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# Effects of Isolated Core Stability Training on Standing Static Postural Control, Recovery of Standing Postural Control and Kicking Velocity in Soccer Athletes

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Effects of Isolated Core Stability Training on Standing Static Postural Control,  
Recovery of Standing Postural Control and Kicking Velocity in Soccer Athletes.

By

Ali El-Kerdi, DPT, MS, PT, CAT(C), ATC/L, CSCS

Submitted in partial fulfillment of the requirements for the degree

Doctor of Philosophy

Department of Interprofessional Health Sciences and Health Administration

Seton Hall University

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Running Head: Effects of Isolated Core Stability Training on Standing Static 2  
Postural Control, Recovery of Standing Postural Control and Kicking Velocity in  
Soccer Athletes

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Postural Control, Recovery of Standing Postural Control and Kicking Velocity in  
Soccer Athletes

**SETON HALL UNIVERSITY**

School of Health and Medical Sciences

Department of Interprofessional Health Sciences and Health Administration

**APPROVAL FOR SUCCESSFUL DEFENSE**

Doctoral Candidate, **Ali El-Kerdi**, has successfully defended and made the required modifications to the text of the doctoral dissertation for the **Ph.D. in Health Sciences** degree during this **Spring Semester 2016**

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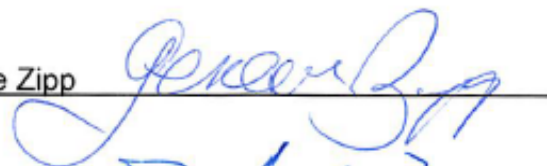
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Date: 3/28/16

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Date: 03/28/2016

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### DEDICATION

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**ABSTRACT**

Effects of Core Stability Training on Trunk Muscle Activation, Postural Control and  
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Ali El-Kerdi, DPT, MS, PT, CAT(C), ATC/L, CSCS

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**BACKGROUND:** About 1/3 of injuries are non-contact in nature and half of these involve the LE's. There are numerous anatomical and physiological mechanisms and systems involved in stabilizing the trunk for movement of the lower extremities. The ability of the trunk to maintain the position and motion of the trunk over the pelvis and LE's is predominantly accomplished via quick postural responses to internal and external forces. These pre-programmed postural responses are integrated within the neuromuscular system. It is theorized that poor core stability is a result of a failure in the neuromuscular system to support the trunk and pelvis over the lower extremities. Poor core stability has also been linked with an increased risk of lower extremity injuries. Poor core stability has also been linked to poor athletic performance via similar mechanisms. Current practice is to train the core in combination with the lower extremities. Improvements in athletic performance has been demonstrated. However, it is difficult to ascertain whether the improvements are due to changes in the trunk, the lower extremities or some combination thereof. Few studies have examined biomechanical measures of postural control following an integrated core stabilization training let alone an isolated approach to core stabilization.

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**OBJECTIVE:** To examine the reliability of the measurements and the effects of an 8-week isolated core stability program on trunk muscle activation, static and dynamic postural stability and kicking velocity in soccer athletes. **DESIGN:** Twenty division II and III soccer athletes (n=10 male, n=10 female) participated in a quasi-experimental randomized pre-post training study (n=10 control, n=10 experimental). The main outcomes were derivative of CoP and trunk muscle surface EMG normalized to %MVC for static postural control tasks TTS as a measure dynamic postural control and kicking velocity. **STATISTICS:** Reliability of the measures were assessed using ICC  $(_{2,K})$ , MDC (95%CI) and SEM's. Between and within group differences pre and post training were assessed using repeated measures MANOVA for static postural stability (CoP and EMG) and repeated measure ANOVA for dynamic recovery of balance and kicking velocity ( $p < .05$ ). **RESULTS:** Good to excellent ICC's with relatively small MDC and SEM's. Further, there was a reduction in CoP deviation and trunk muscle activation during postural control tasks, quicker TTS and increased kicking velocity following training as compared to controls. **CONCLUSION:** Static and dynamic postural control and kicking velocity improved in division II and III soccer athletes following an 8-week isolated core stabilization training. These results begin to elucidate to role of the core and the effects of core stabilization training on standing postural control and performance in athletes. These results have direct implications on clinical intervention for soccer athletes.

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**KEYWORDS:** Core Stabilization, Electromyography, Injury Prevention, Postural  
Control, Time to Stability, Soccer

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## I. INTRODUCTION

### **Background**

Post-traumatic arthritis is one of the most frequent causes of disability following joint trauma (Furman et al., 2007). It is estimated that 10% of Americans who have developed osteoarthritic joints have done so post-traumatically (MacKenzie et al., 2000; Segui-Gomez & MacKenzie, 2003). The development of posttraumatic arthritis may follow a variety of joint injuries but most commonly and predictably develops subsequent to fracture of the articular surface. Because trauma occurs more often in younger individuals, the preponderance of patients at risk for developing posttraumatic arthritis are younger and in the prime income earning years of their life (MacKenzie et al., 2000; Segui-Gomez & MacKenzie, 2003). It is estimated that the cost of injuries in the top five female and male high school sports is \$588 million dollars in direct expenses and \$6.6 billion dollars in indirect expenses each year (Hootman, Dick, & Agel, 2007). Although there are no comparable published estimates for collegiate-aged athletes, it is likely that the costs are similar because the injuries acquired and cost to treat them are similar. A recently published summary of injury surveillance data for 15 major college sports from the period covering 1988 - 2004 showed that a significant proportion of athletic injuries are non-contact in nature (27%) (Hootman et al., 2007). The majority of these injuries involved the LEs (54%) with a significant proportion of non-contact injuries involving anterior cruciate ligament (ACL) tears (Hootman et al., 2007). Further analysis of these data showed

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that soccer athletes acquired the highest percentage of LE injuries (male 69% and female 70%) as compared to other sports and that most of these injuries are non-contact in nature (Agel, Evans, Dick, Putukian, & Marshall, 2007; Dick, Putukian, Agel, Evans, & Marshall, 2007). Core stability training is widely prescribed clinically under the premise of non-contact injury prevention. However, there is little evidence to support this theory.

Core stability refers to the ability of the neuromuscular system to maintain (or return) the trunk in an upright position (Borghuis, Lemmink, & Hof, 2010). This is predominantly accomplished via quick postural responses by the neuromuscular system to both internal and external perturbations (Borghuis et al., 2010). There are integrated central mechanisms (feed-forward and feed-back loops) within the neuromuscular system that respond to these forces (Borghuis et al., 2010). Core stability is defined as the efficiency and capacity of the sensory and motor systems' ability to control the trunk (with the upper extremities) relative to the lower extremities in response to internal (muscle forces) and external perturbations (gravity, contact forces, friction, inertia, etc.) to the body. Core stability is also tied to the efficiency and timing of the anticipatory and feedback control systems which aide in maintaining or resuming an equilibrium position during challenges to posture or movements. Core stability training is accepted clinically for the prevention of non-contact injuries and improved athletic performance. Although core stability training is widely used in the sports arena, few reports have examined its effects on these claims.



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This paper explores the relationships and between core stability, athletic performance and standing postural control.

**Conceptual Framework**

Panjabi (1992) (Panjabi, 1992a, 1992b) described a model of the spinal stability that is widely accepted in the field (Macdonald, Dawson, & Hodges, 2011; MacDonald, Moseley, & Hodges, 2006; McGill, Grenier, Kavcic, & Cholewicki, 2003; McGill & Norman, 1987). The model describes the the spine as being composed of three subsystems: (a) a passive subsystem (inert/non-contractile tissue such as the vertebrae, ligaments and tendons), (b) an active subsystem (muscles); and (c) a neural control subsystem ( central nervous system, the spinal cord and associated nerves) (Panjabi, 1992a, 1992b). The three subsystems work in concert as a dynamic ever changing system to accomplish a balance between mobility and stability. An impairment or malfunction of any component of the system will deleteriously affect overall movement quality of the trunk and may lead to injury or athletic performance deficits. This model and subsequent theory of spinal instability gave rise to the popularity of the prescription of core stabilization training.

**Purpose of the Study and Research Hypotheses**

The long-term goals of this research are to elucidate the role of core stability in LE athletic injuries and improve sports performance in athletes. This will provide prospective evidence that will guide future studies. The purpose of this study is to examine the effects of an 8-week isolated core stability training program on standing

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postural control, trunk muscle activation and kicking velocity in soccer athletes. I hypothesize that:

- 1) There will be excellent ( $ICC > 0.75$ ) test and re-test reliability of all center of pressure and electromyography variables in all 4 tests:
  - a. Single leg stance under eyes open (EO) and eyes closed (EC) conditions for the left (L) and (R) legs
  - b. Tandem stance under eyes open (EO) and eyes closed (EC) conditions for the left (L) and (R) legs
  - c. Self-perturbation for the left (L) and (R) legs
  - d. Kicking Velocity (dominant LE) – 1 variable

I further hypothesize that following 8-weeks of isolated core stability training, athletes will have:

- 2) During single leg stance with EO
  - a. less CoP deviation during single leg stance of right and left legs with eyes open compared to the control group (between group)
  - b. less mean trunk EMG activation during single leg stance of right and left legs with eyes open compared to the control group (between group)
  - c. less CoP deviation during single leg stance of right and left leg with eyes open (within group)
  - d. less mean trunk EMG activation during single leg stance of right and left leg with eyes open (within group)

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3) During single leg stance with EC

- a. less CoP deviation during single leg stance of right and left legs with eyes open compared to the control group (between group)
- b. less mean trunk EMG activation during single leg stance of right and left legs with eyes open compared to the control group (between group)
- c. less CoP deviation during single leg stance of right and left leg with eyes open (within group)
- d. less mean trunk EMG activation during single leg stance of right and left leg with eyes open (within group)

4) During Tandem Stance with EO

- a. less CoP deviation during single leg stance of right and left legs with eyes open compared to the control group (between group)
- b. less mean trunk EMG activation during single leg stance of right and left legs with eyes open compared to the control group (between group)
- c. less CoP deviation during single leg stance of right and left leg with eyes open (within group)
- d. less mean trunk EMG activation during single leg stance of right and left leg with eyes open (within group)

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5) During Tandem Stance with EC

- a. less CoP deviation during single leg stance of right and left legs with eyes open compared to the control group (between group)
- b. less mean trunk EMG activation during single leg stance of right and left legs with eyes open compared to the control group (between group)
- c. less CoP deviation during single leg stance of right and left leg with eyes open (within group)
- d. less mean trunk EMG activation during single leg stance of right and left leg with eyes open (within group)

6) During Self Perturbation

- a. quicker time to stability in both medial/lateral and ant/post directions following self- perturbation (landing task) compared to controls (between group)
- b. quicker time to stability in both medial/lateral and ant/post directions following self- perturbation (landing task) (within group)

7) During Kicking Velocity

- a. improved kicking velocity compared compared to controls (between group)
- b. improved kicking velocity (within group)

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**Significance of the Study**

Despite the wide use of core stabilization training in clinical practice and sports conditioning, few studies were located that have examined these program's efficacy for improving core stability in healthy athletes. No studies were located that examined the role of an isolated core stabilization training on improved standing postural control and sport specific athletic performance. However, there are anatomical and neurophysiological theories and empirical evidence that link poor core stability to LE non-contact injuries. The results of this study will serve as preliminary evidence to direct future studies aimed at accomplishing the long-term research agenda of determining the role of core stability in LE athletic injuries and provide prospective evidence that the use of core stabilization training reduces the risk of non-contact LE injuries and improve sports performance in athletes. This has direct implications on injury prevention programs and clinical interventions for rehabilitation that may ultimately reduce future health care cost to society.

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**CHAPTER II**

**REVIEW OF RELATED LITERATURE**

An estimated one third of all athletic injuries at the collegiate level are non-contact in nature with more than half of these involving the LE's (Hootman et al., 2007). The National Collegiate Athletic Association recommends that future studies investigate the circumstances and characteristics of non-contact LE injuries in more detail to identify possible injury prevention initiatives (Hootman et al., 2007). It is hypothesized that poor core stability may play a role in increasing the risk of LE injuries (Hodges, 2003; Hodges & Richardson, 1997a; Jensen, Laursen, & Sjogaard, 2000; Kibler, Press, & Sciascia, 2006). The anatomical core is defined as the skeletal structure, ligaments and musculature of the lower spine, pelvis, hips and proximal lower extremities (Kibler et al., 2006). The core musculature includes the muscles contributing to the maintenance of the "stability" of the lower spine and pelvis (Putnam, 1993). These muscles include the superficial and deep abdominal wall muscles, pelvic floor muscles, pelvic girdle muscles, erector spinae muscles. These muscles also help to generate and transfer energy during many athletic activities (Putnam, 1993). This ability of the core to maintain or resume the upright position and motion of the trunk over the pelvis and leg in the presence of disturbances is

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predominantly accomplished via quick postural responses by the neuromuscular system to internal and external (Borghuis et al., 2010).

There are feed-forward and feed-back mechanisms that are integrated within the neuromuscular system to respond to these forces (Borghuis et al., 2010). Poor **core stability** has been theoretically linked to LE injuries in athletes (Beckman & Buchanan, 1995; Bullock-Saxton, Janda, & Bullock, 1994; Ireland, Willson, Ballantyne, & Davis, 2003; Zazulak, Hewett, Reeves, Goldberg, & Cholewicki, 2007a, 2007b). Other authors have identified deficiencies in muscle activation and weakness of various key pelvic girdle muscles (gluteus maximus, gluteus medius, and external hip rotators) concluding that these **may** play a role in LE injuries (Beckman & Buchanan, 1995; Bullock-Saxton et al., 1994; Fredericson et al., 2000; Ireland et al., 2003; Leetun, Ireland, Willson, Ballantyne, & Davis, 2004). Due the overwhelming prescription of core stability exercises by rehabilitation and conditioning personnel for the purposes of injury prevention and improved athletic performance, it is essential to begin to examine these claims.

**Anatomical Links between the Core and Lower Extremity Functioning and Movement.**

Core muscle activity is best understood as the pre-programmed integration of local, single-joint muscles and multi-joint muscles to provide stability and produce motion (Kibler et al., 2006). These muscles are responsible for maintaining control of the spine over the pelvis. They also aid in the generation and transfer of energy from

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larger to smaller joints during activity. Further, trunk muscles stabilize the trunk to allow controlled mobility of the extremities, a proximal to distal force generation patterning and the creation of interactive moments that move and protect the extremities (Kibler et al., 2006). Proximal trunk control to allow distal mobility is in part provided by the thoracolumbar fascia. The fascia allows the trunk to be integrated in kinetic chain activities involving the extremities (throwing for example) (Kibler et al., 2006). The fascia plays an important stabilizer role for extremity movements (ball throwing for example) because of its proximal attachment (via the latissimus dorsi) and distal attachment (via the gluteus maximus) (Kibler et al., 2006). The thoracolumbar fascia also has attachments on the internal obliques and transverse abdominus which may further stabilize the trunk during movement (Kibler et al., 2006). There exists further anatomical links between the trunk and the extremities.

Anatomically, the trunk acts as a base for which motion of the distal segments can occur. These motions are influenced not only by the muscles themselves but also by inert tissues. The transversus abdominus muscle helps create a rigid cylinder which enhances the stiffness of the spine (McGill & Norman, 1987). The rectus abdominus and the oblique abdominal muscles on the other hand are activated depending on the direction of the limb movements thereby providing postural support before extremity movements (Arain & Latash, 1995; Cordo & Nashner, 1982; Hodges & Richardson, 1997b; Zattara & Bouisset, 1988). This contraction of the intra-abdominal musculature occurs before limb movements take place to allow for a stable proximal segment for optimal limb movement, muscle activation and force



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production (Hodges, 2003; Hodges & Richardson, 1997a; Jensen et al., 2000). Motor neurons which innervate distal muscles (e.g., gastrocnemius) are located lateral to motor neurons which innervate proximal muscles (e.g., trunk muscles) (Lemon, 2008; Rothwell, 2012). These muscles are controlled by descending motor pathways organized into lateral and medial pathways. The lateral pathways (lateral corticospinal tract and rubrospinal tract) control both proximal and distal muscles and are responsible for most voluntary movements of the extremities (Lemon, 2008; Rothwell, 2012). On the other hand, the medial pathways (vestibulospinal tracts, reticulospinal tracts, tectospinal tract and anterior corticospinal tract) control axial muscles and are responsible for posture, balance, and coarse control of the trunk and proximal muscles (Lemon, 2008; Rothwell, 2012).

The base of the trunk is composed of the lower spine, pelvis and hips (and their related structures) (Kibler et al., 2006). The large musculature associated with the lower spine, hips and pelvis can not only stabilize the trunk but also have the ability to produce a great deal of force and power for athletic activities (Kibler et al., 2006). For example, the glutei have been shown to act as stabilizers of the pelvis over the planted leg to allow forward LE movement (Putnam, 1993; van Ingen Schenau, Bobbert, & Rozendal, 1987). The trunk stabilizers have also been shown to pre-activate to counter balance trunk motion to control LE postures (Hodges & Richardson, 1997a; Willson, Dougherty, Ireland, & Davis, 2005). Hodges et al. (1997) found that trunk stabilization is controlled by central commands by activating the abdominals as a whole and the lumbar multifidi in preparation for reactive forces

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produced by LE movements unrelated to the direction of the movement (Hodges & Richardson, 1997a). Myer et al. (2008) in a review article indicated that this reduction in pre-activation of the trunk and hip stabilizers may result in the inability to control lateral trunk positions which may facilitate knee abduction forces (Myer, Chu, Brent, & Hewett, 2008). This reduction in pre-activation of trunk musculature may result an unstable trunk leading to extraneous movements in the lower extremities possibly resulting in injury.

Proximal trunk control is in part provided by the thoracolumbar fascia. The fascia allows the trunk to play a key role in activities involving the extremities (Kibler et al., 2006). The tightening of the fascia plays an important stabilizer role for extremity movements (ball throwing for example) because of its proximal attachment (via the latissimus dorsi) and distal attachment (via the gluteus maximus) (Kibler et al., 2006). The thoracolumbar fascia also has attachments on the TA and obliques to provide three-dimensional support to the trunk to stabilize it during movements of the extremities (Kibler et al., 2006).

**Neurophysiological Links between the Core and Lower Extremity Functioning and Movement**

Postural stability is achieved and maintained by a complex set of sensorimotor control systems that include sensory input from vision, proprioception and the vestibular system (motion, equilibrium & spatial orientation) (Borghuis et al., 2010). More critical is the integration of this sensory input resulting in motor output to the

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eyes and musculoskeletal system (Borghuis et al., 2010). As the environment changes, the individual reweight their relative dependence on each of the senses (Horak, 2006). For example, walking on cement on a sunny day, a person may rely predominantly on somatosensory senses and less so on visual and vestibular information. However, when standing on an unstable surface, said person may rely more on vestibular and visual information and less on somatosensory inputs for postural orientation (Horak, 2006). The ability to reweight sensory information depending on the environment is important for maintaining postural stability when an individual moves from one sensory context to another (Horak, 2006; Lemon, 2008; Peterka & Loughlin, 2004).

Sensory receptors in the eyes send visual cues to the cerebellum identifying how a person is oriented in space (Hanes, 2006). Afferent input from the musculoskeletal system (proprioceptors from the skin, muscles, joints, etc.) involve sensory receptors that are sensitive to stretch or pressure in the surrounding tissues (e.g. golgi tendon organ) (Hanes, 2006). The sensory impulses originating in the neck (cervicu-ocular reflex) and the lower extremities (feet) are especially important (Hanes, 2006). Proprioceptive cues from the neck indicate the direction in which the head is turned (Hanes, 2006). Cues from the feet indicate the body's movement or sway relative to the type surface (floor, inclined, etc.) and quality of surface (hard, soft, slippery, uneven, etc.) (Hanes, 2006).

These afferent sensory inputs ascend the spinal cord to the cerebellum (the center that coordinates and regulates postural stability and movement) and the cortex

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to be sorted and integrated with learned information (Horak, 2006; Lemon, 2008; Peterka & Loughlin, 2004). The cerebellum, with input from the cortex, provides efferent commands to the musculoskeletal system in the form pre-programmed or learned patterns of muscle activation (e.g. kicking a ball). Contributions from the cerebral cortex includes previously learned information to use a different pattern of movement as the environment changes. The cerebellum is important for making postural adjustments in order to maintain balance (Horak, 2006; Lemon, 2008; Peterka & Loughlin, 2004). Through its input from various receptors, the cerebellum modulates efferent commands to motor neurons to compensate for shifts in body position or changes in load on muscles (Horak, 2006; Lemon, 2008; Peterka & Loughlin, 2004). Further, the cerebellum coordinates movement by changing the timing and amount force generation (Lemon, 2008; Peterka & Loughlin, 2004). Lastly, it also plays a major role in adapting and fine-tuning motor programs to make precise movements through a trial-and-error process. All these patterns are in turn “learned” and stored in the cortex (Lemon, 2008; Peterka & Loughlin, 2004). There are multiple and continuous feedback and feed forward loops that inform anticipatory and compensatory postural adjustments (APAs and CPAs) (Frank & Mendelson, 1990; Lemon, 2008; Peterka & Loughlin, 2004). As sensory integration takes place between the cerebellum and the cortex, efferent output is sent to the musculoskeletal system, the vestibule-ocular reflex and the ocular muscles to control movements of the eyes, head and neck, trunk, and legs to allow a person to maintain postural

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stability during various tasks (Deshpande, Albuquerque, Kauffman, & Guth, 1978; Hanes, 2006; Horak, 2006; Lemon, 2008; Peterka & Loughlin, 2004).

Physiologically, the composition and mechanism of muscle contraction are similar to in the trunk and the extremities (Deshpande et al., 1978; Kibler et al., 2006; Lamoth, van Lummel, & Beek, 2009; Lemon, 2008; Peterka & Loughlin, 2004). Differences are namely in the composition of their fiber types. Trunk muscles are postural in nature and as such are mostly composed of aerobic fibers whereas extremity muscles have a greater combination of aerobic and anaerobic fibers (depending on the individual's training/sport) (Deshpande et al., 1978). The mechanism of contraction of skeletal muscles is the same throughout the body. However, where things differ are in the central nervous system; location of central commands in the homunculus and location of subsequent efferent tracts. According to Rothwell (2012) and Lamouth et al (2009), the location of the efferent motor neurons which innervate the trunk muscles are located medially to those which innervate distal muscles of the extremities (Lamoth et al., 2009; Rothwell, 2012). These muscles are controlled by descending efferent tracts. The lateral tracts (lateral rubrospinal and corticospinal tracts) control both proximal and distal musculature. They are responsible for most voluntary movements of the extremities. The medial tracts, however, (tectospinal, reticulospinal, vestibulospinal and anterior corticospinal tracts) control trunk muscles primarily and are responsible for trunk stability, posture and gross movements of the trunk and proximal muscles (Lamoth et al., 2009; Rothwell, 2012).

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An individual also has the ability to override these processes to a certain extent (Lamoth et al., 2009; Rothwell, 2012). Tuning out noise or a cheering crowd of people to hear a teammate ask for a pass, or co-contract the TA prior to moving the extremities for examples overrides the sensory and motor systems. There is research showing that through neuromuscular training, an individual can a “re-education” or “re-program” the pre-programmed muscle activation patterns that occur reflexively to stabilize the trunk for extremity movements (Hodges, 2003). In essence, the cortex and cerebellum may be re-educated to correct faulty or inappropriate firing patterns.

**Proximal Stability for Distal Mobility**

The function of the core musculature may be by dividing the trunk muscles into local and global categories (Bergmark, 1989). Local muscles are defined as those attaching to the lumbar vertebrae and influencing inter-segmental motion, while global muscles attach to the hips and pelvis and promote mobility and proper orientation of the spine. Bergmark (1989) reported that maintaining balance in these muscles is important because if the local muscles are not functioning properly, movements become inefficient due to compensation of the global muscles thus altering stability (Bergmark, 1989). Nichols added to Bergmark’s work by separating the core musculature into muscles that operate by length dependent and force dependent activation patterns (Nichols, 1994). Muscles operating on length dependent patterns are small, short muscles with small lever arms that typically span one joint (Nichols, 1994). The force dependent muscles cover multiple spinal segments,

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produce higher levels of force, and coordinate multiple joints (Nichols, 1994).

Accordingly, it is the combination of both muscle activation patterns that allows for control of the multi-segmented spine and the neutralizing of forces with small lever arms that typically span one joint (Nichols, 1994). The force dependent muscles cover multiple spinal segments, produce higher levels of force, and coordinate multiple joints. Accordingly, it is the combination of both muscle activation patterns that allows for control of the multi-segmented spine and the neutralizing of forces (Nichols, 1994). Furthermore, these pre-programmed patterns of muscle activation are enhanced by repetition and practice and stored in the cortex and relayed via the cerebellum and efferent pathways to the extremities (Nichols, 1994; Peterka, 2002; Peterka & Loughlin, 2004; Rothwell, 2012). The length dependent patterns are said to provide stability for a single joint and is controlled by alpha afferent fibers (Nichols, 1994). They also are involved in reciprocal inhibition providing stability to joints. The force dependent patterns allow activation of multiple muscles across several joints to generate forces (Nichols, 1994). These patterns are initiated centrally at all levels of the central nervous system and may be found in many trunk-related movements. Examples of these patterns are ample in the literature. It has shown that maximum foot swing velocity during a kicking task is associated with hip flexor muscle activation more so than that of knee extensors (Zattara & Bouisset, 1988). Another example of this patterning is the activation of the contra-lateral gastrocnemius and soleus muscles before rapid upper extremity movements occur (Zattara & Bouisset, 1988) before other patterns of activation proceed up to the

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moving limb through the spine (Cordo & Nashner, 1982; Hirashima, Kadota, Sakurai, Kudo, & Ohtsuki, 2002). It has also been shown that all aspects of baseball pitching has been linked to pattern of muscle activation that begins from the external obliques and distally to the throwing arm (Hirashima et al., 2002). Pre-activation for locomotion causes lateral trunk positions which may facilitate knee abduction forces (Willson et al., 2005). It has been argued that this pre-activation patterns (APAs) allow “stiffening” or “stabilization” of the trunk to provide a stable base on to which extremities can move (Willson et al., 2005).

Furthermore, these postural adjustments originating from the cerebellum act not only to stabilize the trunk prior to movement execution (APAs) but to also correct for execution errors and external perturbations (CPAs) (Frank & Mendelson, 1990; Horak, 2006; Lemon, 2008; Peterka, 2002; Peterka & Loughlin, 2004). This occurs via continuous feedback loops from all three sensory input systems previously discussed (Horak, 2006; Lemon, 2008; Peterka, 2002; Peterka & Loughlin, 2004). These adjustments allow the body to maintain adequate postural control to tolerate forces (internally or from the environment) created by movements (e.g. catching, kicking, sprinting, etc.). This continuous sensory feedback and afferent control contributes to a complex system of processes to allow for postural control allowing the body to remain stable during activities (Frank & Mendelson, 1990; Horak, 2006; Lemon, 2008; Peterka, 2002; Peterka & Loughlin, 2004).

Studies have demonstrated the existence of these APAs and CPA's in conjunction with segmental stretch reflexes to self-initiated movements of the



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extremities (i.e. kicking or moving one's arm) (Cordo & Nashner, 1982; Zattara & Bouisset, 1988). There is evidence that the TA is controlled independently from other abdominal wall muscles (Hirashima et al., 2002; Hodges & Richardson, 1997a, 1997b). In healthy and injury-free individuals, the APAs of the TA are affected by other trunk muscles but not lower extremity movements indicating that it may be controlled in the cortex independently of limb movement (Hirashima et al., 2002). This is not necessarily the case for the other abdominal muscles (Hodges & Richardson, 1997a, 1997b, 1999). This contraction of the intra-abdominal musculature before limb movements takes place to allow for a stable proximal segment for optimal extremity movement and generation (Hodges & Richardson, 1997a, 1997b, 1999). This ability of the core to maintain the position and motion of the trunk over the pelvis and leg is predominantly accomplished via quick postural responses by the neuromuscular system to internal and external forces created by athletic movements (Cordo & Nashner, 1982; Zattara & Bouisset, 1988).

Furthermore, there are biomechanical influences that permit efficient functioning of proximal and distal movements (Kibler et al., 2006). The previously described pre-programmed muscle activations result in anticipatory postural adjustments (APAs). These adjustments allow the body to maintain adequate postural control to withstand internal and external perturbation forces created by athletic movements (e.g. throwing, kicking, running, etc.) (Cordo & Nashner, 1982; Zattara & Bouisset, 1988). During static standing or locomotion, the external forces applied to the body are transferred totally or partially to the lower extremities (LE's) via the

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trunk to be "dissipated" by the ground (Kibler et al., 2006). Since the trunk accounts for approximately 60% of the body's mass (including the upper extremities), it's configuration (position and internal forces) with respect to the LEs determines the means by which the external forces (applied to the trunk) are transferred to the LEs (or just one lower extremity) (Kibler et al., 2006). The core is said to be a critical modulator of LE alignment and loads during dynamic tasks (Myer et al., 2008). The trunk and hip stabilizers have been shown to pre-activate to counter balance trunk motion to control LE postures (Hodges & Richardson, 1997b; Willson et al., 2005). Wilson et al. (2005) found that the trunk stabilization is controlled by central commands by activating the abdominals as a whole and the lumbar multifidi in preparation for reactive forces produced by limb movements unrelated to the direction of the movement (Willson et al., 2005). This reduction in pre-activation of the trunk and hip stabilizers may cause lateral trunk positions which may facilitate knee abduction forces. Further, a decrease in core stability and imbalances in trunk and hip stabilizers may alter lower extremity biomechanics and may lead to non-contact injury due to a lack of control of one's center of mass (Ireland et al., 2003; Zatsiorsky, Gao, & Latash, 2005). Zazulak et al. (2007) in two separate studies reported a link between poor trunk control as measured by trunk proprioception and latency in trunk position recovery following sudden unloading and incidences of LE injuries in female athletes (Zazulak et al., 2007a, 2007b). The authors suggested that the observed deficiencies in trunk and hip stabilizers, which contribute to core

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stability, may explain the mechanisms of non-contact LE injuries in athletes (Zazulak et al., 2007a, 2007b).

If the system controlling the “stability” of the core is compromised (injury, reflex inhibition, delayed onset or firing, etc.) leading to decreased or inappropriate control or activation of the trunk and hip muscles, lower extremity biomechanics may be altered and injury may ensue.

**Model of Poor Trunk Control Leading to Injury**

The base of the trunk is composed of the lower spine, pelvis and hips (and their related structures). The large musculature associated with the lower spine, hips and pelvis can not only stabilize the trunk (Putnam, 1993) but also have the ability to produce a great deal of force and power for athletic activities (Kibler et al., 2006). For example, the glutei have been shown to act as stabilizers of the pelvis over the planted leg to allow forward LE movement (Beckman & Buchanan, 1995; Bullock-Saxton et al., 1994). The trunk stabilizers have also been shown to pre-activate to counter balance trunk motion to control LE. Trunk stabilization is controlled by central commands by activating the abdominals as a whole and the lumbar multifidi in preparation for reactive forces produced by LE movements unrelated to the direction of the movement (Hirashima et al., 2002). This reduction in pre-activation of the trunk and hip stabilizers can result in an unstable trunk over the pelvis leading to extraneous movements in the lower extremities (increased postural sway outside the

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cone of stability) possibly resulting in injury; poor control of lateral trunk positions which may facilitate knee abduction forces.

Another possible mechanism for LE injury may be explained by poor trunk muscle reflex activation or reflex inhibition. Integrated proprioceptive feedback at all levels of the nervous system functions to initiate postural responses both in anticipatory and reactionary fashion in response to perturbation or the environment (Borghuis et al., 2010). Hence, CPA's and APA's contributes to complex neuromuscular processes that underlie postural control and balance, with an important role for timely reflexive neuromuscular responses stabilizing the body (Batson, 2009; Cholewicki, Polzhofer, & Radebold, 2000).

A reflex is defined as a change in muscle activation in immediate response to an external perturbation, thereby leading to a change in force generation (Borghuis et al., 2010). Typically muscle reflex responses adjust for insufficient initial "stability" to limit trunk motion to a safe boundary (Cholewicki et al., 2000; Lariviere, Gagnon, Arsenault, Gravel, & Loisel, 2005). Although trunk muscle reflexes assist in stability and aid in the reduction of energy expenditure and decreased cumulative tissue loading, compared to intrinsic stiffness alone, reflex delay may lead to poor stability of the core (Gardner-Morse & Stokes, 2001; Granata & Wilson, 2001). Reflex delay denotes the time from a perturbation to the onset of reflex activation (muscle contraction) (Franklin & Granata, 2007). Failure to recruit an appropriate and timely contraction can lead to instability (Granata & Wilson, 2001). Studies have documenting decreased trunk proprioception, delayed muscle reflex latencies to

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perturbation and decreased postural control in low back pain patients in support of this theory (Cholewicki et al., 2005; Gill & Callaghan, 1998; Radebold, Cholewicki, Polzhofer, & Greene, 2001). Similar to the pre-activation model above, a delay in muscle activation proximally may result in an unstable trunk leading to extraneous movements in the lower extremities (increased postural sway outside the cone of stability) possibly resulting in injury. The ability to properly coordinate and control the position of the trunk with respect to the lower extremities may reduce the forces at the LE joints especially when inertia can play a significant role.

**Role of the Core in Extremity Functioning, Movement and Injury.**

Further evidence exists that links core stability, muscle timing, muscle strength, trunk proprioception and LE injuries in athletes (Beckman & Buchanan, 1995; Bullock-Saxton et al., 1994; Ireland et al., 2003; Zazulak et al., 2007a, 2007b). However, some of this evidence is deduced from secondary analysis of data with small subject size while other evidence is not based on biomechanical but rather functional assessment of core stabilization.

Trunk proprioception is one component of core stability necessary for precise an accurate control of trunk movement. Zazulak et al. (2007) observed 277 collegiate athletes (140 female, 137 male) for a period of 3 years (Zazulak et al., 2007a). They prospectively examined active and passive trunk proprioception using a trunk rotation protocol. Their findings suggest that impaired trunk proprioception was a predictor of anterior cruciate ligament (ACL) injury risk in female but not male athletes. Further

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analysis of their data revealed that delayed trunk repositioning in the same subject pool following sudden load release was also a predictor of ACL and knee injuries in female athletes but not male athletes (Zazulak et al., 2007b). However, both of these studies are based on secondary data analysis with only 25 out of 277 athletes sustaining knee injuries (11 women, 14 men). The initial intent of these studies was to look at the association between core stability parameters (trunk proprioception and trunk muscle timing) and low back injury rate. The authors retrospectively discovered that there is a link between trunk proprioception and LE injuries. However, their injury sample was very small and the paradigm they used to quantify core stability may not have been challenging enough to pick-up differences in these athletes. Although, these studies show a link between deficiencies in trunk proprioception and LE injury, methodology and sample size were a significant limitation to this study.

There is some evidence associating latencies in pelvic muscle firing pattern to ankle injuries in athletes (Beckman & Buchanan, 1995; Bullock-Saxton et al., 1994). Subjects with a history of severe unilateral ankle sprains demonstrated a delayed onset of firing patterns in the ipsilateral and contralateral gluteus maximus muscle suggesting a link between hip muscle firing delays and ankle injuries (Bullock-Saxton et al., 1994). Although this is a post-ankle injury study making the decision of whether the hip dysfunction was a complication of the injury or present prior to the injury is difficult, yet it does provide a basis for future studies because of the link between hip dysfunction and ankle injury. Subsequently, Beckman et al. (1995) set out to examine the changes in reflexes associated with chronically sprained ankles by

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measuring the reflex response latency of hip and ankle muscles during instantaneous ankle/foot inversion (Beckman & Buchanan, 1995). Twenty subjects were assigned to 2 groups (hypermobility and normal) based on ankle range of motion. Subjects were asked to stand on a platform which provided an instantaneous ankle inversion. Muscle onset latency was measured by surface electromyography over bilateral gluteus medius and peroneal muscles. The authors reported that individuals with a history of ankle sprains and ankle hypermobility demonstrated a delayed latency of activation of the ipsilateral gluteus medius. However, it is difficult to determine whether this delay led to the increased risk of ankle sprains or if it is a consequence of the injury.

Ireland et al. (2003) showed that females with anterior knee pain are more likely to have hip abduction or external rotation weakness than age-matched, asymptomatic, controls (Ireland et al., 2003). Hip abduction and external rotation isometric strength, measured by hand-held dynamometry, were recorded for the injured side of 15 female subjects with patellofemoral joint pain then compared with the corresponding hips of 15 age-matched female controls. They found females with patellofemoral pain had 26% less hip abduction strength and 36% less hip external rotation strength as compared to controls. They concluded that young women with patellofemoral pain are more likely to demonstrate hip abduction and external rotation weakness than age-matched symptomatic controls. These results show an association between hip muscle strength differences and LE injury. This study further emphasizes the biomechanical link between the pelvis and the LEs.

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Myer et al. published a comprehensive LE neuromuscular re-education incorporating trunk stabilization exercises (Myer et al., 2008). Although it was not a research study, they present a comprehensive review of the literature outlining the importance of trunk stabilization and LE neuromuscular re-education training for non-contact LE injury prevention (Myer et al., 2008). This intervention program is based on previously published training programs but it has yet to be validated for the proposed purpose; prevention of non-contact ACL injuries. Hewett et al. (1999) demonstrated a significant reduction in knee injuries in female athletes who participated in a “neuromuscular re-education program” (which include trunk exercises) predominantly focusing on LE plyometrics, as compared to no treatment controls (Hewett, Lindenfeld, Riccobene, & Noyes, 1999). However, this program progresses the athletes to activities in standing. One can argue that training an athlete in standing is more functional. However, this type of combination training makes it difficult to ascertain if the differences observed are due to improvement in core stability, LE functioning or a combination thereof.

Stephen et al. (2008) examined the effects of 10 specific exercises in over 2100 soccer athletes 17 years of age and younger (1073 experimental and 947 control). The exercises included trunk stability, standing dynamic balance, plyometrics and eccentric hamstring strengthening (Steffen, Myklebust, Olsen, Holme, & Bahr, 2008). The authors reported no significant differences in the injury rates between the 2 groups. While the intervention lasted 8-months but there was no mention of progression of the exercises within that period of time. Considering the



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basic concepts of training progression and overload principle, it is highly unlikely that performing 10 simple exercises over a period of 8-months without progression will have any significant improvements in physiology in such a population. Further, of the 10 exercises, only 2 specifically emphasized the trunk musculature (plank and side plank exercises). I plan to intervene with a trunk stabilization and strengthening program which is progressively difficult and significantly more challenging neuro-physiologically. Further, all the exercises in my intervention program are designed to emphasize neuromuscular training of the trunk muscles.

McGuine et al. (2000) examined the relationship between standing postural sway (single leg stance) and susceptibility to ankle injury in high school basketball players (McGuine, Greene, Best, & Levenson, 2000). Athletes were tested at the start of their competitive season then tracked for the remainder of the season. Testing both limbs in unilateral stance using 3 trials of 10-sec of under both eyes open and eyes closed conditions, the researchers found that those athletes with poorer standing postural sway were more susceptible to acquiring an ankle injury. Postural sway was defined as the average degrees of sway per second for the 12 trials concluding that standing postural sway was a predictor of ankle injuries in this cohort of athletes. Although core stability was not measured, one may hypothesize that deficiencies in trunk neuromuscular control may play a role in poor performance on standing postural control tasks which may increase the susceptibility of sustaining ankle injuries.

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Risk factors relative to ankle injuries were studied by Wang et al (2006). They set out to prospectively analyze risk factors which could predict ankle injuries in high school male basketball players (Wang, Chen, Shiang, Jan, & Lin, 2006). These factors included 1-leg standing postural sway, isokinetic ankle strength, and ankle goniometric range of motion. Subjects consisted of 42 high school basketball players without history of injury in the lower extremities within 6 months. The researchers tracked the athlete's injury rates using monthly follow-up questionnaires. The injury data was correlated with the pre-season biomechanical testing. They found that there was a high variation of postural sway in both anterior-posterior and medio-lateral directions corresponding to occurrences of ankle injuries. There were no associations between injury and isokinetic strength and/or ankle range of motion measurements of the ankle. Similarly, core stability was not assessed. Therefore, it is difficult to ascertain whether these athletes had poor core stability at the onset of the season which may have contributed to their poor standing postural control which ultimately was a factor in predicting these types of injuries.

Decreased core stability has been suggested to contribute to the etiology of lower extremity injuries in athletes. Leetun et al. (2004) examined differences in strength measures that could be used to identify athletes at risk for lower extremity injury (Leetun et al., 2004). They believed that athletes with deficiencies in (or a combination of) hip abduction and external rotation strength, abdominal muscle function, and back extensor and quadratus lumborum endurance may be at greater

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risk for lower extremity injury (Leetun et al., 2004). Their data revealed that male athletes produced greater hip abduction, hip external rotation and quadratus lumborum measures than females (Leetun et al., 2004). It was found that athletes who sustained an injury over the course of a season displayed significantly less hip abduction and external rotation strength than uninjured athletes (Leetun et al., 2004). Athletes who did not sustain an injury were significantly stronger in hip abduction and external rotation. They further reported that hip external rotation strength was the only useful predictor of injury (Leetun et al., 2004). These results are similar to those reported by Ireland et al. (2003) who showed that hip abductors and external rotators play an important role in the alignment of the lower extremities (Ireland et al., 2003). Ireland et al. reported that these groups of muscles assist in limiting movement into hip adduction and internal rotation during single limb support (Ireland et al., 2003). Admittedly, Leetun et al. (2004) reported that hip external rotation strength is only one component of core stability and other aspects not included in the study may also have predicted the occurrence of lower extremity injury (Leetun et al., 2004).

### **Relationship between Core Stability Measures and Athletic Performance**

The difficulty in reviewing this literature is the lack of consensus on the definition of “core stability”, the structures comprising “the core” and methods to assess it. Recent attempts to link “core stability” and strength to various generic athletic tasks have revealed mixed results at best. (Gordon, Ambegaonkar, & Caswell, 2013; Nesser, Huxel, Tincher, & Okada, 2008; Okada, Huxel, & Nesser, 2011; Sharrock,

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Cropper, Mostad, Johnson, & Malone, 2011; Shinkle, Nesser, Demchak, & McMannus, 2012; Weston, Coleman, & Spears, 2013). Sharrock et al. found a negative correlation between double leg lowering test (defined in the study as a measure of stability) and medicine ball throwing (Sharrock et al., 2011). However, they found no significant correlation between “core stability” and the forty yard dash, the T-test and vertical jump (Sharrock et al., 2011). One can argue that double leg lower is a mere measure of lower abdominal strength and not “core stability” per se.

Others have compared the ability to throw a medicine ball in various directions in static and dynamic positions (as a measure of “core strength”) with one repetition max lifts and agility drills (as measures of “athletic performance”) (Nesser et al., 2008; Shinkle et al., 2012). The lifts included squats, bench press and push press power maneuver whereas the agility drills tested were 40 yard dash, vertical jump and proagility drill. Results revealed positive correlations between various medicine ball throws and lifts/agility drills performances (Nesser et al., 2008; Shinkle et al., 2012). However, upon closer examination, the results are not consistent with what one would expect physiologically. For example, the authors found positive correlations between throwing a medicine laterally and jumping vertically (Shinkle et al., 2012). The results of the correlations, although positive, were average at best.

Okada et al. (2011) set out to determine the relationship between core stability, functional movement, and performance (Okada et al., 2011). Results of “core stability” tests (trunk flexion, extension and static lateral planks) were compared to

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seven scored functional movements (deep squats, hurdle step, shoulder mobility, trunk stability push up, etc.) and performance tests (backward medicine ball throw, single leg squat, and T-run) (Okada et al., 2011). They reported average correlation between “core stability” and performance results and no correlation between core stability and functional movements (Okada et al., 2011). The authors concluded that core stability and functional movements were not strong predictors of performance and that their clinical assessments of “core stability” do not satisfactorily confirm the importance of core stability on functional movement (Okada et al., 2011).

There is some evidence correlating “core fatigue” with altered cycling mechanics (Abt et al., 2007). Abt et al. ran their subjects through a circuit consisting of 7 exercises to “fatigue the core” between cycling tests. Their results revealed that cyclists had altered cycling mechanics when the “core” muscles were fatigued concluding that poor core strength and endurance may lead to LE injuries (Abt et al., 2007).

There is evidence linking core stability and athletic performance. However, the lack of consensus in defining and measuring performance of the core is a huge hurdle in this area of research. Without an agreed upon definition of the core or a method in assessing it, it is difficult to gauge and compare the effectiveness of various interventions aimed at improving athletic performance and LE injury prevention.

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**The Role of Core Stabilization and Strength Training in Enhanced Athletic  
Performance and Lower Extremity Injury Prevention.**

There are published core stabilization and strengthening programs aimed at improving core stabilization and muscle performance with the underlying premise of non-contact LE injury prevention and improved performance in athletes (Hewett et al., 1999; Myer et al., 2008; Steffen et al., 2008; Weston et al., 2013). Furthermore, there is evidence showing that deficiencies in standing postural control may predict ankle injuries (McGuine et al., 2000; Wang et al., 2006). In general, traditional core stabilization exercise programs incorporate dynamic training using unstable surfaces in a multitude of body positions incorporating the LEs and the core either in isolation or simultaneously. Thus, current practice does not focus on training the core in isolation. It is then difficult to ascertain if the differences observed are due to improvement in core stability, LE functioning or a combination thereof because the trunk was not trained independently of the LE's. The effectiveness of these combined (core and LE) programs for the prevention injuries (Hewett et al., 1999) and enhance athletic performance in athletes (Myklebust et al., 2003; Tse, McManus, & Masters, 2005) is documented. However, the effectiveness of specific targeted exercises of the trunk muscles (deep/superficial abdominals, erector spinae, multifidi, etc.) in relative

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isolation with emphasis on stabilizing muscles (transverse abdominus and lumber multifidi) to increase athletic performance and/or reduce the incidences of LE injuries has been poorly investigated (Weston et al., 2013). However, the current best evidence showing improvements in athletic performance and LE injury prevention with core stability training does not measure biomechanical aspects of core stability (Hewett et al., 1999; Myer et al., 2008; Steffen et al., 2008). It is then inappropriate to make the assumption that core stability was improved. I intend to examine the effects of an isolated core stabilization and strengthening program on improving core stability in young healthy soccer athletes.

The clinical use of core stabilization and strength training in athletes to improve athletic performance is popular (Chappell & Limpisvasti, 2008; Myer, Ford, Palumbo, & Hewett, 2005; Stanton, Reaburn, & Humphries, 2004; Tse et al., 2005; Weston et al., 2013). This is due to the belief that core stability will provide a stronger base for the completion of LE tasks. There are a few reports documenting improvements in non-specific athletic skills (vertical jump height, sprint time, single-leg hop, LE strength) (Myer, et al., 2005) using conditioning programs which incorporate various LE and core stabilization exercises along with LE and core muscle strength and endurance exercises (Chappell & Limpisvasti, 2008; Myer et al., 2005; Stanton et al., 2004; Tse et al., 2005). These studies did not include specific measures of core stability so it is not possible to determine the extent the trunk played a role contributing to this improvement in performance. Further, unless the core is

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treated in relative isolation, it is very difficult to know if this specific component of the intervention is responsible for these changes in athletic performance.

Weston et al. (2013) supposedly quantified the effect of an 8-week “isolated” core training program on selected ball and club parameters during the golf swing (Weston et al., 2013). The intervention consisted of 8 “core” exercises (double-leg squat, bent-leg curl up, superman, supine bridge, prone bridge, quadruped, lunge, and side bridge) chosen on the basis of simplicity, avoidance of trunk lateral flexion, and not needing additional equipment (Weston et al., 2013). One can argue that 2 out of the 8 exercises (lunge and double-leg squat) do not isolate the trunk despite activating trunk musculature. Further, the authors provided a poor description of the prescription and the progression of the intervention. They reported that arm movements were added at week 4 of the intervention. At best, this is a poor attempt at prescribing an “isolated” core stabilization program to measure athletic performance. However they did show improvement in an isometric trunk flexion endurance test which they argue is a measure of core. Finally, following their training program, the authors did show an improvement in club-head speed. This provides promising evidence to support the prescription of isolated core stability training for improvements in athletic performance.

### **Neurophysiological Adaptation Following Core Stability Training**

The main premise of core stability training, is to “re-educate” or “re-program” muscle activation patterns descending from the cortex and cerebellum (Borghuis et



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al., 2010). In essence, making the system more efficient via repetition and trial and error. This type of training is commonly referred to as “neuromuscular control” training (Borghuis et al., 2010). Reflexive factors may be improved via repetition and trial and error to “re-education” or “re-program” the pre-programmed muscle activation patterns can occur under the control of the cortex and cerebellum (Ramnani, Toni, Passingham, & Haggard, 2001). In essence, the cortex and cerebellum are being re-educated to correct faulty or inappropriate firing patterns (Ramnani et al., 2001). An individual also has the ability to override these processes through attentional control to a certain extent (Awh, Belopolsky, & Theeuwes, 2012). For example, an individual can tune out cheering crowd of people to hear a teammate ask for a pass. During core stability training, an individual can be taught to co-contract the TA prior to moving the extremities for examples, to override the sensory and motor systems to correct faulty firing patterns (Awh et al., 2012). There is research showing that through neuromuscular training, an individual can improve trunk and lower extremity control (Chappell & Limpisvasti, 2008; Hewett et al., 1999; Mandelbaum et al., 2005; Ross & Guskiewicz, 2006; Weston et al., 2013; Zazulak et al., 2007b). Published reports have shown that certain muscles in the trunk become anticipatory instead of compensatory following core stability training (Hodges, 2003; Hodges & Richardson, 1999). This change in firing pattern is most likely due to improved efficiency of somatosensory afferent and efferent transmission and learning effects in the cerebellum and cortex. In brief, practice and repetition of movement, while imposing attentional control for co-activation and proper posture,

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leads to neural adaptation and facilitation in the cerebellum and the cortex. This in turn which will improved efficiency of local muscle activation and efferent/afferent transmission leading to improved postural control.

**Standing Postural Control as a Measure of General Athletic Performance.**

Body sway during quiet standing may provide valuable information to characterize changes in standing postural control. Standing postural control has been used by several investigators as a measure of general athletic performance (Bressel, Yonker, Kras, & Heath, 2007; Davlin, 2004; Lamoth et al., 2009; Matsuda, Demura, & Uchiyama, 2008). Investigations have examined the relationship between performance on various standing postural control tasks (double limb stance, single limb stance and tandem stance) and athletic skill levels. These standing postural tasks have been shown to differentiate athletic skill levels (Bressel et al., 2007; Davlin, 2004; Lamoth et al., 2009; Matsuda et al., 2008). Although no biomechanical measures were obtained, this study provides clinical data and insight into methodology regarding the ability to differentiate athletic skill levels using simple clinical postural tests. These tests can easily be used by clinicians to assess core stability in athletes. Lamoth et al (2009) showed that standing with eyes closed and on foam increased variability of standing postural control and that compared to standing with eyes open, standing with eyes closed resulted in less regular sway patterns but with greater local stability (Lamoth et al., 2009). However, they showed that standing on foam resulted in the opposite (Lamoth et al., 2009). Finally, in the

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trained gymnasts, acceleration time-series were less variable, less regular and more stable suggesting that tandem stance variability, as assessed by accelerometer, may be used to differentiate between levels of athleticism in collegiate students (Lamoth et al., 2009). Further evidence exists to support the use of standing postural control tasks to differentiate levels of athleticism. Mastuda et al. (2008) examined differences in standing postural control using single-limb stance (SLS) between soccer athletes, basketball athletes, swimmers, and non-athletes (n=10 in each group) Sway velocity, anterior-posterior sway, horizontal sway, and high-frequency sway were used to quantify the differences between these groups (Matsuda et al., 2008). The authors reported that none of the four groups of athletes showed significant differences in body sway between standing on the dominant leg and standing on the non-dominant leg. However, they did report that soccer athletes had more high-frequency sway and less anterior-posterior sway and horizontal sway than the basketball athletes, swimmers, and non-athletes indicating that that SLS can differentiate between levels of athleticism (Matsuda et al., 2008). Lastly, Davlin (2004) investigated differences in dynamic standing postural control in non-athletes and highly skilled gymnasts, soccer athletes and swimmers who compete at the collegiate division I, professional, elite, or Olympic levels, or their individual coaches believed the athlete performed comparably to these levels (Davlin, 2004; Matsuda et al., 2008). Dynamic standing postural control was measured on a stabilometer. Results showed that athletes had better standing dynamic postural control as compared to non-athletes. Furthermore, gymnasts performed better than all other groups. Soccer athletes and swimmers

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performed similarly which is contradictory to the results obtained by Mastuda et al. (2008) (Davlin, 2004; Matsuda et al., 2008) These results indicate that dynamic standing postural control can differentiate between various levels of athletes and non-athletes alike. I intend to use static and dynamic postural stability measures to differentiate improvements in standing postural control following core stability training.

In summation, improved athletic performance and injury prevention with trunk stabilization and strengthening is at the forefront of clinical practice. The current practice is to train the core while incorporating various LE exercises. However, there are no reports examining the effects of isolated core stability training on improvements in standing postural control and athletic performance. Of those reports that have intervened with trunk stabilization and strengthening exercises and showed enhancement in non-specific athletic performance, none have biomechanically measured the extent to which the core is responsible for this improvement. Further, none of those studies have either trained the trunk in isolation or determine the actual role of the core on improvements of postural control. There are no systematic studies examining the effects of isolated core stabilization and strength training on standing postural control and athletic performance. Based on existing assumptions, improving core stability would thereby provide a stable base upon which the planted LEs function. This may play a role in improving standing postural control which has been used as a measure to differentiate between levels of athleticism. The body of evidence to support the assumption that poor core stability can be a predisposing risk factor for

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LE non-contact injury is narrow at best. The purpose of this investigation is to examine the effects of isolated core stabilization exercises on static and dynamic standing postural tasks and athletic performance measures. The results of this study will add to the body of evidence relative to the effects of core stability on standing postural control and athletic performance tasks.

**Gap in the Literature**

To our knowledge, there has been no studies examining the effects of isolated core stability training on standing postural control, trunk muscle activation and kicking velocity in soccer athletes

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### CHAPTER III

#### METHODS

##### **Institutional Review Board approval**

Per Seton Hall University protocol the research project was submitted to Saint Michael's Medical Center's Institutional Review Board (Newark, NJ) for approval. This project was also submitted to the Einstein Regional Medical Center (Philadelphia, PA) and Philadelphia University (Philadelphia, PA) Institutional Review Boards for approval since recruiting and testing took place in those institutions. The project was approved by all three boards. Please see Appendix A for approval letters.

##### **Experimental Design**

This project is composed of two experiments; 1) a core stability study (randomized controlled pretest and posttest quasi experimental design) and 2) a test-retest reliability and precision study. For the training study, 20 subjects were recruited and stratified based on gender into 2 groups (isolated core stability training and control). Subjects in the training group were required to undergo two testing sessions (pre and post training), participate in an 8-week isolated core stabilization program and required to maintain a detailed physical activity log over a period of 8 weeks. Please see Appendix E for the training protocol and progression criteria. The subjects in the control group were tested twice eight-weeks apart and were also required to

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maintain a detailed physical activity log over that period of 8 weeks to evaluate for confounding variables. Please see Appendix G the Training Log. For the reliability portion of the study, the first 10 subjects were recruited to undergo a 2<sup>nd</sup> testing session the same day (4 hours later) to assess reliability and precision of the procedures and instrumentation. Figure 1 illustrates the project components.

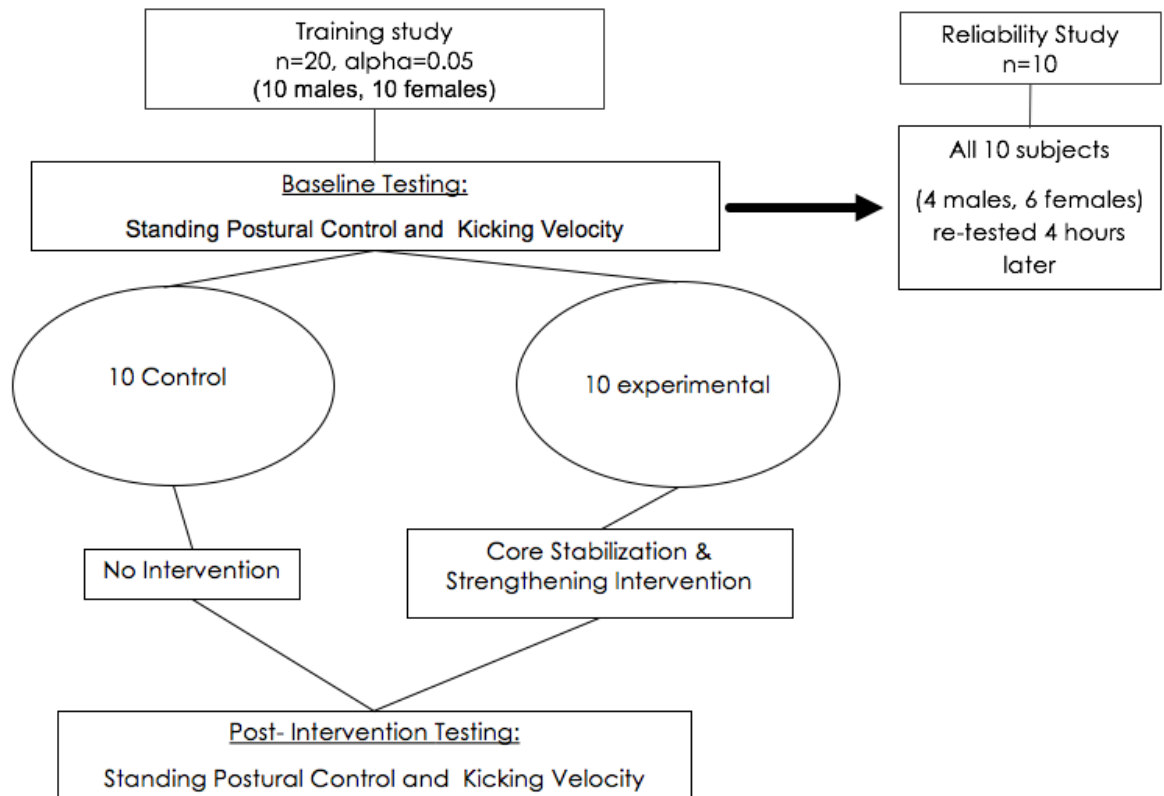


Figure 1. Illustration of the Study Design

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**Recruitment Strategy**

Subjects were recruited from area colleges with collegiate D1-D3 soccer programs through flyers posted on various campuses in and around the greater Philadelphia metropolitan area (See Appendix B).

**A Priori Power Analysis**

A Priori Power Analysis of all variables based on the first 5 subjects in each group was conducted to determine the number of subjects needed for the study. Table 1 provides subject demographic data for the pilot study whereas Table 2 provides the results of the power analysis. The averaged effect size and power for each variable indicated a sample size between 5-40 subjects depending on the variables.

Recognizing that 40 subjects was an outlier (based on EMG) and that the average sample size required was 16 (min=5, max=40), it was determined that 16 subjects were indicated. However, to account for attrition and possible over-estimation of the effect size, 20 subjects (10 in each group) were tested for the training study. IBM SPSS (Version 23.0; Chicago, 2015) was used to obtain Eta Squared and G\*Power statistical software (Version 3.1.9.2; Germany, 2016) (Faul, Erdfelder, Buchner, & Lang, 2009; Faul, Erdfelder, Lang, & Buchner, 2007) was used to obtain power and sample size.



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Table 1  
*Subject Demographic Data for the Pilot Study (n=10)*

	Age (years)	Height (cm)	Mass (kg)	BMI (kg/m <sup>2</sup> )	Gender	Leg dominance
Control	19 ± 4	169 ± 6	72 ± 13	24 ± 5	Male = 2 Female = 3	Left n=1 Right n=4
Experimental	19 ± 2	167 ± 5	70 ± 11	25 ± 4	Male = 2 Female = 3	Left n=0 Right n=5

Table 2  
*Results of the Preliminary Study's Variable Effect Size and Power Obtained for Sample Size Estimation (n=10)*

	Alpha	Effect size	Power	Sample size
CoP	.05	2.83	.8	5
EMG	.05	.46	.8	40
Self-perturbation	.05	.93	.8	12
Kicking Velocity	.05	2	.8	5

COP: Center of Pressure, EMG: Electromyography

**Inclusion Criteria**

Soccer players (18 to 35-year-old) who are currently participating in regular competitive soccer at the professional, intercollegiate or club level. Athletes may be “in” or “out” of season but must be currently physically active (3-5x/week) and who had no history of absolute and relative contraindications to exercise (Pescatello, 2013)

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**Exclusion Criteria**

Athletes with History of low back pain <6 months old or any injury which required the athlete to seek medical attention or be excluded from activity participation for more than 3 days within the past 6 months.

**Variables**

**Independent variable**

The overall goal of this training program is to improve core stability and strength in soccer athletes while minimizing training effects on the lower extremities. The program consists of an 8-week of core stabilization and strength training organized in 4 phases of progressively more difficult exercises. This program targets the core musculature in 4 positions; supine, quadruped, side-lying and prone. Each athlete progressed independently through the exercises as indicated within each phase and within each body position. The athlete progressed to the next phase of exercises for that position once he/she was able to complete all the repetitions of the last exercise in the set while maintaining good form/technique as defined in the training program. See Appendix E for a more detailed program explanation and progression criteria to move to subsequent phases.

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**Dependent Variables:** Table 3 is a summary of all dependent variables and their abbreviations.

1. Normalized mean trunk muscle EMG (%MVC): right and left rectus abdominus, internal obliques, external obliques, transversus abdominus, erector spinae and multifidi. EMG was measured during pre-post training testing for static postural control only. EMG was not collected during the training itself as it was measured during the self-perturbation test and kicking task.
2. Center of Pressure (CoP) variables of Maximal (MAX) displacements (mm) in the medial-lateral (x) and anterior-posterior (y) directions, Root Mean Square (RMS) displacements (mm) in the medial-lateral (x) and anterior-posterior (y) directions, and the Mean Velocity (PATH) (mm/s) was measured during static single limb stance and tandem stance.

Time to Stabilization (TTS) – is an outcome variable derived from CoP data that has been previously used to determine ankle and trunk postural deviations in individuals with functional and/or chronic ankle instability (Brown, Ross, Mynark, & Guskiewicz, 2004; Colby, Hintermeister, Torry, & Steadman, 1999; Ross & Guskiewicz, 2004; Ross, Guskiewicz, & Yu, 2005; Wikstrom, Tillman, & Borsa, 2005). The TTS is a measure of dynamic stability that analyzes the anterior-posterior (y) and medial-lateral (x) during a period when an individual is recovering from a self-perturbation task (landing from a jump on a single leg) and returning to static stance (Brown et al., 2004; Colby et al., 1999; Ross & Guskiewicz, 2004; Ross et al.,

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2005; Wikstrom et al., 2005). The variable is thought to reflect several factors involved in balance, including postural control, mechanical stability, and proprioception (Brown et al., 2004). It is also thought to reveal strength and proprioceptive deficits in the lower extremity (Ross, 2003 #232). The TTS variable was obtained using a jump protocol described by Ross et al. (2005) (Ross et al., 2005). See **Dynamic Recovery of Standing Postural Control** section below for a full description of the derivation and calculation of the TTS variable

3. Kicking velocity – 1 step kick velocity measured by a sports radar.

Center of pressure and EMG data were collected during static postural control tests {Single-limb stance (SLS), tandem stance (TAN)}. Center of pressure was collected to derive time to stability measure (TTS) in both medial-lateral (x) and anterior-posterior directions (y). CoP data was used to deduce traditional variables: Maximal (MAX) displacements (mm) in the medial-lateral (x) and anterior-posterior (y) directions, Root Mean Square (RMS) displacements (mm) in the medial-lateral (x) and anterior-posterior (y) directions, and the Mean Velocity (PATH) (mm/s). These variables have been previously used for balance assessment and as general athletic performance measures in athletes (Bressel et al., 2007; Davlin, 2004; Lamothe et al., 2009; Matsuda et al., 2008). Electromyography data will be collected on key core muscles groups: the lumbar multifidi, transversus abdominus, internal oblique and external obliques. Raw EMG data was rectified and heart rate stripped accordingly to

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derive mean EMG activity for comparisons. EMG was normalized using maximal voluntary contraction specific to the individual trunk muscle group.

Table 3

*List of All Dependent Variables with their Abbreviations*

<b>Abbreviation</b>	<b>Variable Definition</b>
MAXx (mm)	Maximal center of pressure deviation medial – lateral
MAXy (mm)	Maximal center of pressure deviation Anterior - Posterior
RMSx (mm)	Root mean square medial - lateral
RMSy (mm)	Root mean square Anterior - Posterior
Mean Velocity (mm/s)	Velocity of the center of pressure normalized to 60 sec
RA (%MVC)	Mean electromyography of rectus abdominus muscle normalized to maximal voluntary contraction (MVC)
O/TA (%MVC)	Mean electromyography of Internal obliquus / Transversus abdominus muscles normalized to MVC
EO1/2 (%MVC)	Mean electromyography of External obliquus muscle normalized to MVC
Mult (%MVC)	Mean electromyography of Lumbar Multifidus muscle normalized to MVC
LES (%MVC)	Mean electromyography of Lumbar Erector Spinae muscle normalized to MVC
TES (%MVC)	Mean electromyography of Thoracic Erector Spinae muscle normalized to MVC

%MVC: Percentage of Maximal Voluntary Contraction

### **Instrumentation and Signal Processing**

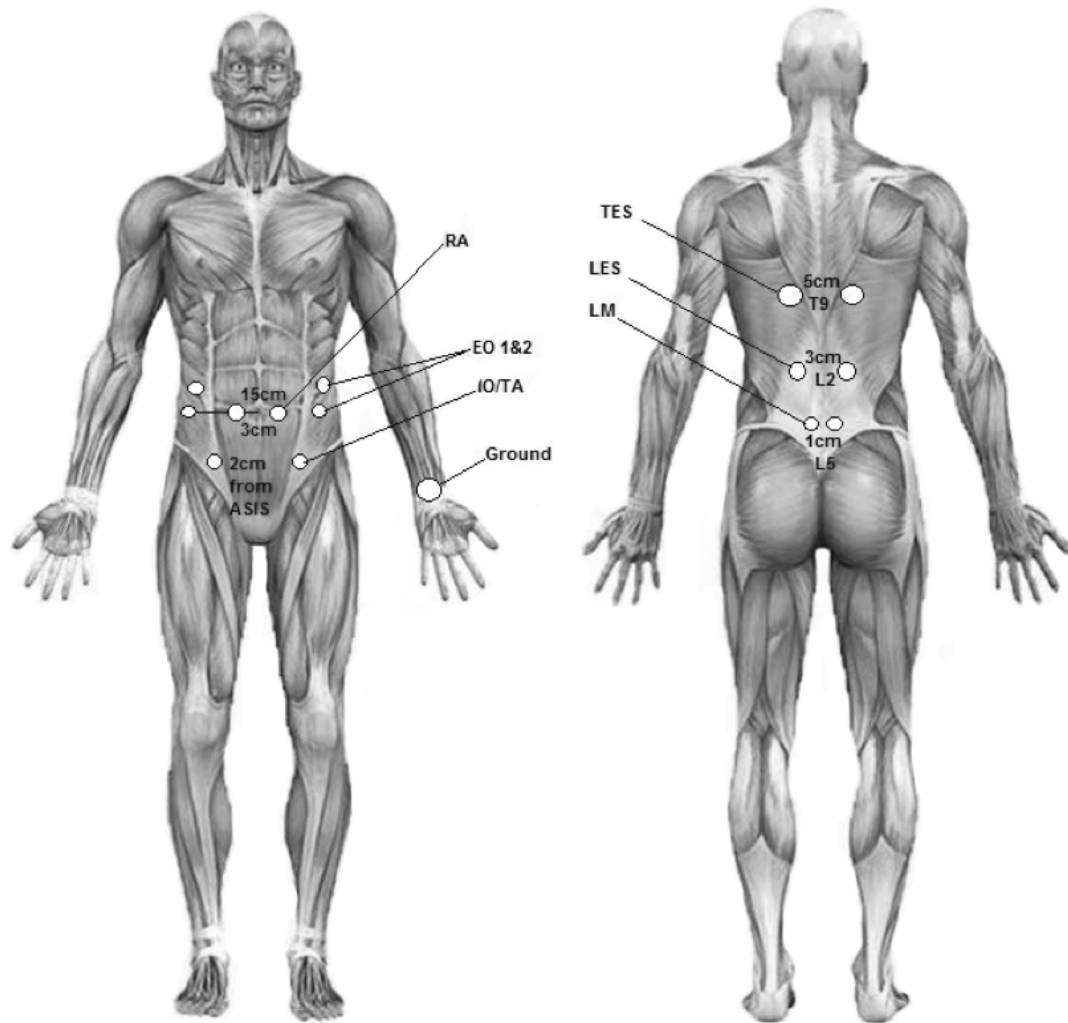
An integrated force plate (P-6000) and wireless EMG system (FREE EMG 300 with an internal amplifier noise of 1.5 vrms) by BTS Bioengineering (Brooklyn NY) was used to collect raw CoP and EMG data. The wireless EMG has a 50-meter signal rang to the receiving unit and a 350 meter rang from the receiving unit to the data collection computer. Raw EMG were also sampled at 4000Hz and transmitted

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wirelessly to a receiver digitally transferred the data unprocessed to a dedicated laptop.

The raw EMG signal with 20-450 bandwidth was pre-amplified by 3bd gain then band pass filtered at 10-350 Hz. Using custom-written Matlab programs (Mathworks v8.5), the EMG signal was full wave rectified and low pass filtered (Butterworth) with a cut off frequency of 3.14Hz. EMG will then be normalized to maximal voluntary contraction (MVC); please refer to **Trunk Muscle Mean EMG Normalization Procedures** section for details. Electrodes were attached to the skin of the subject with a non-allergenic double-adhesive interphase. Pre-gelled bipolar Ag/AgCl (silver chloride) electrodes were placed over muscle motor points (See Figure 2) and used to collect raw EMG. Standard skin preparation was followed for electrode application (shave area, skin abrasion then apply alcohol) to ensure good adhesion and conductivity. Electrodes were placed parallel to the direction of the muscle fibers per best practice in surface EMG capture (Merletti, 1999; Merletti & Parker, 2004). Raw digital force plate data was sampled at 1000Hz, then filtered using a 12.53 Hz 4<sup>th</sup> order Butterworth filter (Brown et al., 2004). EMG and CoP data was post processed using using custom-written Matlab and Statistics Toolbox Release R2015b (Version 8.5; The Mathworks Inc. Natick, MA, 2015) to obtain dependent variables.

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*Figure 2.* Electrode Placement for Trunk Electromyography. Obtained with permission and modified from AskTheTrainer.com. Retrieved from <http://anatomy.askthetrainer.com/>

### **Electrode Specifications**

Pre-gelled bipolar Ag/AgCl (silver chloride), electrode with 20-450Hz bandwidth with a sampling frequency of 2000 Hz were used. The electrodes have a Common Mode Rejection Ratio (CMRR) > 80dB, 10  $\Omega$  impedance and 16-bit signal

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resolution. Lastly they also have a maximally flat Butterworth filter and a 909X amplification at base output.

A Vertec2 Jump Trainer (Sports Imports, Columbus, OH) was used to for the jump protocol to obtain center of pressure data to derive the TTS variable. The SR3600 Sports Radar speed gun (Homosassa, FL) with a speed range of 10-250 mile/hour and a resolution +/- 1 mile/hour was used to record kicking velocity. Lastly, a Mikasa digital pressure gauge was used to ensure that the ball pressure was consistent (12.4-12.6 psi)

### **Procedures**

Upon arrival, subjects were consented and asked to complete a health history questionnaire (Appendix X). The PI oriented them to the session and answered any questions the subject had prior to testing

### **Body height and weight measurement**

The subjects were asked to remove footwear to measure their height and weight using a digital scale and standard tape measure.

### **Surface EMG Preparation and Placement**

The PI placed skin sensors on 15 areas on the subject on their abdomen and spine. The preparation for application of skin sensors followed ISEK standards (Merletti, 1999; Merletti & Parker, 2004) and consisted initially of shaving the area if



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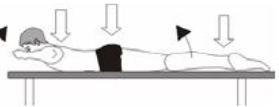


the subject was hairy using a single-use disposable dry-razor. Using a dry-razor is a common medical procedure in conjunction with similar research and events like sports taping, bandaging and recoding electrocardiography. The skin was then cleaned with an alcohol prep pad to remove any lotion, grease etc. to ensure proper adhesion and conductivity. The skin sensors were placed following standardized muscle locations as described by Noraxon(Konrad, 2006) and ISEK (Merletti, 1999; Merletti & Parker, 2004)

**Trunk Muscle Mean EMG Normalization Procedures**

Next, trunk muscle maximal voluntary contraction (MVC) was obtained for EMG normalization. The procedure for collecting the MVC followed the guidelines by Konrad (2006). The subject was asked to slowly yet progressively reach maximum effort after 3 –5 seconds, then hold the position for 3 seconds and promptly relax (see Table 4 for details). The subjects were verbally encouraged to resist harder to ensure that maximal effort was produced. To decrease the chance of injury, subjects were instructed to avoid any “jerky” contractions. Continuous EMG recording was obtained for a single MVC trial for each muscle group. Specific trunk muscle MVC order was performed in random order for each muscle group to avoid systematic fatigue or error. Trunk muscle MVCs were calculated based on a 2-6 second linear envelope to utilize the EMG when the target muscle had reached its maximum contraction.

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Table 4  
*Procedures for Obtaining Trunk Muscle Maximal Voluntary Contraction for EMG Normalization. (Konrad, 2006)*

Muscle Tested	Position	Procedure
External Obliques		In side lying, using belts to secure the hips and legs, the subject is asked to side bend and remain fixed early in the flexion position. Downward counterforce is applied on the shoulders. The test is repeated while subject is lying on the other side to obtain Peak EMG for the opposite External Obliques
Erector spinae & Multifidii		In prone lying, using belts to secure the hips and legs, the subject is asked to extend the trunk and LE's. Downward counterforce is applied bilaterally on the upper trunk.
Rectus Abdominus		In a 30 degree trunk flexed-crook lying position with legs secured, a downward counterforce is applied bilaterally on the upper trunk.
Internal Obliques		In a 30 degree trunk flexed and right rotated-crook lying position with legs secured, a counterforce is applied on the left upper trunk. The test is repeated with left trunk rotation and a counterforce is applied on the right upper trunk

EMG: Electromyography. Images reproduced with permission from Noraxon USA, Inc (Scottsdale, AZ)

**Standing Static Posture Control**

Next, the subjects performed standing postural control tasks (SLS and TAN).

The tests (SLS vs TAN) and limb selection (left vs right) were randomized to

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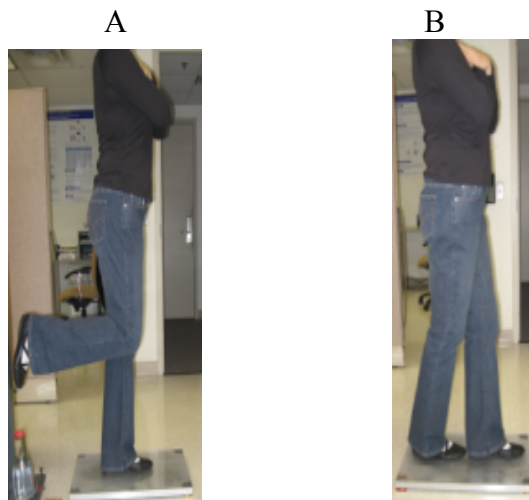
minimize systematic error. However, vision condition was performed with EO then EC.

Single Limb-Stance: One 30-second practice trial and three 30-second testing trials of single-limb-stance on a force plate was performed on each LE. There was a total of 12 testing trials on each LE (3 on each limb with eyes open and 3 on each limb with eyes closed). Athlete was asked to simply stand and balance themselves on one leg (knee slightly unlocked) with their arms crossed over their chest and their opposite knee flexed at 90 degrees (See Figure 3a). Subjects were asked to do their best not to step down with opposite limb. If the subject was unable to do so, the trial was repeated (only one repeated trial was permitted per LE). If an athlete consistently was unable to maintain the testing position (>2 attempts) for 30 seconds, the data was cropped and only the period of time held in test position will be used for comparison. No other instructions were provided.

Tandem Standing: One 60-second practice trial and three 60-second testing trials of tandem-stance on a force plate was performed on each LE. There was a total of 12 testing trials on each LE (3 with each limb in front with eyes open and 3 on each limb in front with eyes closed). The order of initial limb selection will be randomized. Athlete were instructed to shift his/her body weight evenly over both limbs without raising their heel off the force-plate and balance themselves. They were asked to keep their arms crossed over their chest (See Figure 3b). Subjects were asked to do their best not to step down with opposite limb. If the subject was unable to do so, the trial was repeated (only one repeated trial was permitted per LE). If an athlete

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consistently was unable to maintain the testing position (>2 attempts) for 30 seconds, the data was cropped and only the period of time held in test position will be used for comparison. No other instructions were provided



*Figure 3.* Position of athlete for standing postural control tests; a) Single Limb Stance, b) Tandem Stance

### **Dynamic Recovery of Standing Postural Control**

Next, the subjects performed the self-perturbation task. The subject's maximal vertical jump was first assessed using a bipedal vertical jump using a Vertec (Sports Imports, Columbus, OH). To obtain maximal jump height, the subject was instructed to use an individualized jumping technique that allows them to jump as high as possible. They will be allowed to swing their arms as they jumped while holding their reaching arm at maximal shoulder elevation. One practice trial followed by 3 maximal jump heights were recorded. The subjects were then given a visual target for jump height (50% and 55% of their maximal jump height) using the Vertec. While in

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bipedal stance 70 cm away from the center of the forceplate with the Vertec standing above the forceplate, subjects were instructed to jump and land on one leg (see Figure 4 below). They were given a 5 second count-down prior to jumping. They were asked to use only sufficient force to allow them to reach the 50% maximal jump height which was recorded by the Vertec. The subjects were required to touch the Vertec panels or the trial had to be repeated. Subjects were required to reach their minimal mark of 50%, but were permitted to jump between 50% and 55% of their maximum jump height. The subjects were further instructed to lower the reaching arm after touching mark then to cross their arms over their chest as soon as possible and “stick” the landing. They were instructed to “balance” as quickly as possible and remain as motionless as possible in single-leg stance for 20 seconds while CoP data was being collected. Athletes were given four practice trials (2 on each LE) and 8 testing trials (4 on each LE). The trial was repeated if they hopped or touch down with their non-weight-bearing leg during landing or failed to jump within the 50% to 55% jump mark.

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*Figure 4.* Vertec and forceplate set-up for the self-perturbation tasks

Time to stabilization (TTS) was derived using the **Vibration Magnitude Curve-Fit Method** (Ross et al., 2005). The A/P and M/L components of the ground reaction force data were analyzed separately for each subject. The components of the ground reaction force in A/P or M/L were rectified to fit an unbounded third-order polynomial to each component. The range-of-variation means + 3 SDs for each component of the ground reaction force were multiplied by a subject's body weight to obtain a reference variable for each subject that normalized the range-of-variation mean + 3 SDs to body weight. The smallest absolute ground reaction force ranges for the A/P and M/L components are accepted as optimal range-of-variation values. A horizontal line was then inserted over the top of the data of a given ground reaction force component. The value of the horizontal line for a given ground reaction force data (A/P or M/L) is equal to the normalized reference variable for either A/P or M/L.

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The TTS for each component of the ground reaction force is the point at which the unbounded third-order polynomial transected the normalized reference variable.

**Kicking Task**

The subjects were then given a 5-10 min self directed warm-up prior to performing the kicking task. The warm-up did not involve ball handling or kicking to minimize kicking performance practice/learning effects prior to testing. Kicking velocity was assessed as a measure of sport specific performance. Kicking velocity has been previously used in soccer studies and has been showed to be a reliable (Markovic, Dizdar, & Jaric, 2006; Masuda, Kikuhara, Demura, Katsuta, & Yamanaka, 2005). The ball was placed 3.5 meters in front a goal with the speed gun 2.5 meters behind the goal. The set-up was atop a patch of turf to mimic playing surface. Using a one-step kicking technique with their preferred kicking limb, subjected were instructed to kick a soccer ball into the net as forcefully as possible. The athletes were given 3 practice trials and 4 test trials. The subjects were required to use the same limb during the post-test for comparison. Please see Figure 5 for set-up.

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*Figure 5.* Set-up of kicking velocity test. The ball was placed 3.5 meters in front of the goal (white line) and the speed gun was placed 2.5 meters behind the goal.

### **Statistical Analysis**

Intraclass Correlation Coefficients ( $ICC_{2,k}$ ), Minimal Detectable Change using a 95% confidence interval (MDC  $CI_{95\%}$ ) and Standard Error of the Mean (SEM) were obtained using using IBM SPSS (Version 23.0; Chicago, 2015), and Microsoft Excel (Microsoft Office Professional 2013) to quantify the test and retest reliability and precision of the instrumentation.

Power analysis was determined following recruitment and testing of the first 10 subjects (5 in each group) to determine the sample size of 20 total subjects (10 in each group) to obtain a minimal power of .80.



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The pre- and post-training static balance variables for both SLS and tandem stance repeatedly measured with eyes open and closed and for left and right leg were analyzed using a mixed-design repeated measures MANOVA as a particular case of the multivariate linear mixed effects (MLME) model. The model included the fixed effects of group, time, side (left or right), vision condition (open or closed) and a random effect of subject. A Post-hoc test (Wilk's Lambda Approximate F Test) was used to assess the between group differences for all static postural stability tests corresponding to testing the null hypothesis of no group difference in all static balance variables. The mean of three repeated trials for the standing static postural control tests was used for the analysis. Alpha was set at 0.05. No transformation of static balance variables (CoP and EMG) was necessary to satisfy the assumptions of the MLME model.

The pre- and post-training self-perturbation and kicking velocity (TTS) differences were examined using a mixed-design two-way repeated measure ANOVA with the fixed effects of group (control or isolated core stability training) and time (pre- or post-training) and a random effect of subject. Data transformation was not performed since they satisfied the assumptions of the LME model. The difference between the groups were evaluated and tested using the Wilk's Lambda Approximate F Test. Alpha set at 0.05.

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### Subjects

A total of 27 subjects were recruited for this study but only 20 subjects were used for the analysis (n=10 exp, n=10 control). Four subjects completed the study but there were corrupted EMG files during post-testing. The volume of data was too large for statistical substitution. Two subjects dropped out of the study reporting lack of time as the reason and one subject was involved in a car accident and developed low back pain. For demographic data, please see Table 5 below. Following the initial testing, subjects were randomized to either the control or the experimental (core stability training) group. The first 10 subjects were also used for the reliability study and were tested twice on the same day 4 hours apart.

Table 5  
*Subject Demographic Data for all subjects (n=20)*

	Age (years)	Height (cm)	Mass (kg)	BMI (kg/m <sup>2</sup> )	Gender	Leg dominance
Control n=10	20 ± 2	167 ± 6	68 ± 11	24 ± 5	Male = 5 Female = 5	Left n=1 Right n=9
Experimental n=10	20 ± 1	168 ± 4	71 ± 13	25 ± 4	Male = 5 Female = 5	Left n=0 Right n=10

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## CHAPTER IV

### RESULTS

#### **Normality, Homogeneity, Sphericity**

Assumptions were satisfied for normality, homogeneity, sphericity using Box's M, Levine's, Mauchly's on CoP and EMG data.

#### **Reliability Data**

ICC (2,k) values for all variables were good to excellent ranging from .712 to .991. The MDC (CI<sub>95%</sub>) and SEM values in general were small for all variables.

Tables 6-11 summarize the

Table 6

*Reliability Values for Single Leg Stance with Eyes Open*

	Mean	ICC (2,3)	MDC (95% CI)	SEM (s)
MAXx (mm)	42.3±12.6	0.981	4.8	1.7
MAXy (mm)	28.5±3.5	0.991	0.9	0.3
RMSx	8.4±2.4	0.983	0.9	0.3
RMSy	4.9±0.8	0.875	0.8	0.3
Mean velocity (mm/s)	30.2±9.6	0.934	6.8	2.5
RA (%MVC)	6.0±1.4	0.891	1.3	0.5
IO/TA (%MVC)	4.4±1.1	0.982	0.4	0.1
EO1 (%MVC)	8.7±1.7	0.897	1.5	0.5
EO2 (%MVC)	10.9±2.1	0.932	1.5	0.5
Mult (%MVC)	4.0±0.8	0.762	1.1	0.4
LES (%MVC)	4.0±1.1	0.783	1.4	0.5
TES (%MVC)	3.8±1.0	0.985	0.3	0.1

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Table 7  
*Reliability Values for Single Leg Stance with Eyes Closed*

	Mean	ICC (2,3)	MDC (95% CI)	SEM (s)
MAXx (mm)	63.3±11.8	0.988	3.6	1.3
MAXy (mm)	58.3±10.9	0.894	3.8	1.4
RMSx	14.9±3.0	0.981	1.1	0.4
RMSy	12.1±4.2	0.894	3.8	1.4
Mean Velocity (mm/s)	81.9±13.0	0.892	11.8	4.3
RA (%MVC)	7.1±1.9	0.875	1.8	0.7
IO/TA (%MVC)	7.9±1.7	0.888	1.5	0.6
EO1 (%MVC)	12.6±2.0	0.986	0.6	0.2
EO2 (%MVC)	13.9±2.1	0.773	2.8	1.0
Mult (%MVC)	12.9±2.1	0.788	2.6	0.9
LES (%MVC)	13.2±2.1	0.998	0.3	0.1
TES (%MVC)	8.3±1.3	0.981	0.5	0.2

Table 8  
*Reliability Values for Tandem Stance with Eyes Open*

Variable	Mean	ICC (2,3)	MDC (95% CI)	SEM (s)
MAXx (mm)	38.0±9.1	.712	13.5	4.9
MAXy (mm)	33.5±6.4	.792	8.1	2.9
RMSx	7.0±1.9	.712	2.9	1.0
RMSy	5.2±.8	.792	1.0	0.4
Mean velocity (mm/s)	23.4±4.7	.762	6.3	2.3
RA (%MVC)	7.4±1.3	.762	1.8	0.6
IO/TA (%MVC)	6.6±1.0	.783	1.3	0.5
EO1 (%MVC)	11.0±1.1	.779	1.4	0.5
EO2 (%MVC)	12.5±1.9	.987	0.6	0.2
Mult (%MVC)	5.2±.7	.889	0.6	0.2
LES (%MVC)	5.3±.9	.875	0.9	0.3
TES (%MVC)	4.4±1.0	.788	1.2	0.4

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Table 9  
*Reliability Values for Tandem Stance with Eyes Closed*

	Mean	ICC (2,3)	MDC (95% CI)	SEM (s)
MAXx (mm)	80.0±8.0	0.889	7.4	2.7
MAXy (mm)	69.1±8.3	0.888	2.8	1.0
RMSx	10.0±1.5	0.798	0.7	0.3
RMSy	11.6±0.8	0.921	1.9	0.7
Mean velocity (mm/s)	58.4±13.7	0.932	10.7	3.9
RA (%MVC)	7.4±1.3	0.991	0.5	0.2
IO/TA (%MVC)	6.6±1.0	0.891	1.5	0.5
EO1 (%MVC)	11.0±1.1	0.981	0.7	0.3
EO2 (%MVC)	12.5±1.9	0.888	1.5	0.5
Mult (%MVC)	5.2±0.7	0.893	1.9	0.7
LES (%MVC)	5.3±0.9	0.889	2.1	0.8
TES (%MVC)	4.4±1.0	0.981	0.6	0.2

Table 10  
*Reliability Values for Self-Perturbation*

	Mean (s)	ICC (2,4)	MDC (95% CI)	SEM (s)
R TTSx	1.45±.35	.783	.45	.16
R TTSy	1.19±.41	.893	.37	.13
L TTSx	2.01±.63	.764	.84	.31
L TTSy	1.89±.59	.792	.75	.30

Table 11  
*Reliability Values for Kicking Velocity*

Mean (SD) Km/h	ICC (2,4)	MDC (95% CI) (km/h)	SEM (km/h)
58 (8)	.991	2.0	0.7

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**Pre-Post Training Data**

Repeated measures MANOVA revealed between group differences in the experimental group ( $p < .05$ ) for all static postural control variables (CoP and EMG) except for the external obliques (EO1& EO2) and thoracic erector spinae 9TES). This is consistent for both SLS and TAN tests under both eyes open and eyes closed conditions. Figures 6 -9 illustrate the CoP and trunk muscle EMG between and within group differences pre and post training for SLS EO and EC conditions.

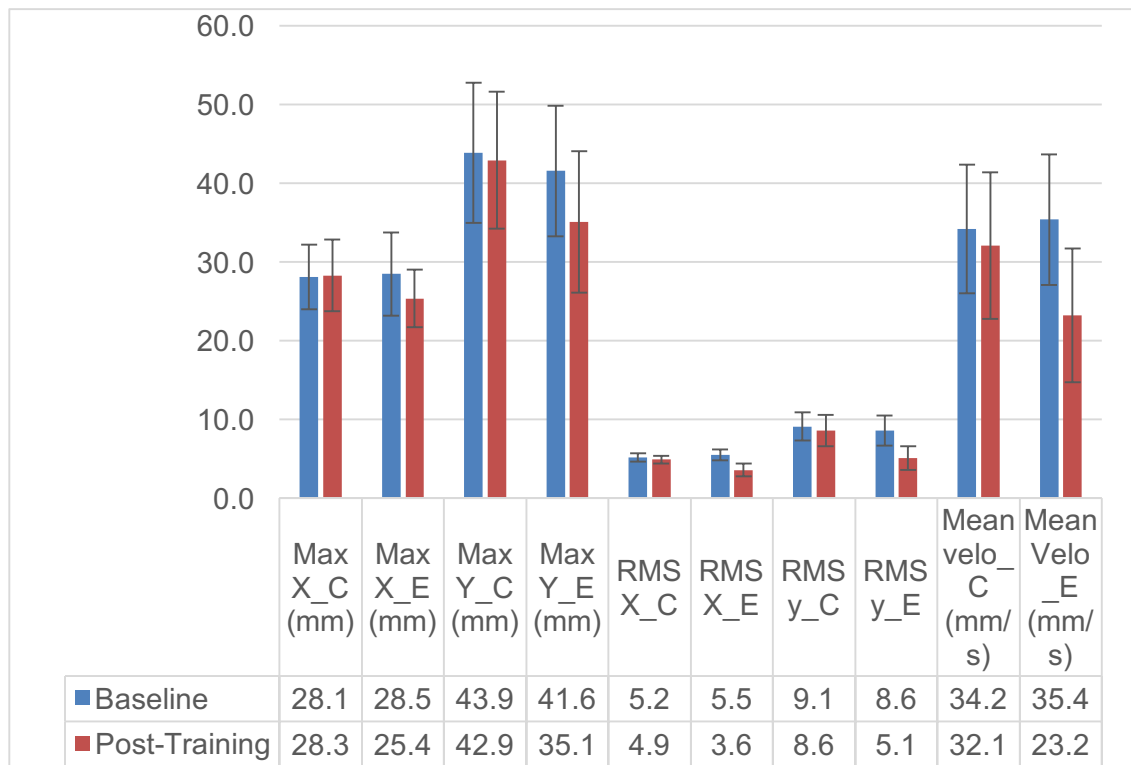


Figure 6. Single Limb Stance CoP Eyes Open pre-post Training. E; Experimental group, C: control group

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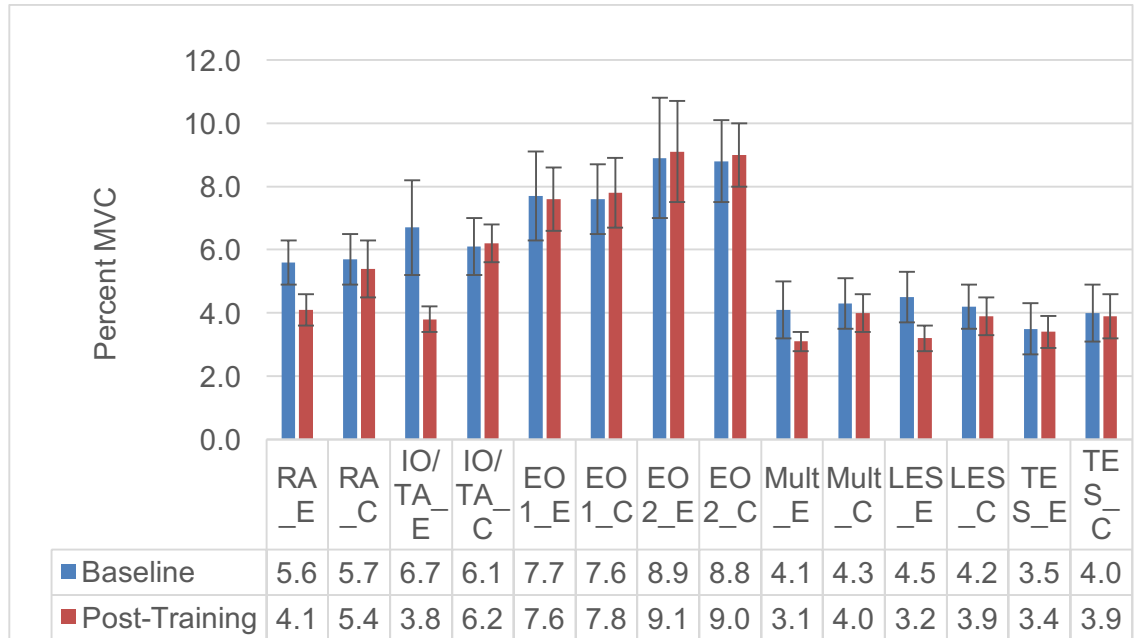


Figure 7. Single Limb Stance Trunk Muscle EMG Eyes Open pre-post Training. E; Experimental group, C: control group, MVC: Maximal Voluntary Contraction

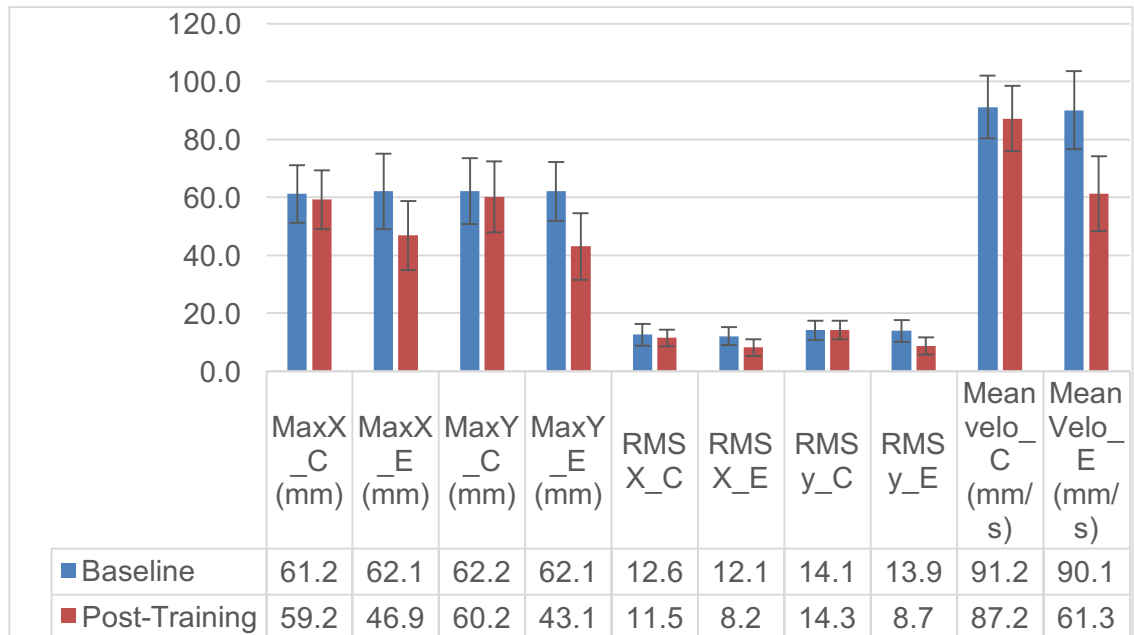


Figure 8. Single Limb Stance CoP Eyes Closed pre-post Training.

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E; Experimental group, C: control group

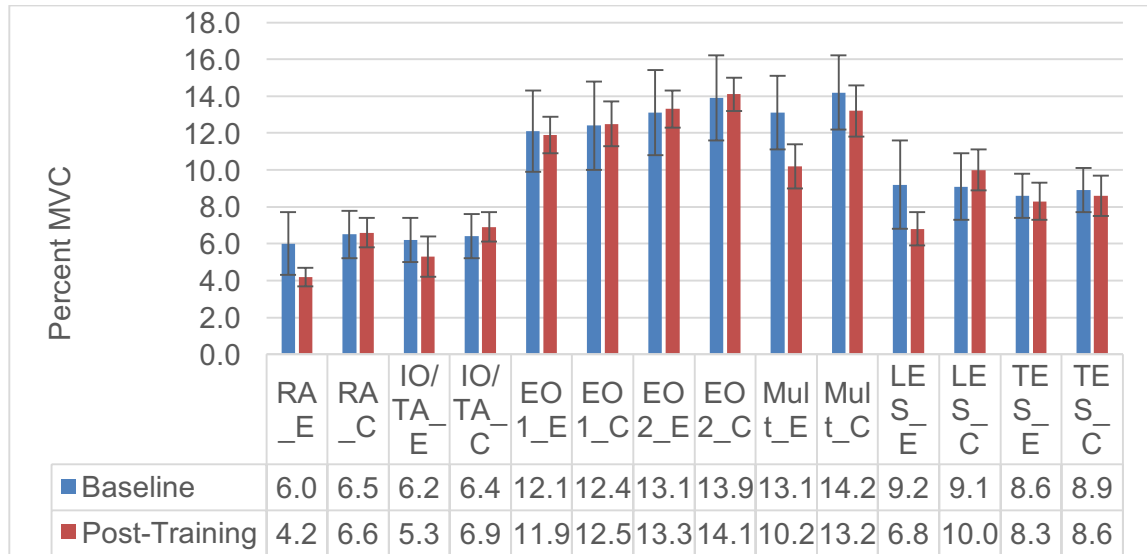


Figure 9. Single Limb Stance Trunk Muscle EMG Eyes Closed pre-post Training. E; Experimental group, C: control group, MVC: Maximal Voluntary Contraction

Figures 10 -13 illustrate the CoP and trunk muscle EMG between and within group differences pre and post training for TAN EO and EC conditions.



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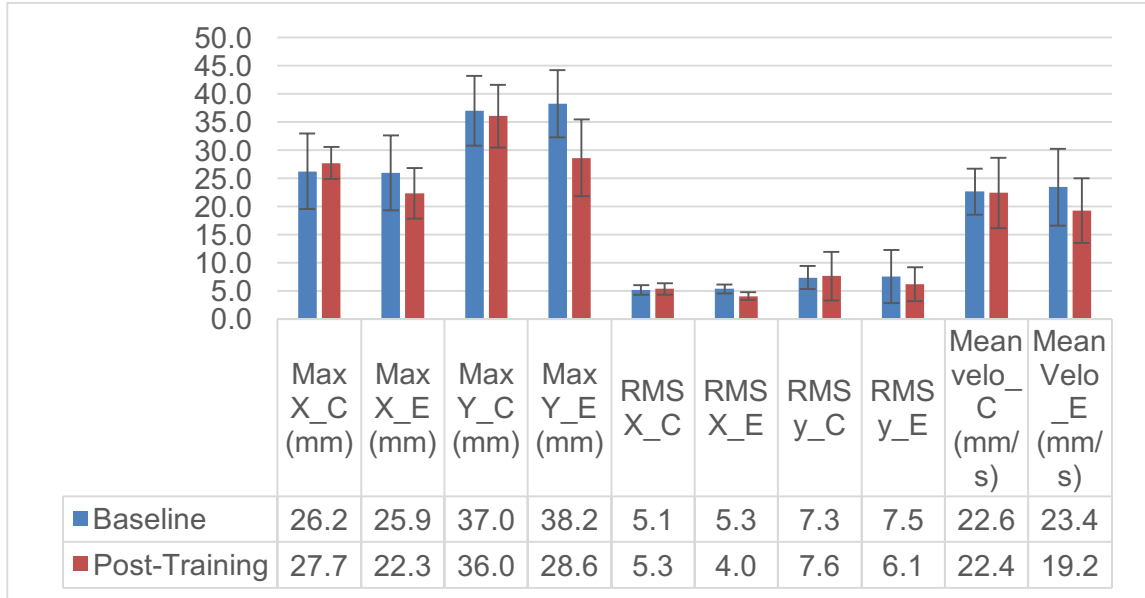


Figure 10. Tandem Stance CoP Eyes Open pre-post Training. E; Experimental group, C: control group

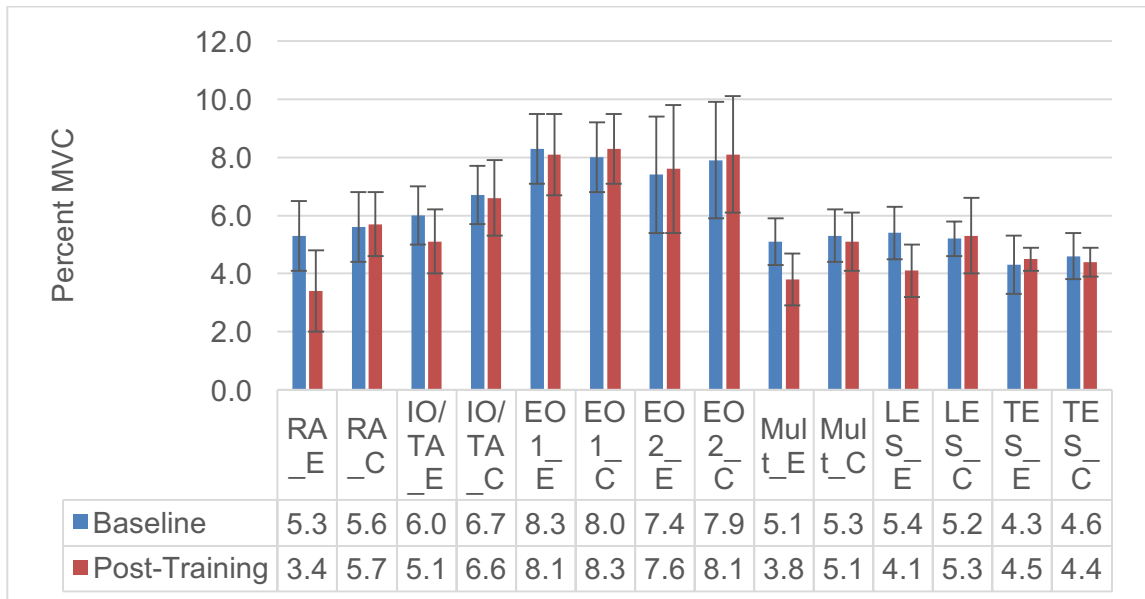


Figure 11. Tandem Stance Trunk Muscle EMG Eyes Open pre-post Training. E; Experimental group, C: control group, MVC: Maximal Voluntary Contraction

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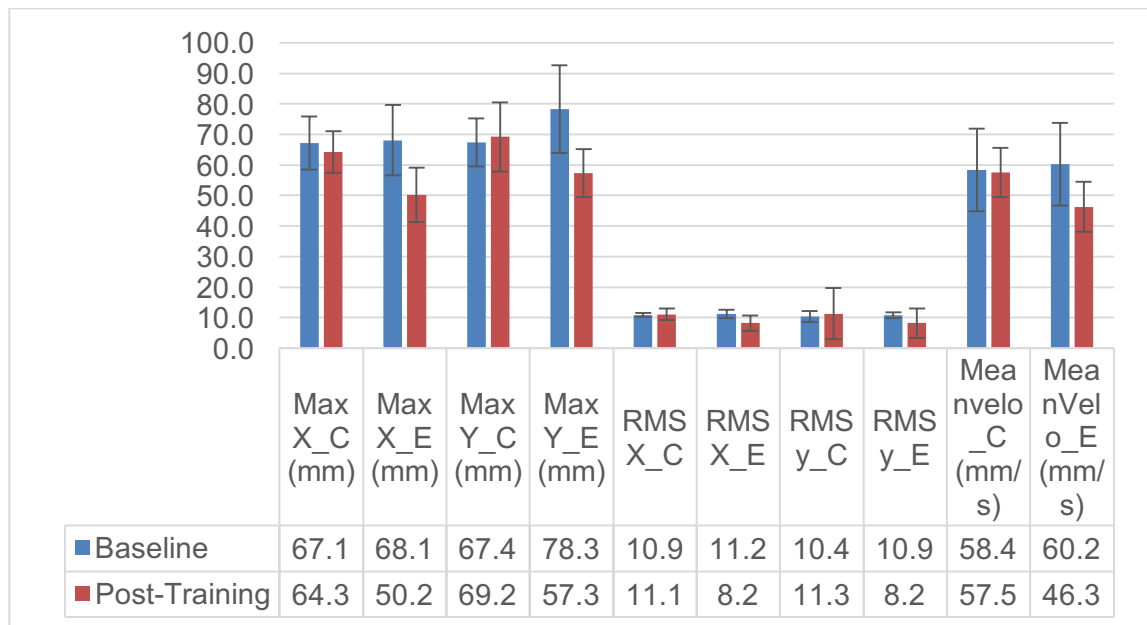


Figure 12. Tandem Stance CoP Eyes Closed pre-post Training. E; Experimental group, C: control group

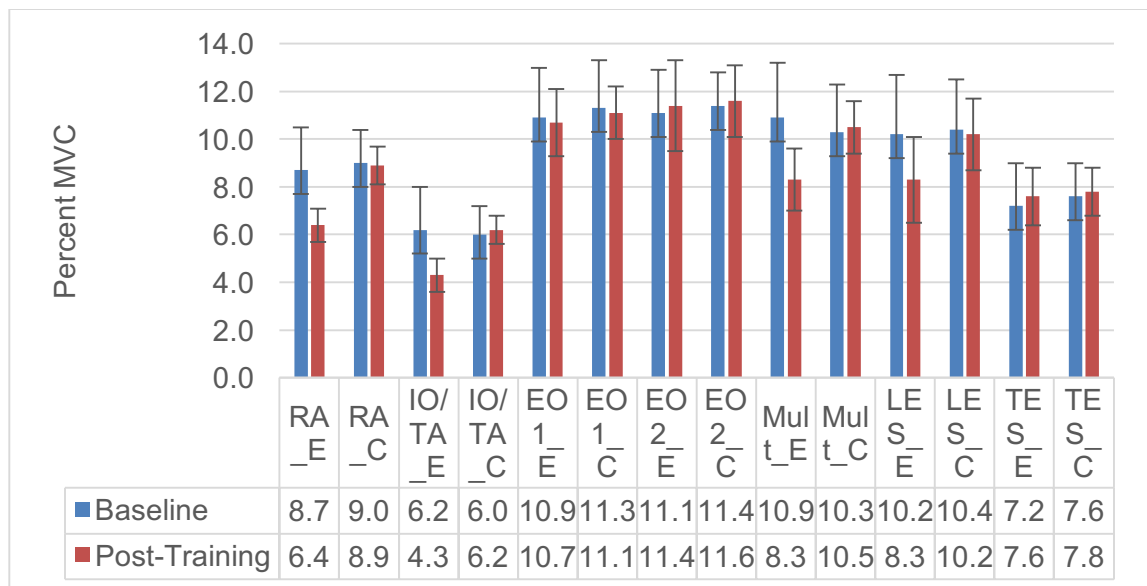


Figure 13. Tandem Stance Trunk Muscle EMG Eyes Closed pre-post Training. E; Experimental group, C: control group, MVC: Maximal Voluntary Contraction

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Repeated measures ANOVA demonstrated between group differences in the experimental group ( $p < .05$ ) of self perturbation (TTS) for both right and left LE's and for kicking velocity. Figures 14-16 below illustrate the TTS (right and left leg) and trunk muscle EMG between and within group differences pre and post training.

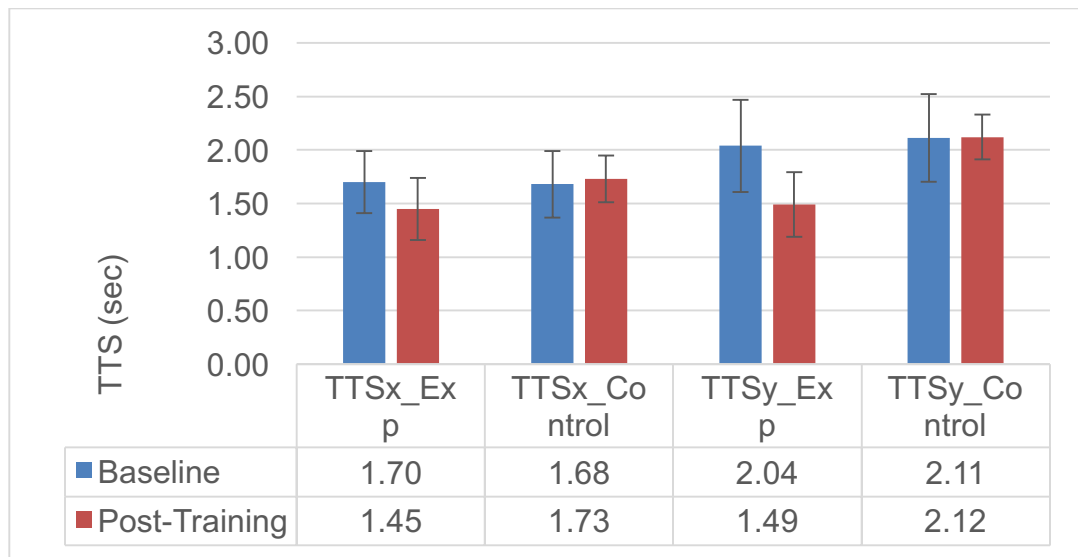


Figure 14. Self perturbation Time to Stability (TTS) pre-post Training for the right lower extremity.  
Exp: Experimental group.

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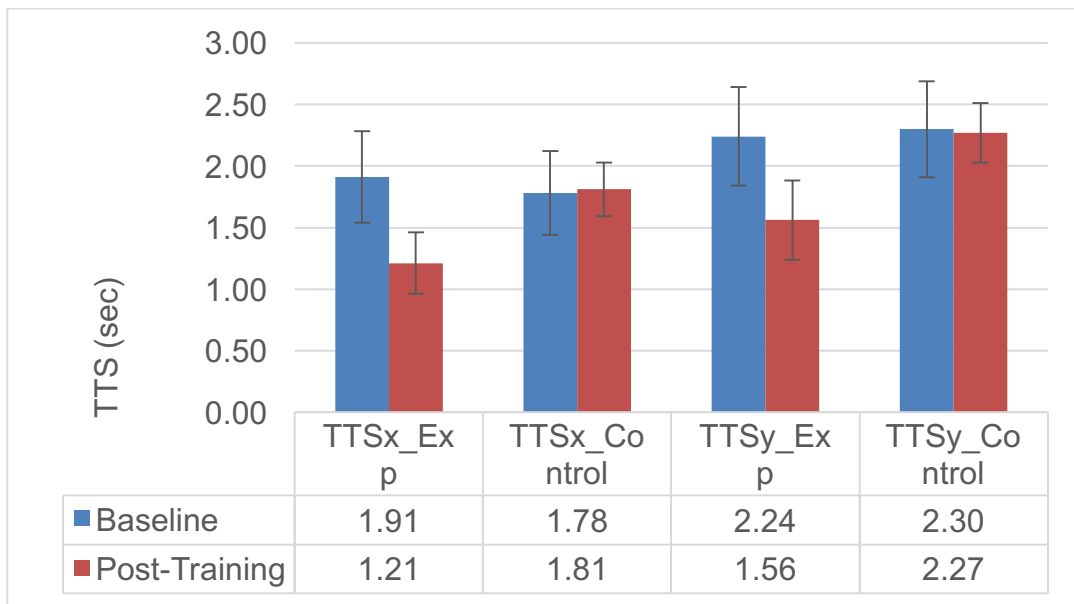


Figure 15. Self perturbation Time to Stability (TTS) pre-post Training for the right lower extremity.  
Exp: Experimental group.

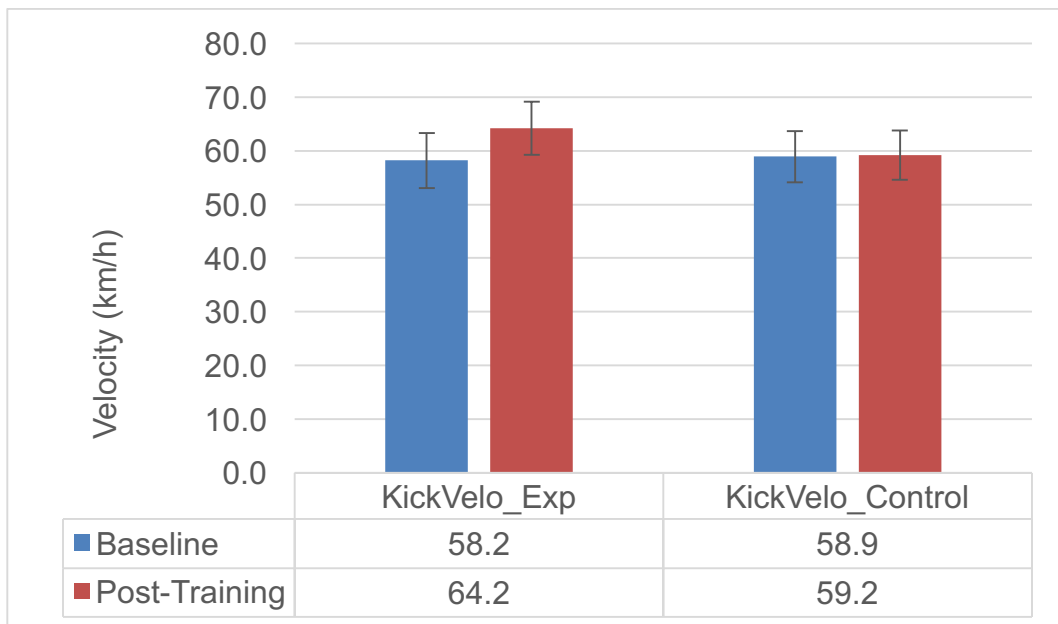


Figure 16. Kicking Velocity pre-post Training.  
Exp: Experimental group.

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**Subject Progression Through the Training Program**

The training program was sufficiently challenging as demonstrated by the changes in postural control and kicking velocity. All of the subjects advanced through to Phase II but none were able to advance to Phase IV during the 8-weeks of training. Table 12 shows The extent of progression of each subject in each category of exercises; emphasized are the number of exercises completed within each phase per category. Table 13 provides the proportion of phase completion per subject.

Table 12.  
*The extent of progression of each subject in each category of exercises. Emphasized are the number of exercises completed within each phase per category.*

	<b>Body Position</b>			
	Supine	Quadruped	Side lying	Prone
Subject 1(M)	P II (6/7)	P II (5/7)	P II (3/4)	P III (2/8)
Subject 2 (F)	PII (5/7)	P II (5/7)	P III (2/10)	P II (4/5)
Subject 3 (M)	P II (5/7)	P II (6/7)	P III (1/10)	P II (2/5)
Subject 4 (F)	P III (3/10)	P III (1/3)	P II (4/4)	P III (3/8)
Subject 5 (F)	P II (7/7)	P II (7/7)	P II (3/4)	P II (5/5)
Subject 6 (M)	P III (3/10)	P III (1/3)	P III (4/10)	P III (3/8)
Subject 7(M)	P III (4/10)	P II (7/7)	P II (4/4)	P II (2/5)
Subject 8 (F)	P II (6/7)	P II (7/7)	P II (4/4)	P II (5/5)
Subject 9(F)	P III (4/10)	P III (2/3)	P III (5/10)	P II (5/5)
Subject10(M)	P II (4/7)	P II (3/7)	P II (2/4)	P II (2/5)

P: phase

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Table 13.

*Percentage of subjects completing each phase within each body position*

	<b>Body Position</b>			
	Supine	Quadruped	Side lying	Prone
Phase I	100%	100%	100%	100%
Phase II	100%	100%	100%	100%
Phase III	40%	30%	40%	30%
Phase IV	0%	0%	0%	0%

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**CHAPTER V**

**Discussion**

The results demonstrated that the procedures were reliable with relatively small MDCs and SEMs. In general, the improvements in postural control and EMG and kicking velocity were larger than the MDCs indicating that the differences were not due to instrument error. The effect size was likely over-estimated and the power under-estimated due to the small sample size. That being said, the results demonstrated that there was statistical improvements in most of the variables measured following an 8-weeks of isolated core stabilization training in division II and III collegiate athletes. However, there were 3 EMG variables (EO1, EO2 and TES) that consistently showed some improvements but not statistically significant ( $p < .05$ ). The core stabilization program was designed to increase trunk control thereby improving standing balance. The rotational exercises were only implemented in the 4<sup>th</sup> phase. Seeing how none of the subjects reached stage 4 over the 8-week period, it is plausible that external obliques (EO1 and EO2) were not stressed sufficiently during training to induce a physiological improvements. Similarly, the thoracic spinae (TES) are predominantly extenders of the upper trunk. There were few exercises specifically addressing upper trunk extension but those mostly emphasized contraction of the transvers abdominus and maintaining good pelvic alignment.

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The training program was designed to be sufficiently difficult to challenge collegiate soccer athletes and to minimize plateau effects of training. Subjects 4, 6 and 9 advanced to phase 3 in at least 3 body positions whereas subjects 5 and 8 were on the verge of entering Phase III exercises.

The theoretical framework steering training protocols to include core stabilization training is founded on the idea that improved trunk stability will improve balance and performance leading to reduced LE injuries. This is based on the principle of proximal stability improves distal mobility (Kibler et al., 2006) which is larger explained by the presence of force coupling, pre-programmed patterns of muscle activation, APA's and CPA's which are enhanced by repetition and practice (Hirashima et al., 2002; Nichols, 1994; Peterka, 2002; Peterka & Loughlin, 2004; Rothwell, 2012). These pre-programmed patterns of muscle activation patterns stored in the motor cortex and relayed via the cerebellum and efferent pathways to the extremities. Chronic exposure to resistance training has been shown to produce marked increases in muscular strength. This increase has been attributed to a range of neurological and morphological adaptations (Folland & Williams, 2007). Further, it's been shown that resistance training alters spinal motor neuron excitability inducing synaptogenesis within spinal cord (Adkins, Boychuk, Remple, & Kleim, 2006). This in turn has been shown to create changes in spinal reflexes (more precisely the H-reflex) that are dependent on the specific behavioral demands of the task (Adkins et al., 2006; Duclay, Martin, Robbe, & Pousson, 2008).



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To reduce the displacement of the center of mass (COM) and CoP, the central nervous system activates trunk and LE CPA's and APA's (Aruin & Latash, 1995; Li & Aruin, 2007, 2009). APA's are the first "line of defense" against the destabilizing effect induced by a predicted perturbation (Yiou, Caderby, & Hussein, 2012). Larger perturbation, such the self-perturbation test used to obtain the TTS variable, required the activation of CPA's (Alexandrov, Frolov, Horak, Carlson-Kuhta, & Park, 2005; Park, Horak, & Kuo, 2004). As such, CPAs are responsible for restoring the position of the COM *following* a perturbation CPA's (Alexandrov et al., 2005; Park et al., 2004). However, APA's have been linked to improvements in performance through modulation during repeated activity (Saito, Yamanaka, Kasahara, & Fukushima, 2014). The effect of training on APAs has also been shown to last even after the cessation of training suggesting a role in improved motor acquisition and function (Saito et al., 2014).

In Summary, the core stabilization training lasted only 8-weeks and improvement is standing balance, recovery of balance and kicking performance. The improvements seen in this study are not likely due to true morphological adaptations but explained by neurological adaptations such as improved timing/efficiency of the force couples and the pre-programmed patterns of muscle activation and improved modulation of APA's and CPA's. Hence the improvements in the "neuromuscular subsystem" as describe by Panjabi's model. So, it follows that all the hypotheses and sub-hypotheses for this study were met.

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The improvements in performance found in this study are echoed by other publications that used a combination/integrated approach to core stabilization training examined using clinical tests and measures (Chappell & Limpisvasti, 2008; Filipa, Byrnes, Paterno, Myer, & Hewett, 2010; Myer et al., 2005; Stanton et al., 2004; Tse et al., 2005). None of these studies examined biomechanical changes relative to core stabilization training. Satu et al. found no change in GRF while running on a forceplate (Sato & Mokha, 2009). However, their training program was only 6 weeks long, arguably not sufficient in duration to induce neuromuscular adaptations.

**Limitations**

The subjects were recruited from various colleges in the greater Philadelphia region over a period of 14 months. College soccer programs have different training regiments and not all the athletes may have had the same level of fitness or motivation. Recruiting proved to be a challenge and multiple IRB's from multiple institutions were required. This further delayed the project. Recruiting over such a large span of time may have resulted in confounding variables. However, every effort was made to limit said variables; educating the athletes, keeping a training log, supervising the sessions, etc. Furthermore, the subjects did not progress towards later stages of program where trunk rotational exercises were incorporated. This was reflected in the results such that the external obliques showed some improvement in activation following training but said improvement was not statistically significant. However, there were improvements in TTS and kicking velocity. These tasks are

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much more difficult and involve multiple system working in concert. That said, one can argue that although the improvement in activation of the external obliques was not statically significant, they were well incorporated in the system and played a role in the improved TTS and kicking velocity. A modification to the current program to incorporate rotational exercises earlier may isolate the external obliques earlier possibly resulting in a statistical difference

The subject pool was a very narrow sample consisting of division II and III soccer athletes. Generalizability to other athletes and sports is cautioned. The physiology and mechanisms by which the improvements in results are hypothesized are universal and there may be applicability of the training program to other sports

The order of tests wasn't completely randomized and there may be implications for learning effects and compounding error. Further, the consenting process and overall testing session from start to finish lasted roughly 120-150 min and may have lead some subjects to be fatigues by the end of the session. However, based on the results, the consistency of the procedures and length of the testing session, it does not appear that fatigue was a major concern.

Lastly, there were issues with EMG transmission and recording in 4 subjects of the subjects and their results were excluded from the study. The wireless technology used by BTS Bioengineering was such that it required verification of interference prior to testing. These 4 subjects were tested in a new location where there was interference unbeknown to the investigator. Once the problem was discovered and the

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issue resolved with the company, future tests involved an additional verification of EMG interference.

**Future Direction**

Future studies will compare integrated core stabilization training to isolated training to assess the extent of the physiological change using similar methodology. Furthermore, recruiting athletes from different sports competing at different levels will allow for more generalizability of the results. Lastly, to test the current narrative that core stabilization training reduces the incidence of LE injury, conducting a longitudinal study spanning several years of an athletes' athletic career with multiple testing session over time may provide evidenced to support said hypothesis.

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## **CHAPTER VI**

### **CONCLUSION**

This study demonstrated that an isolated core stabilization program induced physiological changes resulting in improved balance and kicking velocity. The procedures were reliable and provided one aspect of assessing trunk control and athletic performance. The isolated core stabilization program induced neuromuscular changes which in combination resulted in improved balance and kicking velocity.

#### **Clinical Implications**

For soccer athletes with balance deficits or who have weight bearing restriction, training the core in isolation will assist in improving trunk muscle activation and standing static and dynamic balance. This improvement in neuromuscular function also improved kicking velocity. This training program minimally utilizes the LE and has minimal to no injury risk of injury, thereby may be used with athletes recovering from LE injuries.

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APPENDIX A

IRB Approval Letters

Saint Michael's Medical Center

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**Saint Michael's**  
MEDICAL CENTER  
A MEMBER OF CATHOLIC HEALTH EAST

June 17, 2014

All El-Kerdi, MS, ATC  
1200 West Tabor Road  
Slay Building, Room 134  
Philadelphia, PA 19141

Dear Mr. El-Kerdi:

The protocol and informed consent you presented were approved by the Institutional Review Board on June 17, 2014, for a one-year period through June 17, 2015:

Postural Control and Soccer Performance Difference Following Core Training  
(Protocol, Informed consent and flyer) – Low Risk – #14/14

If any changes/modifications are made to this protocol, the IRB must be notified immediately. If any changes/modifications are made, a new and complete application must be submitted for approval.

All serious adverse effects or deaths must be reported immediately to the IRB. According to the terms of the one-year approval, you must report back to the IRB annually on the progress of the investigation. In approximately ten months, you must request an extension of this approval for an additional twelve-month period, if needed, by writing to the Chairman of the IRB. A brief report must be included with the request for an extension of approval, including the number of patients involved, age, sex, major diagnoses and a brief summary of results. Failure to submit a report to the Saint Michael's Medical Center IRB prior to study expiration will result in expiration of IRB approval and study procedures at your site must cease. These actions require reporting to the Sponsor. Please note that continuation of research after expiration of the IRB approval is a violation of Federal Regulations. Upon completion of every study, a brief summary of results must be sent to the IRB.

Sincerely,

Constantinos A. Costeas, M.D.  
Chairman, Institutional Review Board

mf

cc: Mary Ruzicka, PhD, Seton Hall, IRB  
Dean Brian Shulman, Seton Hall

Postural Control, Recovery of Standing Postural Control and Kicking Velocity in  
Soccer Athletes



June 16, 2015

Ali El-Kerdi, MS, ATC  
1200 West Tabor Road  
Slay Building, Room 134  
Philadelphia, PA 19141

Dear Mr. El-Kerdi:

The protocol and informed consent noted below was reviewed and granted an additional one-year approval by the IRB on June 16, 2015, through June 16, 2016:

Postural Control and Soccer Performance Difference Following Core Training –  
Low Risk – #14/14

If any changes/modifications are made to this protocol, the IRB must be notified immediately. If any changes/modifications are made, a new and complete application must be submitted for approval. All serious adverse effects or deaths must be reported immediately to the Committee.

According to the terms of the one-year approval, you must report back to the IRB as directed at the time of the initial approval of the protocol. In approximately ten months, you must request an extension of this approval for an additional twelve-month period, if needed, by writing to the Chairman of the IRB. A brief report must be included with the request for an extension of approval, including the number of patients involved, age, sex, major diagnoses and a brief summary of results. Upon completion of every study, a brief summary of results must be sent to the IRB. Failure to submit a report to the Saint Michael's Medical Center IRB prior to study expiration will result in expiration of IRB approval and study procedures at your site must cease. These actions require reporting to the Sponsor. Please note that continuation of research after expiration of the IRB approval is a violation of Federal Regulations.

For studies involving drugs for inpatient use, the drug must be deposited with the pharmacy for dispensing. In addition, two copies of the consent form must be signed by the patient. One copy will be kept on the patient's chart, the other filed in the pharmacy.

Sincerely,

A handwritten signature in black ink, appearing to be "Constantinos A. Costeas", written over a horizontal line.

Constantinos A. Costeas, M.D.  
Chairman  
Institutional Review Board

mf

cc: Mary F. Ruzicka, IRB  
Dean Brian Shulman



Postural Control, Recovery of Standing Postural Control and Kicking Velocity in  
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IRB Approval Letters

Einstein Regional Medical Center



APPROVAL OF RESEARCH

March 11, 2015

Ali El-Kerdi, DPT, MS  
MossRehab  
Einstein Medical Center - Philadelphia  
1200 West Tabor Rd  
Philadelphia, PA 19141

Dear Dr. El-Kerdi:

The IRB reviewed the following research:

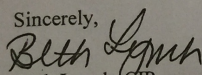
Type of Review:	Modification
Project Title:	Postural Control and Soccer Performance Difference Following Core Training
Investigator:	Ali El-Kerdi, DPT, MS
IRB ID:	4595 EXP
Funding Agencies:	Department Funded/Supported MossRehab Peer Review Committee (as of 9/14)
Grant Title:	None
Grant ID:	None
IND or IDE:	None
Documents reviewed:	<ul style="list-style-type: none"><li>• Modification, signed 3/9/15 -added Philadelphia University as external site</li><li>• Application for Human Research, date updated 3/9/15</li><li>• E-mail from Philadelphia University regarding IRB approval, dated 3/5/15</li><li>• Protocol Summary, dated updated 3/9/15</li></ul>

The IRB approved the research from **March 11, 2015 to February 3, 2016** inclusive.

At least 45 days prior to the study expiration date or within 45 days of study closure, whichever is earlier, you are to submit a completed "FORM: Continuing Review Progress Report" and all required materials to request continuing approval or study closure.

If continuing review approval is not granted before the expiration date of **February 3, 2016** approval of this research expires on that date.

In conducting this research you are required to follow the requirements listed in the Investigator Manual.

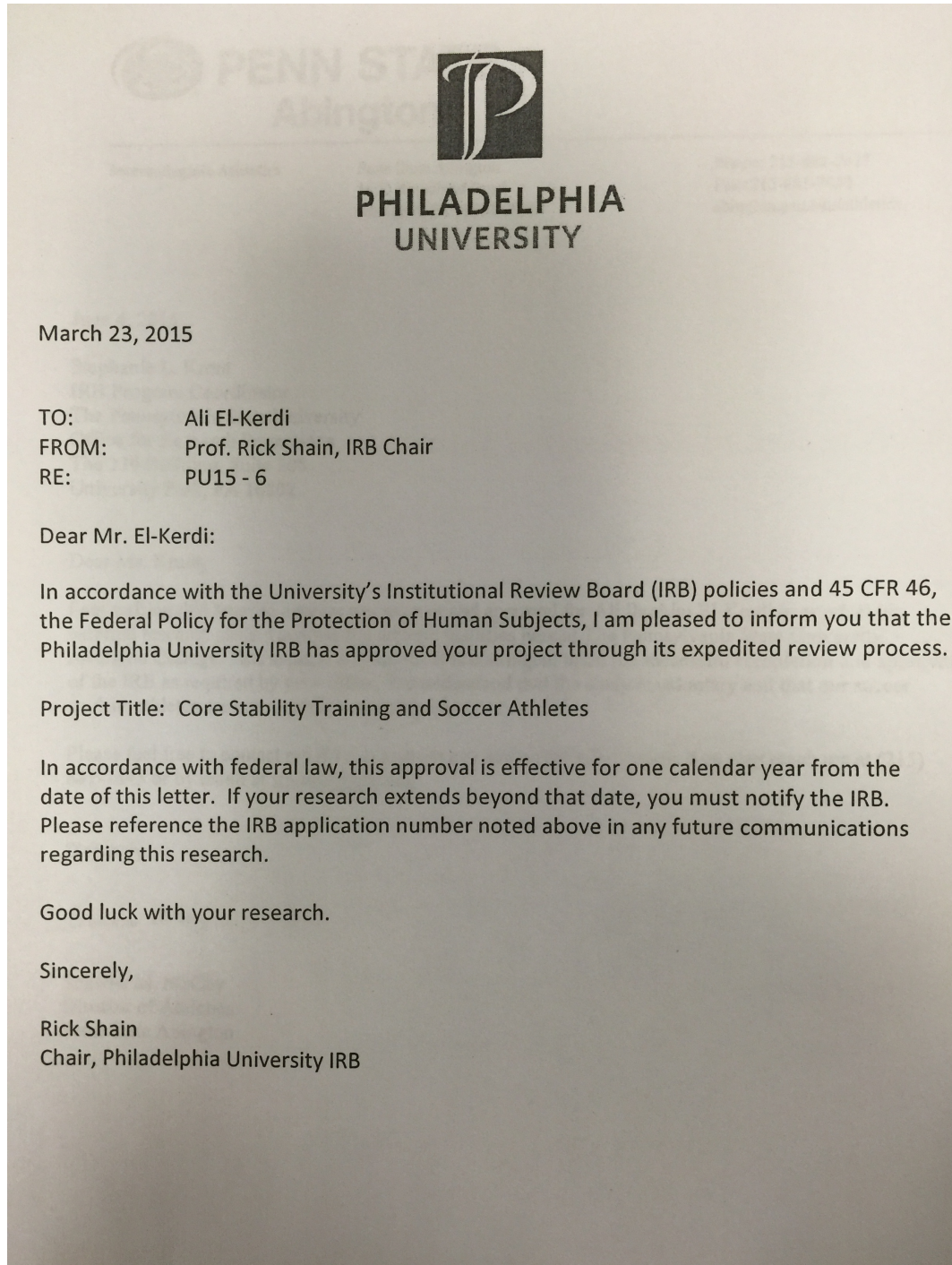
Sincerely,  
  
Beth Lynch, DPT  
Senior IRB Analyst



Postural Control, Recovery of Standing Postural Control and Kicking Velocity in  
Soccer Athletes

**IRB Approval Letters**

**Philadelphia University**



Running Head: Effects of Isolated Core Stability Training on Standing Static 109  
Postural Control, Recovery of Standing Postural Control and Kicking Velocity in  
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**IRB Approval Letters**

**Penn State Abington**

Postural Control, Recovery of Standing Postural Control and Kicking Velocity in  
Soccer Athletes

**Einstein Healthcare IRB#4595 - Postural control and soccer performance difference following core training - PI Ali El-Kerdi**

---

From: **Kahler, Tracie** (tkahler@psu.edu)  
Sent: Wed 7/08/15 3:44 PM  
To: **Ali Ibrahim El-Kerdi** (aelkerdi@hotmail.com) (aelkerdi@hotmail.com)  
Cc: 'smm65@psu.edu' (smm65@psu.edu)

Dear Ali El-Kerdi:

Based on our review of the documents, separate submission for review and approval to Penn State's IRB is not needed.

This decision is based on the following:

No one from Penn State is engaged in the research (i.e., answering questions about the study, obtaining informed consent from subjects, administering the study, having access to private and individually identifiable research data)

Regarding the informed consent forms – any questions should be directed to Pittsburgh researchers and Pittsburgh's IRB:

since no one from PSU is engaged in the research, there should not be a local investigator from Penn State listed on the informed consent form

Penn State should not be mentioned in the consent form

The approval expiration dates on the consent form should be when the Einstein Healthcare Network's IRB granted approval and provided the approval expiration date

The above conditions apply for all PSU campuses (with the exception of Hershey Medical Center) including University Park.

Please do not hesitate to contact me if you have any questions.

Thank you,

Tracie

<http://out150.mail.live.com/out150/mail.mvc/PrintMessages?rktk=us>

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3/13/2016

Outlook.com Print Message

**Tracie L. Kahler MLS, CIP, CIM** (tlk14@psu.edu), Senior IRB Program Leader

The Pennsylvania State University | Office for Research Protections | The 330 Building, Suite 205 | University Park, PA 16802

Direct Line: (814) 865-7955 | Main Line: (814) 865-1775 | Fax: (814) 863-8699 | [www.research.psu.edu/opr](http://www.research.psu.edu/opr)

Postural Control, Recovery of Standing Postural Control and Kicking Velocity in Soccer Athletes

APPENDIX B

Recruitment Flyer



Volunteer Soccer Athletes Needed

Research Study on the Effects of Core Stabilization Training on Balance and Athletic Performance

You may qualify for this study if you are:

- A healthy, male or female professional, intercollegiate or club soccer athlete (in or out of season).
• 18-35 years old
• Currently physically active (3-5x/wk)
• Have no current or previous (> 6 months) history of low back pain which has kept you out of competition, altered your training for > 3 days, or forced you to seek medical attention.

The study will test your standing balance and kicking speed. The testing session lasts 60-90 min. You will then be randomly assigned to one of 2 groups (core stability or control). Ten volunteers will be randomly selected to be re-tested the next day. The training program involves two 1-hour sessions per week of 1 on 1 training for 8 weeks. All the volunteers will be re-tested 8 weeks later.

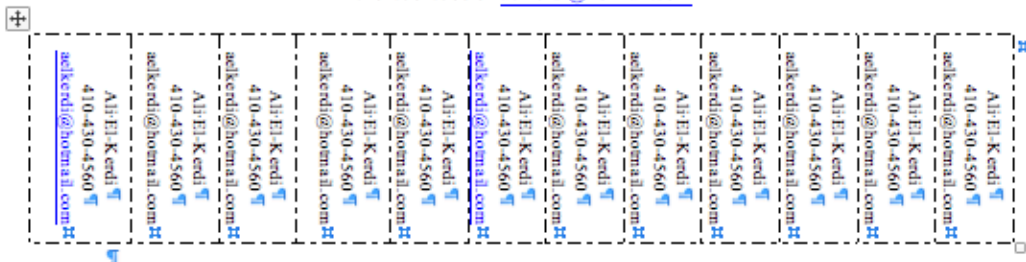
The testing will take place Einstein Hospital at Moss Rehabilitation (1200 West Tabor road, 1st floor Sley building, Philadelphia, PA)

You may earn up to \$30 for your participation in the study.

This research is being conducted by MossRehab Physical Therapists.

For more information, please contact Ali El-Kerdi, DPT, MS, PT, CAT(C), ATC/L, CSCS.

410-430-4560 or aelkerdi@hotmail.com



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**APPENDIX C**

**Consent Form**

**RESEARCH SUBJECT INFORMATION  
CONSENT and AUTHORIZATION  
FORM**

**TITLE OF PROJECT:** Postural control and soccer performance difference following core training

**NAME OF PRINCIPAL INVESTIGATOR:** Ali El-Kerdi

**PRINCIPAL INVESTIGATOR'S PHONE:** 215-456-9858

**PRINCIPAL INVESTIGATOR'S AFTER HOURS PHONE:** 410-4304560

**SPONSOR:** MossRehab Peer Review Committee and Department funded

**Support/Funding Statement:**

MossRehab Peer Review Committee and Department funded

**WHAT IS A CONSENT FORM?**

You are being asked to take part in a medical research study. Before you can make a knowledgeable decision about whether to participate, you should understand the possible risks and benefits related to this study. This process of learning and thinking about a study before you make a decision is known as *informed consent* and includes:

- Receiving detailed information about this research study;
- Being asked to read, sign, and date this consent form, once you understand the study and have decided to participate. If you don't understand something about the study or if you have questions, you should ask for an explanation before you sign this form;
- Being given a copy of your signed and dated consent form to keep for your own records.

The relationship that you have with the study physical therapist is different than the relationship you have with your own physical therapist. Your physical therapist treats your specific health problem with the goal of making you better. The study physical therapist treats all subjects according to a research plan to obtain information about the effectiveness of core stability training with the understanding that you may or may not benefit from your participation in the study. You should ask questions of the study physical therapist if you want to know more about this.



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**PURPOSE OF THE STUDY**

The purpose of the study is to examine the effects of isolated core stability training on trunk strength, standing balance and kicking velocity. It is anticipated that about 40 people will take part in this study here at Einstein.

**DESCRIPTION OF PROCEDURES**

The procedure involves being hooked up to electrodes on your stomach and back muscles. We will then have you stand on a force plate (a device that measures your balance) on one leg then with one foot in front of the other. We will then ask you to jump and land on a force plate. Lastly, you will be asked to kick a soccer ball as fast as you can into a goal. You will then randomly be assigned to either a core stability group or a control group. If you are selected to be in the core stability group you will perform exercises under the supervision of a physical therapist 2x/week for 8 weeks while maintaining a daily exercise log. If you are selected in the control group, you will be asked to keep a daily exercise log for 8 weeks. We will then re-test you in 8 weeks to look for differences in balance and kicking speed

All these procedures are for research purposes only.

The study continues for 8-10 weeks. You are asked to take part in the “testing” 2 times (before and after the 8-weeks of training. Each testing session lasts roughly 2 hours. You may be randomly selected to be tested a 3<sup>rd</sup> time for a reliability study which will take place on the same day as your 1<sup>st</sup> testing session. The training sessions will last about an hour. You will need to be trained 2x/week for 8 weeks. Your total time commitment will be 20-22 hours (4 hours for testing 16 hours for training and possibly an additional 2 hours for the reliability portion if selected).

When the study has ended, you may not be able to continue with treatment that was part of the study.

**RISKS/DISCOMFORTS**

You may experience some mild muscle soreness from the training

**COSTS FOR STUDY PROCEDURES:**

There will be minimal cost to you if you participate in this research you may possibly acquire transportation and parking costs.

**REIMBURSEMENT FOR STUDY PARTICIPATION**

You will receive up to \$30 total for completion of this study. This is for your time and travel costs related to the study. Subjects will be paid via check after completion of W9.

*To receive payment from us, you must agree to disclose your social security number. It will remain confidential. It will not be listed in your research file.*

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*You should know that if Einstein pays you \$600 or more during a calendar year, we must report this to the Internal Revenue Service. This includes money you receive for this study and any other activities at Einstein Healthcare Network. Depending on your personal finances, you may have to pay income tax on the money you collect.*

#### **BENEFITS**

The 8-week core stability training program has been theorized to improve core strength and stability and improve kicking speed. Aside from these hypothesized improvements you should not experience any other significant improvements physiologically.

#### **ALTERNATIVES**

Alternative procedures or treatments do not exist for this study

#### **RIGHTS**

Your participation is voluntary. You can choose to take part or not to take part in the study. If you choose to take part, you can change your mind at anytime and stop taking part in the study. Whatever decision you make, it will not affect your care or the relationship you have with your physical therapists or the Albert Einstein Healthcare Network.

You will be told of any new information learned during the course of the study which might affect your understanding of the information in this consent and your willingness to continue to participate.

Your participation in this study may be ended by the principal investigator or the sponsor if they feel it is in your best interests.

No guarantees have been made as to the results of your participation in the study.

#### **COMPENSATION FOR INJURY:**

In the event of an injury resulting from your participation in this project, you will be provided with clinically appropriate medical care for that injury within the capabilities of the Network. However, Albert Einstein Healthcare Network cannot assure that the medical care and treatment will be provided without charge, and the costs incurred may, ultimately, be your responsibility.

#### **CONFIDENTIALITY / AUTHORIZATION:**

The federal Health Insurance Portability and Accountability Act (HIPAA) requires us to get your permission to use health information about you that we create, collect, or use as part of the research. This permission is called an Authorization.

By signing this form, you authorize the use and sharing of the following information for this research:

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- Information from your medical records that is necessary for this study
- Information we collect from you about your medical history
- Results of biomechanical tests that are necessary for this study
  - Trunk muscle electromyography
  - Standing balance
  - Kicking speed
- Clinical and research observations made during your participation in the research.
- Your age, height, weight and torso length

Any health information that is used or shared under this Authorization will **NOT** include any special health information related to genetic testing, treatment for AIDS/HIV, psychiatric care and treatment, or treatment for drug and alcohol abuse unless specified above.

By signing this form, you authorize the following persons and organizations to receive your protected health information for purposes related to this research

- Members of the research team
- the research sponsor (Albert Einstein Society)
- Any laboratories or other individuals who provides services or analyze health information in connection with this study.

In addition, regulatory agencies that provide research oversight such as the Food and Drug Administration (FDA) or the Office of Human Research Protections (OHRP) or the appropriate offices of Albert Einstein Healthcare Network and its Institutional Review Board (IRB), which is the committee responsible for ensuring your welfare and rights as a research participant, may review and/or photocopy study records which may, if they feel it necessary, identify you as a subject.

If information obtained in the study is published, it will not be identifiable as your results unless you give specific permission.

The Albert Einstein Healthcare Network complies with the requirements of the Health Insurance Portability and Accountability Act of 1996 and its privacy regulations and all other applicable laws that protect your privacy.

We will protect your information according to these laws. Despite these protections, there is a possibility that your information could be used or disclosed in a way that it will no longer be protected. Our Notice of Privacy Practices (a separate document) provides more information on how we protect your information. A copy of the Notice will be provided to you.

The information collected during your participation in this study will be kept indefinitely. Your Authorization for this study will not expire unless you cancel it. You



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can cancel this Authorization at any time by writing to the study investigator at:

Ali El-Kerdi  
1200 West Tabor Road  
Slay Building, Room 134  
Philadelphia, PA  
19141

If you cancel your Authorization, you will not be able to continue to participate in this research. The principal investigator and the research team may continue to use information about you that was collected before you cancelled the Authorization. However, no new information will be collected about you after you cancel the Authorization.

You have a right to refuse to sign this form. If you do not sign the form, you may not be in the research study, but refusing to sign will not affect your health care outside the study.

**WITHDRAWAL FROM STUDY:**

In the event that you withdraw from the study, the study physical Therapist will ask your permission to continue study follow-up, and all clinical data, as it relates to the study, will continue to be collected from your medical records.

**CONTACT INFORMATION:**

If you feel that you have not been adequately informed of your rights with respect to the privacy of your health information or if you feel the privacy of your health information has not been adequately protected, you can contact the Network's Privacy Office at: Gratz Building, 1000 West Tabor Rd, Philadelphia, PA 19141, (215) 456-0485 or [privacy@einstein.edu](mailto:privacy@einstein.edu).

All questions regarding your participation in this study, or in the event of injury, all questions pertaining to that injury will be answered by Ali El-Kerdi, DPT, MS, PT, CAT(C), ATC/L, CSCS (Physical Therapist) or his/her designate who can be reached at 215-456-9858.

For any questions pertaining to your rights as a research subject, you may contact Robert Wimmer, MD, chair of the Institutional Review Board, Albert Einstein Healthcare Network, Paley Bldg., First Floor, (215) 456-6243.

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**UNDERSTANDING OF PARTICIPATION:**

The information in this consent form has been explained to me and all of my current questions have been answered. I have been encouraged to ask questions about any aspect of this research study at any time. Whenever I ask questions, the questions will be answered by a qualified member of the research staff or by the investigator(s) listed on the first page of this consent form.

By signing this form, I agree to participate in this research study and give authorization to use the information collected for this research as explained in this consent form. A copy of this consent form will be given to me.

\_\_\_\_\_  
Printed Name of Subject

\_\_\_\_\_  
Subject Signature  
(Relationship, if kin or guardian signs for subject)

\_\_\_\_\_  
Date:

\_\_\_\_\_  
Printed Name of Person Holding Consent Discussion

\_\_\_\_\_  
Signature of Person Holding Consent Discussion

\_\_\_\_\_  
Date:

Witness to consent when applicable:

**Witness Statement:** Your signature indicates that you were present during the informed consent discussion of this research for the above named participant, that the information in the consent form and any other written information was verbally discussed with the participant (or legally authorized representative) in a language that he/she could understand, that he/she was given the chance to ask and receive answers to his/her questions, that the decision to take part in the research was freely made by the

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participant (or legally authorized representative) who indicated his/her consent and authorization to take part in this research by:

- Signing his/her name
- By making his/her mark
- Other means: \_\_\_\_\_  
Explain

Printed Name of Witness: \_\_\_\_\_

WITNESS SIGNATURE: \_\_\_\_\_

DATE: \_\_\_\_\_

TIME: \_\_\_\_\_

**INVESTIGATOR'S STATEMENT**

I, the undersigned, certify that to the best of my knowledge, the subject signing this consent form has had the study fully and carefully explained by me or a member of the study staff and has been given an opportunity to ask any questions regarding the nature, risks, and benefits of participation in this research study.

INVESTIGATOR OR DESIGNEE\*: \_\_\_\_\_

SIGNATURE

\_\_\_\_\_ Date

**\*DESIGNEE REFERS TO CO-INVESTIGATOR OR SUB-INVESTIGATOR ONLY.**

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APPENDIX D

Health History Questionnaire



Medical Intake Form

**General Information:**

Subject #: \_\_\_\_\_ Age \_\_\_\_\_  
Height: \_\_\_\_\_ cm Weight: \_\_\_\_\_ Kg

**Current Training History:** (Please circle where appropriate)

- \* At what level do you currently compete? College D1 D2 D3 Other Please specify: \_\_\_\_\_
- \* Are you currently competing in or out of season? In Out Other Please specify: \_\_\_\_\_
- \* How many times per week do you practice soccer? 1 2 3 4 5 6 7 other: \_\_\_\_\_
- \* How many soccer games do you play per week? 1 2 3 4 5 6 7 other: \_\_\_\_\_
- \* How often do you weight train per week? 1 2 3 4 5 6 7 other: \_\_\_\_\_
  - \* How many are core training sessions? 1 2 3 4 5 6 7 other: \_\_\_\_\_
- \* How many cardio sessions do you participate in per week? (aside from practice) 1 2 3 4 5 6 7 other: \_\_\_\_\_
- \* Do you currently compete in any other sport(s)? Yes / No Please specify: \_\_\_\_\_
  - \* At what level do you compete? \_\_\_\_\_
  - \* How many days per week? 1 2 3 4 5 6 7 other: \_\_\_\_\_
- \* Are you currently participating in a core stabilization and/or strengthening program? Yes / No  
 If yes, how long ago did you begin this program? \_\_\_\_\_ Days / Months / Years  
 Please provide examples of exercises Frequency/Duration/Intensity  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

**Medical History:**

Date of last Physical: \_\_\_\_\_ Reason: \_\_\_\_\_

- \* Please list any medical conditions/illnesses that you are currently have:  
 \_\_\_\_\_  
 \_\_\_\_\_
- \* Please list all illnesses and/or injuries incurred during the past year (including any episodes of low back pain):  

Date	Injury/Illness	Treatment
_____	_____	_____
_____	_____	_____
- \* Are you currently taking any medications: Yes No Prescription Nonprescription  
 If yes, please list:  

Name of medication	Reason for Taking Medication	Dosage (Quantity & Frequency)
_____	_____	_____
_____	_____	_____
- \* Do you have any allergies and drug reactions: Yes \_\_\_\_\_ No \_\_\_\_\_  

_____ Cephalosporin (ex. Ceclor, Keflex)	_____ Aspirin	_____ Penicillin	_____ Codeine
_____ Xanthines (ex. Theophylline)	_____ Tetracyclines	_____ Erythromycin	_____ Sulfa Drugs
_____ No known allergies/drug reactions	_____ Other: (Please specify) _____		
- \* Are you currently taking over the counter supplements? Yes / No  
 If yes, please list:  

Name of Supplement	Reason for Taking Supplement	Dosage (Quantity & Frequency)
_____	_____	_____
_____	_____	_____

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Have you ever had an illness that:		Specify/Details
Required you to stay in a hospital:	Yes / No	_____
Required surgery:	Yes / No	_____
Lasted longer than one week:	Yes / No	_____
Caused you to miss more than 3 days of competition:	Yes / No	_____
Is related to allergies: (Hay Fever, hives, asthma, insect bits)	Yes / No	_____

Do you presently wear:		Specify/Details
Specify/Details		_____
Prescription Glasses:	Yes / No	_____
Contact Lenses:	Yes / No	_____

• Do you presently or have you ever been diagnosed with the following conditions?

	Yes / No	Specify
Cardiovascular disease	Yes / No	_____
High Blood Pressure	Yes / No	_____
Anemia/Blood disease	Yes / No	_____
Respiratory Problems	Yes / No	_____
Convulsions/Epilepsy/Seizures	Yes / No	_____
Diabetes	Yes / No	_____
Cancer/Tumors	Yes / No	_____
Migraines	Yes / No	_____
Allergies	Yes / No	_____
Arrhythmia	Yes / No	_____
Other: (Please list)		_____

• Do you presently have or have you ever been diagnosed with the following conditions:

	Yes / No	Date	Severity	Frequency
Drug/Alcohol Dependence	Yes / No	_____	_____	_____
Concussion	Yes / No	_____	_____	_____
Cerebral Trauma	Yes / No	_____	_____	_____
Headaches	Yes / No	_____	_____	_____
Memory Loss	Yes / No	_____	_____	_____
Nausea	Yes / No	_____	_____	_____
Numbness and/or Tingling	Yes / No	_____	_____	_____
Chest Pain	Yes / No	_____	_____	_____
Heart Murmur	Yes / No	_____	_____	_____
Unexplained Shortness of Breath	Yes / No	_____	_____	_____
Dizziness/Fainting	Yes / No	_____	_____	_____
Fatigue/Weakness of Limbs	Yes / No	_____	_____	_____
Skin Disease / problems	Yes / No	_____	_____	_____
Severe Infection	Yes / No	_____	_____	_____
Hepatitis/Aids	Yes / No	_____	_____	_____
<b>Women:</b>				
Pregnant or possibly	Yes / No	_____	_____	_____
Other Gynecological Difficulties	Yes / No	_____	_____	_____
Other:		_____	_____	_____

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**APPENDIX E**

**Core Stabilization Training Program**

**Intervention Program**

The following pages describe the intervention program starting with an overview of the program and rationale for the specific exercises and progression to be prescribed. The overview also indicates what intervention in addition to the exercise program should and may be prescribed and what interventions are not allowed as part of the research study.

**Intervention Overview:**

This 8-week core stabilization and strength program consists of **4 phases** of progressively more difficult exercises. The overall goal of this program is to improve core stability and strength of soccer athletes. This program targets the core musculature in 4 positions; supine, quadruped, side-lying and prone. These muscles include: the deep and superficial abdominals, multifidi, paraspinals and pelvic girdle. The athlete will progress through the exercises as indicated within each phase. The athlete can progress to the next phase of exercises for that position once he/she is able to complete all the repetitions of the last exercise in the set while maintaining good form/technique

**Stabilization Exercise Training Phases Rationale and Goals**

Phase I

The goal of phase I is to teach the athlete how to activate in isolation the transverse abdominus muscle during various basic exercises. The subsequent phases build on this by increasing the level of difficulty of the exercise by changing body positions and/or having the athlete performs the exercise on an unstable surface. Athlete should be seen at least 2 times per week during Phase I training. Athlete may progress to Phase II exercises when any of the following criteria have been met:

- When the athlete can perform ADIM in prone or quadruped and maintain it for 10 seconds without feedback (trunk remains still and breathing is normal) for 30 consecutive repetitions.
- When most difficult exercises in Phase I can be performed

Phase II

The goal of phase II is to gradually build on phase I exercises by adding movements of the extremities and/or altering visual input physiologically stressing the neuromuscular system inducing adaptation. The athlete should be seen at least 2

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times per week initially during Phase II training. Treatment frequency may be dropped to once per week at the researcher's discretion, if the athlete can perform his/her exercises independently and correctly. Athlete may progress to Phase III exercises when most difficult exercises in Phase II can be performed

Phase III

Phase III training attempts to bring the core muscle co-contraction to a subconscious phase by adding perturbations and distractions. It builds on phase II by increasing the amount of perturbation. Athlete should be seen at least 2 times per week initially during Phase III training. Treatment frequency may be dropped to once per week at the therapist's discretion, if the athlete can perform his/her exercises independently and correctly.

Phase IV

The goal of phase IV is to add a level of difficulty to the exercises that would not only prepare the athlete for higher level perturbations caused by varying surfaces but also to strengthen the trunk musculature while on an unstable surfaces with altered visual input. Athlete should be seen at least 2 times per week initially during Phase IV training. Treatment frequency may be dropped to once per week at the therapist's discretion, if the athlete can perform his/her exercises independently and correctly.

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Phase I Exercises

There are 3 exercises with a progression recommendation in phase I


**Goal:** To teach activation the transverses abdominus muscle during various basic exercises.

**Progression:**

Subject may progress to Phase II after meeting the criteria listed at the end of each section of this phase.

**Instruction:**

Begin with constant feedback. Decrease amount of feedback until subject can perform exercise/maneuver without feedback.

Exercise or Activity
Produce and explore lumbar spine motion and find neutral position.
Demonstrate diaphragmatic breathing in neutral position.
<p>1. ADIM – abdominal draw-in maneuver; activation of transverse abdominal muscle in quadruped; begin with 5 second hold for 10 repetitions; work to 30 second hold for 10 repetitions.</p> <p>Verify performance with palpation 2 cm medial to ASIS. Feel for slow development of tension in that area.</p> <p>Any of the following substitutions indicate that the ADIM is NOT being performed correctly:</p> <ul style="list-style-type: none"> <li>▪ holding breath</li> <li>▪ performing a posterior pelvic tilt</li> <li>▪ increasing weight bearing through the heels</li> <li>▪ excessively recruiting external oblique muscles</li> <li>▪ performing a fast, phasic contraction</li> </ul>

2. Quadruped ADIM. same as above in quadruped position



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3. Multifidus co-contraction with transverse abdominal muscle; prone over pillow arm lift; begin with 5 second hold for 10 repetitions; work to 10 second hold for 30 repetitions.

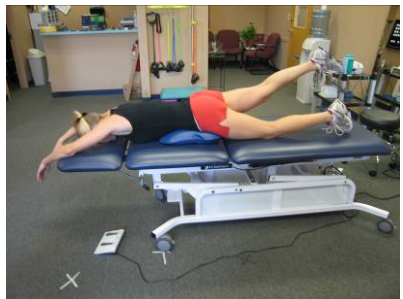
Verify performance with palpation in lower lumbar paravertebral area. Feel for slow development of tension in that area.

Any of the following substitutions indicate that the multifidus contraction is NOT being performed correctly:



- extending lumbar spine
- rotating lumbar spine
- developing muscle tension through length of thoracolumbar paravertebrals
- performing a fast, phasic contraction



4. Multifidus co-contraction with transverse abdominal muscle; prone over pillow with leg lift; begin with 5 second hold for 10 repetitions; work to 10 second hold for 30 repetitions



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<b>Exercise or Activity</b>
<p><b>ADIM performed with all activities listed below.</b> <b>All Exercises are initially performed 3set of 10 repetitions progressing to 30 consecutive repetitions</b> <b>Begin with exercises #1</b></p>
<p>1. Subject lies supine with hips and knees flexed. Slides one heel out and straightens knee and then returns. Repeats on opposite side. Use pressure feedback device to verify maintenance of neutral position. Palpate transverse abdominals to verify contraction. When subject can perform 30 repetitions maintaining co-contraction, he/she may progress to exercise #3.</p>

<p>2. Same position as exercise #1. Extends one knee so heel of foot is a few inches above table surface. Holds for 2 seconds. Returns and repeats on opposite side. Use pressure feedback device to verify maintenance of neutral position. Palpate transverse abdominals to verify contraction. When subject can perform 30 repetitions maintaining co-contraction, he/she may progress to exercise #4.</p>

<p>3. Same position as exercise #1. Extends one knee so heel of foot is a few inches above table surface and simultaneously flexes opposite shoulder so hand is a few inches above table surface. Holds for 2 seconds. Returns and repeats on opposite side. Use pressure feedback device to verify maintenance of neutral position. Palpate transverse abdominals to verify contraction. When subject can perform 30</p>

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repetitions maintaining co-contraction, he/she may progress to exercise #5.



4. Same position as exercise #1. Both feet are held off the table surface. Extends one knee so heel of foot is a few inches above table surface. Holds for 2 seconds. Returns and repeats on opposite side. Use pressure feedback device to verify maintenance of neutral position. Palpate transverse abdominals to verify contraction.



5. Same position as exercise #1. Both feet are held off the table surface. Extends one knee so heel of foot is a few inches above table surface and simultaneously flexes opposite shoulder so hand is a few inches above table surface. Holds for 2 seconds. Returns and repeats on opposite side. Use pressure feedback device to verify maintenance of neutral position. Palpate transverse abdominals to verify contraction.



**Progression:**

Subject may progress to Phase II when he/she is able to maintain ADIM and hold leg extension and a flexed shoulder for 2 seconds for 30 repetitions without feedback (on both right and left sides).

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**Phase II Exercises**

There are 4 exercises with recommended progressions. The level of difficulty of the exercises is increased as the athlete's performance improves.

**Goal:** To gradually build on Phase I exercises by adding movements of the extremities and/or altering visual input.

**Progression:**

Subject may progress to Phase III after meeting the criteria listed at the end of each section of this phase.

**Instructions:**

Begin with constant feedback. Decrease amount of feedback until subject can perform exercise/maneuver without feedback. Phase II exercises are replaced with the following:

**Supine Bridging Progression**

**ADIM performed with all activities listed below**

**Begin with exercise #1**

1. Subject lies supine with hips and knees flexed and elbows on table. Performs ADIM then bridges (lifts pelvis with both legs) and holds for 5 seconds. Use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions maintaining contraction, he/she may progress to exercise #2.



2. Same position as exercise #1. Performs ADIM and then bridges or lifts pelvis and holds position. Then marches in place alternately lifting right foot and left foot. Pelvis must remain level. Stick may be placed across ASISs to insure that pelvis stays level. When subject can perform 30 repetitions of marching on each side, he/she may progress to exercise #3.

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3. Same position as exercise #1. Performs ADIM, lifts one foot off table surface, then bridges (lifts pelvis with one leg) and holds for 2 seconds. Pelvis must remain level. Stick may be placed across ASISs to insure that pelvis stays level. When subject can perform 30 repetitions of marching on each side, he/she may progress to exercise #4.



4. Same position as exercise #1. Performs ADIM then bridge (lifts pelvis with both legs), then alternate shoulder flexion for 5 seconds. Pelvis must remain level. Stick may be placed across ASISs to insure that pelvis stays level. When subject can perform 30 repetitions of marching on each side, he/she may progress to exercise #5.



5. Same position as exercise #1. Performs ADIM then bridges (lifts pelvis with both legs) – subject then extends knee and holds for 5 seconds. Pelvis must remain level. Stick may be placed across ASISs to insure that pelvis stays level. When subject can perform 30 repetitions of marching on each side, he/she may progress to exercise #6.



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6. Same exercise as #5 except that the elbows are off the table and crossed over chest. Pelvis must remain level. Stick may be placed across ASISs to insure that pelvis stays level. When subject can perform 30 repetitions of marching on each side, he/she may progress to exercise #7.



7. Same exercise as #6 with eyes closed. Pelvis must remain level. Stick may be placed across ASISs to insure that pelvis stays level. When subject can perform 30 repetitions of marching on each side, he/she may progress to Phase III bridging exercises



**Quadruped Progression**

**ADIM performed with all activities listed below**

**Begin with exercise #1**

1. Subject in quadruped position or on hands and knees. Performs ADIM and then flexes one shoulder raising arm just below height of shoulder. Spine must remain

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level and still. May place stick across back to insure that subject is not rotating or extending spine. Returns and repeats on opposite side. Researcher may palpate to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #2.



2. Same position as exercise #1. Performs ADIM and then extends one hip raising leg just below height of pelvis. Spine must remain level and still. May place stick across back to insure that subject is not rotating or extending spine. Researcher may palpate to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #3.



3. Same position as exercise #1. Performs ADIM and then extends one shoulder raising arm just below height of shoulder hip and simultaneously extends opposite hip raising leg just below height of pelvis. Spine must remain level and still. May place stick across back to insure that subject is not rotating or extending spine. Researcher may palpate to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #4

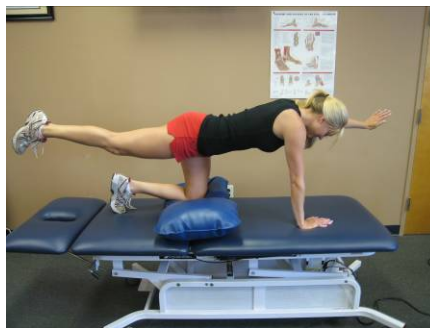
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4. Same exercise as #3 except knees are resting on an unstable surface such as a dynadisc or a foam roll. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #5



5. Exercise performed as in #4, but with eyes closed. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #6



6. Same exercise as #4, except hands and knees are resting on an unstable surface such as a dynadisc or a foam roll. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #7



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7. Same exercise as #6, except with their eyes closed. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to Phase III quadrupedal exercises.



**Side-lying Side Support Progression**

**Begin with exercise #1**

1. Subject lies on side with hips extended and knees flexed, propped on elbow of bottom side arm (partial side plank). Hand of opposite arm is placed on top side hip. Performs ADIM and then lifts hip off table surface moving into a side plank position. Holds for 5 seconds. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #2.



2. Subject lies on side with hips and knees extended. Props on elbow of bottom side

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arm (full plank). Hand of opposite arm is placed on top side hip. Performs ADIM and then lifts hip off table surface moving into a side plank position. Holds for 5 seconds. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #3.



3. Same as exercise #1 except with eyes closed. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #4.



4. Same as exercise #2 except with eyes closed. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to Phase III side-lying side support exercises.



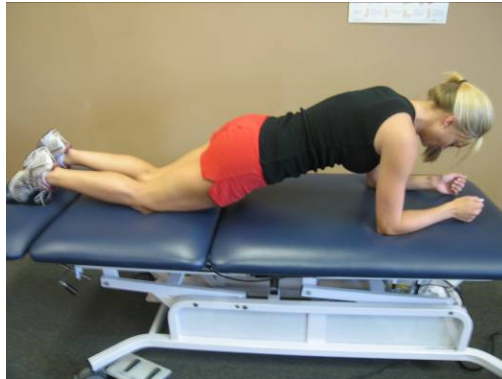
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**Prone Plank Progression**

**ADIM performed with all activities listed below**

**Begin with exercise #1**

1. Subject in prone position. Performs ADIM and while on elbows raises trunk off table keeping knees bent and in contact with table (partial plank). Spine must remain level and still. May place stick across back to insure that subject is not rotating or extending spine. The researcher may use palpation to verify maintenance of transverse abdominal contraction. Holds for 10 seconds. When subject can perform 30 repetitions while maintaining contraction, he/she may progress to exercise #2.



2. Subject in prone position. Performs ADIM and while on elbows raises trunk of table keeping only toes in contact with table (full plank). Spine must remain level and still. May place stick across back to insure that subject is not rotating or extending spine. The researcher may use palpation to verify maintenance of transverse abdominal contraction. Holds for 10 seconds. When subject can perform 30 repetitions while maintaining contraction, he/she may progress to exercise #3.



3. Same position as #2. Subject then extends one hip off table 4" then repeats with other arm. Spine must remain level and still. May place stick across back to insure that subject is not rotating or extending spine. Holds for 10 seconds. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions while maintaining contraction, he/she may

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progress to exercise #5.



4. Same position as in #2. Subject then flexes one shoulder raising arm just below height of shoulder then repeats with other arm. Spine must remain level and still. May place stick across back to insure that subject is not rotating or extending spine. Holds for 10 seconds. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions while maintaining contraction, he/she may progress to exercise #4.



5. Same position as #2. Subject then flexes shoulder and extends opposite hip off table 2" then repeats with other side. Spine must remain level and still. May place stick across back to insure that subject is not rotating or extending spine. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to Phase III prone lying exercises.

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**Phase III Exercises**

There are 4 exercises with recommended progressions in this phase. The level of difficulty of the exercises is increased as the athlete's performance improves.

**Goal:** The goal of Phase III exercise is to increase the amount of perturbation by overloading the neuromuscular system.

**Progression:**

Subject may progress to Phase IV after meeting the criteria listed at the end of each section of this phase.

**Instructions:**

Begin with constant feedback. Decrease amount of feedback until subject can perform exercise/maneuver without feedback. Phase II exercises are replaced with the following:

**Supine Bridging Progression**

**ADIM performed with all activities listed below**

**Begin with exercise #1**

1. Subject lies supine with hips and knees flexed and elbows on table with feet flat on Swiss ball. Performs ADIM then bridges (lifts pelvis with both legs) and holds for 5 seconds. Use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions maintaining contraction, he/she may progress to exercise #2.



2. Same as exercise #1 except with elbows off table. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions maintaining contraction, he/she may progress to exercise #3.

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3. Same as exercise #1 except knees are extended and with heels on ball. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions maintaining contraction, he/she may progress to exercise #4.



4. Same as exercise #3 except with elbows off table. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions maintaining contraction, he/she may progress to exercise #5.



5. Same as exercise #1 with addition of alternating overhead shoulder flexion. Pelvis must remain level. The researcher may use palpation to verify maintenance of transverse abdominal contraction. Stick may be placed across ASISs to insure that



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pelvis stays level. When subject can perform 30 repetitions maintaining contraction, he/she may progress to exercise #6.



6. Same as exercise #5 but with elbows off table. Pelvis must remain level. The researcher may use palpation to verify maintenance of transverse abdominal contraction. Stick may be placed across ASISs to insure that pelvis stays level. When subject can perform 30 repetitions maintaining contraction, he/she may progress to exercise #7.



7. Same as exercise #3 with the addition of knee curling towards trunk. Athlete then returns to starting position then returns from bridge position to resting. Pelvis must remain level. Stick may be placed across ASISs to insure that pelvis stays level. When subject can perform 30 repetitions maintaining contraction, he/she may progress to exercise #8.



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8. Same as exercise #7 except elbows off table. Pelvis must remain level. Stick may be placed across ASISs to insure that pelvis stays level. When subject can perform 30 repetitions maintaining contraction, he/she may progress to exercise #9.



9. Same as exercise #3 but now athlete has to raise one heel off ball then returns to starting position - repeats on the other side. Subject then returns from bridge position. Pelvis must remain level. Stick may be placed across ASISs to insure that pelvis stays level. When subject can perform 30 repetitions maintaining contraction, he/she may progress to exercise #10.



10. Same as exercise #9 except with elbows off table. Pelvis must remain level. Stick may be placed across ASISs to insure that pelvis stays level. When subject can perform 30 repetitions maintaining contraction, he/she may progress to level IV

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bridging and Supine on Ball exercises.



**Quadruped Progression**

**ADIM performed with all activities listed below**

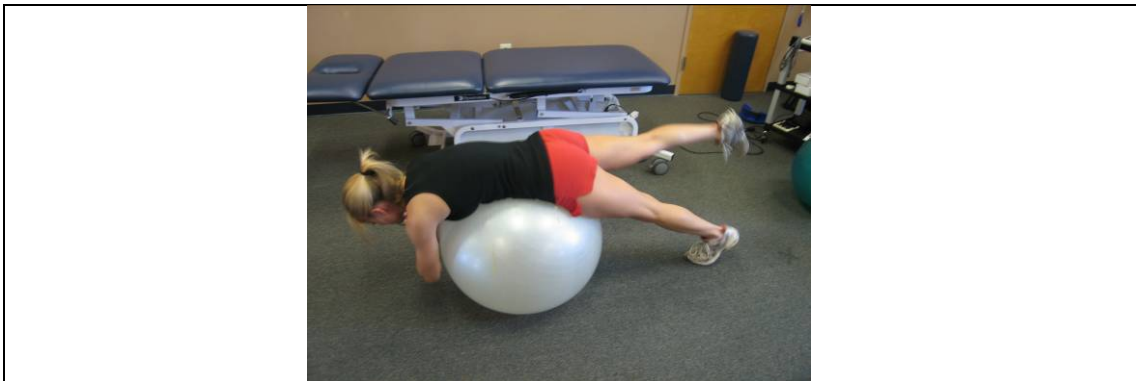
**Begin with exercise #1**

1. Subject lying on Swiss ball with toes on ground. Performs ADIM and then flexes one shoulder raising arm just below height of shoulder. Spine must remain level and still. May place stick across back to insure that subject is not rotating or extending spine. Returns and repeats on opposite side. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #2.



2. Same position as exercise #1. Performs ADIM and then flexes one hip raising leg just below height of pelvis. Spine must remain level and still. May place stick across back to insure that subject is not rotating or extending spine. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #3.

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3. Same position as exercise #1. Performs ADIM and then extends one shoulder raising arm just below height of shoulder hip and simultaneously extends opposite hip raising leg just below height of pelvis. Spine must remain level and still. May place stick across back to insure that subject is not rotating or extending spine. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to Phase IV Quadruped exercises.



**Side-lying Side Support Progression**

**Begin with exercise #1**

1. Subject lies on side with hips extended and knees flexed. Feet rest on unstable surface such as a dynadisc or foam roller (full-side support). Props on elbow of bottom side arm. Hand of opposite arm is placed on top side hip. Performs ADIM and then lifts hip off table surface moving into a side plank position. Holds for 5 seconds. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #2.

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2. Same as #1 except athletes then abducts shoulder raising arm over head and repeats slowly for 5 sec. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #3.



3. Subject lies on side with hips extended and knees flexed (partial side support). Feet rest on unstable surface such as a dynadisc or foam roller. Props on elbow of bottom side arm. Hand of opposite arm is placed on top side hip. Performs ADIM and then lifts hip off table surface moving into a side plank position. Holds position and then abducts hip raising leg 18" above opposite leg. Use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #4.

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4. Same as exercise #1 but with elbow on unstable surface NOT feet. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #5.



5. Same as #1 except athletes then abducts hip and repeats slowly for 5 sec. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #6.

6. Same as exercise #3 but with elbow on unstable surface NOT feet – hold for 5 seconds. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #7.

7. Same as exercise #3 but with elbow on unstable surface NOT feet AND with the addition of simultaneously abducting shoulder raising arm over head. Use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #8.



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8. Same as exercise #5 but in full side plank position. Use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #9.



9. Same as exercise #3 but with elbow on unstable surface NOT feet AND with the addition of simultaneously abducting hip slowly for 5 seconds. Use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #10

10. Same as #1 but with elbow on unstable surface NOT feet AND with then athlete abducts hip and repeats slowly for 5 sec. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to Phase IV Side-lying Side Support Progression

**Prone Lying Progression**  
**ADIM performed with all activities listed below**

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**Begin with exercise #1**

1. Subject in prone position. Performs ADIM and while on elbows raises trunk off table keeping knees bent and in contact with table (partial plank). Elbows are on unstable surface such as foam roll or dynadisc. Spine must remain level and still. May place stick across back to insure that subject is not rotating or extending spine. The researcher may use palpation to verify maintenance of transverse abdominal contraction. Holds for 10 seconds. When subject can perform 30 repetitions while maintaining contraction, he/she may progress to exercise #2.



2. Same as exercise #1 but in full plank position. Spine must remain level and still. May place stick across back to insure that subject is not rotating or extending spine. The researcher may use palpation to verify maintenance of transverse abdominal contraction. Holds for 10 seconds. When subject can perform 30 repetitions while maintaining contraction, he/she may progress to exercise #3.



3. Same as exercise #2 except that the athlete then flexes one shoulder raising arm just below height of shoulder then repeats with other arm. Spine must remain level and still. May place stick across back to insure that subject is not rotating or extending spine. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions while maintaining contraction, he/she may progress to exercise #4.

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4. Same as exercise #2 except that the athlete then extends one hip off table 2” then repeats with other hip. Spine must remain level and still. May place stick across back to insure that subject is not rotating or extending spine. The researcher may use palpation to verify maintenance of transverse abdominal contraction. Holds for 10 seconds. When subject can perform 30 repetitions while maintaining contraction, he/she may progress to exercise #5.



5. Same as exercise #2 except that the athlete then simultaneously flexes shoulder and extends opposite hip off table 2” then repeats with other side. Spine must remain level and still. May place stick across back to insure that subject is not rotating or extending spine. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to Phase IV prone lying exercises.



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**Phase IV Exercises**

There are 5 exercises with recommended progressions in this last phase. The level of difficulty of the exercises is increased as the athlete's performance improves.

**Goal:** to add a level of difficulty to the exercises that would not only prepare the athlete for higher level perturbations caused by varying surfaces but also to strengthen the trunk musculature while on an unstable surfaces with altered visual input.

**Progression:**

As listed within each section of this phase.

**Instructions:**

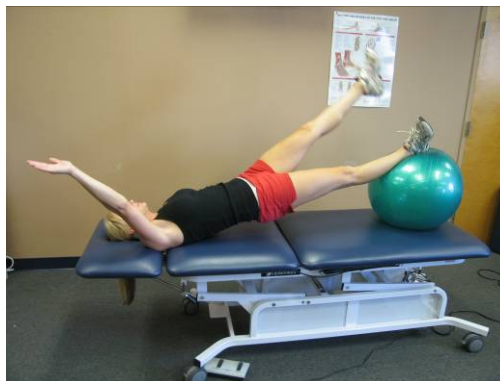
Begin with constant feedback. Decrease amount of feedback until subject can perform exercise/maneuver without feedback. With the exception of *side-lying side support exercise #8* Phase III exercises are replaced with the following:

**Supine Bridging Progression**

**ADIM performed with all activities listed below**

**Begin with exercise #1**

1. Subject lies supine with hips and knees extended and elbows on table with heels on Swiss ball. Performs ADIM and then bridges or lifts pelvis. Subject raises one heel off ball returns to starting position then repeats on the other side all while alternating shoulder overhead flexion. Subject then returns from bridge position. Pelvis must remain level. Stick may be placed across ASISs to insure that pelvis stays level. When subject can perform 30 repetitions maintaining contraction, he/she may progress to exercise #2.



2. Same as exercise #1 except with eyes closed. Pelvis must remain level. Stick may be placed across ASISs to insure that pelvis stays level. When subject can perform 30 repetitions maintaining contraction, he/she may progress to exercise #3.

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3. Same as exercise #1 except that the subject now raises one heel off ball, curls opposite leg towards trunk, returns to leg extended position then repeats on opposite leg. Subject then returns to starting position. Subject then returns from bridge position. Pelvis must remain level. Stick may be placed across ASISs to insure that pelvis stays level. When subject can perform 30 repetitions maintaining contraction, he/she may progress to exercise #4.



4. Same as exercise #3 but with eyes closed. Pelvis must remain level. Stick may be placed across ASISs to insure that pelvis stays level. When subject can perform 30 repetitions maintaining contraction, he/she continues this exercise until the end of the 8 week training period.

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**Supine on Ball Progression**

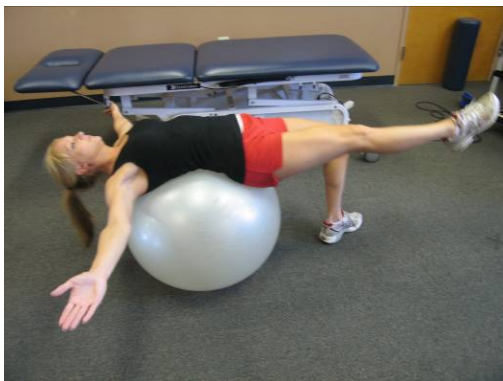
**ADIM performed with all activities listed below**

**Begin with exercise #1**

1. Subject lies on ball with feet resting on ground and knees flexed to 90 degree. Shoulders are abducted to 90 degrees. Subject performs ADIM and marches in place. Pelvis must remain level. When subject can perform 30 repetitions maintaining contraction, he/she may progress to exercise #2.



2. Same position as exercise #1. Subject performs ADIM and extends one knee. Returns to starting position and extends the other knee. Pelvis must remain level. When subject can perform 30 repetitions maintaining contraction, he/she may progress to exercise #3.



3. Same position as exercise #1. Subject performs ADIM and extends one knee and performs a straight leg raise. Returns to starting position and extends the other knee. Pelvis must remain level. When subject can perform 30 repetitions maintaining contraction, he/she may progress to exercise #4.

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4. Same position as exercise #1. Subject performs ADIM and shifts torso side-to-side over ball. Pelvis must remain level. When subject can perform 30 repetitions maintaining contraction, he/she may progress to exercise #5.



5. Subject lies on ball with feet resting on ground and knees flexed to 90 degree. Shoulders are flexed to 90 degrees holding a ball in hands. Subject performs ADIM and rotates torso repeatedly over ball. Must maintain ADIM. When subject can perform 30 repetitions maintaining contraction, progressively heavier hand weights may be added instead of ball. He/she continues this exercise until the end of the 8 week training period.



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**Quadruped Progression**

**ADIM performed with all activities listed below**

**Begin with exercise #1**

1. Subject lying on Swiss ball with feet NOT touching ground. Performs ADIM and then flexes one shoulder raising arm just below height of shoulder. Spine must remain level and still. May place stick across back to insure that subject is not rotating or extending spine. Returns and repeats on opposite side. Use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #2.



2. Subject lying on Swiss ball with feet NOT touching ground. Performs ADIM and then extends one hip raising leg just below height of pelvis. Spine must remain level and still. May place stick across back to insure that subject is not rotating or extending spine. Use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #3.



3. Subject lying on Swiss ball with feet NOT touching ground. Performs ADIM and then flexes one shoulder raising arm just below height of shoulder and simultaneously extends opposite hip raising leg just below height of pelvis. Spine must remain level and still. May place stick across back to insure that subject is not rotating or extending spine. Use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions maintaining contraction,



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progressively heavier hand/ankle weights may be added. He/she continues this exercise until the end of the 8 week training period.



**Prone Lying Progression**

**ADIM performed with all activities listed below**

**Begin with exercise #1**

1. Subject in prone position. Performs ADIM and while on elbows raises trunk off table keeping knees bent and in contact with table (partial plank). Subject goes up in push up position by placing hand on table and extending elbow starting with one arm then the next. Spine must remain level throughout motion. May place stick across back to insure that subject is not rotating or extending spine. When subject can perform 30 repetitions while maintaining contraction, he/she may progress to exercise #2.

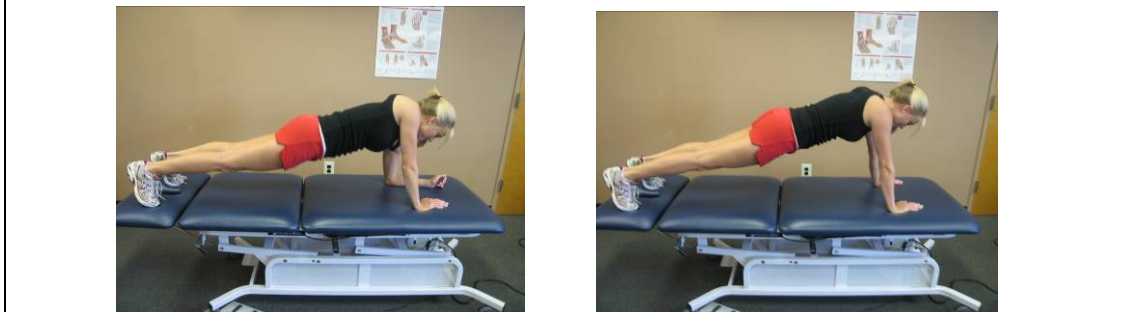


2. Same as exercise #1 one but with elbows on unstable surface such as foam roll or dynadisc. Spine must remain level throughout motion. May place stick across back to insure that subject is not rotating or extending spine. When subject can perform 30 repetitions while maintaining contraction, he/she may progress to exercise #3.

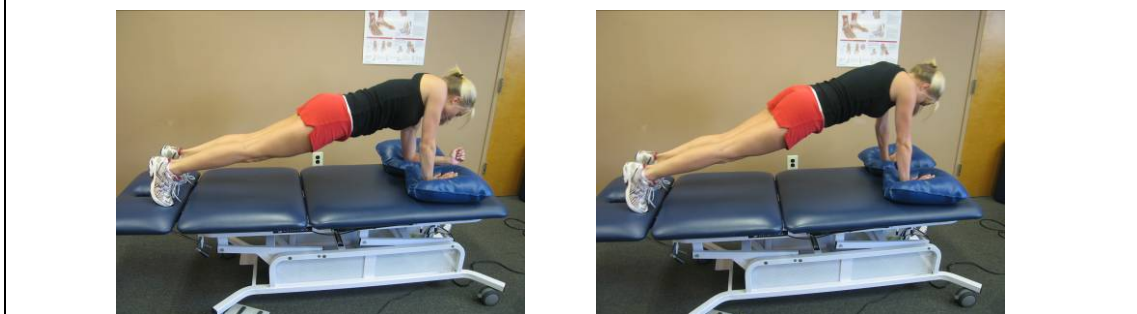
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3. Same as exercise #1 but in full plank position. Spine must remain level throughout motion. May place stick across back to insure that subject is not rotating or extending spine. When subject can perform 30 repetitions while maintaining contraction, he/she may progress to exercise #4.



4. Same as exercise #3 but with both elbows on unstable surface such as foam roll or dynadisc. Spine must remain level throughout motion. May place stick across back to insure that subject is not rotating or extending spine. When subject can perform 30 repetitions while maintaining contraction, he/she may progress to exercise #5.



5. Same as exercise #3 but with both elbows and feet on unstable surface such as foam roll or dynadisc. Spine must remain level throughout motion. May place stick across back to insure that subject is not rotating or extending spine. When subject can perform 30 repetitions while maintaining contraction, he/she may progress to exercise #6

6. Performs exercise #4 with eyes closed. When subject can perform 30 repetitions

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while maintaining contraction, he/she may progress to exercise #5.



7. Performs exercise #5 with eyes closed. When subject can perform 30 repetitions maintaining contraction, he/she continues this exercise until the end of the 8 week training period.

**Side-lying Side Support Progression**  
**Begin with exercise #1**

1. Subject lies on side with hips extended and knees flexed. Elbow and Feet rest on unstable surface such as a dynadisc or foam roller (full-side support). Props on elbow of bottom side arm. Hand of opposite arm is placed on top side hip. Performs ADIM and then lifts hip off table surface moving into a side plank position. Holds for 5 seconds. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #2.



2. Subject lies on side with hips extended and knees flexed (partial side support). Feet rest on unstable surface such as a dynadisc or foam roller. Props on elbow of bottom side arm. Hand of opposite arm is placed on top side hip. Performs ADIM and then lifts hip off table surface moving into a side plank position. Holds position and then abducts hip raising leg 18" above opposite leg. Use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30

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repetitions on each side while maintaining contraction, he/she may progress to exercise #4.



3. Same as #1 except athletes then abducts shoulder raising arm over head and repeats slowly for 5 sec. The researcher may use palpation to verify maintenance of transverse abdominal contraction. When subject can perform 30 repetitions on each side while maintaining contraction, he/she may progress to exercise #3.






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**APPENDIX F**





**Core Stabilization Training Program Tracking Sheet**

**Phase I Exercises**

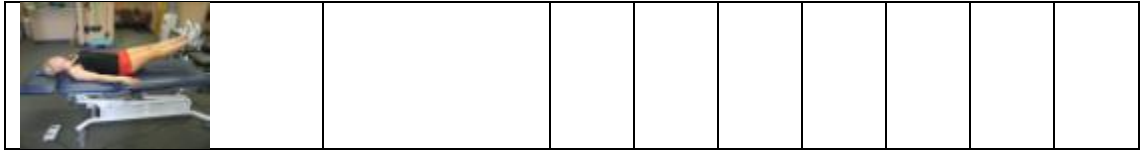
Exercise	Date:	M	T	W	Th	F	S	S
Abdominal Draw-in (ADIM) 	repetitions:							
	comments:							
Quadruped ADIM 	repetitions:							
	comments:							
Multifidus co-contraction with transverse abdominal muscle (prone over pillow arm lift) 	repetitions:							
	comments:							
Multifidus co-contraction with transverse abdominal muscle (prone over pillow with leg lift)	repetitions:							
	comments:							

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<b>Exercise</b>	<b>Date:</b>	<b>M</b>	<b>T</b>	<b>W</b>	<b>Th</b>	<b>F</b>	<b>S</b>	<b>S</b>
Crook lying-ADIM-heel slide 	repetitions:							
	comments:							
Crook lying-ADIM-SLR 	repetitions:							
	comments:							
Crook lying-ADIM-Alt SLR and arm lift 	repetitions:							
	comments:							
Supine – Straight Leg Raise 	repetitions:							
	comments:							
Supine Bilateral Straight Leg Raise	repetitions:							
	comments:							

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**Progression:**

Subject may progress to Phase II when he/she is able to maintain ADIM and hold leg extension and a flexed shoulder for 2 seconds for 30 repetitions without feedback (on both right and left sides)





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**Phase II Supine Exercises**

Exercise	Date:	M	T	W	Th	F	S	S
Crook lying-ADIM-Bridging 	repetitions:							
	comments:							
Crook lying-ADIM-Bridging-Alt marching 	repetitions:							
	comments:							
Crook lying-ADIM-Bridging-Alt arm flex 	repetitions:							
	comments:							
Crook lying-ADIM-1leg Bridging 	repetitions:							
	comments:							
Crook lying-ADIM-Bridging-knee extension 	repetitions:							
	comments:							
Crook lying-ADIM-Bridging-knee	repetitions:							







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extension (Elbows off table) 	comments:							
Crook lying-ADIM- Bridging-knee extension (Elbows off table) (Eyes Closed) 	repetitions:							
	comments:							

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**Phase II Quadruped Exercises**




Exercise	Date:	M	T	W	Th	F	S	S
Quadruped ADIM – Alt shoulder Flexion 	repetitions:							
	comments:							
Quadruped ADIM – Alt Hip extension 	repetitions:							
	comments:							
Quadruped ADIM – Alt shoulder flexion and hip Extension 	repetitions:							
	comments:							
Quadruped ADIM – Alt shoulder flexion and hip Extension (Knees on foam or dynadisc) 	repetitions:							
	comments							
Quadruped ADIM – Alt shoulder flexion and hip Extension (Knees on foam or dynadisc) (Eyes Closed)	repetitions:							
	comments:							

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<p>Quadruped ADIM – Alt shoulder flexion and hip Extension (Knees and hands on foam or dynadisc)</p> 	<p>repetitions:</p>								
<p>Quadruped ADIM – Alt shoulder flexion and hip Extension (Knees and hands on foam or dynadisc) (Eyes Closed)</p> 	<p>repetitions:</p>								
	<p>comments:</p>								






Postural Control, Recovery of Standing Postural Control and Kicking Velocity in  
Soccer Athletes

**Phase II - Side-lying Side Support Exercises**

Exercise	Date:	M	T	W	Th	F	S	S
Partial Side Plank (Knees bent) 	repetitions:							
	comments:							
Full side plank 	repetitions:							
	comments:							
Partial Side Plank ( Knees bent) (Eyes closed) 	repetitions:							
	comments:							
Full side plank (Eyes closed) 	repetitions:							
	comments							

Postural Control, Recovery of Standing Postural Control and Kicking Velocity in  
Soccer Athletes

**Phase II - Prone Plank Exercises**






Exercise	Date:	M	T	W	Th	F	S	S
Partial plank (Knees bent) 	repetitions:							
	comments:							
Full plank 	repetitions:							
	comments:							
Full-plank – hip extension 	repetitions:							
	comments:							
Full plank – Shoulder flex 	repetitions:							
	comments							
Full plank alt shoulder/hip raises 	repetitions:							
	comments:							

Postural Control, Recovery of Standing Postural Control and Kicking Velocity in  
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**Phase III - Supine Exercises**




Exercise	Date:	M	T	W	Th	F	S	S
Bridging – feet on Swiss ball 	repetitions:							
	comments:							
Bridging – feet on Swiss ball (Elbows off table) 	repetitions:							
	comments:							
Long bridging-heels on Swiss ball 	repetitions:							
	comments:							
Long bridging-heels on Swiss ball (Elbows off table) 	repetitions:							
	comments:							
Long bridging-heels on Swiss ball Alt shoulder Flex 	repetitions:							
	comments:							

Postural Control, Recovery of Standing Postural Control and Kicking Velocity in  
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<p>Long bridging-heels on Swiss ball Alt shoulder Flex (Elbows off table)</p> 	<p>repetitions:</p>							
<p>Long bridging-heels on Swiss ball-Knee curls</p> 	<p>repetitions:</p>							
<p>Long bridging-heels on Swiss ball-Knee curls (Elbows off table)</p> 	<p>repetitions:</p>							
<p>Long bridging-heels on Swiss ball Lift heel off ball</p> 	<p>repetitions:</p>							
<p>Long bridging-heels on Swiss ball Lift heel off ball (Elbows off table)</p> 	<p>repetitions:</p>							
<p>comments</p>								

Postural Control, Recovery of Standing Postural Control and Kicking Velocity in  
Soccer Athletes

**Phase III Quadruped Exercises**

Exercise	Date:	M	T	W	Th	F	S	S
Lying on Swiss ball feet on ground ADIM – shoulder flexion 	repetitions:							
	comments:							
Lying on Swiss ball feet on ground ADIM – Hip Flexion 	repetitions:							
	comments:							
Lying on Swiss ball feet on ground ADIM – Alt shoulder and hip Flexion 	repetitions:							
	comments:							





Postural Control, Recovery of Standing Postural Control and Kicking Velocity in  
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**Phase III Side-lying Support**

Exercise	Date:	M	T	W	Th	F	S	S
Side plank Feet on foam or Dynadisc 	repetitions:							
	comments:							
Side plank Feet on foam or Dynadisc Shoulder Abduction 	repetitions:							
	comments:							
Partial Side plank Knees on foam or Dynadisc Shoulder Abduction 	repetitions:							
	comments:							
Partial Side plank Knees on foam or Dynadisc Hip Abduction 	repetitions:							
	comments:							

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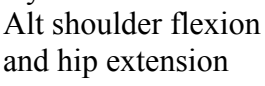
Side plank Feet on foam or Dynadisc Hip Abduction	repetitions:							
	comments:							
Side plank Elbow on foam or Dynadisc	repetitions:							
	comments:							
Partial Side plank Elbow on foam or Dynadisc Shoulder Abduction 	repetitions:							
	comments:							
Side plank Elbow on foam or Dynadisc Shoulder Abduction 	repetitions:							
	comments:							
Partial Side plank Elbow on foam or Dynadisc Hip Abduction	repetitions:							
	comments:							

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Side plank Elbow on foam or Dynadisc Hip Abduction	repetitions:							
	comments:							


Postural Control, Recovery of Standing Postural Control and Kicking Velocity in  
Soccer Athletes

**Phase III Prone Exercises**

Exercise	Date:	M	T	W	Th	F	S	S
Partial Plank Elbows on foam or Dynadisc 	repetitions:							
	comments:							
Plank Elbows on foam or Dynadisc 	repetitions:							
	comments:							
Plank Elbows on foam or Dynadisc Alt shoulder flexion 	repetitions:							
	comments:							
Plank Elbows on foam or Dynadisc Alt hip extension 	repetitions:							
	comments:							
Plank Elbows on foam or Dynadisc Alt shoulder flexion and hip extension 	repetitions:							
	comments:							





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Postural Control, Recovery of Standing Postural Control and Kicking Velocity in  
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**Phase IV Bridging Exercises**


Exercise	Date:	M	T	W	Th	F	S	S
Long bridging-ADIM – heels on Swiss ball Alt shoulder and hip flexion 	repetitions:							
	comments:							
Long bridging-ADIM – heels on Swiss ball Alt shoulder and hip flexion (Eyes Closed) 	repetitions:							
	comments:							
Long bridging-ADIM – heels on Swiss ball 1-leg curl 	repetitions:							
	comments:							
Long bridging-ADIM – heels on Swiss ball 1-leg curl (Eyes Closed) 	repetitions:							
	comments							

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**Phase IV Supine Exercises**

Exercise	Date:	M	T	W	Th	F	S	S
Supine on Swiss ball – feet on ground – shoulders Abd at 90 Marching in place 	repetitions:							
Supine on Swiss ball – feet on ground – shoulders Abd at 90 Alt LAQ's 	repetitions:							
Supine on Swiss ball – feet on ground – shoulders Abd at 90 Alt SLR's 	repetitions:							
Supine on Swiss ball – feet on ground – shoulders Abd at 90 Shifting torso over ball side-to-side 	repetitions:							
	comments							

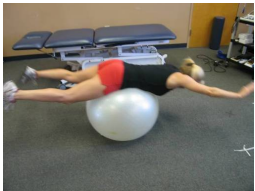


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Supine on Swiss ball – feet on ground – shoulders Abd at 90 Torso Rotation 	repetitions:							
	comments:							






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**Phase IV Quadruped Exercises**



Exercise	Date:	M	T	W	Th	F	S	S
Prone over Swiss ball – hands and feet not touching ground Alt shoulder flexion 	repetitions:							
	comments:							
Prone over Swiss ball – hands and feet not touching ground Alt hip extension 	repetitions:							
	comments:							
Prone over Swiss ball – hands and feet not touching ground Alt shoulder and hip extension 	repetitions:							
	comments:							

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**Phase IV Plank Progression**

Exercise	Date:	M	T	W	Th	F	S	S
<p>Partial plank into push up position by alt elbow extension (Upper body marching)</p> 	repetitions:							
<p>Partial plank into push up position by alt elbow extension (Upper body marching) (Elbows on foam or dynadisc)</p> 	repetitions:							
<p>Plank into push up position by alt elbow extension (Upper body marching)</p> 	repetitions:							
	comments:							



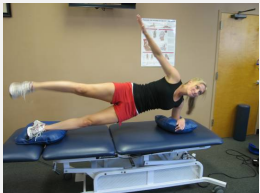
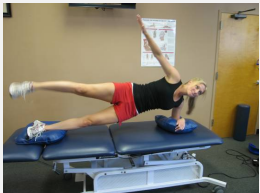
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<p>Plank into push up position by alt elbow extension (Upper body marching) (Elbows on foam or dynadisc)</p> 	<p>repetitions:</p>							
	<p>comments</p>							
<p>Plank into push up position by alt elbow extension (Upper body marching) (Elbows and feet on foam or dynadisc)</p>	<p>repetitions:</p>							
	<p>comments:</p>							
<p>Plank into push up position by alt elbow extension (Upper body marching) (Elbows on foam or dynadisc) Eyes Closed</p> 	<p>repetitions:</p>							
	<p>comments:</p>							
<p>Plank into push up position by alt elbow extension (Upper body marching)</p>	<p>repetitions:</p>							
	<p>comments:</p>							



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**Phase IV Side-Lying**

<p>Side plank Elbow and feet on foam or Dynadisc</p> 	<p>repetitions:</p>							
<p>Partial Side plank Elbow and knees on foam or Dynadisc Shoulder and hip Abduction</p> 	<p>repetitions:</p>							
<p>Side plank Elbow and feet on foam or Dynadisc Shoulder and hip Abduction</p> 	<p>repetitions:</p>							
<p>Side plank Elbow and feet on foam or Dynadisc Shoulder and hip Abduction</p> 	<p>comments</p>							



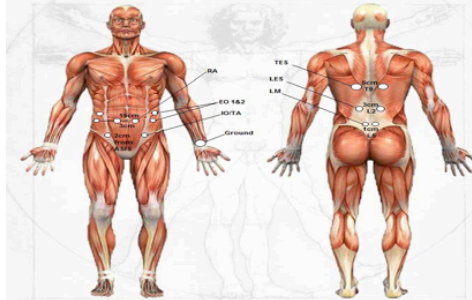


Postural Control, Recovery of Standing Postural Control and Kicking Velocity in Soccer Athletes

**Surface Landmark Template**

**Procedures for Activating Electrodes**

- 1) Turn PDA on
- 2) Click on **ACTIVATE**
- 3) Click **START** on bottom left
- 4) Manually swipe probe over magnet so that the LED light blinks. Simultaneously, the corresponding probe will turn green on the PDA
- 4) Once all probes have been activated, click **STOP** then **EXIT**
- 5) Click on **REMOTE** then on **MENU** then on **CAPTURE**
- 6) On the next screen, click on **ARM**
- 7) Click **LOCK**



Date:  
Subject #

Notes:

Red = Right  
Blue = Left

**Electrode Placement**

- \_\_\_ RA: 3cm lateral to Umbilicus
- \_\_\_ EO1: 15cm lateral to Umbilicus
- \_\_\_ EO2: 5cm above and 5cm medial of EO1
- \_\_\_ IO/TrA: 2cm below and medial ASIS & above Inguinal ligament
- \_\_\_ LM: 2cm lateral to L5 SP
- \_\_\_ ES: 3cm lateral to L2 SP
- \_\_\_ TES: 5cm lateral to T9 SP

**Electrode Assignment**

- B1: L RA
- B2: L EO1
- B3: L EO2
- B4: L IO/TrA
- B5: L LM
- B6: L ES
- B7: L TES
- R1: R RA
- R2: R EO1
- R3: R EO2
- R4: R IO/TrA
- R5: R LM
- R6: R ES
- R7: R TES

Tester Initials:

**EMG MVC Testing Template**  
XXX\_T/RT/PT\_MVC

Muscle Tested	Position	Procedure
External Obliques		<ul style="list-style-type: none"> <li>- Use belts to secure the hips and legs</li> <li>- Side bend/remain fixed early in the flexion position</li> <li>- Apply downward counterforce to shoulders</li> <li>- Repeat on opposite side</li> </ul>
Erector spinae & Multifidii		<ul style="list-style-type: none"> <li>- Use belts to secure the hips and legs</li> <li>- Perform trunk and bilateral LE</li> <li>- Apply downward counterforce <u>bilal</u> upper trunk</li> </ul>
Rectus Abdominus		<ul style="list-style-type: none"> <li>- Use belts to secure the hips and legs</li> <li>- Trunk 30deg flexed-crook lying</li> <li>- Apply downward counterforce <u>bilal</u> upper trunk</li> </ul>
Internal Obliques		<ul style="list-style-type: none"> <li>- Use belts to secure the hips and legs</li> <li>- Trunk 30deg flexed and <b>right rotated</b>-crook lying</li> <li>- Apply downward counterforce on <b>Left</b> upper trunk</li> <li>- Repeat on opposite side</li> </ul>

**Instructions:**  
slowly yet progressively reach **maximum** effort after 3 –5 seconds, then **hold** the position for **3 seconds** and promptly relax

**Collect continuous EMG file**

Date:  
Subject #

Notes:

Tester Initials:



Postural Control, Recovery of Standing Postural Control and Kicking Velocity in Soccer Athletes

**Standing Balance Template**

\* Zero force plate



- Ask to get in position
- Wait 3 seconds
- Click Capture



**SINGLE LIMB STANCE (1 practice trial - 3 test trials Eyes OPEN) (30s)**

File Names: XXX_T/RT/PT_SLS_EO_Trial#	L1	R1	L2	R2	L3	R3
Stepping:	_____	_____	_____	_____	_____	_____
Lifting or uncrossing hands off chest:	_____	_____	_____	_____	_____	_____
Forefoot or heel lifted:	_____	_____	_____	_____	_____	_____
Hip moved >30 degrees flexion or abduction:	_____	_____	_____	_____	_____	_____
Out of test position >5 seconds:	_____	_____	_____	_____	_____	_____
<b>Score:</b>	_____	_____	_____	_____	_____	_____

**SINGLE LIMB STANCE (1 practice trial - 3 test trials Eyes CLOSED) (30s)**

File Names: XXX_T/RT/PT_SLS_EC_Trial#	L1	R1	L2	R2	L3	R3
Stepping:	_____	_____	_____	_____	_____	_____
Opening eyes:	_____	_____	_____	_____	_____	_____
Lifting or uncrossing hands off chest:	_____	_____	_____	_____	_____	_____
Forefoot or heel lifted:	_____	_____	_____	_____	_____	_____
Hip moved >30 degrees flexion or abduction:	_____	_____	_____	_____	_____	_____
Out of test position >5 seconds:	_____	_____	_____	_____	_____	_____
<b>Score:</b>	_____	_____	_____	_____	_____	_____

**TANDEM STANCE (1 practice trial - 3 test trials Eyes OPEN) (60s)**

File Names: XXX_T/RT/PT_Tan_EO_Trial#	L1	R1	L2	R2	L3	R3
Stepping:	_____	_____	_____	_____	_____	_____
Lifting or uncrossing hands off chest:	_____	_____	_____	_____	_____	_____
Forefoot or heel lifted:	_____	_____	_____	_____	_____	_____
Hip moved >30 degrees flexion or abduction:	_____	_____	_____	_____	_____	_____
Out of test position >5 seconds:	_____	_____	_____	_____	_____	_____
<b>Score:</b>	_____	_____	_____	_____	_____	_____

**TANDEM STANCE (1 practice trial - 3 test trials Eyes CLOSED) (60s)**

File Names: XXX_T/RT/PT_Tan_EC_Trial#	L1	R1	L2	R2	L3	R3
Stepping:	_____	_____	_____	_____	_____	_____
Opening eyes:	_____	_____	_____	_____	_____	_____
Lifting or uncrossing hands off chest:	_____	_____	_____	_____	_____	_____
Forefoot or heel lifted:	_____	_____	_____	_____	_____	_____
Hip moved >30 degrees flexion or abduction:	_____	_____	_____	_____	_____	_____
Out of test position >5 seconds:	_____	_____	_____	_____	_____	_____
<b>Score:</b>	_____	_____	_____	_____	_____	_____

Date: \_\_\_\_\_  
Subject #: \_\_\_\_\_

Notes:

Odd #d trials are for the L LE

Even #d trials are for the R LE

Odd #d trials are for the L LE front

Even #d trials are for the R LE in front

Tester Initials: \_\_\_\_\_

**Jumping Template**

**JUMPING SET UP**

Dominant Lower Extremity \_\_\_\_\_ L / R

Date: \_\_\_\_\_  
Subject #: \_\_\_\_\_

**MAX JUMP Height**

The max of 3 Test trials – **No EMG OR FP data collection**

**MAX Height 1:** \_\_\_\_\_ inch

**MAX Height 2:** \_\_\_\_\_ inch

**MAX Height 3:** \_\_\_\_\_ inch

**50% of MAX Height:** \_\_\_\_\_ inch

**MAX Height:** (2.54 x \_\_\_\_\_ inch) \_\_\_\_\_ cm

50% of Max Height \_\_\_\_\_ cm

**Stabilization Jump Test**

- Place Vetec to 50% of max jump height from above
- Ask subject to perform 2 legged squat jump **up to 50% of max** then land on **dominant LE with arms crossed**.
- Allow **4 practice trials** (2 on each LE) and **8 test trials** (4 on each LE)
- File Name: XXX\_T/RT/PT\_TTS\_Trial#
- While standing on plat form 70cm away from Vetec, Click "Capture" then give "**JUMP**" command.
- Collect 20 seconds of **total data**

Notes:

Odd #d trials are for the L LE

Even #d trials are for the R LE

Tester Initials: \_\_\_\_\_

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**Kicking Template**

**KICKING SET UP**

Distance of ball from goal (4m) \_\_\_\_\_ m  
Distance of gun to net (2.8m) \_\_\_\_\_ m  
Ball Pressure(12.5 PSI) \_\_\_\_\_ PSI

**Collect EMG**

File Name:  
XXX\_T/RT/PT\_K\_L/R\_Trial#

Date:  
Subject #

**Self Directed Warm-up completed** Y / N  
**Kicking Foot** L / R

**1-STEP KICK (3 practice trial - 4 data trials)**

Practice Kick Trial 1: \_\_\_\_\_ Km/h  
Practice Kick Trial 2: \_\_\_\_\_ Km/h  
Practice Kick Trial 3: \_\_\_\_\_ Km/h

-----  
Kick Trial 1: \_\_\_\_\_ Km/h  
Kick Trial 2: \_\_\_\_\_ Km/h  
Kick Trial 3: \_\_\_\_\_ Km/h  
Kick Trial 4: \_\_\_\_\_ Km/h

**Average Velocity:** \_\_\_\_\_ Km/h

Notes:

Tester Initials:

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**APPENDIX I**

**Data Collection Procedures and Subject Instructions**

**Procedures and Subject Instructions**

**Data Collection**

1. Set up of equipment
2. Activate electrodes per instructions on template.
3. Set-up electrodes per instructions on templates
4. Collect trunk MVC per instructions on template.

**Static Standing Balance**

Single Limb-Stance:

Instruction provided to subjects prior to testing is standardized:

**“Keep your arms crossed across your chest. While standing-up straight on one leg with your knee slightly unlocked , balance yourself. The goal is stay as still as possible and not touch your other foot to the ground or force plate. Keep the knee bent to 90 degrees”.**

1. While in “**Monitor**” mode, ask subject to step on plate and perform 1 -30 second practice trial with eyes open on each leg.
  - Observe to make certain FP and EMG are working ok
2. Have them step off the plate
3. Click “**New**”
4. Enter the appropriate file name
  - **File name:** XXX\_Test (T/RT/PT)\_TAN\_EO/EC\_Trial #
  - **Note:** odd # trials for L LE, even # trials for R LE
5. Click “**Monitor**”
6. Have them step back on the plate
7. Click “**Capture**” to start data collection
  - For the test trials, once balance obtained (~3sec) click “**Capture**”
8. Collect data for 30 seconds
9. Click “**Capture**” to stop data collection
10. Click “**Save**”
11. Repeat on opposite leg (**Steps 2 through 10**)
12. Record 3 consecutive trials of 30 seconds each with eyes open (EO) separated by a 30 second rest period between each trial for each LE (**6 total trials**)
13. Repeat **Steps 1 through 10** with Eyes Closed (EC)

Tandem Standing:

Instruction provided to subjects prior to testing is standardized:

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**“Put one foot in front of the other having your heel touch your toes. Keep your arms crossed across your chest. While standing-up straight with your weight evenly distributed over both feet without your raising your heel off the ground, balance yourself. The goal is stay as still as possible.”**

1. While in “**Monitor**” mode, ask subject to stand heel-to-toe on plate and perform 1 -60 second practice trial with eyes open on each leg.
  - Observe to make certain FP and EMG are working ok
2. Have them step off the plate
3. Click “**New**”
4. Enter the appropriate file name
  - **File name: XXX\_Test (T/RT/PT)\_TAN\_EO/EC\_Trial #**
  - **Note:** odd # trials for L LE, even # trials for R LE
5. Click “**Monitor**”
6. Have them step back on the plate
7. Click “**Capture**” to start data collection
  - For the test trials, once balance obtained (~3sec) click “**Capture**”
8. Collect data for 60 seconds
9. Click “**Capture**” to stop data collection
10. Click “**Save**”
11. Repeat on opposite leg (**Steps 2 through 10**)
12. Record 3 consecutive trials of 60 seconds each with eyes open (EO) separated by a 30 second rest period between each trial for each LE (**6 total trials**)
13. Repeat **Steps 1 through 10** with Eyes Closed (EC)

### Dynamic Standing Balance

#### Vertical Jump Test

Instruction provided to subjects prior to max height jump testing is standardized:

**“Standing with your feet shoulder width apart, bend your knees, swing your arms and jump as high as you can and slap the rods”**

- The subject stand with dominant arm extended over head to line-up the bottom of the Vertec
- The subject is then asked to jump vertically as high as possible using a squat jump procedure.
- Subject “slaps” Vertec rods to mark max jump height
  - Collect 3 max jump trials
  - Set the Vertec rods to correspond to between 50-55% of their maximum of the 3 max height jump (not the average max height)

#### Stabilization Jump Test

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Instruction provided to subjects prior to 50% max height jump testing is standardized:

**“Standing with your feet shoulder width apart, bend your knees, swing your arms and jump and touch the bottom rod of the Vertec then land on one foot and immediately cross your arms over your chest and regain your balance. Stay as still as possible. ”**

1. Place Vertec 70 cm away from the subject (center of the force plate)
  - Make sure that the Vertec rods are set to 50-55% of their maximum of the 3 max height jump (not the average max height)
2. While on platform 70 cm away from center of the plate, ask subject to perform 2 legged squat jump up and forward and touch rods(**50-55% of max**) and land on **LLE then cross their arms over chest as soon as possible and stay as still as possible.**
3. Allow **4 practice trials** (2 on each LE)
4. Have subject step off the plate and back onto platform
5. Click “New”
6. Enter the appropriate file name
  - File Name: **XXX\_T/RT/PT\_TTS\_Trial#**
  - **Note:** odd # trials for L LE, even # trials for R LE
7. While subject is standing on platform 70cm away from Vetec
  - Click “**Monitor**” then “**Capture**” to start the data collection.
8. Give “**JUMP**” command.
9. Collect 20 seconds of **total data**
10. Click “**Capture**” to stop data collection
11. Click “**Save**”
12. Have subject step off the plate and back onto platform
13. Repeat on opposite leg (**Steps 2 through 12**)
14. Record **8 test trials** (4 on each LE)

**Kicking Velocity**

- Set up speed gun 2.8 meters behind goal
- Set-up ball 4 meters from goal
- Have the subjects perform 5-10 minutes of self-directed warm-up/stretching session – No ball kicking.

Instruction provided to subjects prior to testing is standardized:

**“You are only allowed to take one step before kicking the ball as hard as you can into the goal.”**

- Record 3 consecutive practice kicks with dominant LE
- Record 4 consecutive trial kicks into goal

**Note which limb the kicked was performed with**

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APPENDIX J

Permission from Noraxon to use images in Table 4 from “The ABC of EMG; A Practical Introduction to Kinesiological Electromyography” (Konrad, 2006)

On Thu, Apr 7, 2016 at 10:29 AM, Brent Perkins <[brent.perkins@noraxon.com](mailto:brent.perkins@noraxon.com)> wrote:

We will grant permission as long as he gives proper credit to Noraxon.

Sincerely,

**BRENT PERKINS**

CEO/President

**NORAXON**

Phone: 480-443-3413

Fax: 480-371-2754

Mobile: 480-392-3862

Skype: brent.perkins.noraxon

15770 N. Greenway Hayden Loop #100 | Scottsdale, AZ 85260 | USA

Permission from AskTheTrainer.com to use the image in *Figure 2*. Electrode Placement for Trunk Electromyography

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Date: Wed, 6 Apr 2016 14:42:43 -0700  
Subject: Re: Ask The Trainer General Inquiry  
From: mark@askthetrainer.com  
To: aelkerdi@hotmail.com

Hi Ali,

I have no issues with you using it.

Best Regards,

Mark Behnken  
AskTheTrainer.com

On Wed, Apr 6, 2016 at 1:30 PM, AskTheTrainer.com <[mail@askthetrainer.com](mailto:mail@askthetrainer.com)> wrote:

Name: Ali el-kerdi

Email: [aelkerdi@hotmail.com](mailto:aelkerdi@hotmail.com)

Date: 04/06/2016

Website: <http://anatomy.askthetrainer.com/>

Subject: I am using the body diagram in my dissertation and need permission to use it. The University would like me to get permission since it will be "published" in proquest and internally in the library system

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