VALIDITY OF THE SCHULTZ SLAM TEST (SST) AS A CORE POWER MEASURE IN FOOTBALL

HUMBOLDT STATE UNIVERSITY

By

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Abstract

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Daniel G. Schultz

Purpose: To evaluate the validity the Schultz Slam Test (SST) as a measure of core performance in Division II collegiate American football players. Reliability, as well as convergent, content and divergent groups’ validity were assessed. Methods: Collegiate Division II redshirt football players (N = 22; height 185.00 ± cm, mass 102.62 ± kg) had core power measured using the Schultz Slam Test (SST [developed for this research] and a 60-s maximum sit-up test with a built-in 30-s test), and core endurance measured using the McGill protocol (McGill, 2007). A standardized testing battery for athletic performance measures (3-repetition maximums for the power clean, back squat, and bench press, as well as vertical jump height) was also measured to assess convergent validity of the core tests. To establish content validity, seven strength and conditioning coaches with at least 5 years of football experience were asked to view a video of core tests and then complete a questionnaire. To establish divergent groups’ validity the SST scores of college-level players were compared with SST scores of 20 high school football players. Results: The SST was a reliable test in colligate (r = .852, p = .000) and high school players (r = .941, p = .000). The only significant correlation between SST and football performance was squat relative to bodyweight (1.63 ± .26 kg; r = -.505). There were no significant correlations between athletic performance and sit-up. The McGill right, left lateral hold and total score best related to athletic performance. The McGill
right lateral hold was significantly correlated with the relative power clean (1.20 ± 0.18; \( r = .680 \)), relative squat (1.63 ± 0.26; \( r = .708 \)) and vertical jump height (27.61 ± 2.92 inches; \( r = .515 \)). The McGill right lateral hold was significantly correlated with the relative power clean (1.20 ± 0.18; \( r = .773 \)), relative squat (1.63 ± 0.26; \( r = .801 \)) and vertical jump height (27.61 ± 2.92 in; \( r = .520 \)). The total McGill was significantly correlated with the relative power clean (1.20 ± 0.18; \( r = .518 \)), and relative squat (1.63 ± 0.26; \( r = .477 \)). The McGill extension was significantly correlated with absolute bench press (133.71 ± 27.91; \( r = -.468 \)). Validity of the SST was supported by establishing content and divergent groups’ validity, yet convergent validity of SST was not shown. Coaches believed that the SST was the most sports-specific test and the McGill protocol was the most practical test. The McGill protocol, although static in nature, did relate to football performance (large effect; Hopkins, 2009). The HSU players’ SST times were significantly faster than high school players (\( t[40] = 6.70, p = .000 \)). Conclusion: No one test is able to accurately predict football performance measures. Medicine ball throws in different planes of motion should be tested to determine a relationship to football performance variables.
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CHAPTER ONE

Introduction/Literature Review

The skeletal core of our body is composed of the spine, thorax, hips, pelvis, and femurs. These structures are interconnected and supported to create movement via the attachment of muscles, tendons, ligaments and general surrounding fascia to each other (Bergmark, 1989; Kibler, Press, & Sciascia 2006; Myers 2001). The core can be considered to be the link between the upper and lower body, where the bony segments can be likened to chain links connected via joints (Willardson, 2007). There are 29 pairs of different muscles that comprise the musculoskeletal system of the core, all of which serve different functions (Faries & Greenwood, 2007). The body needs the core musculature for daily tasks, such as carrying groceries, as well as for dynamic tasks used in many sports; the core muscles are needed for human movement at all times. Core training is a highly debated concept with regard to performance in many sports among strength and conditioning professionals.

Core Concepts

The core is thought to be composed of local and global musculature, each of which carries out different roles (Bergmark, 1989). According to Faries and Greenwood (2007), the muscles that have shorter moment arm lengths and attach directly to the spine are generally referred to as the local musculature of the core. The local muscle groups are more inclined to be composed of type I or slow twitch fibers, which have a higher capacity for endurance than type II muscle fibers. The transverse abdominis and the multifidi are the main local muscles involved in the stabilization of the spine, although
there are more muscles involved (Bergmark, 1989; Cholewicki & Van Vliet, 2002; Lehman, 2004). If the spine is not stable, there is not an efficient transfer of forces to the global core musculature and therefore to the limbs, creating an “energy leak” (McGill, 2006, p. 293).

The muscles that are capable of creating movement and torque about the spine are generally referred to as the global musculature of the core. The global muscles have longer moment arms and tend to be predominantly type II muscle fibers (Bergmark, 1989; Faries & Greenwood, 2007). The global muscles come into play during the high resistance or high speed tasks that require greater than 40 percent of the maximum voluntary contraction of the muscle (Faries & Greenwood, 2007). Main global muscles of the body include the rectus abdominis, psoas major, and erector spinae.

Local core musculature is the foundation with which the global musculature can generate movement off of. Both muscle groups rely on each other and, when working in harmony, may lead to an increase in sports performance (Behm, Cappa, & Power, 2009; McGill, McDermott, & Fenwick 2009; Sato & Mokha, 2009). The local musculature can be thought of as a stable concrete foundation (if functioning properly), and global musculature can be thought of as a crane helping to move objects from the concrete base. The crane arm would represent the arms and legs of the body.

**Muscular Attributes of the Core**

Different muscular demands on the core require that the demand be met with different core musculature attributes. Stability of the torso and spine may be the main core attribute in some settings that require balance and accuracy, such as gymnastics
events. Strength or power throughout the core musculature may be the main goal for athletes such as shot putters, football lineman, or strongman competitors. According to Willardson (2007), strength and power in regards to the core should be approached using a different paradigm than for a patient suffering low back injury. A low back pain patient may just want to rehabilitate and strengthen the torso muscles enough to be functional again; whereas, an athlete wants to have the strongest, most powerful and balanced core for their sport.

McGill, McDermott and Fenwick (2009) conducted a study using EMG signals from various sites of core musculature on strongmen to compare differences among competitors. The best competitor was the one who was able to “activate the stiffening muscles” of the core “to the highest degree” (McGill et al., 2009). This higher degree of contraction, measured as an EMG signal, may be related to performance in some instances. Conversely, endurance of the torso may be the most important core attribute in events such as long distance cycling, as suggested by McGill (2006). The need for these attributes may change even from moment to moment in sports like football, where core balance may be needed one second and core power later in the play (Leetun et al., 2004). All of the muscular attributes of the core mentioned are related to athletic performance in one respect or another.

The terms “core stability”, “core endurance”, “core strength”, “core power” have often been used interchangeably in the literature (Faries & Greenwood, 2007), yet some researchers have defined these particular constructs (Bergmark, 1989; Faries & Greenwood, 2007; Kibler et al., 2006; Willardson 2007). All of these core attributes may
be called on at different times during a particular sport. Contraction dynamics of muscles can change to meet differing demands for stiffening, for force production, and for rapid movements, according to McGill et al. (2009). A quarterback playing American football may have to buttress tortional forces about his spine from a defender hitting him in the shoulder, and then throw the football. During this one play from scrimmage the athlete has to employ different attributes of the core musculature.

**Core stability.** Kibler et al. (2006, p. 190) defined core stability as “the ability to control the position of the trunk over the pelvis and leg to allow optimum production, transfer and control of force and motion to the terminal segment in integrated kinetic chain activities”. In order to maintain core stability, the trunk needs to be controlled in all planes of motion and stay in line with the hips. Panjabi (1992, p. 384) defines core stability as the “capacity of the stabilizing system to maintain the intervertebral neutral zones within physiological limits”. A stable core is able to keep the spine in neutral alignment during increased demands put on the core musculature in athletics. Finally, Willardson (2007, p. 10) refers to stabilizing in his definition of the core and states that the core is “the muscles that control and stabilize the lumbar spine and pelvis”. Core stability is involved with all athletic movements involving the extremities and is needed for the athlete to remain injury free (McGill, 2009; Nesser, Huxel, Tincher, & Okada, 2008).

**Core endurance.** Endurance of the core musculature can be thought of as how long the muscles of the core are able to function at a given task (Dendas, 2010; Gamble, 2007; Kibler et al., 2006; Willardson, 2007). Muscles that can sustain prolonged
contractions are less likely to fatigue and can continue to provide support to the torso over time, reducing the chance of injury and maintaining sport performance (Nesser et al., 2008). Core muscular endurance has been found to be associated with injury prevention, in that poor muscular endurance has been related with occurrences of low back pain (McGill, 2007; Rissanen et al., 2002). If core musculature does not have the endurance to sustain a neutral spine, then the movement of the spine will be perturbed and injury is more likely.

**Core strength.** Strength, in reference to the core, can be defined as the ability of a muscle to exert or withstand force or actively control spine stability through the regulation of this force in core musculature (Faries & Greenwood, 2007). The terms core strength and core stability tend to be interchanged with each other, because it is believed that it takes core strength in order to achieve the core stability that is needed for a task. Furthermore, Dendas (2010, p. 9) suggests “that core strength is a necessity for core stability, meaning that there cannot be one without the other; the core musculature has to possess both”. If the local muscles that are responsible for stabilization of the torso are stronger, then they may be able to keep the spine in a neutral position and transmit forces through it under the increased demands of sports, thus increasing stability. The ability of the global muscles to exert or withstand forces and either create or buttress (stabilize) movement is considered strength. Both local and global muscles can display strength.

**Core power.** Power is the product of force and velocity, but can also be represented as \( \text{Power} = \frac{\text{Work}}{\text{Time}} \). Unfortunately, there are not clear descriptions of core power in the current literature. Generally, core muscle power is implied to be the
ability of the core musculature to be able to withstand or exert high amounts of force in short amounts of time, so that power is able to be transferred through the torso (McGill, 2007). Accordingly, many of the measures used to test football players in the weight room, such as the power clean and vertical jump, are representations of power about the hip. Cowley and Swensen (2008) explain that power, along with strength and endurance, is a part of a continuum of overall core stability. Dendas (2010, p.10) states that core power “can be thought of as explosive concentric contractions of the musculature over a certain amount of time against an object, such as throwing a weighted medicine ball”. Cowley and Swensen (2008) measure torso power using medicine ball throws, although they also refer to these tests as measures of “core stability”, adding to the confusion with regard to core terminology. Importantly, according to McGill (2006), “if the spine is experiencing high angular velocity (actual spine bending) together with high bending torque, the risk of injury is high…. The “power” in the protected athlete comes from the hips, not the back”. Said in another way, actual power among the muscular acting on the vertebral joints (i.e. lumbar spine) may, in some circumstances, not be considered a good thing, due to the high risk of herniated discs and the like.

**Core Muscular Attributes and Sports Performance**

The law of specificity is an important concept that relates to discussion of the core and performance. This law states that applied demands end in specific results (Baechle & Earle, 2002). If training is not specific to testing protocols, the athlete will not do as well as they possibly can. An athlete that predominately uses the ATP-PC energy pathway in their sport and training will have a hard time doing well when performing an endurance
test. Performance attributes and performance measures differ from sport to sport, by position, and even by sex. Ikeda, Kijima, Kawabata, Fuchimoto and Ito (2007), for example, demonstrated that a side medicine-ball throw did relate to power and physical ability in males but not in females, possibly due to differences in body structure (e.g., Q angle), distribution of muscle, and experience. Multiple factors need to be considered when creating sports-specific performance assessments.

In order for a core performance test to be specific, several things need to be considered relative to the athlete’s particular sport (Baechle & Earle, 2002; Bompa & Carrera, 2005). The predominant energy system used in the test must be the same as in the sport in order to be specific. A similar neuromuscular firing pattern exercise technique needs to be employed in the test as in the sport. The range of motion used in the core performance test needs to be similar to the sport. Does the athlete perform their particular sport while standing, as in football, or while sitting, as in rowing? What planes of motion are the athletes working in during their particular sport? A valid sports-specific test will take all of these points into account.

Core strength and stability have, dependent on the measure used, been found to relate to sport performance in some athletes (Behm et al., 2009; Dendas, 2010; McGill et al., 2009), yet often the relationship is moderate at best (Dendas, 2010; Nesser et al., 2008; Sato & Mokha, 2009). Furthermore, some core measures failed to significantly relate to performance at all (Dendas, 2010; Nesser et al., 2008; Nesser & Lee, 2009; Tse, McManus, Masters, 2005). Although the evidence for the role of core attributes in performance is not clear, many strength and conditioning specialists use core exercises in
their training regimens to improve the performance of the athletes. Different sports put different demands on the athlete, so the ability to develop these given attributes can help improve performance in the sport. Different core exercises and tests are used for different reasons in the strength and conditioning field and it is important to optimize the fit of the core assessment to the sport.

**Assessment of core muscular attributes in sport.** Physical fitness tests are used to determine the level of fitness of an athlete and create a personal benchmark to beat in the future. Many sports testing batteries include tests such as a timed run (Behm et al., 2009; Sato & Mokha, 2009) or maximum weighted Olympic lifts, which indirectly capture attributes of the core, since the core is activated during these lifts (Hamlyn, Behm, & Young, 2007). Additionally, almost all sports include some type of core-specific exercise tests. The most commonly used of these core assessments are explained in the following paragraphs.

A very commonly used measure of abdominal muscular endurance is the sit-up test for time (AAHPERD, 1980; U.S. Army Physical Fitness Training, 1992). The amount of sit ups an athlete does in a given amount of time is a good representation of muscular endurance or power, depending on the amount of time over which the test is conducted (Augustsson et al., 2009). The 30-sec sit-up test is an assessment of core power, due to the short time allowed, although some authors argue that the 60-sec test is also a power test (Sparling, Millard-Stafford, & Snow, 1997). The sit-up test is not recommended for people with low back pain, due to the excessive low back compressive loads (McGill, 2007).
The partial curl-up test differs from a sit-up test, in that the torso is not lifted up to the vertical position, the arms are by the sides of the torso, and only the head and shoulders are lifted off the floor. The partial curl-up protocol is described by the National Strength and Conditioning Association (NSCA) as a measurement of abdominal muscle endurance (Baechle & Earle, 2002). In this test the subject assumes the supine position on the ground with arms by their side and fingers touching a mark on the ground or a mat. The subject then curls up, sliding the hands 12 cm for individuals younger than 45 and 8cm for those older than 45 toward the feet, then returning back down to the starting position at a pace of 40 curl ups per minute. In this test, the subject continues until failure, or until he/she is able to reach a maximum of 75 repetitions (Baechle & Earle, 2002).

The McGill protocol (McGill, 2008) is another commonly performed assessment of core endurance but, unlike dynamic sit-up and curl-up tests, it is a static test. The McGill protocol consists of tests that have been shown to correlate to lower back pain in the athletic training and clinical settings (i.e., the ability for a low back pain sufferer to return to work, Biering-Sorensen, 1984). The protocol includes front plank stabilization, side plank stabilization, and an isometric cantilevered hip extension off a bench, all held for time. A subject that is able to hold the isometric poses for a long time is considered to have less risk of low back pain. Decreased torso extensor endurance, measured using the McGill protocol, has been related to increased instances of lower back pain. McGill (2008) however, suggests that low back pain is more related to the balance of endurance of the core musculature than to the amount of time a pose can be held. Recently,
researchers have used the McGill protocol to assess the core in athletic settings (Dendas, 2010; Nesser et al., 2008; Nesser & Lee, 2009).

The Star Excursion Balance Test (SEBT) has been used in clinical and sports settings to measure the functionality of the lower body including the core (Sato & Mokha, 2009). The SEBT has been shown to be a reliable measure of lower body stability and is an indirect measure of core stability (Kinzey & Armstrong, 1998). In this test a “star” is put on the ground using four pieces of tape with lines separated 45 degrees, resulting in two overlapping “X” figures. The subject then reaches as far as possible in any direction down the tape line with their foot. The subject reaches as far as that they can and holds the position for 3 seconds in order to show they are able to maintain control. The furthest distance reached is then recorded. The total length reached is divided by the leg length of the subject, and that then equals their SEBT score. Subjects with more core stability theoretically would be able to maintain balance at a longer excursion distance (Kinzey & Armstrong, 1998).

The electrical activity of the muscle, as measured using Electromyography (EMG), has also been used to assess core performance (Raymond, Tse & Wong, 2007). EMG is a record and analysis of myoelectric signals generated by the muscles. The EMG signal changes based on the differences in physiological states of the muscles, according to Konrad (2005). EMG can be used to assess the percent of maximal voluntary contraction of a given muscle, which in turn can be related or compared to other measures (Konrad, 2005). Researchers are able to use EMG to determine what muscles are activated and to what degree they are activated. Some studies suggest that a higher
degree of core activation may lead to better performance (Behm et al., 2009; McGill, 2009). With EMG, researchers are able to more accurately assess what muscles are being used and when they are being used during a given task.

Finally, medicine ball throws have also been used to test core attributes (Cowley & Swensen, 2008; Dendas, 2010; Earp & Kraemer, 2009; Ikeda, Kijima, Kawabata, Fuchimoto, & Ito, 2007; Ikeda, Miyatsuji, Kawabata, Fuchimoto, & Ito, 2009; Mayhew et al., 2005). Medicine balls are used in many sports training programs for the purpose of gaining specific strength and power (Cowley & Swensen, 2008); therefore it makes sense to use them to test athletes. Cowley and Swensen (2008) created the Front and Side Abdominal Power Tests in which the subjects used medicine balls as the testing modality. Dendas (2010) created the Medicine Ball Explosive Sit-up Throw test (MBESTT), an adaption from the Cowley and Swensen (2008) abdominal power tests, in order to assess core power in athletes. Cowley and Swensen (2008), as well as Dendas (2010), developed medicine ball tests that are performed in the seated position and may therefore be limited with regards to sports specificity.

There are many exercise techniques that can be performed using a medicine ball, but for the purpose of this review only those done in the standing position will be fully discussed, as these are specific to most sports. The standing tests most relevant to this review include the Backward Overhead Medicine Ball toss (BOMB) (Mayhew et al., 2005) and the Fast Side Medicine Ball Toss (FS-MBT)/Side Medicine Ball toss (S-MBT) (Ikeda et al., 2007; Ikeda et al., 2009). These tests are plyometric, in that they involve a
pre-stretch of the muscles in the torso followed by an explosive contraction of the previously stretched muscles (Baechle & Earle, 2002).

The BOMB is basically an overhead medicine ball throw for distance. According to Mayhew et al. (2005), the BOMB consists of standing with the toes on a line or baseline of a court while grasping a medicine ball with both hands. The subjects then flex their knees, and lower the ball to approximately the height of the knees. The subject then extends the legs, hips, and raises the shoulders. The shoulders are then brought into flexion and the ball is tossed backward over the head of the athlete. The objective of the throw is to get the greatest horizontal distance possible. The movement of the BOMB takes place in the frontal plane (Mayhew et al. 2005).

Ikeda et al. (2007) created a medicine ball protocol that is performed in a different plane than the BOMB (Mayhew et al., 2005). In the S-MBT the subject starts with the medicine ball grasped in both of their hands. The subject then rotates at the trunk to the side opposite the throwing direction as a counter-movement. The counter-movement is followed by rotating the trunk to the throwing direction, attempting to throw as far as possible in the S-MBT, and to throw as fast as possible in the FS-MBT. These tests are performed in the transverse plane, which takes place by twisting of the trunk. Many sports movements involve trunk twisting, due to the dynamic nature of different sports (Ikeda et al., 2007).

**Core attributes and endurance sports performance.** Tse et al.(2005) conducted a torso-strengthening program to determine if it would improve various performance measures in college-aged rowers. Two times a week for 8 weeks a torso
strengthening program was employed for the core training group \((n=25)\), while the control group \((n=20)\) did not receive a core work out protocol. The specific training protocols were not discussed. Functional performance measures were assessed: vertical jump, broad jump, shuttle run, 40-m sprint, overhead medicine ball throw, and 2,000-m maximal rowing ergometer test. The McGill protocol (2007) was used as a measure of the core and was related to the functional performance measures, including the 2,000-m ergometer test. At the end of the 8-week program both of the groups performed similarly in the performance measures. The core-training program may not have been specific enough to elicit a response in the core musculature related to rowing. Tse et al. (2005) also suggested that 8 weeks was not enough time to get the muscular adaption needed for improved performance.

Behm et al. (2009) measured trunk muscle activation of various dorsal and ventral muscles in the torso using EMG in subjects who ran on a treadmill. The purpose of the study was to collect EMG activation data during two intensities of running and to compare this activation to EMG data during torso exercises in trained and untrained runners. There were 13 subjects, 7 were elite tri athletes and the rest of the subjects were non runners. To activate the trunk, subjects were asked to perform 30 curl ups as well as a Biering-Sørensen (1984) isometric back extension for a maximum of 180 seconds. The subjects were then asked to run 30-minute trials on the treadmill at an intensity equal to 60% and 80% of their VO\(_2\) max. The EMG data was analyzed and compared between the two groups of runners. The triathletes generally performed better on the treadmill speed as well as the Biering-Sørensen (1984) isometric back extension. Behm et al. found that
the activation of the trunk muscles in the triathletes was greater than that of the non-runners during the trials. This increased ability to keep the musculature of torso activated may have contributed to their stability and better performance (Behm et al., 2009).

Sato and Mokha (2009) studied distance runners in an attempt to determine whether or not improvements in core strength would relate to improved 5000-m performance. The effects of 6-week core strength training program on ground reaction forces, stability of the lower extremity, and overall running performance were measured in recreational and competitive runners. A total of 28 subjects were split into two groups that were training for an upcoming marathon. The training group executed a 6-week core strengthening core training program along with their regular marathon training. The control group continued with the run training and did not perform the core strengthening program. Sato and Mokha found that the group that performed the core exercises had better running times in the 5000-m run. However, core stability, measured by the Star Excursion Balance Test, as well as the other measures, including ground reaction forces, were not improved in the core training group. Run times were much faster to begin within the core training group, which may have influenced the results. The core training may not have been specific enough to increase balance or the ground reaction forces in the runners (Sato & Mokha, 2009).

Nesser and Lee (2009) used the McGill protocol (2007) to determine if there was a relationship between what they referred to as “core strength” and strength variables (max squat and bench press) as well as performance variables (counter movement vertical jump, 40-yard dash and 10-yard shuttle run) among Division I female soccer players. The
athletes completed the strength and performance testing prior to their off-season conditioning program. Nesser and Lee (2009) found no significant correlations between the measures of core strength and strength/performance variables and concluded that core strength should not be the focus of strength and conditioning programs to improve sport performance, but neither should core strength be neglected in training.

**Core attributes and strength and power performance.** McGill et al. (2009) examined torso EMG data of strong man competitors doing various events to compare muscle activation across performance levels. The strongman events consisted of the farmers walk, the left and right hand suit case carry, the super yoke walk, the right and left shoulder keg walk, log lift, tire flip and atlas stone lift. The athletes completed each competitive event with EMG pads placed at different locations on the body. After the events, the data points were analyzed and compared, noting the different performances of the athletes. McGill concluded that the best performance in strongmen may have been due to the power generated at the hips while maintaining a stable spine. The top performing athletes were able to transmit hip power through a stiff spine and to the hands the most efficiently, enabling the athlete to lift increased weights. McGill et al. (2009) showed evidence that, in a group of strongmen, the athlete that contracted the local bracing muscles of the core to the greatest extent performed the best in particular strongman events.

Nesser et al. (2008) investigated relationships between core stability and various strength and performance variables in Division I football players. The athlete’s strength (1-RM bench press, 1-RM power clean and 1-RM squats) and performance variables
(countermovement vertical jump, 20- and 40-yd sprints, and a 10-yd shuttle run) were measured. The athletes were then tested for core endurance/strength using the McGill protocol, using maximal torso isometric holds for time. The strength variables and performance variables for the athletes were then correlated to the results in the McGill protocol. Nesser et al. (2008) found statistically significant moderate to weak correlations between the McGill measures and performance variables. Nesser et al. (2008) concluded that an increase in core strength will not significantly improve performance, and thus should not be the major focus in strength and conditioning programs.

Dendas (2010) used a medicine ball toss, a sit-up test of 30sec and 60sec, and the McGill protocol to relate to strength and performance variables among Division II football players. Dendas (2010) created the Medicine Ball Explosive Sit-up Throw Test (MBESTT), as modified from the front abdominal power test developed by Cowley and Swensen (2008). The MBESTT was comprised of two phases. The first phase was a seated medicine ball chest press for distance at the athlete’s optimum angle of projection. The second phase consisted of a sit up coupled with a medicine ball chest pass for distance. Of the two trials, the difference in distance between the best (i.e., the furthest) of the six throws for the two phases of the MBESTT was used as an indirect measure of core power. The MBESTT was only significantly related to the absolute bench press; there were moderate (non-significant) correlations with all the other performance measures. The 60-sec sit up test significantly correlated ($p < .05$) with the relative power clean (i.e., power clean expressed relative to body mass), relative squat, relative bench
press, vertical jump height, 40-m sprint time, and 20-m sprint time. Dendas (2010) found no significant correlations between McGill protocol measures and performance.

**Standing medicine ball tosses as measures of sport performance.** Previously used measures of the core have fallen short with regard to relation to sports performance measurements and, with exception to sit ups (Dendas, 2010), no tests of the core explain much of performance in football, the sport of interest for this review. Football athletes need to exert considerable power in a standing position, thus the question remains as to if practical standing measures of power, such as medicine ball tosses (Ikeda et al., 2007; Ikeda et al., 2009; Mayhew, 2005) could relate to football performance. To answer this question, it is first important to understand what exactly is measured in the performance of a standing medicine ball toss.

Ikeda et al. (2007) examined the factors that influence performance on various anaerobic side medicine ball tosses. The researchers also tried to determine what accounts for the differences in performance among trained males and females in trunk rotation power. A total of 26 (16 male and 10 female) moderately-trained participants performed trunk rotation power medicine ball tosses (single tosses for distance using various weighted medicine balls), an isometric maximal trunk rotation torque test, and various sport performance tests, including a maximum bench press, maximum parallel squat, and countermovement squat jump (for peak power). No significant correlations were found between the medicine ball throw performance and the other measures in the women tested. In the men however, significant correlations were found between how fast/far they were able to toss the medicine ball and how well they were did in the
performance measures. Maximal rotational torque in the male participants correlated positively with their parallel squat as well as the maximal bench press. Females were only able to produce 62% of the power that males produced, which is indicative of the differences in biomechanical factors between men and women. Ikeda et al. (2006) suggest that performance in the lifts and maximal trunk rotation torque contribute to performance in the standing medicine ball tosses, and that side medicine-ball throw tests are fundamental indicators of full body explosive power, regardless of technique.

Ikeda et al. (2009) again used medicine balls as a modality, assessing core power and trunk rotation among male basketball players using EMG. The purpose of the study was to compare EMG activity of the trunk musculature during the fast side medicine-ball throw between long and short throwers. The two groups, short throwers and long throwers, were separated out by their ability to throw the medicine-ball in a previous test. The research team then applied surface EMG to all the throwers at various locations of the torso in order to see differences in EMG activity. A significant difference in the EMG activity was found between the groups. The long throwers were able to contract their obliques to a greater degree than that of the short throwers. Performance was related to the ability of the subjects to activate their obliques (as well as other torso muscles) to a greater degree, and therefore, they threw the medicine-ball further (Ikeda et al., 2009).

Mayhew et al. (2005) studied 40 Division II collegiate level football players to determine the relationship between performance on the backward overhead medicine ball throw and power production. The best ball toss performance (measured as horizontal distance) from three trials, in which a 7-kg medicine ball was thrown backwards over the
athlete’s head, was related to power production measured during a countermovement vertical jump performed on a force plate. The backward overhead medicine ball toss distance was only moderately (significantly) correlated to peak and average jump power, but when power was expressed relative to mass no significant correlations were found. Mayhew et al. (2005) stated that a medicine ball toss may be more complicated in form then a total body explosion performance, such as a jump; the backwards medicine ball toss therefore has limited potential as a predictor of total body explosive power.

**Limitations of current core testing paradigms.** There are problems with the current core testing paradigms, due to the fact that, besides the sit-up test (Dendas, 2010), there are no practical tests that have been shown to have meaningful correlations to strength and power in football players. All of the core tests performed in the Dendas (2010) and Nesser et al. (2008) studies are done in either a prone, supine or side position with the athlete’s body on the ground. During a majority of athletic events, and in football specifically, the athlete is on their feet transmitting ground reaction forces through his torso in order to complete the athletic task. The musculoskeletal system pushes against the ground and in turn, the ground pushes back (Newton’s third law), as force passes through the body and through the rest of the fibrous net of the body to the hands (Myers, 2001). In order for the athletic task to be completed, ground reaction forces will have to go through the torso and act on the body to create movement.

The core musculature changes the way that it is activated when standing versus being in other positions. McGill et al. (2009) collected EMG data measured in core musculature during exercises in a standing position, as well as on the ground, in eight
healthy men. McGill et al. (2009) showed a decrease in activity of the muscles in the torso when doing standing exercises, because joints are not isolated and the force is spread over multiple muscles. The standing overhead cable push and the prone walk out exercise, for example, are both similar movements performed in the sagittal plane. In the study by McGill et al. (2009), sagittal walkouts were performed by starting in a pushup position; the subjects “walked” their hands forward, creating a body bridge, to a distance which they felt they could maintain that posture. The overhead cable push started with the cable handle in both hands with the arms outstretched overhead. The instruction for the cable push was for the subject to constrain the flexion motion only at the hips. First, subjects stood on both feet and then repeated the cable push on one foot. Higher EMG activation of the rectus abdominis was recorded for the walkouts, while the internal obliques were the main muscle groups activated in the overhead cable push. McGill et al. (2009) explains that the muscles of the torso are contracting and relaxing differently when the body is standing. For this reason, a standing abdominal protocol might be more predictive of athletic performance than a protocol performed sitting or in the supine position.

Isometric contraction protocols that assess the core (e.g., the McGill protocol, McGill, 2007) only test the muscles at the length that they are at during the specific test being done and are not specific to dynamic motion. In the athletic setting the body is not in a static position, the body is in motion and moving different joints through different ranges of motion. The core needs to buttress forces and transmit force through itself in order move athletically. Hamlyn et al. (2007) tested trunk muscle activation in dynamic
weight training exercises and isometric instability exercises. The subjects performed an 80% 1-RM deadlift as well as squat. The EMG data from these lifts were compared to EMG data taken during a static side bridge and prone superman. A significantly higher level of activation of the lower abdominals, external obliques, upper lumbar erector spinae and lumbar-sacral erector spinae muscle groups was found during the squat and deadlift than during static hold exercises (Hamlyn et al., 2007). Static hold exercises may be better predictors of core endurance than core power or strength, whereas dynamic movement assessments, especially those performed in standing position, may better mimic muscle activation during strength exercises such as squats.

When performing the deadlift and squat lifts all the muscles of the torso are activated, particularly the lower abdominals, upper lumbar erector spinae and lumbar-sacral erector spinae muscle groups (Hamlyn et al., 2007). A deadlift is considered the proper form for picking up weighted objects, such as a medicine ball in a slam or groceries off the ground. There is no EMG data that the author can find to date regarding torso muscle activation in such exercises as the power clean. Although, the first motion of the power clean is a deadlift, which according to Hamlyn et al. (2007) is known to activate the muscles of the core. The stone lift, a common strongman event, has been shown to activate the anterior and posterior muscles of the torso (McGill et al., 2009), although the spine is not in a neutral position, it is in flexion. All of the previously listed exercises use similar muscle groups and similar muscle activation patterns of the core, although they do vary to a degree. A core test of football performance therefore should be one in which muscle activation patterns are similar to those in these key lifts.
Football performance is commonly measured by lifting parameters such as the back squat, the power clean and the bench press as well as other speed/power tests such as the 40-yard dash, the shuttle run and vertical jump, to name a few basic measures. The average football play time changes depending on style of play and the like, but is generally around 5.5 seconds (DeFranco, 2010). A single play can last as long as 15 seconds and a shorter play can be done in as little as a second. The movement patterns of the hip and knee joints of the tests in the sagital plane, particularly the power clean, closely mimic the movement patterns during blocking and tackling, that is why they hold merit as valuable tests in the recruiting of potential players. Drafted NFL players outperformed their non drafted counterparts significantly in combine measures (Sierer, Battaglini, Mihalik, Shields, & Tomasini, 2008). That said, according to Robbins (2011), different football positions display different physical characteristics in that football lineman are found to be significantly slower in sprint times than defensive backs. Football linemen are also significantly stronger in lifting protocols than defensive backs (Robbins, 2011).

**Statement of the Problem**

Most power sports, such as football, require the use of anaerobic metabolism for a majority of their ATP production (Powers & Howley, 2009). The current tests that are being administered to measure the core (e.g., MBESTT, sit ups, and McGill protocol) in football players or in other groups (S-MBT, F-MBT) are more endurance based, or require a single maximum burst of energy involving the ATP-PC system for generation of ATP. None of these tests, perhaps with the exception of the sit-ups, correlated well to
football performance measures (Dendas, 2010; Nesser et al., 2008). The McGill protocol does not involve dynamic movement, and single all-out efforts do not replicate the repeated all-out power movements in football. Thus, even a single medicine ball toss (for furthest distance or the fastest toss) is unlikely to relate strongly to performance in football, even though Ikeda et al. (2007) showed it related to trunk rotational power in males.

According to Dendas (2010), the core attribute measure that best related to performance in collegiate-level football players was the sit-up test for time. The limitation of the sit-up test, as a core measure related to football performance, is that it is performed in a supine position on the floor, which is not sport specific. For these reasons, a new core test needs to be developed that can be conducted quickly on the field and relates to measures used in football performance. Therefore, the purpose of this study was to evaluate the validity of a newly designed test, the Schultz Slam Test (SST), as a measure of core performance in Division II collegiate American football players. Reliability, as well as convergent, content and divergent groups’ validity were assessed.

**Hypothesis**

It was hypothesized that the newly designed SST would be judged as a superior measure of core performance in football, based on input recorded by strength and conditioning coaches (i.e., content validity). The SST was expected to relate better to the football performance measures than either the sit-up or McGill protocol (2007) (i.e., convergent validity). College football players were expected to score significantly higher on SST than high school football players (i.e., divergent groups’ validity).
Assumptions

It was assumed that all athletes would follow directions to perform to the best of their abilities on all of the testing protocols.

Practical Applications

Strength and conditioning professionals rely on practical, field-based tests that relate to athletic performance. Tests need to be designed that are sports specific, easy to administer, have minimal equipment, and which have been shown to relate to athletic performance. Good tests relate to the demands of the sport in terms of planes of motion, neuromuscular firing patterns and duration of effort. If preliminary validation of the SST is established, and if the test is further validated (perhaps using criterion measures such as EMG), it may one day be recommended as a valuable assessment tool for strength and conditioning specialists working with football players.
CHAPTER TWO

Methods

Experimental Design

In order to establish preliminary validation support for the SST as a test of core power specific to football, reliability as well as convergent, content and divergent groups’ validity was determined. Reliability was assessed using test-retest methods. Convergent validity was determined by relating SST scores and two scores from other tests of the core to football performance measures. Content validity was assessed by football strength and conditioning coaches who were asked to view a video of the principal investigator performing the SST as well as two other tests of the core; the coaches then evaluated these tests to determine which best represented the demands of football on the core best. Coaches also were asked to identify strengths and limitations of each of the three core tests with respect to the ability to capture demands on the core in football. Divergent groups’ validity was established by comparing scores on SST in football players at the high school level to players at the Division II level.

The newly-designed test, the Schultz Slam Test (SST), involved 10 repetitive slams of a 30-lb, sand-filled medicine ball to the ground for time. The other tests of core attributes that have been used to relate to football performance and which also were measured in this study were the sit-up test and the McGill protocol (2007). The sit-up test is a maximal effort test, conducted for 60 sec, with number of sit-ups recorded at both 30- and 60-sec times. The McGill protocol (2007) measures how long isometric contractions,
that support the body in a plank position, can be held for time. Football performance was measured using established measures (Dendas, 2010; Nesser et al., 2008); these were the power clean, squat, bench press and vertical jump for height.

**Participants**

Redshirt football players \( n = 22 \) on the Humboldt State University Division II team participated in the part of the study designed to establish convergent validity. The Humboldt State University coaching staff, along with the head strength and conditioning coach gave permission to recruit the redshirt football athletes. The Principal Investigator (PI) approached athletes individually, during scheduled mandatory workouts, to inform them of the opportunity to participate. Athletes were then asked to read an informed consent document (Appendix A) and were given brief verbal explanation of the procedures, risks and time required. Following consent, the athlete was asked to complete an injury/athletic history questionnaire (Appendix B). To be included in the study athletes needed to be free from injury and not currently be in pain. Athletes needed to be experienced in Olympic-style weightlifting (minimum of 3 months); experienced in medicine-ball throws (minimum of 3 months); and experienced in performing full sit-ups (minimum of 3 months). All 22 of the athletes who were recruited met the inclusion criteria and completed all of the tests. These inclusion criteria were similar to those used in Dendas (2010). Athletes, whose anthropometric measures were administered by the strength and conditioning staff prior to the start of the study, were asked to release this information in the informed consent.
To establish content validity, seven strength and conditioning coaches with at least 5 years of football experience were recruited to participate. The potential coaching participants were identified by the HSU head strength and conditioning coach as peer colleagues that he felt were likely to respond. The principal investigator emailed strength and conditioning coaches links to videos of the SST, the sit-up test and the McGill protocol (2008) and an informed consent document (Appendix C). The coaches, after reviewing the videos, were asked to respond to questions concerning the exercises specificity to the use of the core musculature in football and limitations of each test. A sample of this questionnaire can be found in Appendix D. Face and representation validity, subcategories of content validity, were established through a consensus of experts answering the questionnaire.

To establish divergent groups’ validity, redshirt football players scores on the SST were compared with SST scores of 15 high school football players. The high school athletes were recruited from the McKinleyville High School (McKinleyville, CA) football program. McKinleyville high school is a Division III high school program. The McKinleyville High School head coach granted permission to recruit football players from the team. The PI then attended a week of off-season football conditioning. The PI introduced himself, briefly explained the research and handed out a cover letter (Appendix E) and informed consent (Appendix F). The players under the age of 18 had their parent sign an informed consent document; the cover letter and the informed consent were sent home with participants and returned the following day. After all of the
paperwork was returned, the two-day familiarization period began. The SST took place on two other consecutive days and data was collected.

**Core measures**

Core power was measured by the SST and maximum sit-ups in 30 and 60 seconds. The strength and conditioning staff administered the tests and checked that proper form was carried out by the athlete as well as recording their scores. These scores were recorded on a data sheet (Appendix G) after the participant completed each test. This information was then related to the maximum lifting scores of the athlete as well as to performance on the vertical jump as part of the procedures establishing convergent validity.

**Schultz Slam Test.** Core power was measured by the sand-filled medicine ball slam for time using the SST. This measurement was considered an indirect measurement of core power, in that the whole body is in motion transmitting forces through the torso during this test. In the SST, the athlete started in a standing position with the sand filled-medicine ball directly in the front and center of them with toes on a taped line on a turf field. The 13.61-kg (30-lb) medicine ball was placed on an“X” taped on the turf .3m (1 foot) away from the line (and the athlete). The athlete was instructed to bend down with a straight back, using the hips and legs, to pick up the ball, as in a deadlift. The athlete then proceeded to lift the ball over his head until the body was straight, and the ball was over the head. The athlete then directed the energy of the ball down towards the field turf and, as fast as possible, threw the ball back to the ground, aiming for the X, utilizing the
stretch shortening properties of the anterior muscles of the torso. Upon picking up the medicine ball again after the slam the posterior muscles of the body are lengthened and soon after shortened to bring the body to a standing position, the posterior muscles of the torso utilized the stretch shortening cycle. The process repeated itself until the ball made contact with the ground 10 consecutive times. The test administrator started the stopwatch on the first movement of the subject and stopped the watch as soon as the 10th slam of the ball hit the turf. SST repetitions did not count unless the body was straight during completion of the upward phase of the slam and medicine ball broke the plane of the head. Verbal instructions and rules of the SST can be found in Appendix H.

The rationale for the SST being more football-specific than existing tests of the core can be built using a number of arguments. The first segment of movement in the SST is similar to the deadlift, which highly activates the core musculature (Hamlyn et al., 2005). When slamming the ball down to the ground the movement utilizes the stretch shortening cycle on the anterior muscles of the torso. When the ball is being picked up, the muscles of the posterior (the gluteus muscles, hamstrings and back extensors muscles) are utilizing the stretch shortening cycle to lift the body back up. The average football play lasts approximately 5.5 seconds long (Defranco, 2011), but time of plays constantly change based on different variables. An athlete may play 15 or more plays in a row with very little or moderate rest periods between them. The demands placed on the average football athlete changes from situation to situation. A football athlete relies extensively on the phosphagen and fast glycolysis energy pathways in order to continue performance (Powers and Howley, 2009). The duration of the SST, based on preliminary
testing, was expected to be in the range of 10 to 15 seconds, which utilizes the phosphagen and fast glycolysis energy pathways (Powers & Howley, 2009).

**Sit-up test.** The sit-up test was also used as a test of core power. The methods for the sit-up and verbal instructions to the athlete can be found in Appendix I. These identical methods were used in previous research (Dendas, 2010) and copyright permission to use the description of those methods was obtained.

**McGill protocol.** The McGill protocol was used as a test of core endurance (2008). A detailed version of the methodology can be found in Appendix J. These identical methods were used in previous research (Dendas, 2010) and copyright permission to use the description of those methods was obtained.

**Football Performance Measures**

Performance in football is measured in a variety of ways. One of the more established and recognized measures is the NFL combine, which consists of collecting data on maximal back squats, cleans, bench press repetitions, and vertical jump, among many other tests of speed and mental capabilities. The PI does want to stress however, that the best predictor of future performance in football is the athlete’s past performance in football. Maximal lifting ability and speed measures are only a portion of what is assessed in the recruiting process. In the current research, data was collected on each athlete for maximum back squats, bench press, cleans, and vertical jump. For the purpose of this study no 40-yard dash or any other running test was administered, due to a request by the coaching staff to try and minimize the chance of injury to the athletes. The measures used to assess football performance in this research include elements of the
NFL combine and are standard football assessment measures used in Division II strength and conditioning programs around the country.

The National Football League as well as National Collegiate Athletic Association (N.C.A.A.) coaches evaluate potential players with many assessments in order to help guide their recruiting. Among these measures is the ability of the athlete to perform in common performance variables: vertical jump, 40-yard dash, and 10-yard shuttle run, as well as strength/power variables: squat, clean and bench press (Dendas, 2010, Nesser & Lee, 2009, Shinkle et al. 2012). Drafted National Football League (NFL) players have been shown to have significantly better scores in the above-mentioned variables than undrafted lineman (Sierer et al., 2008). Drafted lineman also significantly outperformed their non-drafted counterparts in many performance and strength/power variables (Robbins, 2010; Sierer et al., 2008). Weightlifting measures are one important piece of information, among other things, to help a coach in recruiting a player and estimating playing ability.

Humboldt State University strength and conditioning staff use the vertical jump, 40-yard dash, and strength/power variables (squat, clean and bench press) as standard measures of football performance; these tests are also used to help identify general team strength/power deficits. Football performance measures were used in the current study because they are accepted representations of strength and power. The tests used in this study were: power clean, the back squat, the bench press, and the vertical jump. Protocols for these tests are described in detail in Appendix K along with verbal commands. These identical methods were used in previous research (Dendas, 2010).
**Procedures**

Prior to the beginning of testing, the PI trained coaches on testing protocols so multiple coaches could administer tests. The coaches were given the verbal commands of each core test as well as a demonstration by the principal investigator. This familiarized the strength and conditioning specialists with the tests to be conducted. Coaches were also instructed on how to record scores for the SST, McGill protocol (2008) and sit-ups (see form found in Appendix G).

In order to establish preliminary validation support for the Schultz Slam Test (SST) as a test of core power specific to football, reliability as well as convergent, content, and divergent groups’ validity was determined. Reliability was assessed using the test-retest method. The sequence of testing core measures is detailed in the following sections; a calendar of all the scheduled tests can be found in Appendix L.

To establish convergent validity, tests of the SST, the sit-up and the McGill protocol (2008) were conducted. The testing of the football redshirt athletes took place over a 2-week period (November 28th - December 9th 2011) during regularly scheduled workouts at 2 pm. Upon entry into the facility, the redshirt athletes signed the informed consent (Appendix A) and completed the athletic/injury screening questionnaire, found in Appendix B (Monday, November 28th). The height and weight measures were taken 3-weeks prior to the beginning of the study, so athletes were asked to release this information in the informed consent document.

The Schultz Slam Test (SST) took place over four sessions all on different days, the first two of which were familiarization (or practice) sessions (November 28th, day 1
and December 1st, day 2). The practice sessions to familiarize the athletes with the SST took place towards the end of the scheduled workout session, so athletes were already warm. During the familiarization practice sessions the athletes were instructed on the form and guided with verbal commands (Appendix H); this was followed by a demonstration of the SST. Each athlete did 20 repetitions, two sets of 10 repetitions, during the two separate familiarization sessions. At least one minute recovery was taken in between these two practice trials of 10 repetitions each. All sessions took place under the supervision of Humboldt State strength and conditioning staff members to ensure proper feedback information regarding form. A similar pattern of familiarization was used by (Ikeda et al., 2007).

The sit-up test took place on day two, Tuesday, November 29th at the beginning of the regularly scheduled football workout. As athletes entered the facility they were asked to warm up doing a standard Lumberjack Iron warm up. The warm-up consisted of lifting an Olympic barbell and performing 6 upright rows, 6 muscle snatches, 6 good mornings, 6 squat presses, 6 dead lifts, 6 overhead squats and 6 overhead lunges. Following the warm-up, subjects rested for a period of at least 2-minutes before performing the sit-up test. Methods, along with verbal commands, for the sit-up can be found in Appendix J. Athletes showed up to their regular work out and were tested in the 60-second sit-up test with 30-sec repetitions recorded as well.

The McGill protocol was used to test core endurance of the athletes on day four, Friday, December 2nd. Detailed methods for the McGill protocol, as well as verbal commands, can found in Appendix J. The athletes were tested before they begin their
regularly scheduled workout. As athletes entered the facility they were asked to do the same warm-up as that for the sit ups. Following the warm-up, subjects rested for a period of at least 2 minutes before being assigned to a group. There were four stations, assigned by groups, where coaches gave the athletes verbal commands as well as a demonstration for the particular exercise in the McGill protocol. The athletes rotated among the four stations to complete the front plank, side plank, flexion hold and extension tests.

On day five (December 5\textsuperscript{th}) and six (December 6\textsuperscript{th}) the core was tested using the SST. The data from the two days was used to establish test-retest reliability in the SST. Athletes were instructed on the form through verbal commands (Appendix H) of the SST followed by a demonstration. Each athlete was timed on the SST and their times were recorded as per the methods.

The following 3 days (December 7\textsuperscript{th}-9\textsuperscript{th}) were designated as make-up days so athletes who missed any sessions had 3 days to make up any missed tests.

On February 1, 2012 e-mails were sent out to coaches to evaluate content validity. The email contained a link to videos of the PI performing the SST, sit-up test, and McGill protocol (2007). The order of the videos was counterbalanced. The email contained an informed consent (Appendix C), the directions, and questions used to establish content validity (Appendix D). The PI sent out a reminder e-mail on February 8, 2012 if no response to the initial e-mail was received before this date. The data from the questionnaire was recorded as the emails were received in order to establish content validity. Additionally, descriptive comments from the coaches were recorded.
To establish divergent groups’ validity the principal investigator conducted the SST on McKinleyville high school football players starting Monday, March 19th. The same procedures for the familiarization and testing periods were used in the high school athletes as was used in the collegiate players. The PI introduced himself at a team meeting and gave perspective student athlete subjects a parent cover letter (Appendix E) and an informed consent document (Appendix F). After handing out documents, the PI gave a brief schedule of the testing periods. The perspective student athletes were then instructed to return the completed informed consent to the PI the following day, before being included in the testing protocol. Again, there was a total of four sessions of SST testing: two familiarization and two actual testing days of the SST. Testing did not start until informed consent documents were collected.

**Statistical Analyses**

To determine test-retest reliability of the SST, Pearson Product Moment Correlation Coefficients were computed (i.e., relating scores on the two trials for each group of athletes tested). In addition, dependent t-tests were used to determine if there were differences in the mean SST scores between trials. Pearson Product Moment Correlation Coefficients were used to determine the relationship between performance on each of the three core test measures and the four football performance measures in order to assess convergent validity. Magnitudes of the effect of the correlations were determined as follows: trivial < 0.10; small ≤ 0.10-0.29; moderate 0.30-0.49; large 0.50-0.69; very large 0.70-0.89; and nearly perfect 0.90-0.99. Single-sample Fisher’s Z tests were used to test whether the zero-order correlations between SST and the football
performance measures were significantly different than the correlations of the other core
tests to football measures. Lastly, mean differences in SST scores between high school
football players and HSU redshirt athletes were analyzed using an independent groups t-
test. The data was analyzed using the Statistical Package for the Social Sciences (SPSS;
IBM corporation, Chicago, IL, version 19.0). The criterion for statistical significance was
set at an alpha level of \( p \leq .05 \).

**Operational Definitions.**

1. **Core Stability-** The ability of the vertebral columns to stay neutral and encompasses
   power, strength, and endurance.

2. **Core Power-** The SST as well as the 60 and 30-sec sit-up test was used to assess core
   power. The best time out of two properly executed tests of 10 repetitions of ball slams
   (recorded to the nearest .01 sec) was used as the final score for SST. Raw SST scores
   were used. Secondary, SST scores relative to bodyweight were used so that the results
could be related to Dendas (2010) and Nesser et al. (2008). The number of complete
   sit-ups that the athlete is able to do in 30 and 60 seconds was used as measures of core
   power.

3. **Power Clean 3-Repetition Maximum (3-RM) -** The completion of three consecutive
   repetitions of the power clean (i.e., starting with hips lower than the shoulders and a
   straight back, pulling loaded bar from platform, extending the hips and knees. Then
   catching the loaded bar on the shoulders in a semi-squat position and successfully
   ending a fully standing position) (load measured in pounds then converted to
   kilograms). Absolute as well as relative measures were used.
4. Back Squat 3-RM - The completion of three repetitions of the back squat under the squatters own power (i.e., starting with a loaded bar across posterior deltoids and slowly lowering the hips by flexing at the hips and knees until the top of the thigh is parallel to the ground, and then returning to a standing position) (load measured in pounds and converted to kilograms). Absolute as well as relative measures were used.

5. Bench Press 3-RM - The completion of three repetitions of the bench press under the bench pressers own power (i.e., starting with a pronated grip on a loaded bar at over the upper chest/neck area with the elbows fully extended and slowly lowering the bar to the chest, touching the chest and returning to staring position) (load measured in pounds then converted to kilograms). Absolute as well as relative measures were used.

6. Vertical Jump Height - Vertical height jumped by the participant measured in inches (rounded to the nearest .5 inch).

Limitations

The following limitations are noted, as they may have affected the outcomes of this study:

1. Redshirt athletes were tested the week after Thanksgiving break. A carry over from lack of exercise over the break time may have affected times on all of the core measurement protocols.

2. Attempts to standardize recovery periods between testing measures and training were made, but it was impossible to fully control rest periods for all athletes.
3. Different athletes had different experience levels with regards to the core measurement tools.

4. Some athletes may not have performed to the best of their abilities due to lack of effort.

**Delimitations**

1. Only football athletes were assessed in this particular study.

2. Athletic performance was not assessed for all standardized measurements for football (e.g., 40-yard dash, 10-yard shuttle run and broad jump).

3. Athletic performance was only assessed with selective standardized measurements for football (e.g., maximum power clean, maximum squat, maximum bench)

4. Only content, convergent and divergent groups’ validity were examined.
CHAPTER 3

Results

This study was designed to determine the validity of established core tests (sit-ups and McGill protocol) as well as a newly designed core test (SST) as measures of performance in Division II American Football players. Specifically, to establish preliminary validation support for the SST as a test of core power specific to football, reliability as well as convergent, content and divergent groups’ validity was determined. Reliability was assessed using test-retest methods. Statistics were analyzed using SPSS (IBM Corp., Chicago, IL, USA) version 19.0, with the criterion for significance set at an alpha level of \( p < .05 \). Results are presented for each type of validity in order: convergent, content and divergent groups.

Subject Descriptive Characteristics of HSU Football Redshirts

The descriptive characteristics of the 22 redshirt football players who successfully completed the convergent validity portion of the study can be found in Table 1. Offensive and defensive players were studied, including: line backers (\( n = 4 \)), defensive line (\( n = 5 \)), defensive backs (\( n = 2 \)), offensive line (\( n = 7 \)), a wide receiver (\( n = 1 \)), kickers (\( n = 2 \)), and a quarterback (\( n = 1 \)).

Table 1

<table>
<thead>
<tr>
<th>Subject Characteristics for HSU Redshirt Football Players (( N = 22 ))</th>
<th>( M )</th>
<th>( SD )</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>18.23</td>
<td>.43</td>
<td>18-19</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>185.99</td>
<td>7.18</td>
<td>170.18-195.58</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>102.62</td>
<td>19.13</td>
<td>72.57-136.08</td>
</tr>
<tr>
<td>Med-Ball experience (months)</td>
<td>14.86</td>
<td>15.23</td>
<td>3-48</td>
</tr>
<tr>
<td>Sit-up experience (months)</td>
<td>91.09</td>
<td>11.51</td>
<td>72-108</td>
</tr>
<tr>
<td>Olympic-lifting experience (months)</td>
<td>7.77</td>
<td>5.42</td>
<td>3-24</td>
</tr>
</tbody>
</table>
Reliability of SST in HSU Redshirt Football Players

The reliability of the SST was calculated using the test-retest method. The two trials of SST were administered on two consecutive days. The correlation between SST 10 repetition times on trial 1 and 2 was $r = .852$ with $p < .0001$. The correlation between SST 20 repetition times on trial 1 and 2 was $r = .929$ with $p < .0001$. No mean differences were found between time of trial 1 of SST 10 repetition ($M = 12.58, SD = .98$ sec) and time of trial 2 of SST 10 repetition ($M = 12.41, SD = .94$ sec), $t(21) = 1.471, p = .156$. No mean differences were found between time of trial 1 of SST 20 repetition ($M = 24.75, SD = 1.78$ sec) and time of trial 2 of SST 20 repetition ($M = 24.63, SD = 1.72$ sec), $t(21) = .882, p = .388$.

Relationships between Core Stability and Athletic Performance

The descriptive statistics for all the core measures and athletic performance measures are found in Table 2. The hypothesis for the current study was that the SST was expected to relate better to the football performance measures than either the sit-up or McGill protocol measures (2007) (i.e., convergent validity). Pearson Product-Moment Correlations were used to examine the relationships between the core measures and measures of athletic performance. The intercorrelations between measures of the core and measures of athletic performance can be found in Table 3.

With regard to the SST and its relation to performance variables, no statistically significant correlation was shown, with exception of that between best SST 20 and squat relative to body weight ($r = -.505, p = .017$), but the relationship was in the expected direction (i.e. faster SST times related to better performance variables). The sit-up test
and McGill flexion did not relate to the performance variables. The McGill extension related to absolute bench press \((r = -0.468, p = 0.028)\). Clean relative to bodyweight related to right lateral hold \((r = 0.680, p = 0.001)\), to left lateral hold \((r = 0.773, p = 0.000)\) and total McGill \((r = 0.518, p = 0.013)\). Squat relative to body weight related to right lateral hold \((r = 0.708, p = 0.000)\), left lateral hold \((r = 0.801, p = 0.000)\), and total McGill \((r = 0.477, p = 0.025)\). Vertical jump was related to right lateral hold \((r = 0.515, p = 0.014)\) and left lateral hold \((r = 0.520, p = 0.013)\).

Table 2
Core Measures and Athletic Performance Measures for HSU Redshirt Football Players \((N = 22)\)

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean (M)</th>
<th>SD (SD)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best SST 10 rep (sec)</td>
<td>12.29</td>
<td>.88</td>
<td>11.04-14.10</td>
</tr>
<tr>
<td>Best SST 20 rep (sec)</td>
<td>24.44</td>
<td>1.68</td>
<td>21.52-27.31</td>
</tr>
<tr>
<td>30-sec Sit-up *</td>
<td>22.71</td>
<td>3.58</td>
<td>14.00-27.00</td>
</tr>
<tr>
<td>60-sec Sit-up *</td>
<td>41.10</td>
<td>8.97</td>
<td>17.00-54.00</td>
</tr>
<tr>
<td>Flexion (sec)</td>
<td>155.03</td>
<td>58.56</td>
<td>30.00-238.00</td>
</tr>
<tr>
<td>Extension (sec)</td>
<td>105.80</td>
<td>32.04</td>
<td>51.20-175.00</td>
</tr>
<tr>
<td>Right Lateral Hold (sec)</td>
<td>85.80</td>
<td>31.18</td>
<td>32.20-44.20</td>
</tr>
<tr>
<td>Left Lateral Hold (sec)</td>
<td>87.49</td>
<td>29.56</td>
<td>32.10-144.00</td>
</tr>
<tr>
<td>McGill Total Score (sec)</td>
<td>434.11</td>
<td>98.41</td>
<td>215.5-604.6</td>
</tr>
<tr>
<td>Vertical Jump (in)</td>
<td>27.61</td>
<td>2.92</td>
<td>22.50-34.00</td>
</tr>
<tr>
<td>Clean/BW</td>
<td>1.20</td>
<td>.18</td>
<td>.87-1.51</td>
</tr>
<tr>
<td>Clean (kg)</td>
<td>120.30</td>
<td>15.66</td>
<td>92.99-151.96</td>
</tr>
<tr>
<td>Squat/BW</td>
<td>1.63</td>
<td>.26</td>
<td>1.12-2.00</td>
</tr>
<tr>
<td>Squat (kg)</td>
<td>164.22</td>
<td>26.72</td>
<td>111.13-201.85</td>
</tr>
<tr>
<td>Bench Press/BW</td>
<td>1.31</td>
<td>.19</td>
<td>.95-1.68</td>
</tr>
<tr>
<td>Bench Press (kg)</td>
<td>133.71</td>
<td>27.91</td>
<td>90.72-190.51</td>
</tr>
</tbody>
</table>

Note: 3-RM values for the power clean, squat, and bench press are presented as absolute scores and relative to body weight (BW). *The data for the sit-up test for one subject was removed prior to analysis, due to a lack of subject effort perceived by the tester.
Table 3

<table>
<thead>
<tr>
<th></th>
<th>Best SST 10</th>
<th>Best SST 20</th>
<th>30-sec Sit-up</th>
<th>60-sec Sit-up</th>
<th>Flexion (sec)</th>
<th>Extension (sec)</th>
<th>Right Lateral Hold (sec)</th>
<th>Left Lateral Hold (sec)</th>
<th>McGill Total Score (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean/BW</td>
<td>-.252</td>
<td>-.354</td>
<td>.374</td>
<td>.377</td>
<td>-.060</td>
<td>.327</td>
<td>.680**</td>
<td>.773**</td>
<td>.518*</td>
</tr>
<tr>
<td>Clean (kg)</td>
<td>-.344</td>
<td>-.319</td>
<td>-.223</td>
<td>-.253</td>
<td>-.270</td>
<td>-.265</td>
<td>.185</td>
<td>.232</td>
<td>-.118</td>
</tr>
<tr>
<td>Squat/BW</td>
<td>-.335</td>
<td>.505*</td>
<td>.458</td>
<td>.414</td>
<td>-.028</td>
<td>.091</td>
<td>.708**</td>
<td>.801**</td>
<td>.477*</td>
</tr>
<tr>
<td>Squat (kg)</td>
<td>-.344</td>
<td>-.405</td>
<td>-.051</td>
<td>-.115</td>
<td>-.186</td>
<td>-.417</td>
<td>.208</td>
<td>.254</td>
<td>-.104</td>
</tr>
<tr>
<td>Bench /BW</td>
<td>-.166</td>
<td>-.308</td>
<td>.307</td>
<td>.313</td>
<td>-.063</td>
<td>-.079</td>
<td>.374</td>
<td>.462</td>
<td>.194</td>
</tr>
<tr>
<td>Bench (kg)</td>
<td>-.155</td>
<td>-.179</td>
<td>-.157</td>
<td>-.173</td>
<td>-.166</td>
<td>-.468*</td>
<td>-.115</td>
<td>-.104</td>
<td>-.139</td>
</tr>
<tr>
<td>Vertical (in)</td>
<td>-.067</td>
<td>-.334</td>
<td>.064</td>
<td>.093</td>
<td>-.267</td>
<td>.204</td>
<td>.515*</td>
<td>.520*</td>
<td>.227</td>
</tr>
</tbody>
</table>

Note: 3-RM values for the power clean, squat, and bench press are presented as absolute scores and relative to body weight (BW). *p ≤ .05. **p ≤ .01

Content Validity

Seven strength and conditioning coaches, who were considered experts in their field, were queried to establish content validity (see Appendix D). The strength and conditioning coaches had an average of 159 months professional experience, an average of 131.43 months of experience in training football, and have spent an average of 77.57 months in their current position. All the strength and conditioning coaches met the inclusion criteria of at least 5 years of experience with training football teams. The strength and conditioning coaches worked at Division II (n = 2) and Division I (n = 5) schools. All seven coaches were male.

The strength and conditioning coaches responses to questions regarding specificity and practicality of the three core tests (SST, Sit-up, McGill) are presented in...
Table 4. The number 1 was given to the test ranked most specific/practical to football performance. The number 3 was given to the test that was ranked the least specific/practical to football performance.

With regard to specificity of the core tests for football, the SST was the most specific ($M = 1.14$, $SD = .38$), the McGill protocol ranked second ($M = 2.00$, $SD = .58$ sec) and the sit-up ranked third ($M = 2.86$, $SD = .38$) according to coaches data. All of the coaches except one thought that the SST best represented movements that take place in football (i.e., specificity); one coach believed that the McGill protocol best represented movements in football.

With regard to practicality of the tests of football, the McGill protocol was deemed the most practical ($M = 1.43$, $SD = .79$). The SST and sit-up were tied for second most practical ($M = 2.29$, $SD = .76$) according to the seven strength and conditioning coaches. All of the coaches believed that the core was very important in various functions in the sport of football.
Table 4

<table>
<thead>
<tr>
<th></th>
<th>Sit-up Specificity</th>
<th>Sit-up Practicality</th>
<th>McGill Specificity</th>
<th>McGill Practicality</th>
<th>SST Specificity</th>
<th>SST Practicality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coach A</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Coach B</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Coach C</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Coach D</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Coach E</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Coach F</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Coach G</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

1 = most specific/practical to football performance  
3 = least specific/practical to football performance

The strength and conditioning coaches were also asked which test best represents movements that take place during a football game. The coaches responded that the SST \((n = 6)\) and the McGill protocol \((n = 1)\) best represented the movements in football. The six strength and conditioning coaches who thought that the SST best represented movements in football believed that it activated the muscles of the core, where as the strength and conditioning coach who thought that the McGill protocol best represented movements in football believed that it activated the muscles of the core. Yet, the coach that chose the McGill protocol did not believe the time duration of that test used similar
energy systems to those used in football. Five out of the six coaches that chose the SST as
the test that best represented movements in football, believed that it used a similar energy
system as used in football. Finally, all of the coaches “strongly agreed” that core
strength/stability/power influence performance in football.

All of the responses to the open-ended questions having to do with listing
strengths and limitations to each of the three tests as a measure of football performance
are shown in Appendix M. In general, regarding the McGill protocol, coaches believed
that it was practical but was not dynamic in nature. The coaches thought the sit-up test
was reliable, basic and easily tested. The down side to the sit-up was that it was not
performed on the feet or in an athletic position. The SST was considered to be dynamic
and explosive, as in the sport of football, although hard to measure according to coaches.

**Subject Descriptive Characteristics of High School Football Players**

The descriptive characteristics of the 20 McKinleyville high school football
players who successfully completed the divergent groups’ portion of the study can be
found in Table 5. There were players of different positions studied, including: line
backers ($n = 3$), offensive/defensive line ($n = 9$), wide receiver/defensive backs ($n = 2$),
running backs ($n = 3$), and quarterbacks ($n = 3$).
Table 5

<table>
<thead>
<tr>
<th>Subject Characteristics for High School Football Players ($N = 22$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>$M$</strong></td>
</tr>
<tr>
<td>Age (years)</td>
</tr>
<tr>
<td>Height (cm)</td>
</tr>
<tr>
<td>Mass (kg)</td>
</tr>
<tr>
<td>Med-Ball experience (months)</td>
</tr>
<tr>
<td>Sit-up experience (months)</td>
</tr>
<tr>
<td>Olympic-lifting experience (months)</td>
</tr>
</tbody>
</table>

**Reliability of the SST in High School Football Players**

Reliability of the SST was calculated using the test-retest method. The two trials of SST were administered on two separate consecutive days. The correlation between SST 10 repetition times on trial 1 and 2 was $r = .941$ with $p < .0001$. The correlation between SST 20 repetition times on trial 1 and 2 was $r = .982$ with $p < .0001$. No mean differences were found between time for trail 1 of SST 10 repetition ($M = 15.27, SD = 1.47$ sec) and time for trail 2 of SST 10 repetition ($M = 15.15, SD = 1.62$ sec), $t(40) = 7.242, p = .000$. No mean differences were found between time for trail 1 of SST 20 repetition ($M = 31.1, SD = 4.05$ sec) and time for trail 2 of SST 20 repetition ($M = 30.67, SD = 3.81$ sec), $t(40) = 6.703, p = .000$.

**Best SST Times in High School vs HSU Redshirt Football Players**

To establish divergent groups’ validity the best SST 10 repetition times and the best SST 20 repetition times were recorded in both HSU football players and McKinleyville high school football players. The high school SST 10 repetition time averaged 15.06 sec ($SD = 1.54$ sec). The high school SST 20 repetition time averaged
30.56 sec ($SD = 3.9$ sec). The HSU redshirt football player SST 10 time averaged 12.29 sec ($SD = .88$ sec). The redshirt football player SST 20 time averaged 24.44 sec ($SD = 1.68$ sec). Independent samples $t$-tests revealed significantly faster SST 10, $t(40) = 7.24$, $p = .000$ and SST 20 times, $t(40) = 6.70$, $p = .000$ in HSU redshirt football players compared to the McKinleyville high school football players times. A graphic representation of SST scores in HSU redshirt football players and McKinleyville high school football players is found in Figure 1.

![SST Times in College and High School Football Players](image)

Figure 1. Comparison of SST times in college and high school football players. **$p \leq .01$**
CHAPTER 4

Discussion

The core can be considered to be the link between the upper and lower body. During sporting events force is transferred through the core enabling the body to move (Willardson, 2007). Although it is accepted that athletes should train their core musculature, the relationship between core stability/strength/power and athletic performance has not been firmly established (Dendas, 2010; Nesser et al., 2008; Nesser & Lee, 2009; Tse, et al., 2005). In some instances core strength and stability have, dependent on the measure used, been found to relate to sport performance (Behm et al., 2009; Dendas, 2010; McGill et al., 2009), yet often the relationship is moderate at best (Dendas, 2010; Nesser et al., 2008; Sato & Mokha, 2009). There have been very few studies on the core and its relationship to football, although a lot of emphasis in training is directed at this area (Dendas, 2010; Nesser et al., 2008). Therefore, the purpose of this study was to evaluate the validity of a newly designed core test, the Schultz Slam Test (SST), as a measure of performance in American football players. Reliability as well as convergent, content and divergent groups’ validity were assessed.

Reliability of the SST was measured in both the college and high school football players. The two trials of SST were administered on two separate consecutive days, with time for 10 rep and 20 rep times recorded each day the test was administered. The SST was found to have “acceptable” or “above-average acceptable” reliability (Baumgartner et al., 2007) in both the college redshirts and high school football players. Furthermore, no mean differences were found between time of trial 1 of SST 10 and trial 2 of SST in
both groups of athletes. In order for a test to be valid it has to be reliable, and the SST is considered a statistically acceptable reliable test.

Convergent validity was tested by correlating the SST and other core test measures with football performance variables in the college-aged athletes. The scores for the maximum lifts (clean, squat, bench) and vertical jump of the athletes were correlated with the SST, sit-up, and McGill scores and can be found in Table 3. Contrary to expectation, the SST did not relate to football performance measures any better than other core tests that have been previously investigated. All SST correlations were in the expected direction (i.e., a faster SST time related to a greater weight lifted [expressed in absolute and relative terms] and a higher vertical jump), but they were generally “weak” (trivial, small, or moderate, effect; Hopkins, 2009) and were not statistically significant. There was only one statistically significant relationship between the SST and football performance and that was a “moderately strong” (large effect; Hopkins, 2009) inverse relationship between SST 20 time and amount of weight lifted in the squat expressed relative to body weight. No significant relationships were found between sit-up scores and any of the football performance measures. The McGill protocol, specifically the right/left holds and total score, showed “moderate” to “strong” (moderate, large, and very large effect; Hopkins, 2009) relationships to weight lifted in clean and squat when expressed relative to body weight. The right and left holds were also “moderately” to “strongly” (large effect: Hopkins, 2009) related to vertical jump scores.

Content validity was tested by sending a survey to seven strength and conditioning coaches who asked about the three core tests (SST, sit-up, and McGill). The
strength and conditioning coaches’ rank ordered the tests on specificity and practicality, answered some open-ended questions, and made comments on exercises (Appendix M). The SST was deemed the most specific test for assessment of the core in football players, followed by McGill protocol, then the sit-up. The McGill protocol was ranked as being the most practical according to coaches. Both the sit-up and SST were equally ranked in practicality by the coaches behind the McGill protocol.

Divergent groups’ validity of the SST was tested by comparing the mean scores of the HSU football redshirts and their high school counterparts in the repetition times. It was hypothesized that the college-aged football players would have a faster time than high school players. The mean SST scores for the college football players were significantly faster in both the SST 10 and SST 20 than their high school counterparts.

With regard to convergent validity the SST was expected to relate most strongly to football performance variables due to the standing position, the dynamic nature of the test, and the plane of motion. Interestingly, coaches (who received a questionnaire) believed that the SST was the most specific core test with regard to the sport of football. A specific core test should mimic the actions of the sport, to some degree, and relate to performance variables. The SST in the current study was not related to performance in the college redshirt players, although coaches deemed it the most specific core test. There are a number of possible reasons why the SST failed to relate to performance measures, such as the nature of medicine ball used and/or the population tested.

The nature of the medicine ball used may have affected the SST times, due to the fact that high force used on the slam did not necessarily mean a faster time. The increased
force applied to the ball was dissipated when the med-ball hit the ground, because it was filled with sand and did not bounce back up. This may be a factor as to why the SST did not relate to maximal lifting protocols. Also, slamming the ball down as forcefully as possible did not result in the fastest times. Maximum power output occurs at approximately 30% of maximum force (Baechle & Earle, 2002).

The med-ball was malleable, so when picked up it would change its shape, making players lose grip, making times slower (observed by the PI). The players grip on the ball factored in to the SST times because of the constant changing shape of the ball when slammed. It is hard to have a standardized test if the grip constantly changes on the implement being used. An athlete’s grip should not be a limitation on a test assessing the core.

The subject population tested may have factored in to the reason why the SST failed to correlate with the performance variables. It is also important to note that the redshirt athletes are not as refined in Olympic lifting technique and medicine ball experience as the active players. Weight lifting experience ($M = 49.95, SD = 2.52$ months) among football players from the same University as those in the current study who were studied by Dendas (2010), was significantly higher than in the current study ($M = 7.77, SD = 5.42$ months). There was large variability in experience of redshirts tested in this study. Athletes who are redshirt seniors (5 years on the roster) may have 5 more years of Olympic lifting experience under a certified strength and conditioning coach than the incoming redshirt football players. Weight lifting experience is important because inexperienced players may not have been able to accurately portray their true hip
power, which in turn affected maximal lifting ability. Medicine ball experience may factor into the lack of correlation of SST scores to football performance variables.

Dendas (2010) tested a population whose medicine ball exercise experience in the college aged football players was over two times higher ($M = 33.76$, $SD = 20.61$ months) then the redshirt football players ($M = 14.86$, $SD = 15.23$ months). Coaches who answered the questionnaire believed that the SST related to movements that take place in football more than the other core tests. The SST is more “dynamic” in nature, more “explosive”, and is done in a standing position. According to the coaches, the SST movement is similar to movements that take place in football. The drawbacks of the SST were that it is “not rotational”, and there is not a lot of “overload on the core musculature” according to coaches.

While sit-ups failed to relate to performance in the current study, Dendas (2010) found that there were significant correlations between 60-sec sit-up test and many of the football performance measures (clean/BW, squat/BW, bench press/BW, vertical jump height, 40-meter, and 20-meter sprint times). This does not match what happened in the current study where there were no relationships between either the 30-sec or the 60-sec sit-up and the clean, squat, bench press and vertical jump. This may be due to the different subject populations of the two studies. Another reason that sit-ups did not relate to performance variables may have been the lack of experience in weightlifting of the redshirt football players. A lack of technique in weightlifting tests results in a lighter load lifted (Everett, 2008).
Again, Dendas (2010) studied a more experienced group and the athletes in her group were generally much stronger and powerful (squat, bench press and vertical jump) than subjects in the current study based on a comparison of lifting scores. Dendas (2010) tested older athletes ($M = 20.05$, $SD = 1.43$ years) than the redshirt football players ($M = 18.23$, $SD = .43$ years). In the current study only redshirt athletes were used, which on average have a lower performance capability, with regard to football. The younger male football players may not have developed as much physically (i.e. have as much testosterone) as their counterparts on the active roster (Baechle & Earle, 2002). On average the redshirt football player had a lighter body mass ($M = 102.62$, $SD = 19.13$kg) than the players Dendas (2010) tested ($M = 114.31$, $SD = 18.30$kg). The experience and lifting data presented in the prior paragraphs and data in this paragraph may present a reason why a population inexperienced in weight lifting would not show a relationship between SST scores and performance variables.

To the author’s knowledge, the only other study that used sit-ups as a core power/endurance measure in relating to football performance was in Dendas (2010). Sit-ups were related “moderately” to “strongly” related to football performance measures in that study (large and very large effect; Hopkins, 2009). In the current study there was no relationship between sit-ups and any of the football performance variables. If the weightlifting data is not totally accurate this can affect the correlation data between sit-ups and football performance. More data is needed in this area in order to come to a solid conclusion.
Sit-ups are also performed in a supine position and all the performance variables are done in a standing position. The difference in body position may be why there are inconsistencies in the relationships of sit-ups to football performance. Coaches believed that the sit-up was the least specific of the three core tests, so it is not surprising that the sit-up did not relate to performance variables. More research is needed in this area in order to see how sit-ups correlate to performance variables in football players in order to come to a conclusion.

Including the current study, two studies have been done in which scores on the McGill protocol have been related to football performance (Dendas 2010, Nesser et al., 2008). The McGill protocol was found to have a “moderately strong” correlations with maximal lift scores (i.e., large and very large effect; Hopkins, 2009) (Dendas 2010, Nesser et al., 2008) in football players and in soccer players as well (Nesser & Lee 2009). The McGill protocol is more endurance based and isometric, so the muscles of the core are not moving though the range of motion. When performing the maximal lifts and performance variables there is one maximum burst or a short series of maximal bursts calling on a different energy system than that of the McGill protocol. These movements often require the joints to go through a vast range of motion. For the reasons listed, it is a surprise that the McGill protocol has “moderately strong” correlations (large and very large effect; Hopkins, 2009) to performance across multiple published studies (Dendas 2010, Nesser et al., 2008, Nesser & Lee 2009) and in this current study.

Relationships between McGill and football performance may be due to the similar neutral position of the torso when performing the exercises in the McGill protocol and
Olympic lifts and squats (McGill, 2009). With proper form the spine is in a protected neutral position in Olympic lifting and while performing the McGill protocol. While relationships are not present across all the McGill protocol holds and performance variables, different aspects (flexion, extension, R/L, and total McGill) were related across the three studies (Dendas 2010, Nesser et al., 2008 and the current study) of football performance. In the current study, it is noted that the right/left flexion and total McGill scores “moderately related” (large and very large effect; Hopkins, 2009) to clean relative to body weight and squat relative to body weight. These findings are interesting because these exercises take place in different planes of motion than football performance variables. Lateral torso muscles may contract during a lift if the moment arm in either lateral direction increases in order to maintain stability of the barbell. If the weight shifts laterally during the squat or clean, and the moment arm of the weight gets longer, the weight increases on the side with the longer moment arm. Coaches also, surprisingly, listed the McGill protocol as the most practical test to administer to large groups of people. Coaches believed that the McGill protocol was “measurable, practical, reliable and a multi plane test” as well as being “easy to administer”.

Divergent validity for the SST as a core test for football was supported in the current study. The SST times were collected in the high school football players SST using the same methodology as with the college football players. The high school football players performed more poorly (slower times) on the SST. The high school football players were much younger and had less experience with the medicine ball and weightlifting.
Recently there has been a lot of research in the area of the torso or core musculature. There has been an attempt to explain the role of the core in many different populations of people. There have been a few studies in which scores on core measures have been related to performance in college-aged healthy adults (Nikolenko et al., 2011, Okada, T. et al., 2011). Wagner (2011) also conducted a study involving female soccer players, core tests and soccer performance variables. The most relevant and recent study to emerge is a study conducted by Shinkle et al. (2012) involving medicine ball core tests and football performance measures.

Nikolenko et al. (2011) investigated whether the FAPT and SAPT related to performance variables (40 yard sprint, 5-10-5 shuttle and vertical jump) and max back squat in healthy college-aged individuals. Results revealed one significant relationship between FAPT, SAPT and max back squat. The authors concluded that there was a weak correlation and that more specific tests needed to be developed in order to yield better correlations. Okada et al. (2011) reported on core stability, functional movement screening and performance. They tested a healthy college-aged population that was free of injury. The authors concluded that there was no strong correlation between the measures of the core and performance measures on the functional movement screening, Okada et al. (2011).

Wagner (2011) tested college-aged female soccer players using isometric exercises as well as dynamic medicine ball throws (FAPT, SAPT). The dynamic tests have been used in the past and were shown to be reliable (Cowley & Swenson, 2008). The dynamic and static core variables were correlated to soccer performance variables.
Interestingly, static core tests correlated better with performance measures than did the dynamic tests (FAPT, SAPT). These results are consistent with the literature and the current study in that the static McGill test related to dynamic performance variables.

Shinkle et al. (2012) conducted the most relevant study involving the core and its role in football performance measures. The researcher investigated the relationship between different types of medicine ball throws and football performance measures (push press, vertical jump, 5-10-5 shuttle run, 40 yard sprint, max bench and max squat). The medicine ball throws were done with the core static and dynamically contracted and took place in different planes of motion. There were significant correlations between different medicine ball throws and the performance variables, although the medicine ball tosses did not relate to the sprinting measures as strongly. This seems to be the first study to show a “moderate” (moderate to large effect; Hopkins, 2009) relationship between a series of medicine ball throws and performance variables. As in the current study, medicine ball tosses were used to replicate the dynamic nature of football and sports for that matter. In Shinkle et al. (2012) there is no one medicine ball-toss that relates to all the performance variables. Interestingly, static medicine balls and dynamic medicine ball throws both related “moderately” (moderate to large effect; Hopkins, 2009) to at least one performance variable. This study indicates that the core is important in “creating” force and “transferring” ground reaction forces through it and to the hands/feet/sports implement. Shinkle et al. (2012) used medicine balls in conjunction with full body movements, as in the current study by the PI, in an attempt to relate these tests to performance variables.
Future research is needed in order to establish a link between the core and football performance. With regard to football “performance”, the best predictor of future performance in football is the athlete’s past performance in football. Performance measures that are accepted in the strength and conditioning field for the sport of football (used in the current study) do not always relate to actual football performance on the field. A field test, or series of field tests, needs to be developed in order to assess an athlete’s potential football ability. If a testing protocol is found to relate to football performance measures (clean, squat, bench, vertical jump, and speed measures) it can be incorporated in order to enhance the training for an athlete as well. In order to improve what is known from the current study, the testing population needs to be more experienced than the population used with regard to weight lifting and medicine ball experience. Also the medicine ball used in this study may have skewed results. If a bouncing medicine ball was used the results may differ. With a bouncing medicine ball the force applied on the downward phase of the slam will affect how fast the ball bounces back up. The time frame or repetition range of the test can be altered to see if the results change. If another 10 repetitions were added, the football players may have reached their lactic acid thresholds and the results would differ. Another recommendation would be to design a device to control for the range of motion of each repetition of the slam. At the top of the range of motion there could be a device that the tester hits, set according to the height of the tester, to better control for range of motion. This device would help standardize the way that the test is conducted. Medicine ball tests in different planes of movement may be good tests as well.
There is no field test of the core currently available in which there is a strong relationship to football performance variables, leaving the research open to how much the core influences athletic ability. A new-sport specific test needs to be developed in order to accurately portray the movements that take place during football. The McGill protocol is the only test that has been shown to have some consistent relationships to football performance variables (Dendas 2010, Nesser et al., 2008) as in this study. The McGill protocol is not considered a sport specific test to football (Dendas 2010, Nesser et al., 2008, Shinkle et al., 2012).

Practical applications of this data are that there is not one field test able to capture the core and its relationship to performance. The human torso is related to performance but the manner in which it relates is unclear. It is clear that both the local and global muscle groups are both important in training for many sports (Bergmark, 1989). The SST may be an excellent training modality, but the way that the test is currently conducted will not allow it to be an accurate predictor of football performance variables. While SST was shown to have content and divergent groups’ validity, convergent group validity was not supported in the current study. Convergent validity may be proved for the SST if it is slightly modified or more controlled for repetition range of motion. Sport specific tests for football need to be performed in a standing position and involve athletic movements. A series of medicine ball throws in different planes (similar to the planes of McGill protocol) are very effective training modalities in football.
References


Appendix A: Informed Consent for HSU Football Players
Validity of the Schultz Slam Test as a Core Power Measure in Football

INFORMED CONSENT FOR PARTICIPATION FOR HSU FOOTBALL PLAYERS

Please read the following as it provides information about this research study. Please understand that you are being asked to volunteer in this study and it is your choice to participate. By signing this form you are indicating that you have been informed of the nature of the study including the risks and benefits of its association and want to participate.

Principal Investigator:

Daniel G. Schultz, B.S., CSCS, USAW
Humboldt State University
415-328-4059
dgs15@humboldt.edu

Project Description:

The purpose of this study is to evaluate whether a new test of core muscle power can be used as measure of football performance. This research will test the repeatability of the new test and will help determine if the new test can measure athletic performance in football.

Consent:

1. You must be at least 18 years old to participate in this study.
2. Your participation in the research study is voluntary.
3. You may choose not to participate at all, or you may refuse to participate in certain procedures or answer certain questions or discontinue your participation at any time without penalty or loss of benefits.

Procedures:

If you agree to participate in this study, you will:

1. Be asked to participate in testing that will take place over an 11-day period at the StudentRecreation Center at Humboldt State University (Nov. 28–Dec. 9, 2011). Each of the tests you will do will take place on a different day.
2. Complete a demographic and athletic background questionnaire. The athletic background questionnaire will determine final eligibility for the study.

3. Have your core power measured with a new test that involves slamming a weighted medicine ball to the ground repeatedly. You will do this test four times over four different days, with each testing session taking approximately 10 minutes.

4. Have your core power measure with a 60-second maximal sit-up test. This test will take approximately 10 minutes to complete.

5. Have your core endurance measured with four isometric endurance tests. These tests will approximately take 10 minutes each to complete.

6. Have your athletic performance measured with a standardized vertical jump height protocol. This test will be completed **only once** during the testing period on specified days.

7. Agree to release the data collected during routine testing of football players the weeks of Nov 7th and 14th to the investigator. This data includes: height, weight, vertical jump score, and maximal weight lifting scores for the power clean, back squat, and bench press.

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**Possible Risks:**
This study involves bouts of all-out efforts in the new test of core muscle power, the sit up test, and the four isometric endurance tests.

1. (    ) You may experience discomfort that is associated with this type of strenuous, all-out bouts of exercise.

2. (    ) You may experience muscle soreness that lasts for up to 72 hours from performing any of these activities.

3. (    ) There is a possibility of injuring yourself while performing any of these activities. Proper supervision and instruction will be provided to minimize the chance of injury. Standardized procedures for testing will be followed. Emergency equipment and trained personnel will be available to respond to any unusual situations should they arise.

---

**Benefits:**
You will receive your scores for the new test, the sit up test, as well as for the four isometric endurance tests. Your scores may help you determine any individual strengths or weaknesses.
Confidentiality/Anonymity:

You understand that participation in this study is completely voluntary. The only people who might access your scores are National Strength and Conditioning Association Certified Strength and Conditioning Coaches collecting data, the Head Strength and Conditioning Coach, non-certified strength and conditioning coaches collecting data, and the Principal Investigator. The demographic and athletic background information collected during testing will be treated as privileged and confidential as described in the Health Insurance Portability and Accountability Act of 1996. The Principal Investigator will only have access to your demographic and athletic background information.

Confidentiality will be protected by the following ways: (a) results will be presented as group data in any presentations and publications; and (b) all data will be stored in a password-protected computer that is only accessible by the Principal Investigator. You may discontinue participation at any time without penalty. Your participation in this research project will not involve any additional costs to you. You understand that you will not receive any compensation to participate in this study. Results of testing will be confidential and will not be released unless individual participant consent is given; otherwise your name will be assigned a number to analyze data for anonymity purposes.

Institutional Contacts:

For questions regarding this study, please contact the Principal Investigator using the contact information above. If you have questions regarding your rights as a participant, any concerns regarding this project, or any dissatisfaction with any part of this study, you may report them—confidentially, if you wish—to the Dean for Research & Sponsored Programs, Dr. Rhea Williamson at Rhea.Williamson@humboldt.edu or (707) 826-4189.

I understand that she will answer any questions I may have concerning the investigation or the procedures at any time. I also understand that my participation in any study is entirely voluntary and that I may decline to enter this study or may withdraw from it at any time without jeopardy. I understand that the investigator may terminate my participation in the study at any time.

Signature:
Your signature below indicates your voluntary agreement to participate in this study.

I, __________________________________ have read and agree to participate in this study as described above.

(Please PRINT Your Name Here)

____________________________________  _____/_____/_____

(Please SIGN Your Name Here)  (Date)
Appendix B: Athletic Background/Personal Information Screening Questionnaire
Athletic Background/Personal Information Screening Questionnaire

1. Name: ________________________

2. Date: _________________________

3. Date of birth expressed as Month/Day/Year:____________________

Please circle/mark ONE of the following:

4. ( ) Yes or ( ) No: Are you currently injured?

5. ( ) Yes or ( ) No: Do you have chronic back pain?

6. ( ) Yes or ( ) No: Do you have any medical condition made worse by exercise?

7. ( ) Yes or ( ) No: Do you have any previous musculoskeletal injury or neurological condition that may impair your ability to perform any of the core power and endurance tests and/or athletic performance measures?

8. Position on the Humboldt State University football team:___________________

9. Months of sit-up experience:____________________

10. Months of medicine-ball throw/push experience:__________________

11. Months of Olympic weightlifting experience:___________________
Appendix C: Informed Consent for Strength and Conditioning Coaches
INFORMED CONSENT PARTICIPATION FOR DIVISION II STRENGTH AND CONDITIONING COACHES

Please read the following as it provides information about this research study. Please understand that you are being asked to volunteer in this study and it is your choice to participate. By signing this form you are indicating that you have been informed of the nature of the study including the risks and benefits of its association and want to participate.

Principal Investigator:

Daniel G. Schultz, B.S., CSCS, USAW
Humboldt State University
415-328-4059
dgs15@humboldt.edu

Project Description:

The purpose of this study is to evaluate whether a new test of core muscle power can be used as measure of football performance. The researcher is interested in the opinions of a panel of experts as to how the new test relates to football, compared to previously used core muscle measures.

Consent:

1. You must be at least 18 years old to participate in this study.
2. Your participation in the research study is voluntary.
3. You may choose not to participate at all, or you may refuse to participate in certain procedures or answer certain questions or discontinue your participation at any time without penalty or loss of benefits.

Procedures:

If you agree to participate in this study, you will:

1. Be asked to view a 15-minute video of core tests
2. Be asked to complete a questionnaire relating to what you saw in the video
3. In total, your participation in this research should take no longer than 30 minutes to compete.
Possible Risks:
N/A

Benefits:
You will help to further the research regarding the tests relevant to football performance measures.

Confidentiality/Anonymity:
You understand that participation in this study is completely voluntary. The only people who might access your scores are National Strength and Conditioning Association Certified Strength and Conditioning Coaches collecting data, the Head Strength and Conditioning Coach, non-certified strength and conditioning coaches collecting data, and the Principal Investigator. The demographic and athletic background information collected during testing will be treated as privileged and confidential as described in the Health Insurance Portability and Accountability Act of 1996. The Principal Investigator will only have access to your demographic and athletic background information.

Confidentiality will be protected by the following ways: (a) results will be presented as group data in any presentations and publications; and (b) all data will be stored in a password-protected computer that is only accessible by the Principal Investigator. You may discontinue participation at any time without penalty. Your participation in this research project will not involve any additional costs to you. You understand that you will not receive any compensation to participate in this study. Results of testing will be confidential and will not be released unless individual participant consent is given; otherwise your name will be assigned a number to analyze data for anonymity purposes.

Institutional Contacts:
For questions regarding this study, please contact the Principal Investigator using the contact information above. If you have questions regarding your rights as a participant, any concerns regarding this project, or any dissatisfaction with any part of this study, you may report them—confidentially, if you wish—to the Dean for Research & Sponsored Programs, Dr. Rhea Williamson at Rhea.Williamson@humboldt.edu or (707) 826-4189.

Signature:
Your signature below indicates your voluntary agreement to participate in this study.
I, _______________________________ have read and agree to participate in this study as described above.

(Please PRINT Your Name Here)

____________________________________  ____/____/____

(Please SIGN Your Name Here)  (Date)
Appendix D: Coaches Questionnaire
**Strength and Conditioning Coaches Questionnaire**

1. What Division is the University you currently coach at? ______________

2. How long have you been at that level for? ______________

3. How many years of professional experience do you have in total? ______________

4. How many years of professional experience do you have in football total? ______________

Please view each video of an exercise via the links provided in order below, and then answer the questions that follow.

A, A, A (all three)
B
C

5. Rank the order of the tests on a scale of 1 to 3. The number 1 will be given to the test most specific to football performance. The number 3 will be given to the test that is the least specific to football performance.

   A___
   B___
   C___

6. Rank the order of the tests on a scale of 1 to 3 on practicality with regard to assessment of core in football players. The number 1 will be given to the test most practical. The number 3 will be given to the test least practical.

   A ___
   B ___
   C ___

7. Which test best represents movements that take place during a football game (check one)?
8. Does the test you identified in question #7 activate the muscles of the core?  
   Yes___ No___

9. Does the time duration, of the test you identified in question #7, use similar energy systems to those used in football?  
   Yes___ No___

10. List strengths (+) and limitations (-) of each test as a possible measure of football performance.

   Exercise A:  
       (+'s)    
       (-'s) 

   Exercise B:  
       (+'s)    
       (-'s) 

   Exercise C:  
       (+'s)    
       (-'s) 

11. Core strength/stability/power influence performance in football?  
    
    Strongly agree___ Agree___ Neutral___ Disagree___ Strongly disagree___

12. Please list any comment you have about the three tests you viewed (relevant to football) that has not been addressed in the questions above:
Appendix E: Cover Letter
High School Football Player Cover Letter

Dear Parent/Guardian of a Football Athlete,

My name is Daniel Schultz and I am a graduate student at Humboldt State University working towards completing my Master’s Degree. I am conducting a research project as a requirement towards my degree, and am writing to you to determine whether I will be able to test your son in a new test of core muscle power as part of this research.

The purpose of this study is to evaluate whether this new test of core muscle power can be used as measure of football performance.

In order for your child to be included in the study, could you please review the informed consent document together with your son, and if you have no questions, could you please sign and date the form. If any questions or concerns arise my contact information can be found on the informed consent document attached.

Thank you,

Daniel Schultz
Appendix F: Informed Consent for High School Football Players
The Relationship between Core Power and Athletic Performance in Division II Football Players

INFORMED CONSENT FOR PARTICIPATION FOR MCKINLEVILLE HIGH SCHOOL FOOTBALL PLAYERS

Please read the following as it provides information about this research study. Please understand that you are being asked to volunteer in this study and it is your choice to participate. By signing this form you are indicating that you have been informed of the nature of the study including the risks and benefits of its association and want to participate.

Principal Investigator:
Daniel G. Schultz, B.S., CSCS, USAW
Humboldt State University
415-328-4059
dgs15@humboldt.edu

Project Description:

The purpose of this study is to evaluate whether a new test of core muscle power can be used as measure of football performance. This research will test the repeatability of the new test and will help determine if the new test can measure athletic performance in football.

Consent:

1. You must be at least 18 years old to participate in this study or have parental consent.
2. Your participation in the research study is voluntary.
3. You must have been medically cleared for participation in football by Marin Catholic High School.
4. You may choose not to participate at all, or you may refuse to participate in certain procedures or answer certain questions or discontinue your participation at any time without penalty or loss of benefits.

Procedures:
If you agree to participate in this study, you will:
1. Be asked to participate in testing that will take place over a 7-day period in January 2012 at the Marin Catholic High School Football Field. Each of the four tests you will do will take place on a different day.
2. Complete a demographic and athletic background questionnaire. The athletic background questionnaire will determine final eligibility for the study.
3. Have your core power measured with a new test that involves slamming a weighted medicine ball to the ground repeatedly. You will do this test four times over four different days, with each testing session taking approximately 10 minutes.

Possible Risks:
This study involves bouts of all-out efforts in the new test of core muscle power, the sit up test, and the four isometric endurance tests.

1. ( ) You may experience discomfort that is associated with this type of strenuous, all-out bouts of exercise.
2. ( ) You may experience muscle soreness that lasts for up to 72 hours from performing any of these activities.
3. ( ) There is a possibility of injuring yourself while performing any of these activities. Proper supervision and instruction will be provided to minimize the chance of injury. Standardized procedures for testing will be followed. Emergency equipment and trained personnel will be available to respond to any unusual situations should they arise.

Benefits:
You will receive your scores for the new test, the sit up test, as well as for the four isometric endurance tests. Your scores may help you determine any individual strengths or weaknesses.

Confidentiality/Anonymity:
You understand that participation in this study is completely voluntary. The only people who might access your scores are National Strength and Conditioning Association Certified Strength and Conditioning Coaches collecting data, the Head Strength and Conditioning Coach, non-certified strength and conditioning coaches collecting data, and the Principal Investigator. The demographic and athletic background information
collected during testing will be treated as privileged and confidential as described in the Health Insurance Portability and Accountability Act of 1996. The Principal Investigator will only have access to your demographic and athletic background information.

Confidentiality will be protected by the following ways: (a) results will be presented as group data in any presentations and publications; and (b) all data will be stored in a password-protected computer that is only accessible by the Principal Investigator. You may discontinue participation at any time without penalty. Your participation in this research project will not involve any additional costs to you. You understand that you will not receive any compensation to participate in this study. **Results of testing will be confidential and will not be released unless individual participant consent is given; otherwise your name will be assigned a number to analyze data for anonymity purposes.**

**Institutional Contacts:**

For questions regarding this study, please contact the Principal Investigator using the contact information above. If you have questions regarding your rights as a participant, any concerns regarding this project, or any dissatisfaction with any part of this study, you may report them—confidentially, if you wish—to the Dean for Research & Sponsored Programs, Dr. Rhea Williamson at Rhea.Williamson@humboldt.edu or (707) 826-4189.

I understand that she will answer any questions I may have concerning the investigation or the procedures at any time. I also understand that my participation in any study is entirely voluntary and that I may decline to enter this study or may withdraw from it at any time without jeopardy. I understand that the investigator may terminate my participation in the study at any time.

**Signature:**

Your signature below indicates your voluntary agreement to participate in this study. For participants under the age of 18 a parent signature is required.

I, __________________________________ have read and agree to participate in this study as described above.

*(Please PRINT participant Name Here)*
____________________________________     ___/___/___

(Please SIGN participant Name Here)       (Date)

____________________________________     ___/___/___

(Signature of Parent or Guardian)          (Date)
Appendix G: Record Sheet
The Validity of the SST in Football players

<table>
<thead>
<tr>
<th>Name</th>
<th>For PI Only:</th>
</tr>
</thead>
</table>

Make sure all tests are completed on assigned days!

**Day 1:**

Max Sit-ups: ________________

**Day 2:**

McGill tests:

<table>
<thead>
<tr>
<th>Flexion:</th>
<th>Extension:</th>
<th>R Lateral:</th>
<th>L Lateral:</th>
</tr>
</thead>
</table>

**SST:**

HT1: ________________

HT2: ________________

**Day 3:**

**SST:**

HT3: ________________

HT4: ________________

**Day 4:**

**SST:**

Video 1: ________________

**Day 5:**

**SST:**

Video 2: ________________
Appendix H: Verbal Commands for SST
Verbal Commands for SST

SST

1. The starting position will consist of standing in an athletic position with knees slightly bent. The clock will begin as soon as you make a movement.

2. Bend down with a straight back, using the hips and legs, to pick up the ball as in a deadlift or power clean.

3. Lift the ball over the head while simultaneously straightening the body at the knees, hips and ankles. If the ball does not go over the head the repetition will not count and you will need to retest.

4. Once the ball is over the head throw the ball as fast as possible back towards the X taped on the ground.

5. Follow through with the hands and bring the body back down into a semi squat position in order to grab the ball and repeat again.

6. This process will be repeated until 10 repetitions are reached upon which time the timer will stop the watch.

7. If the body does not break the plane of the top of the head and the body does not straighten at the hips and knee, then the athlete will be disqualified and stopped from testing. The test may be re-done after a 5-minute resting period.
Appendix I: 60-sec Sit-up Test with Verbal Commands
60-sec sit-up test

The 60-second maximum sit-up test, with a built-in 30-second test, was modified from similar tests described by Augustsson et al. (2009) and the National Strength and Conditioning Association (NSCA) (Baechle & Earle, 2002). Athletes laid supine on the field turf with knees flexed to 90° and hips flexed about 45° (Baechle & Earle, 2002). Fingers were interlocked behind the neck and the feet secured down by a fellow teammate (Augustsson et al., 2009; Baechle & Earle, 2002). Time started on the word "go" and athletes flexed the trunk up far enough to have their elbows touch their thighs. Athletes then lowered their trunk back toward the turf until the scapula came in contact with turf (as per Augustsson et al., 2009). The athletes were not permitted to touch their head or hands against the field turf during the 60 seconds (Baechle & Earle, 2002). Each up-down cycle counted as a successful repetition of the sit-up. At 30 and 60 seconds, the test administer records the number of successful repetitions. Subjects only performed one sit-up trial.

Sit-up Verbal Commands

60-sec max sit-ups

1. Lay on the turf with the knees bent at roughly 90 degrees
2. Interlock the fingers behind the head
3. On the “go” command, perform sit-ups as quick as possible without pulling on the neck
4. Elbows need to touch the thighs in the upward portion of the movement
5. Lower the torso down to the ground until the upper back hits the turf

6. Do not let the hands or head touch the turf

7. Perform as many repetitions as possible in the 60-sec timeframe

8. 1 sit-up consists of the upward portion of the sit-up as well as the downward portion
Appendix J: McGill Protocol with Verbal Commands
McGill Protocol

Trunk muscular endurance, a component of core stability, was assessed with a protocol developed by McGill (2008). Since spinal stability is required for nearly every dynamic movement, there is an obvious need to have balanced muscular capacities among the trunk flexors, extensors, and lateral muscles (McGill, 2008). The McGill protocol consisted of the: (a) trunk flexion test; (b) a modified Biering-Sorensen trunk extension test (Biering-Sorensen, 1984); (c) right flexion test; and (d) left flexion test. The tests were scored as individually held isometric postures for time (recorded in seconds, to the nearest .1 sec) (McGill, 2008). Verbal instructions, as well as brief demonstrations, for all core endurance measures were given to subjects prior to testing. In order to ensure recovery between the four measurements, subjects rested a minimum of 5 minutes between tests, but were allowed to rest longer if they felt the need to. In addition to the individually scored test, all four test times were combined to create a total core score.

Trunk flexion test

The flexor test starts with the subjects in a sit-up position with their back resting against a wedge that is angled 55° from the floor. The knees and hips of the subjects were flexed to 90° with the arms folded across the chest and hands resting on the shoulders. The feet were held down at the top of the foot by a partner. Reiman et al. (2010) used a similar modified version of the trunk flexion test, and reported a strong correlation to the original McGill procedures. Subjects were instructed to hold the isometric posture, and
then the wedge was pulled back 10 cm. Time started when the wedge is moved back and time ended when any part of the subjects' back touched the wedge (McGill, 2008).

**Biering-Sorensen trunk extension test**

The extensor test started in the "Biering-Sorensen position", adapted from Biering-Sorensen (1984), with subjects lying prone on a workout bench with their anterior superior iliac spine (ASIS) aligned with the table's edge, leaving the upper body planked out over the edge of the bench. The knees, hips, and pelvis were secured by a partner, which was a modification from McGill, who used straps. Reiman et al. (2010), used a similar modified version of the trunk extension test, and reported a strong correlation to the original McGill procedures. The arms were folded across the chest and hands will be rested on the shoulders. Subjects were instructed to maintain a horizontal position with their body in a straight line before the time started. Time stopped when the subjects broke the horizontal position by dropping their upper body (McGill, 2008).

**Right and left flexion tests**

The lateral musculature tests started with the subjects lying sideways (i.e., side-bridge position) on the field turf. The legs were fully extended and the subjects had to place the top foot in front of the lower foot to increase their base of support width. The subjects had to support themselves on the involved elbow while the uninvolved arm was placed on the opposite shoulder. Subjects were instructed to lift their hips off of the turf, creating a straight line with their body. Time started once subjects were in this position. Time stopped when the subjects could no longer maintain the straight line position and the hips lower toward the turf (McGill, 2008).
McGill protocol Verbal Commands

**Right Flexion**

1. Lay on your right side with legs fully extended
2. Place the top foot in front of the lower foot
3. Put the left hand on the right shoulder
4. Lift the hips off the ground and use the right arm as a support to hold the body, the body should be straight.
5. Hold that position for as long as possible
6. Time will stop when you are no longer able to maintain a straight line from the shoulders to the ankles. In other words as soon as the hips lower.

**Left Flexion**

1. Lay on your left side with legs fully extended
2. Place the top foot in front of the lower foot
3. Put the right hand on the left shoulder
4. Lift the hips off the ground and use the right arm as a support to hold the body, the body should be straight.
5. Hold that position for as long as possible
6. Time will stop when you are no longer able to maintain a straight line from the shoulders to the ankles. In other words as soon as the hips lower.

**Trunk Flexion**

1. Sit with the knees bent at roughly 90 degrees with back against a wedge
2. Cross the arms against the chest and hands on the shoulders
3. A partner will hold the feet down
4. The wedge will be moved
5. Hold the position for as long as possible
6. Time will stop as soon as the back touches the wedge.

Trunk Extension

1. Lay on the bench with the face towards the ground
2. Align the ASIS with the end of the bench, leaving the upper body cantilevered off
   the end of the bench
3. The legs will be held down
4. Cross the arms against the chest and hands on the shoulders
5. Hold the body in a straight plank for as long as possible.
6. Time will stop as soon as the shoulders begin to lower towards the ground
Appendix K: Football Performance Measures and Demographics
Football Performance Measures and Demographics

Mass and height

The mass and height of each participant was taken by the football strength and conditioning staff with a calibrated scale (Health-o-Meter, Illinois) prior to the start of testing for the current study. If measures had not been taken, subjects wore regular practice attire without shoes and were weighed in. Mass was measured to the nearest 0.5 lb, and then converted to kilograms (kg). Standing height was taken with participants standing, without shoes, on the Health-o-Meter weight platform with back, heels, and buttocks against scale. The measuring device was laid over the tallest point of the participant’s head. Height was measured to the nearest 0.5 inch, and then converted to centimeters (cm).

Athletic performance measures

For this study, football players had their playing ability assessed by performing standardized tests that evaluate strength, power, and speed. Standardized test batteries typically include: (a) the power clean; (b) the back squat; (c) the bench press; and (d) the vertical jump (Berg et al., 1990; Black & Rowndy, 1994; Burke et al., 1980; Daniel et al., 1984; Fry & Kraemer, 1991; Kuzmits & Adams, 2008; Nesser et al., 2008; Sawyer, Ostarello, Suess & Dempsey, 2002). This standardized battery of tests is part of the Humboldt State University (HSU) Strength and Conditioning Program's regular assessment protocol, and was used for this study. Assessing players is critical, not only because test scores allow strength coaches to plan yearly training programs, but also because the aforementioned measures relate to player performance in competition.
(Allerheiligen&Arce, 1983). Athletes were always under the direct supervision of the football strength and conditioning staff for all of their test trials. All rest times during testing followed those recommended by the NSCA (Baechle& Earle, 2002).

**Power clean.** The procedures for the power clean were modified from those suggested by Baechle and Earle (2002). One-repetition maximums (1-RM) were not used by the HSU football strength and conditioning staff due to safety concerns; instead 3-RM tests were used. Athletes performed a warm-up protocol with an Olympic weightlifting bar (an Ivanko [20 kg] Olympic Weightlifting Barbell model OBS-20 kg). The warm-up consisted of two sets of 5 repetitions of overhead lunges, and two sets of 5 repetitions of high pulls. After at least 1-min of rest, athletes performed their 3-RM power clean max test using an Olympic weightlifting bar, proper NSCA prescribed technique (Baechle& Earle, 2002), and an initial load based on a previous recorded estimated 1-RM by the Head Strength and Conditioning Coach. Subjects had a maximum of 10 seconds recovery between each repetition. If the initial 3-RM test was successful, then the athlete had the opportunity to try another 3-RM test with a heavier load that they felt comfortable at attempting. If the participant was unsuccessful at catching the load at shoulder height, they were allowed to retest with the current load after 2 minutes of rest. If unsuccessful again, the load used during the previous successful 3-RM test was to represent the final mass lifted. Final mass lifted was recorded in pounds then converted into units of kilograms (kg).

**Back-squat.** The procedures for the back squat were modified from those suggested by Baechle and Earle (2002). Due to safety concerns 3-RM tests were used instead of 1-RM
tests. Athletes performed five sub-maximal warm-up sets (consisting of 5-10 repetitions) of the back squat, which was assigned by the Head Strength and Conditioning Coach. The initial load used in the 3-RM back squat test was based on a previous recorded estimated 1-RM by the Head Strength and Conditioning Coach. Subjects had a maximum of 10 seconds of recovery between each repetition. If the athlete successfully completed the initial 3-RM test load with proper technique, at the discretion of the overseeing strength coach, they were allowed to attempt a heavier load. The strength coach and the athlete decided if the load lifted represented a successful 3-RM. If the participant was unsuccessful at lowering and fully pressing up the load, the athlete was allowed to retest with the current load after 2 minutes of rest. If unsuccessful again, the load used during the previous successful 3-RM test represented the final mass lifted. Final mass lifted was recorded in pounds then converted into units of kilograms (kg).

**Bench press.** The procedures for the bench press were modified from those suggested by Baechle and Earle (2002). Due to safety concerns 3-RM tests were used instead of 1-RM tests. Athletes performed five sub-maximal warm-up sets (consisting of 1-6 repetitions) of the bench press with a light load, which was assigned by the Head Strength and Conditioning Coach. The initial load used in the 3-RM bench press test was based on a previous recorded maximum by the Head Strength and Conditioning Coach. Subjects had a maximum of 10 seconds between each repetition. If the athlete successfully completed the initial 3-RM test load with proper technique, at the discretion of the overseeing strength coach, they were allowed to attempt a heavier load. The strength coach and the athlete decided if the load lifted represented a successful 3-RM. If the participant was
unsuccessful at lowering and fully pressing up the load, the athlete was allowed to retest with the current load after 2 minutes of rest. If unsuccessful again, the load used during the previous successful 3-RM test represented the final mass lifted. Final mass lifted was recorded in pounds then converted into units of kilograms (kg).

*Vertical jump height.* Vertical jump height was measured with a Vertec (Sports Imports, Columbus, OH) using modified procedures from Baechle and Earle (2002). The Vertec was positioned in the back of the training facility. Participants had their standing reach measured first with their dominant arm against the Vertec. The standing reach height marker was then adjusted to the tip of the athlete’s middle finger on their dominant hand. Once the Vertec was properly adjusted, participants stood approximately a foot and a half away from the apparatus (measured from the outside edge of their dominant foot), so not to touch the apparatus during their jump, and performed a standard countermovement jump (CMJ).

The CMJ was performed by having the participants first standing straight up with feet shoulder width apart and flat on the ground. Participants then quickly moved their hips down and backwards into a semi-squat position and immediately exploded upwards to jump. As this movement was happening, the arms were moving back during the downwards phase, and then move upwards during the explosion phase. When the participant was at the peak of their upward phase of the jump they extended their dominant hand into the air in attempt to displace the Vertec measuring vanes. The displacement of the vanes was used as the vertical jump height (per ½-inch increment) of each participant (Baechle & Earle, 2002). Each athlete continued to attempt jumping trials
until they were unable to displace measuring vanes on two consecutive jumps. The vertical jump height on the Vertec was measured as the difference between the standing reach and the jumping reach of each participant. The vertical jump test was performed under the supervision of the football strength and conditioning staff.
Appendix L: Testing Schedule Calendar
## Testing Schedule

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Appendix M: Strength and Conditioning Coaches Responses
Strengths of the McGill Protocol:
Coach A: It covers core endurance in many planes.
Coach B: Measurable, practical and reliable. Multi plane test.
Coach C: Easy to Administer, Effective for deeper core musculature, (i.e. Transverse Abdominus&QuadratusLumbordum)
Coach D: Similar Body Positions to FB, Targets Important Muscle Groups
Coach E: Good strengthening/stability exercises, Could be used in a warm up as activation movements, Could be used at close of a work out as strengthening/stability movements
Coach F: Increases core static strength and increases strength of stabilizers.

Weaknesses of the McGill Protocol:
Coach A: This series of exercises is static endurance of the core.
Coach B: Not Dynamic.
Coach C: Not Dynamic, No rotational component, Not from a standing position.
Coach D: Non athletic position, Non athletic movement.
Coach E: Hard to Measure with Team, What Makes It Successful Test?, Not Standardized
Coach F: Exercises could be performed without correct technique, Technique could diminish and put stress on wrong parts of the body.
Coach G: Does not incorporate movement, sports are dynamic.

Strengths of the Sit-up:
Coach A: Hip flexion strength
Coach B: Measurable, practical and reliable.
Coach C: Easy to administer, Good measure of rectus abdominus, and hip flexor endurance
Coach D: Easilly Tested, Can Create Scoring System, Reps or Time , Position Standards
Coach E: Descent strengthening exercise, Very basic, Very familiar to most athletes.
Coach F: Increases basic core strength

Weaknesses of the Sit-up:
Coach A: Targets only a small groups of muscles.
Coach B: Single plane of motion, does not include the transverse plane of motion.
Coach C: More Dynamic, but feet are anchored, No Rotational component, Not from a standing position.
Coach D: Non athletic position, Non athletic movement.
Coach E: Too Basic
Coach F: Limited Range of Motion, Isolation Exercise.
Coach G: Single movement and joint exercise

Strengths of the SST:
Coach A: Helps with explosive power.
Coach B: Dynamic in nature, as in the sport of football. Explosive.
Coach C: Fairly easy to administer. Far more dynamic in nature. Done from a standing position.
Coach D: Specific Explosive Movement
Coach E: Activates core/hip muscle groups. Total body exercise (back, shoulders, hips and abdominals). Great exercise or warm up exercise. Intensity could be increased by size of ball as well as length of movement.
Coach F: Increases core strength. Multi-movement exercise. Similar energy system used in football (3-5 sec per rep).

Weaknesses of the SST:
- Coach A: Not enough overload on the core musculature.
- Coach B: Single plane of motion. Hard to measure.
- Coach C: Difficult to assess actual strength. No Rotational component. Duration / Rep Goal may diminish. Desired form / power output.
- Coach E: Hard to measure.
- Coach F: Limited to size of ball.

Comments:
- Coach B: Of the 3 tests the McGill protocol would be most likely my choice to administer. It’s easy to measure and can be applied to large groups. It also doesn’t need any equipment. Although the McGill protocol is not dynamic, as the sport of football is, it does involve holding a posture in 2 planes and 3 directions and holding the postures necessary in numerous athletic movements in football. It is also a good way to determine fitness levels of newcomers to any program.
- Coach C: I believe the exercises depicted as A are great for determining an athlete’s potential to return to more demanding exercises and as a way to maintain overall core strength/fitness. Exercise B is a more demanding exercise which can also be utilized similar to the isometrics depicted in A, however the athlete should not be pulling on their head, and the anchoring of the feet call the hip flexors into a much greater role. In addition, the exercise itself may be contraindicated as well as A1 for those who suffer from lower back issues (common in football). Also, B although adequate for overall muscular endurance is not necessarily appropriate for determining actual core strength. Exercise C, is for more beneficial to Football because it is first done from the feet and secondly it is far more ballistic in nature, but still difficult to assess true core strength for football. This does not nullify the exercises ability to activate and strengthen the core, especially for a quarterback, it is still more difficult to assess true core strength as core strength is multi-planar and more dynamic in nature.
- Overall, I believe all three categories of exercises are good exercises and serve as an adequate progression (A=McGill to B=Sit-up to C=SST) in helping an athlete develop core strength in the flexion / extension movements about the hip. When training the core, and this may beyond the scope of this study, more attention needs to be paid to muscles that rotate not only the trunk but also the hips. Football is a dynamic, violent, ballistic
sport played from the feet, and although the exercises that train flexion/extension of the hips/spine are an effective training means, appropriate core strength is developed via axial loading of the spine, stabilizing the body in space with varying loads, and with rotational forces/actions. True core strength is total body integration for maximal stabilization and power output.