursion Balance Test (SEBT). This test involves dynamic movement which can accurately quantify the body’s ability to handle forces as the body moves through a functional ROM. It is a test specifically able to quantify and measure dynamic stability in the lower extremity. Beyond that it is a challenging test that can be used to evaluate dynamic stability in multiple directions and movements.[14] This test has also been deemed a fair assessment tool for subjects with chronic ankle instability.[15] Individuals with lower extremity injury have been shown to take longer to stabilize using this test than matched healthy individuals. [15, 16]
This deficit in the SEBT score has also been associated with differing kinematic data at joints proximal to the injured joint. Gribble et. al.[17] showed that subjects with Chronic Ankle Instability had less knee and hip flexion when performing an SEBT Measure after fatigue. Delahut et al.[18] showed that subjects with functional ankle instability had an increase in rectus femoris electromyography (EMG) when performing a side to side hopping task. Herrington et al.[19] showed a deficit in reach distance for ACL deficient patients. This shows that the compromise in dynamic stability may be due not only to the injuries suffered by the joint but to a change or a pre-existing abnormality up the whole kinetic chain. Other studies have shown that athletes with lower ability to produce force in hip abduction and external rotation were correlated with a higher incidence of knee and ankle injury, both acute and chronic.[20, 21] The improvement in different aspects in the kinetic chain could lead to a decrease in the time needed to stabilize the body. This would constitute an increase in the dynamic stability of the body. The core serves as the center of the kinetic chain.[3, 22] This ability for the core musculature to absorb, transfer, control and produce force throughout the body makes it makes it an integral part of the kinetic chain. The control of the core provides a linking system to the rib cage and the pelvis and can affect mobility and function of the extremities.[20, 23] Lack of control in the core may contribute to the bodies inability to achieve dynamic stability or could lead to a situation that can cause injury.[24]

2.2 Core
The focus of this study is on the core and its potential ability to affect dynamic stability. The core has been defined in many ways. Some define it as the whole of the trunk including all muscular that crosses the hip and shoulders. Others have defined it as the lumbopelvic region where everything above the pelvis and below the sternum is considered core musculature.[3, 25-29] Others define it as the hip musculature and all musculature surrounding the lumbar spine.[3] For the definition of this paper the core musculature will be considered the muscles above the pelvis and below the ribcage.

The core muscular in this sense has been divided into two categories, the global and local stabilizing systems. Some authors have defined these muscles that control stability of the spine (Local) and muscles that produce force for movement (Global).[30] This definition of local and global is not accounting for the integrated fashion in which the core is utilized to provide spinal stability and movement. According Borghuis et al[3] a low level of co-contraction is needed to ensure stiffness of the spine against minor perturbations. After that direction-specific muscles reflex response is important for spinal stiffness against sudden larger perturbations. The definition settled on for this study is the local muscles are responsible for individual spinal segment control and the global muscles are the other muscles in the core.

The local musculature is made up of the multifidus, rotators, interspinal, and intertransverse muscles.[7] These muscles have a high density leading researchers to think that they are responsible for sensory information about the position and loads applied to the spine as well as individual segments of the spine. These muscles can also help control spinal stiffness at different segments of the spine. These muscles also function as monitors for the proprioceptive condition of the stability of the spine.[31]
While not being able to produce gross movement in the spine these muscles are very important as far as feedback to spinal stability and assisting in stiffening segments of the spine. This ability to stiffen certain segments of the lumbar spine can assist in the delicate balance between mobility and stiffness needed to be seen in the spine.

The global musculature is made up of the rectus abdominus, internal oblique, external oblique, transverse abdominus, quadrates lumborum, longissimus thoracis and erector spinae. These muscles are responsible not only for gross spinal stability but also for force production for movement in the core.[7] While many of these muscles are responsible for gross movement in the lumbar spine (internal and external oblique, rectus abdominus and longissimus) some of the global muscles can also contribute to stability of the spine. The co-contraction of these muscles can also help with the support of the spine.

The level that the core contributes to dynamic stability has not been researched extensively. The ability for the core musculature to stiffen the spine and control gross movement of the torso has been thought to contribute to spinal stability. It has been shown that in both lower extremity and upper extremity movements the core musculature pre activates in anticipation of forces being applied to the spine.[32] This could show that possible strengthening or training of the core can help contribute to an overall increase in dynamic stability.[33] This could be attributed to an stabilization of the spine while allowing enough movement to properly complete the task. It could also be attributed to the ability of the core musculature to control the momentum of the torso and upper extremity. This can eliminate excessive forces on the lower extremity. Another possible improvement could be in the strength of the muscles in the forces acting in the sagittal, frontal and transverse planes. Since the SEBT measures are performed in these planes,
possible strengthening and coordinating of the core musculature could help control those forces. The last possible way that training the core could improve dynamic stability could be through stabilizing the spine and giving the lower extremity a stable base through which to control the forces of the landing from.

Kahle and Gribble[12] tried to use a core strengthening program to increase dynamic stability measured using the Star Excursion Balance test. The results showed no significant difference in the performance between the control group and the experimental group.

The possible problem with this study was in the exercises chosen to increase the core strength and stability. The exercises chosen used either a double leg base of support or were isotonic contractions. The Star Excursion Balance Test is a unilateral movement with much of the motion happening in the lower extremity and the core requiring mainly isometric contraction to provide stability to the spine. For optimal performance in core activities the training regimen must include training specificity.[34] By using a more specific training model an improvement may be elicited.

Sato and Mokha[33] also used a core stability training program to try and increase dynamic stability in the core. They were interested in the affects of core stability on dynamic stability in relation to decreasing ground reaction forces in runners. They also used the Star Excursion Balance Test to test for dynamic stability. The results showed a significant increase in scores in the Star Excursion Balance Test in training for both the core stability training group and the control group. The core stability training group did increase its score on the test more than the control group but not to a significant effect.
These are two studies which show a non-significant increase in dynamic stability using the star excursion balance test. The exercises chosen in both studies seemed to be exercises geared towards hitting every muscle in the core rather than a training regiment specifically designed to increase aspects of core stability in the test given. Sato had multiple dependant variables that were being tested and therefore couldn’t design a study around any one particular variable to possibly increase. Review of the study indicates the main focus was increasing performance in running, which a significant difference was found. The increase in running performance did not include a decrease in group reaction forces or a significant increase in Star Excursion balance Testing. Kahle and Gribble[12] focused on just increasing overall dynamic stability using the Star Excursion Balance test. With the three reach distances all being in a different direction it would have fully challenged the core in its ability to assist dynamic stability. With seven of the ten exercises chosen by Kahle and Gribble[12] focused on strengthening the flexors of the abdominal wall perhaps dynamic stability had been able to increase in the posteriomedial reach distance but not in the medial or anteriomedial reach. For core stability training to increase dynamic stability the aspects of core stability must be taken into account as well as specificity for the activity being done.

2.3 Core Stability

Kibler et al[5] defined core stability as “the pre-programmed integration of local, single joint muscles and multi-joint muscles…” Borghuis et al. described core stability as “Core stability is related to the body’s ability to control the trunk in response to internal
and external forces.”[3] This integration of core musculature is used to both stiffen the spine to allow it to accept loads and produce gross movement of the entire core structure. This shows that there are multiple areas of core stability to be considered. This major interest in core stability started with the concept of the neutral spine being very important in the San Francisco Spine Institute’s manual title *Dynamic Lumbar Stabilization Program.[35]*

Core stability can be categorized into three categories. These categories are the passive, active and neural aspects of the body.[27, 36] All three of these categories must be functioning at some level to be able to produce any kind of stability. As the intensity of an action increases so can the demand in one or multiple of these areas. A deficit in one or more of these areas can also have lingering effects on core stability.

The passive system of dynamic stability can be categorized by the bones, ligaments, tendons and connective tissue that connect the body. These tissues can’t be actively controlled by the neural system but can still provide a resistance to forces and motions that may compromise dynamic stability. The resistance these tissues can provide against a force is minimal. In a cadaver spine with intact ligaments and bones, but no muscles, the structure will fail under loads greater than twenty pounds.[25, 28, 29, 37] This system of the body can’t be trained through traditional exercise to be able to increase dynamic stability.

The active system of dynamic stability refers to the muscles of both the global and local muscular systems. This tissue can be actively contracted to put opposing forces on bones and ligaments to further resist forces that may affect dynamic stability. These
muscles can also manipulate tissues they are connected with to further enhance the passive stability of the core. This system is able to be trained by increasing the strength and endurance of these muscles core stability could be increased.

The neural system of core stability is made up of the Central Nervous System (CNS) and the Peripheral Nervous System (PNS). This system is able to process the forces acting both internally and externally on the body and control the active system at an appropriate level of intensity to resist the forces that threaten dynamic stability. This is very important for dynamic stability. Borghuis et al. stated that “Efficient movement function and the maintenance of balance during dynamic tasks are more complex than merely adequate force production from core muscles”. [3] For this to occur every muscle action must be coordinated appropriately at the right time and with the right amount of force to produce the motion or stabilization needed. [6, 38] There is also an inverse relationship between the length of time and the amount of postural stability. [32]

In relation to dynamic stability the endurance of the core musculature has often been thought of as a possible predictor for injury. It has been shown that core stability and proprioception has been an indicator for lower extremity injury it has not been shown if CST can increase scores in core endurance tests. McGill et al. [10] devised 4 tests to test for core endurance. These tests involve a test for the anterior, posterior and bilateral musculature endurance. These tests can show the muscular endurance in just the global musculature of the core. Stanton at al. [39] also references a test for core stability as well as showing that core stability training has a positive effect on this test. As was stated earlier despite not being able to control the individual spinal segments the core muscular can contribute to overall core stability by increase in intra-abdominal pressure and by co-
contraction. The question this study is hoping to answer is if an improvement in core stability endurance can be accomplished in 4 weeks of core stability training.

2.4 Dynamic Stability and Core Stability

The argument that improving core stability will enhance dynamic stability has been made.[6, 40-42] The ability of the body to maintain dynamic stability requires the neuromuscular control of all segments to the joint in motion, both proximal and distal. The core of the body reacts from disturbances in dynamic stability by transferring forces through the trunk using the core musculature.[42] According to Zazulak et al.[42] “Core stability, as generally defined in the sports medicine literature, is a foundation of trunk dynamic control that allows production, transfer, and control of force and motion to distal segments of the kinetic chain.” Panjabi [43] defines it as “the capacity of the stabilizing system to maintain intervertebral neutral zones within physiological limits” This establishes a possible link between the body’s core stability, which is specifically the core musculatures ability to stabilize the spine, and the body’s ability to stabilize in dynamic movement.

To further emphasize this point Zazulak et al. published 2 papers[6, 42] showing an increase knee injury rate in female athletes who scored lower on proprioception and neuromuscular control of the trunk. In the first paper dealing with the effects of core proprioception they attached subjects to a chair that stabilized all body segments and produced a rotation force at the L4-L5 junction.[6] Subject’s auditory and visual cues from the apparatus were cut off. The subject then had to press a button when they
believed their core had been rotated into a neutral position. It showed a significant
difference in the degrees of rotation in the active proprioceptive repositioning, which
involved the subjects to actively bring themselves back to 0 degrees of rotation and hit a
button when they felt they were there, between those female athletes that injured their
knee or specifically injured their meniscus.

The second study dealt with the athlete ability to control their core musculature
after sudden release from a perturbing force.[42] The subjects were placed in a custom
built chair that limited all motion of the hips and legs. The subjects were attached to a
quick release magnetic release system. They were then made to resist against 30% of
their Maximum Voluntary Contraction (MVC). The subject would resist and at a random
time the quick release system would release. The subjects were measured for the amount
of displacement seen in their core after sudden release of the perturbing force. It was
found that there was a significant difference between the subjects that sustained knee
ligament and meniscal injuries and the subjects that did not in the displacement of the
core.

These two studies show that there may be a relationship between the stability of
the body’s core and the overall dynamic stability. Furthermore they show that it is
possible that by increasing core stability that lower extremity injuries could potentially be
prevented. With the SEBT measure being a test of lower extremity dynamic stability, an
increase in core stability could increase the reach distance healthy subjects are able to
achieve.

In order for core stability to positively affect dynamic stability a few components
have to be met. The spine must be stiffened and stabilized in this stiffened position to
allow for control of the weight in the torso and upper extremity. This control is important for ensuring that the center of gravity in the individual does not exceed the base of support and result in instability. The core must also be able to allow for mobility of the spine at appropriate times in the movement to allow for correct movement patterns and proper absorption from forces acting on the body, both internal and external. This is appropriate because as the position of the body changes the position of the spine will need to change as well. Excessive stiffness of the spine will not allow for this change and can result in abnormal biomechanical compensations to this. Too little stiffness in the spine will not create a stable base for movement. The core muscles must be able to control this balance between spinal stiffness in mobility. Lastly the core must provide a stable base in order for lower and upper extremity muscles to pull against. These include the gluteals, hamstrings and hip flexors for the lower extremity and the latissimus dorsi of the upper extremity. This stable base for contraction is important for overall control of dynamic stability. It is also important for force generation, from the lower or upper extremity,[22, 44-46] for movements in both ADL and sport scenarios. Core stability training has been shown to increase performance in vertical jump exercises, showing that an increasingly stable base to contract against could increase overall force production in the lower extremity.[47, 48]

Myer et al.[49] performed a study which tested the effect of plyometric training versus dynamic stability and balance training on various aspects of female athletic performance. In the study the group that underwent dynamic stability and balance training decreased the standard deviation of the center of pressure data in the medial/lateral direction in a single leg hopping exercise. In this dynamic stability training
core exercises on an unstable surface which included both use of a Swiss ball and bridging exercises. While the training also included balance the potentially for core stability exercises to increase dynamic stability still exists.

In another study by Kaji et al.[22] subjects were split between a core stability training group and a control group and tested for postural sway in a quiet standing exercise. Results from this study showed that subjects who performed stability exercises showed a decrease in Medial Lateral (ML) sway, ML sway standard deviation, Anterior Posterior (AP) sway speed, ML sway speed, combined sway speed and sweep speed. The result of this was an acute affect of the core stability training. The post-measurement was taken only one minute after execution of exercises. This study while not increasing stability in a dynamic activity still shows an increase in stability with the use of core stability exercises.

2.5 Exercises

Instability training is best for training the local muscles of the core.[50] By training the muscles to incorporate proper stiffness in the spine as well as against instability in similar movements the core musculature can be programmed to activate accordingly to prevent instability of the spine or upper extremities to affect the overall dynamic stability of the body. Many clinical practices try to incorporate strengthening into the development of core musculature using core instability exercises. The need for this is usually not necessary as it takes as little as one to twenty-five percent of MVC of the core muscles to provide sufficient stability to all motions.[3, 51] Incorporated with
the overall strengthening of the extensors of the spine as well as the transverse abdominus which is important for increasing intra-abdominal pressure the endurance of all the global movers of the lumbar spine must be considered. The transverse abdominus is very important for overall spinal stability and stiffness. Training the transverse abdominus is important for the ability of the core musculature to “brace”. [4] The program assigned for an increase in core stability should also be gradual in progression and focus initially on maintaining a neutral spine, then activating and maintaining a neutral spine under external loads and finally using dynamic and sport specific movements to train the core in the motions and maneuvers needed. [4, 7, 8] The use of unilateral resistance movements or resistance movements on unstable surfaces with lighter weights can also be utilized to enhance the stability and neuromuscular function of the core. [7]

Some have hypothesized that endurance in core musculature is more important than strength. [7, 8, 27, 52] This is likely because the previously established need for activation of the core musculature to achieve spinal stability is minimal. For dynamic stability endurance may not play a great role unless the body is already fatigued. Madigan and Pidcoe [53] examined this in their study which looked at joint kinematics in a fatigue landing scenario. The subjects performed two single leg landing activities and three single leg squats. They repeated this cycle until the subjects felt fatigued. Force plate and electromagnetic motion analysis was used to capture ground reaction forces and kinematic data. The results showed a significant difference in the knee and ankle flexion as the body became fatigued.

This shift in maximum joint angle with fatigue is similar to the excessive knee flexion seen in subjects with compromise dynamic stability due to chronic ankle
instability.[54] These changes in kinematic data can be cause for a compromised in
dynamic stability or even injury. The higher endurance core musculature might have in
relation to this kind of fatigue might be able to provide better core stability in the areas of
a stiffened spine or stable base for lower extremity musculature to contract against. As it
was discussed earlier in this paper the stability training allowed for a more forceful
vertical jump.[47] This same stability might be able to be used in eccentric contractions
to control the center of gravity of the body to improve overall control during a fatigued
state.

The ability for the muscles to be able to produce multiple strong contractions to
ensure a stable spine during movement such as the reach distances seen in the SEBT
measurement may be of some concern when measuring dynamic stability. It is important
in developing exercises for core stability to focus on the endurance of both the local and
global musculature. It is also important to make movements as specific as possible to the
exercise being performed. This includes training the core muscles to maintain a stiffened
and supported spine as well as a stable base for the lower extremity to contract against in
a unilateral movement. Lastly the training of the core musculature must be done in a way
to emphasize the decrease base of support that the body has during a single leg reaching
task.

2.6 Conclusion

The role that core stability plays in dynamic stability has been explored here.
There are several factors in the core musculature that could enhance dynamic stability
and the literature related to this is conflicted. Some of the problems related to research on the core are centered in the lack of consistency on what is considered the core and what is not. There is also inconsistency on what is considered to be the most important components of core stability training. The possible role that core stability can play in dynamic stability and how much core stability training can affect this is still being discovered. The hopes of this current study are to determine if a four week core stability training protocol can decrease time to stabilization measurements and increase global core muscular stability.
Chapter 3:

Methods

3.1 Experimental Design

This was a randomized control trial using a 1-within, 1-between study design, with 2 independent and 8 dependant variables. Group and Time were the independent variables. Three reach distances with the SEBT (anterior, posteriolateral and posteriomedial), a core stability test and global core muscular endurance tests (flexor, extensor, right and left bridge) will provide the dependant variables.

3.2 Subjects

The number of subjects were Core Stability Training=15 and Control=15. Subjects were college aged females (18-29). Subject demographic data is presented in Table 1. All subjects performed the Sahrmann core stability tests and only subjects with a core stability score of 1 or less were admitted into the study. Subjects were without a previous history of injury that would affect dynamic stability. Subjects were also free of any medical condition that might have been worsened by participation in this study. The number of subjects was determined from sample sizes used in a previous study.[12]
3.3 Instrumentation

A Custom Built Star Excursion Balance Testing mat was used to record reach distances. A Custom constructed wedge with angles at 60 degrees was used for the muscular endurance tests. (Appendix C) A Prestige Medical adult blood pressure cuff was used for the Sahrmann Stability Test.

3.4 Procedures

Subjects completed a health history form prior to this study. The health history form was used as a pre-participation screening in order to exclude subjects who may be at risk. On the form, participants were asked if they have had any lower extremity injuries, balance disorders or concussions. Approved subjects were then asked to read and sign an informed consent form and were assigned an identification number to ensure confidentiality. During the study, the subject’s number was used for identification purposes instead of the subject’s name.

In the Athletic Training Research Laboratory at the University of Toledo, subjects were allowed ten minutes to stretch or warm-up as needed, followed by the Sahrmann core stability test. Subjects were given 2 minutes rest after the Sahrmann test and then asked to perform the SEBT. Subjects were given 4 practice trials before testing began.[14] Subjects were then tested in the SEBT. Up to one minute rest was given in between reach directions.[14] After engaging in the SEBT subjects were tested using the Global Muscular Endurance tests. The Endurance Tests tested flexor, extensor and side
bridging endurance. Three to five minutes of rest were given in between the tests to allow for recovery. This was the pre testing session. These tests were administered 5 weeks after the subjects were initially tested. For the training group this coincided with the week after the last training session. Each testing session took approximately one hour to complete.

3.4.1 Sahrmann Stability Test

Subjects were positioned supine on a table. An inflatable pad was placed under their lordotic curvature and inflated to 40 mm Hg. The test involved 5 levels and subjects were given a rating based on which levels they could complete.[39]

Level 1: The subject was lying with their arms and legs flat on the table. The subject activated the abdominal musculature to brace the trunk without any movement occurring. The subject then raised one leg to 100 degrees of hip flexion with a comfortable knee flexion. The opposite leg was then brought into the same position with a change of no more than 10 mm Hg. This served as the starting position for all other levels. If a subject was only able get one leg into position without a change of 10 mm Hg or more the subject receives a score of 0.5. If a subject was not able to get any legs into position they received a score of zero.

Level 2: From the start position the subject slowly lowered 1 leg until the heel touched the table. The subject then fully extended the knee and returned to the starting position.
Level 3: From the start position the subject lowered one leg until it was 12 cms above the ground. The leg was then fully extended and then returned to the starting position.

Level 4: From the Start position the subject slowly lowered both legs until the heels touched the ground and then the legs were slid out until fully extended. The legs were then returned to a starting position.

Level 5: From the start position both legs were lowered until 12 cms above the ground. The subject then extended both legs fully and returned to the starting position.

To move onto the next level the task had to be completed without more than a 10 mm Hg change in the inflatable pad under the subject’s back. Pictures of this test are provided in Appendix B.

3.4.2 Star Excursion Balance Testing (SEBT)

The subjects then performed the Star Excursion Balance Test for dynamic stability. The SEBT grid consists of 3 tape measures attached to the ground at 135 degrees between the posterior lateral and posterior medial compared to the anterior and 90 degrees between the posterior lateral and posteriomedial reach distances. A picture of the SEBT grid is provided in Appendix C. The subject performed a single leg stance in the middle of the grid, their stance leg on the Anterior-Posterior reach direction lines. The subject was then asked to reach with their non-weight bearing leg as far as they could along a reach direction. For this study this included the anteriomedial, posteriolateral and
posteriomedial reach directions. The subject reached as far as they could while maintaining their balance, touching down lightly with the most distal part of their foot and then returned to the starting position. The subject then performed 4 practice reaches in each reach direction. After a two minute rest, 3 reach trials were performed in each direction with a 30 second rest between attempts and 1 minute rest between reach directions. If the subject touched down with the whole non-weight bearing foot, moved the stance leg from starting position or was unable to regain starting position after touching down the subject had to perform the trial again.

The leg length of the stance leg was measured with the subject on a plinth from the ASIS down to the base of the medial malleolus.[55] This value was used to normalize the reach distances.

### 3.4.3 Global Muscular Endurance tests

Subjects then performed a flexor endurance test, an extensor endurance test and a right and left side bridge test.(Appendix A) [10] For the Flexor Endurance test the subject leaned against a wedge at a 60 degree angle. The subject had their feet on the floor and knees and hip at 90 degrees. Arms were crossed over the chest. The wedge was then pulled back 10 cm and the subject had to maintain position as long as possible. The position was considered not being maintained when the subject touched the wedge again. The subject was be timed with a stopwatch and was measured for the number of seconds they were able to maintain the position
The Extensor endurance test was performed by having the subject lie prone on a table with their feet, legs and hips anchored to the table. The subject’s upper body was extended in a cantilever fashion over the edge of the table. Arms were crossed over the chest. A surface was 25 cms below the edge of the table and the subject’s body rested on this until the test started. The subject was instructed to achieve a position parallel to the testing surface and hold this for as long as possible. Time in seconds was measured by a stopwatch again and time was stopped when the subject touched the resting surface again.

The side bridge was performed once on each side. The subject lay on their side on a mat. They were allowed to have their top foot in front of the lower foot for support. Subjects were instructed to lift their hips off the mat and try to achieve a straight line over the length of the body. A straight line was determined and instructed by the tester. The subject supported themselves on the bottom elbow and the feet. The uninvolved arm was crossed over chest. The subject was timed in seconds using a stop watch and time was stopped when the subject’s hips touch the mat. Three to five minutes were given between each endurance test to allow full recovery.

After pre-testing, each subject was randomly assigned to either the Core Stability group or Control group. The investigator familiarized all subjects with the total number of exercises and proper techniques. Two days after pre-testing the subjects in the Core Stability group began the exercise protocol. The program lasted for four weeks, with the exercises performed three times a week and lasting approximately one-half hour each session. All subjects were asked to not change their exercise habits for the duration of the study.
Post-testing consisted of the same testing protocol as the pre-testing session and took place within a week of completion of the exercise program. The subjects of the core stability group had to attend ten of the twelve (83%) of the exercise sessions to be included in the analysis of the study.

### 3.4.4 Core Stability Exercises

The core exercise incorporated several muscle groups in each exercise. The exercises included bridging (both sides, prone and supine) on one leg, Back extension on a physioball, supine knee raise with physioball under shoulders, Seated marching on the physioball ball with opposing arm and leg action, Lunges onto an unstable surface and single leg squats. The subjects performed the bridging for 15 seconds on the side and supine bridging and 25 seconds on the prone bridging with a progression of 5 seconds in the 3rd and 4th weeks. Two sets of each bridging were completed with 1 minute rest in between sets. Subjects performed seated marching and supine knee raise for 20 seconds per set, 2 sets with 5 seconds added in the 3rd and 4th weeks. One minute rest was given between sets. Subjects performed 12 reps per set for the back extensions, single leg squats and lunges for 2 sets. Week 3 they progressed to 15 reps and week 4 they progressed to 3 sets at 12 reps per set. One minute rest was given between sets.

The pre-and post-testing sessions and the exercise interventions were performed in the Athletic Training Research Laboratory at the University of Toledo under supervision by the primary investigator.
3.5 Statistics

Microsoft Excel was used to record the subject’s assigned identification number along with personal data such as sex, age, height, mass, dominant leg and data collected during all testing sessions. After all of the data have been collected, the information was entered into the SPSS for Windows (version 17.0, SPSS Inc, Chicago, Il) statistics program. For the statistical analysis of the data, descriptive statistics for the means and standard deviations for the group demographics were compared with simple t-tests to ensure homogeneity of the groups. Baseline data were compared between groups using independent samples t-tests. There were no significant differences between groups. (Table 1) Therefore for each dependant variable the differences between the pre and post test were calculated and then compared between the groups using an independent t-test. Significance was set a priori at p < .05.
Chapter 4

Results

4.1 Baseline

Groups were not statistically significant at baseline across all baseline test and subject demographics. Table 1 shows all baseline measurements as well as statistics.

Only 13 subjects in the core stability training group and 14 subjects in the control group qualified for post testing. Of the two subjects eliminated in the intervention group neither completed the number of training sessions necessary to qualify for post-testing with one completing only 9 and the other completing only 8. The subject eliminated from the control group revealed to the investigator that after the initial testing session she began an exercise regime.
Table 1.1: Baseline Measurements and Statistics

<table>
<thead>
<tr>
<th>Group#</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Sig.</th>
<th>Effect Size</th>
<th>95% C.I. Lower, Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight(Lbs)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Int</td>
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<td>.138</td>
<td>-.59</td>
<td>-1.34, 0.20</td>
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<tr>
<td>Con</td>
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<td>35.02409</td>
<td>35.02409</td>
<td>.138</td>
<td>-1.34, 0.20</td>
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<tr>
<td>Height(inches)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Int</td>
<td>64.4231</td>
<td>2.49872</td>
<td>.121</td>
<td>-.61</td>
<td>-1.37, 0.18</td>
</tr>
<tr>
<td>Con</td>
<td>66.0357</td>
<td>2.70658</td>
<td>66.0357</td>
<td>.121</td>
<td>-1.37, 0.18</td>
</tr>
<tr>
<td>Leg Length(Cm)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Int</td>
<td>78.7692</td>
<td>4.87175</td>
<td>.125</td>
<td>-.61</td>
<td>-1.36, 0.18</td>
</tr>
<tr>
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<td>4.30052</td>
<td>81.5714</td>
<td>.125</td>
<td>-1.36, 0.18</td>
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<td>Sahrmann Test(lvl)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Int</td>
<td>.1154</td>
<td>2.1926</td>
<td>.169</td>
<td>-.54</td>
<td>-1.24, 0.29</td>
</tr>
<tr>
<td>Con</td>
<td>.2857</td>
<td>.37796</td>
<td>.2857</td>
<td>.169</td>
<td>-1.24, 0.29</td>
</tr>
<tr>
<td>Anterior reach(%)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Int</td>
<td>61.24</td>
<td>5.93</td>
<td>.489</td>
<td>-.28</td>
<td>-1.03, 0.49</td>
</tr>
<tr>
<td>Con</td>
<td>63.38</td>
<td>9.36</td>
<td>63.38</td>
<td>.489</td>
<td>-1.03, 0.49</td>
</tr>
<tr>
<td>PosterioLat reach(%)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Int</td>
<td>96.37</td>
<td>7.491</td>
<td>.210</td>
<td>-.49</td>
<td>-1.24, 0.29</td>
</tr>
<tr>
<td>Con</td>
<td>100.20</td>
<td>7.964</td>
<td>100.20</td>
<td>.210</td>
<td>-1.24, 0.29</td>
</tr>
<tr>
<td>PosterioMed Reach(%)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Int</td>
<td>95.84</td>
<td>6.69</td>
<td>.110</td>
<td>-.65</td>
<td>-1.40, 0.15</td>
</tr>
<tr>
<td>Con</td>
<td>100.28</td>
<td>7.197</td>
<td>100.28</td>
<td>.110</td>
<td>-1.40, 0.15</td>
</tr>
<tr>
<td>Flexor Test(sec)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Int</td>
<td>189.9231</td>
<td>87.51330</td>
<td>.742</td>
<td>0.13</td>
<td>-0.63, 0.88</td>
</tr>
<tr>
<td>Con</td>
<td>178.8571</td>
<td>84.90797</td>
<td>178.8571</td>
<td>.742</td>
<td>-0.63, 0.88</td>
</tr>
<tr>
<td>Extensor Test(sec)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Int</td>
<td>157.1538</td>
<td>84.38982</td>
<td>.562</td>
<td>0.23</td>
<td>-0.54, 0.98</td>
</tr>
<tr>
<td>Con</td>
<td>140.5</td>
<td>62.04682</td>
<td>140.5</td>
<td>.562</td>
<td>-0.54, 0.98</td>
</tr>
<tr>
<td>R.Bridge Test(sec)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Int</td>
<td>78.2308</td>
<td>21.61849</td>
<td>.747</td>
<td>0.12</td>
<td>-0.63, 0.98</td>
</tr>
<tr>
<td>Con</td>
<td>75.2143</td>
<td>26.08618</td>
<td>75.2143</td>
<td>.747</td>
<td>-0.63, 0.98</td>
</tr>
<tr>
<td>L.Bridge Test(sec)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Int</td>
<td>75.4615</td>
<td>20.42717</td>
<td>.492</td>
<td>0.27</td>
<td>-.5, 1.02</td>
</tr>
<tr>
<td>Con</td>
<td>68.7143</td>
<td>28.82688</td>
<td>68.7143</td>
<td>.492</td>
<td>-.5, 1.02</td>
</tr>
</tbody>
</table>

*Reach directions were percentage of Leg length. Significance set at a priori level of (p=.05)

# Group labels and numbers Int=Intervention(n=13) Con=Control(n=14)
4.2 Differences Pre-Post between Groups

The difference in the change pre-post between the groups yielded 4 significant differences. The change in the Posteriolateral (\(p=.007\)) and Posteriomedial (\(p=.042\)) reach directions as well as the right (\(p=.021\)) and left side bridges (\(p=.002\)) were significantly different between the groups. Effect sizes for these were Posteriolateral E.S.=0.83(0.28,1.90) Posteriomedial E.S.=0.60(0.02,1.59), R.Bridge E.S.=0.95(0.13,1.71) and L.Bridge E.S.=1.33(0.46,2.11). Complete Statistics for all dependant variables can be found in Table 2.

Table 1.2: Pre-Post Difference Measurements and Statistics

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Sig.</th>
<th>Effect Size</th>
<th>95% C.I. Lower, Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sahrmann Test(lvl)</td>
<td>Int</td>
<td>.5</td>
<td>1.04083</td>
<td>.123</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>Con</td>
<td>.0357</td>
<td>.30786</td>
<td></td>
<td>-0.17,1.37</td>
</tr>
<tr>
<td>Anterior reach(%)</td>
<td>Int</td>
<td>2.93</td>
<td>3.315</td>
<td>.176</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td>Con</td>
<td>.49</td>
<td>5.448</td>
<td></td>
<td>-0.25,1.29</td>
</tr>
<tr>
<td>PosterioLat reach(%)</td>
<td>Int</td>
<td>9.58</td>
<td>6.457</td>
<td>.007*</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td>Con</td>
<td>2.23</td>
<td>6.634</td>
<td></td>
<td>0.28,1.90</td>
</tr>
<tr>
<td>PosterioMed Reach(%)</td>
<td>Int</td>
<td>5.27</td>
<td>7.181</td>
<td>.042*</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td>Con</td>
<td>-.99</td>
<td>7.906</td>
<td></td>
<td>0.02,1.59</td>
</tr>
<tr>
<td>Flexor Test(sec)</td>
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<td>208.81110</td>
<td>.135</td>
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<tr>
<td></td>
<td>Con</td>
<td>21.5714</td>
<td>100.49471</td>
<td></td>
<td>-0.19,1.35</td>
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<tr>
<td>Extensor Test(sec)</td>
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<td>51.21448</td>
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<td></td>
<td>Con</td>
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<td>R.Bridge Test(sec)</td>
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<td>.021*</td>
<td>0.95</td>
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<td></td>
<td>Con</td>
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<td>20.22090</td>
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<td>0.13,1.17</td>
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<tr>
<td>L.Bridge Test(sec)</td>
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<td>15.68153</td>
<td>.002*</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td>Con</td>
<td>-1.8571</td>
<td>18.46351</td>
<td></td>
<td>0.46,2.11</td>
</tr>
</tbody>
</table>
Chapter 5

Discussion

5.1 Summary

As we hypothesized there was an increase in dynamic stability with core stability training, although in only two of the three directions of the SEBT. There was a significant effect in the posteriolateral and posteriomedial reach directions, while in the anterior reach direction was not statistically different. The second hypothesis stated that an increase in core muscular endurance would be seen with core stability training. This is true for the right and left side bridge tests which showed significant increases; however the flexor and extensor endurance tests were not significant. As with the anterior reach direction of the SEBT the Sahrmann Stability Test, flexor and extensor endurance tests showed non-significant increases.

5.2 Sahrmann Stability Test
The pre-post results of the Sahrmann Stability test were not statistically different when the difference pre-post between the intervention and control groups were compared. (Table 2) There was a moderate effect size, yet, the confidence interval crossed zero. (Table 2) A possible explanation for this lack of significant difference in the Sahrmann Stability Test measure was a lack of standardization for practice trials or instruction to the subject. Stanton et al [39] details the procedure for the Sahrmann stability test and gives an excellent reliability coefficient of 0.95. This article [39] did not specify potential for a learning curve to the test based on trials. The possibility for poor scores of this test may not be associated with a lack of core stability, but rather a lack of familiarity and understanding of the function. All subjects had the test explained and demonstrated to them by an investigator. All leg motions in the Sahrmann Stability Test are done with as much knee bend as feels comfortable to the subject. Some subjects even after being shown the test with comfortable knee bend still began the initial movement with a straight leg raise. This will cause a flattening of the spine changing the pressure on the pressure sensor underneath the lower back very dramatically. By initiating the motion in this way flexibility of the hamstrings may also have become an issue. Other subjects would initiate the motion very quickly and this may have affected the scores on the test. Without standardization of practice trials or specific instruction to subjects other factors such as flexibility or a poor strategy adopted to perform the task may interfere with the measure of core stability.

Stanton et al. [39] was able to produce a significant pre-post effect on the Sahrmann Stability Test as well as a prone stability test using a 6 week core stabilization program. This also suggests that the reason for a lack of significance in the stability test
in this study may be due to a training period that was too short, 4 weeks compared to 6, or not of sufficient intensity, as the two studies used different core stability interventions. With our current study using only females and Stanton et al.[39] using only males as well as the core stability interventions being different, the comparisons between the two may be difficult to assess.

The effect size may have been affected by the large standard deviations in the intervention subjects’ score; 1.04083 levels compared to .30786 levels in the control group. Possibly by increasing numbers in the groups a true effect size might become more apparent, if the standard deviations could have been condensed.

5.3 Anterior Reach Direction

The anterior reach direction in the SEBT was also non-significant between groups with a moderate effect size that had confidence intervals crossing zero. (Table 3) Studies have noted that a decrease reach distance due to fatigue or injury has been due to a lack of flexion in the knee.[15, 17] With an increased knee flexion subjects must also have enough eccentric quadriceps strength to support their body as well as sufficient dorsiflexion in their ankle to allow to knee to flex. The intervention’s aim in this study was to increase the core musculatures neuromuscular control to allow for optimal movement and control of the spine. This ability to control the spine may have been less active in the anterior reach direction because of the lack change in the position of the upper body and the angles in the lumbar vertebrae. The intervention did not focus on
increasing eccentric quadriceps activity or flexibility in the ankle which may be the two most important factors in being able to reach in the anterior direction.

5.4 Posteriolateral and Posteriomedial Reach Directions

Both the Posteriolateral and the Posteriomedial reach performances increased significantly pre-post in the intervention group when compared to the pre-post change of the control group.(Table 2) These comparisons had strong associated effect sizes (posteriolateral reach: d=1.12; posteriomedial reach: d=0.83), with confidence intervals that did not cross zero.(Table 2) Gribble et al.[15] noted that in the posterior reach directions that a decrease in hip flexion may have accounted for decreased maximal reach distances in the posterior direction for subjects with chronic ankle instability (CAI). This decrease in hip flexion could be attributed to a decrease ability for the spine to actively stiffen and support the mass of the upper body as it is moved in the sagittal plane to account for the distribution of weight that needs to be achieved to maintain the center of gravity within the narrowed base of support during the reach distance task. Reaching into the posteriolateral and posteriomedial directions is achieved as one integrated motion involving the frontal, sagittal and transverse planes. It appears that the core stability intervention may have helped facilitate this coordinated movement. Further research may need to quantify the specific patterns of muscle activation that would help to explain this performance improvement.

To allow the foot of the reaching limb to reach down the posteriolateral direction the hip must externally rotate on the fixed stance limb. To counteract the displacement
this internal rotation has on overall stability, the lumbar spine must side bend and rotate in the direction of the stance limb. This is an eccentric contraction of the obliques and erector spinae group on the stance leg side. During the task performance, arm movements are controlled by having them remain on the hips; potentially placing more reliance on maintenance of the center of gravity with motion at the lumbar spine. As stated before, to allow maximum reach distance the body must be displaced in the frontal and sagittal planes. In the sagittal plane the lumbar spine must flex to account for the posterior movement of the reaching leg as well as the flexion of the hip to allow the reaching leg to extend as far back as possible. The extension of the reaching hip and the flexion of the reaching hip must be accounted for by flexion of the lumbar spine. This flexion must be supported by an eccentric muscle contraction of the erector spinae and local stabilizer multifidus.[43, 56] It is possible that all spinal stability in these motions would come from the eccentric contractions of these muscles with contribution of increased abdominal pressure during the farthest reaching point to enhance spinal stability. This increase in spinal stability might be useful during the farthest reach distance and would necessitate either the use of the transverse abdominus or co-contraction of the entire lumbar spine musculature. A study by Grenier and McGill[57] would suggest that abdominal bracing through co-contraction might be used to stiffen the spine, but the ability for the spine to move through the range of motion needed to allow the subject to reach as far as possible might be compromised by this action. While stiffening of the spine through this activity might help at the most difficult position of the reach distance eccentric contractions of the lumbar musculature would account for the control of the mass of the upper body during the motion.
Through training an increase in the control of the extensor musculature of the lumbar spine as well as an increase in the ability of the obliques and erector spinae group to properly support the spine in the rotated and lateral flexed position could account for the increased reach distances in this direction.

As explained for the posteriolateral direction, an increase in hip flexion is needed in the posteriomedial direction.[15] In this direction the need for a strong eccentric extensor contraction is needed for the body to offset the reaching leg. The body must also compensate for the reach by laterally flexing over the stance leg. This once again must be done in a manner allowing the spine enough motion to achieve the desired position to offset the mass distribution of the reaching leg while also keeping the spine stiff enough to transfer forces acting on the body across the kinetic chain.[3]

As seen in the posteriolateral direction training of the extensor core musculature, as well as the neuromuscular control of the lateral flexors and local stabilizing muscles, might improve the body’s ability to maintain the center of mass over the base of support.

5.5 Sagittal Plane Endurance Tests (Flexor & Extensor)

The changes pre-post in the flexor and extensor endurance tests showed non-significant values when compared between groups. The effect size for the flexor test was moderate ($d=0.60$) and for the extensor test was weak ($d=0.30$) with both confidence intervals crossing zero. (Table 2) There are two possible explanations as to why this occurred. The first explanation is that the intervention was developed as mainly a way to
increase core stability. Aside from the planks, the intervention focused very little on isometric contractions and was not specific enough to elicit a training response. The second explanation is that the intervention was not of sufficient intensity or volume to increase these tests. With the intervention group having averages of 189 seconds in the flexor and 157 seconds in the extensor the maximum training for endurance activities, the prescribed intervention of 2 sets of 35 seconds for the front plank and 2 sets of 30 seconds for the back plank may not have been enough to cause the subjects to improve to a significant level.

5.6 Frontal Plane Endurance Tests (Right and Left Side Bridge)

The difference pre-post between the intervention group and the control group was statistically significant. (Table 2) The effect sizes for these tests were strong for both the Right Bridge \((d=0.95)\) and the Left Bridge \((d=1.33)\). The significance in these activities as opposed to the non-significance in the frontal plane activities may be explained by the frequency of the training intensities. The Right Bridge and Left Bridge averages in the intervention groups were 78 sec. and 75 sec. and the maximum training stimulus for endurance was 2 sets of 25 seconds. Perhaps this was of significant intensity to elicit a training effect. Another explanation to the increase is that the activity of the side plank may be stressful to the shoulder and the subjects in the intervention group were able to acclimate to the discomfort or stress on the shoulder over the intervention which allowed them to hold the position longer than the control. The difference in significance between
the left and right side could be explained by 10 of the 13 intervention subjects being right
foot dominant. This might lead to a less effective training effect on the right side due to
the right side being at a higher pre-intervention level than the left. Further research on
core stability training may need to consider the influence of limb dominance.

5.7 Core Stability Training and its Effects on Dynamic Stability

It has been shown that scores on core proprioceptive and neuromuscular control
tests could be predictors for lower extremity injury.[6, 42] There is also evidence that the
SEBT could be used as a lower extremity injury predictor.[2] It has also been shown in
this study and by Kahle and Gribble[12] that core stability training can have an effect on
dynamic stability using the SEBT. The core could be a key to either predicting injury or,
through intervention could be trained as a way to prevent injury. The core links the upper
body mass with the lower extremity and failure to be able to properly control the core
could lead to excessive forces being applied to the lower extremity which could result in
injury. Factors to consider with this are not just the ability for the core to properly
stabilize the spine and control the trunk but also its ability to do so in a fatigued scenario.
Abt et al.[58] showed that after a fatigue protocol the kinematics of a cyclist lower
extremity are changed. This may also be true in activities that would involve more weight
bearing and theoretically involve a higher activation of the core to maintain proper form.
A deficit in neuromuscular control or endurance in the core could be a cause behind acute
and overuse non-contact lower extremity injuries.
5.8 Conclusions

The evidence has shown that core intervention training can be successful in increasing overall dynamic stability in tasks that might require more coordination of the core musculature to displace and control the upper body mass. There is evidence here and in other studies that by just training the core overall dynamic stability can be positively affected with a strong magnitude of change. There is also evidence that a 4 week intervention might be enough to cause a significant training effect, with a strong magnitude of change in core global muscular endurance.

5.9 Future Research

Further research is needed in this area to be able to provide instruction and a determined number of practice trials for the Sahrmann stability test. Research is also needed to examine the kinematic and trunk muscle activation during the SEBT. Lastly a standard core stability training program that would produce significant results in core stability and core muscular endurance would help increase the reliability of studies utilizing a core training intervention.
References


Appendix A

Core Muscular Endurance Tests

A:
B:

Flexor endurance test. A is starting position. B is testing position with wedge pulled back 10 centimeters.[10]

Extensor endurance test.[10]
Side Bridge Endurance Test.[10]
Appendix B

Sahrmann Stability Test

First half of Level 1. Raise one foot up to 100 degrees flexion
Level 1 completed. This serves as the starting position for all other levels.

Level 2 involves touching one foot down on the ground and sliding it all the way out before bringing it back to starting position.
Level 3 involves bringing the foot down to 12 cms above the ground and extending the foot all the way before bringing it back to starting position.

Level 4 involves touching both feet down on the ground and slinging them out until they are extended and bringing it back up to starting position.
Level 5 involves bringing both feet down to 12 cms above the ground and extending the legs fully before bringing the legs up to starting position.
Appendix C

SEBT Mat

If the subject was left footed the Posterolateral and Posteriomedial directions were opposite.