

A CORRELATION AMONG CORE STABILITY, CORE STRENGTH, CORE
POWER, AND KICKING VELOCITY IN DIVISION II COLLEGE SOCCER
ATHLETES

A THESIS

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THESIS APPROVAL

Graduate Athletic Training Education


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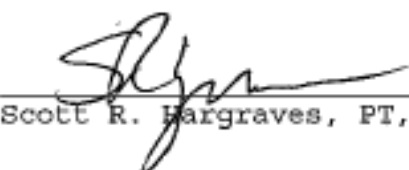
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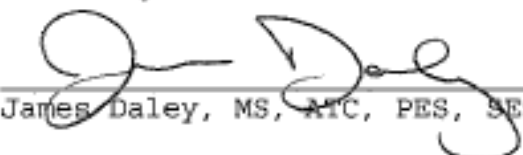
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INTRODUCTION

The correlation between core stability and athletic performance has not been determined in the available literature. Although several researchers have attempted to quantify the relationship between core stability/strength and functional performance, recent findings suggest that further research is needed to investigate important components and measurement of core stability in relation to athletic performance.^{1,2} Therefore, the primary purpose of this study was to examine the relationship among core power, core strength, core stability, and athletic performance in college soccer athletes. It is important to examine the correlation to assess core power and its effect on athletic performance because core power is an integrated component of core stability, strength and endurance during dynamic movement.¹

In addition to the lack of current scientific evidence to support the correlation between core function and athletic performance, a valid core assessment has not been established yet. Therefore, the secondary purpose of this study was to establish a valid assessment tool of core. It

would be beneficial to clarify the definition of core power, as a component of core stability, and its effect on performance in the field of sports science.

Recently, two research groups^{1,3} investigated the relationship between core stability and athletic performance in a sports specific manner. These researchers assumed that selecting core tests that are specific to performance capabilities is a key to investigate the relationship between two variables successfully. By estimating the tests of core stability that have similar movement patterns of the specific athletic performance, researchers were able to analyze the core muscular contributions in dynamic movement. Wagner³ and Dendas¹ successfully observed the relationship between the function of the core and athletic performance; although their conclusions conflicted within the context of core stability and its effect on athletic performance.

Dendas¹ investigated the relationship between athletic performance and core stability in Division II football players. Athletic performance included 3-repetition maximums for the power clean, back squat, and bench press, as well as vertical jump height, and 40m sprint time with a 20m split time.¹ Findings showed a significant relationship

among athletic performance, 60s and 30s maximum sit-up tests, and the McGill trunk flexion test. While it was hypothesized that the Ball Explosive Sit-up Throw Test (MBESTT) would show a significant relationship to the core power, scores on the MBESTT were not related to scores on any of the other measures of core stability.¹ The researcher stated that "a 30-second or 60-second sit-up test is the best field test of core stability currently available"^{1(p79)} in measuring athletic performance in collegiate football players.

Wagner³ identified the relationship between core fitness and tests of soccer sport performance in female soccer players. The researcher defined core fitness as "the combination of isometric core stability and concentric core strength to perform a task of sport performance."^{3(p8)} According to the researcher, isometric core strength (ISC) was used to evaluate the ability of the core to provide a stable base of support using the trunk flexion and bilateral rotation core strength test, while concentric functional core strength (CFCS) was used to evaluate the ability of the core to produce and transfer forces to the limbs using the front abdominal power test (FAPT) and side abdominal power test (SAPT). The researcher compared these

two types of core tests with the soccer-style standing kick and throw-in for maximum speed to examine the role of core function on soccer athletic performance. Results indicated that ICS correlated more strongly with tests of soccer sport performance than CFCS. These findings conflicted with other studies and rejected the research hypothesis.³ The researcher assumed that ICS elicited a greater muscular activation due to a larger load placed on the core, which could have resulted in a greater correlation with tests of soccer athletic performance.³

In comparing these studies, Dendas' findings suggested that core power has a greater contribution to athletic performance in football player than ICS. On the other hand, Wagner's finding suggested that ICS has a greater contribution to soccer performance (standing kick and throw-in) than CFCS. Although both researchers have established valid assessments of core and athletic performance, their findings leave the question, which type of core function has a greater contribution to athletic performance? In other words, is it necessary to assess core stability with a test involving limb movements (specifically of the upper and/or lower extremity) in order

to identify the contribution of core to athletic performance (involving upper and/or lower extremity)?

Theoretically, the core musculature is the kinetic link between the lower and upper bodies and should have direct influence on the kinetic chain on athletic performance. Thus, the purpose of the present study was to examine whether the core has a significant role in providing a base of support for optimal lower extremity function, and the ability to produce and transfer force to the distal segments during a functional soccer task, specifically maximal kicking velocity. Findings may help to generate a valid means of assessing core stability on a base of all core functions, and may be able to guide future studies testing sport performance with the use of core training.

METHODS

This section includes the following subsections: research design, subjects, instruments, procedures, hypotheses, and data analysis.

Research Design

A correlational design was used to determine whether core stability (Rotatory Stability test), core strength (the Double Leg Lowering test) and core power (60s Maximum Sit-Up test) are related to soccer performance (kicking speed). Subjects performed the Functional Movement Screen (FMS) as their warm up, which was conducted by a peer researcher who is a certified FMS specialist. A limitation of the study is the inability to generalize the results beyond DII male soccer players.

Subjects

The subjects were volunteer male student athletes from California University of Pennsylvania's (NCAA Division II) soccer team (n~20). The subjects had some familiarity with

the testing protocols; core training and soccer style kicking as the result of collegiate team participation and training. Subjects needed to be actively participating and/or competing with the varsity soccer team at the time of testing. All subjects in the study read and signed an Informed Consent Form (Appendix C1) prior to participation in the study. Subject information and data collection were contained and documented by the researcher (Appendix C2). Each participant's identity remained confidential and was not included in the study.

Preliminary Research

Preliminary research was performed prior to beginning the research study. The researcher conducted trials with the core tests; the 60s Maximum Sit-Up test (60s MSUT), the Double Leg Lowering test (DLLT), and the soccer kicking test (SK) to become familiar with the equipment, determine a time frame for testing sessions, and identify any modifications that were made to the testing procedures. All test directions were provided using the same text (Appendix C8). The researcher was familiar with the equipment including; sphygmomanometer; 360° universal goniometry and

JUGS™ radar gun. These preliminary trials were conducted on two physically active students within the same age-range as the desired subjects.

Instruments

The instruments used in this study were a Subject Information Sheet/ Data Collection Sheet (Appendix C2), the Rotary Stability Test (FMS 2x6in board), the 60s MSUT, the DLLT (sphygmomanometer and 360° universal goniometer), and the SK (JUGS™ radar gun) (Appendix C4).

Subject Information/Data Collection Sheet

Demographic information was collected on a Subject Information/Data Collection Sheet (Appendix C2). The sheet included questions regarding: (a) date of birth (age), (b) type of kick used, (c) kicking leg, and (d) years of soccer experience, (e) position.

Rotary Stability Test (RS)

The RS is one of seven tests used to test functional movement by the Functional Movement Screen (FMS),⁴ and was used to grade core stability. The FMS is an assessment tool

comprised of seven different movements to identify asymmetry and dysfunctions of movement pattern within the body. This RS test consists of multi-plane trunk stability during a combination of asymmetric upper and lower extremity movement, which requires proper neuromuscular coordination and energy transfer through the trunk (Appendix C5). Not only has the FMS been widely used, but the reliability of the FMS has been reported to have an intraclass correlation coefficient (ICC) value of 0.98.⁵ The range of scores for each test on the FMS are from zero to three; three being the best possible score.⁴ A score of three is given if the subject performs the movement of RS correctly without any compensation (Appendix C5-Figure 4). A score of two is given if the person is able to complete the movement with compensation (Appendix C5-Figure 5). If the requirements for a score of two are not met, then a score of a 1 is given (Appendix C5-Figure 6). If there is pain with the movement, a final score of a zero will be given for the RS test.

Double Leg Lowering Test (DLLT)

The modified double leg-lowering test was used to grade core strength (Appendix C6). The test was adopted

from Zingaro's study.⁶ The lower the subject can lower the legs correlates to a stronger core.⁶⁻⁸ The degree from starting point (hip flexed to 90°) to ending point was used for data analysis. A blood pressure cuff was used to measure the pressure under the back during the DLLT. A 12-inch, 360° degree universal goniometer was used to measure the angle of hip flexion during the core strength testing. The angle of hip from 90° of hip flexion was measured with a goniometer when the pressure of the sphygmomanometer dropped below 20mmHg.^{6,9} This is unlike the double leg-lowering test, which takes a measurement at 40 mmHg. The DLLT has been found to be reliable; the ICC for repeated measures of the DLLT was 0.98.⁷ Core strength was interpreted by the hip angle at the time of pressure change where a greater angle indicated greater core strength. An average score of three trials was used for data analysis.⁶ The verbal directions for the test are described in Appendix C8.

60s Maximum Sit-Up test (60s MSUT)

Core power was measured by the maximum sit-ups in 60 seconds. The 60s MSUT was adopted from similar tests described by Dendas.¹ Reliability for the timed sit-up tests

have previously been established.^{1,10} Dendas reported that test-retest reliability coefficients for 60s timed sit-up test was statistically significant ($r = 0.862$).¹ Augustsson et al¹⁰ also reported an ICC of 0.93 with a 95% confidence interval of 0.77.¹⁰ Each up-down cycle was counted as a successful repetition of the sit-up. The subject had to flex the trunk up until the elbows touched the thighs and then lower the trunk back until the scapulae came into contact with the floor for a successful sit-up. The test was scored as maximal number of correct sit-ups within the 60-second time period.^{1,10} Higher numbers of repetitions indicates better core power. Subjects only performed one sit-up trial per testing session.¹ The length in depth directions of the test are described in Appendix C8.

Soccer Kicking Test (SK)

Prior to kicking assessment, the subjects performed a series of dynamic warm-up exercises adapted from Wagner's study.³ The warm-up consisted of two laps of jogging, 10 yards of hip external rotation, forward lunges, backward lunges, lateral squat, high knees, butt kickers, side shuffle, Carioca, A-skip, power skip, and straight leg kick followed by the leg swing to front/back and side to side in

place. The subjects started with two laps of jogging from the start point, and then were instructed dynamic warm up at the station where the cones were set up for the dynamic warm-up.³ After performing the leg swing by the fence, the subjects had kicking/passing warm-up with the partner for five minutes.^{11,12} Soccer performance was evaluated with a dynamic soccer-style kick for maximal speed. The speed of a dynamic instep, toe kick or shoelace kick (top of the foot) while attempting to kick a dead ball as hard as possible was used to seek the dynamic stability of the core in the current study.³ The maximum kicking velocity (meters per second, m/s) was assessed with use of the JUGS™ radar gun (Jugs Sports, Tualatin, OR), which was placed behind the soccer goal. The ball was placed 5m from where the ball was struck.^{11,12} The radar gun is a good instrument to measure soccer kicking velocity.¹¹ According to Sedano et al,¹¹ the speed of soccer kicking measured by radar and the measurement protocol was validated by a photogrammetry system. A value of $R_{xy} = 0.998$ was obtained in this study.¹¹ According to Sedano et al,¹² there was a positive correlation ($r_{xy} = 0.994$, $p < 0.05$) between the maximal kicking speeds registered by the radar gun and those recorded by high speed video camera. The JUGS™ radar gun

has a reported accuracy of ± 0.4 display unit and range of speeds of 40-200kph.¹³ Using a radar gun to measure the soccer kicking velocity has been reported reliable.¹² The radar gun was calibrated by manufacture instruction prior to the study.¹³ A standard size five soccer ball was used for the test. Higher speeds indicated better kicking performance in this case. The subjects had two practice trials. Average of three kicks after the practice trials was recorded.

Procedures

Once approved by the Institutional Review Board at California University of Pennsylvania (Appendix C3), the study took place over a 3-day period which consisted of an orientation meeting with a practice trial of each test on Day 1 and two testing days, Day 2 and 3. Orientation and testing were conducted at the Phillipsburg soccer complex at California University of Pennsylvania.

On Day 1, the researcher had a meeting with all potential subjects and explained the concept of the study and offered the Informed Consent Form (Appendix C1) in order for them to understand the requirements and risks of

involvement in the study. Qualifications for the subjects (mentioned in the subject section), requirements, testing date (approximately 7 days later), and approximate time frame for entire study, 20 minutes on each of the two testing days, were announced. Then the subjects, who met the qualifications, had a practice session for all core tests.

All subjects, who met the qualifications, were asked to participate in the rest of the study. Day 2 consisted of a warm up using the FMS and measurement of two core assessments. Prior to the core testing session, the subjects performed the FMS assessed by a peer researcher who is a certified FMS specialist. The following testing were performed in the following order; Core stability test (RS as a part of the FMS); Core strength test (DLLT); Core power test (60s MSUT). Day 3 consisted of a series of dynamic warm ups and soccer performance assessment (SK).

Warm Up 1: Functional Movement Screen (FMS)

The following seven tests for the FMS served as the warm-up for the core testing and were conducted by a peer researcher who possesses the FMS certification. The assessment variables included: (1) Deep Squat; (2) Hurdle

Step; (3) In-line Lunge; (4) Shoulder mobility; (5) Active Straight Leg Raise; (6) Trunk Stability Push Up; (7) Rotatory Stability (RS).⁴ Scores of the RS were used as the assessment of core stability in the current study.

Rotatory Stability Test (RS) for Core Stability

For the RS, the subject was in a quadruped position with shoulders and hips at 90° relative to the torso with the FMS kit, a 2x6 in board (Appendix C4-Figure 1), parallel to the spine in between the hands and the knees. The ankles were in a dorsiflexed position. The subjects then flexed the shoulder while extending the same-side hip and knee, and then slowly brought the elbow to the same-side knee while remaining in line over the board. For a score of a 3 on the RS, the subject must perform the task correctly using the same-side leg and arm while keeping the torso parallel to the FMS kit board and keeping the elbow and knee in line with the FMS kit board (Appendix C5-Figure 4). A score of a 2 was given, the subject performed a diagonal pattern using the opposite shoulder and hip in the same manner as for a score of a 3 (Appendix C5-Figure 5). The knee and opposite elbow had to make contact over the FMS kit. If the requirements for a score of a 2 were not

met, then a score of a 1 was given (Appendix C5-Figure 6). If there was pain with the movement, a final score of a zero was given for the RS test. The researcher viewed the movement from the side of the subject. After completing the FMS, the subjects moved to the core testing session. All subjects performed the core tests in the following order; DLLT; 60s MSUT.

Double Leg Lowering Test for Core Strength

The DLLT began with the athlete in a supine position. A sphygmomanometer was placed beneath the umbilicus. Once the sphygmomanometer was placed in a correct position, the subject flexed his hips into 90° with full knee extension and arms laid along the side of the body with hands palm down on the field (Appendix C6-Figure 7). However, the knees were flexed slightly to reduce tension on the hamstrings, which allowed subjects to flex their hips to 90°. The goniometer was placed at the hip joint. The stationary arm was placed parallel to the mid axillary line of the torso (parallel to the floor) and the moveable arm was parallel to the longitudinal axis of the femur.⁶ The subject was instructed to relax the abdominal muscles to 20 mmHg and told to 'flatten out the back,' in a drawing-in

motion, to stabilize the lumbar spine and increase the pressure of the sphygmomanometer to 40 mmHg.⁶ Then the legs were slowly lowered, maintaining the posterior pelvic tilt until the pressure of the sphygmomanometer drops below 20mmHg (Appendix C6-Figure 8). The subject's legs were held by the researcher once the pressure of the sphygmomanometer got to below 20mmHg or when this pelvic position could no longer be maintained. Then the goniometer measurement of hip joint was taken while being held the legs so that the athlete did not have to keep contraction of the abdominal muscles and hold the leg position during the goniometer measurement. The subject performed the test three times with one minute rest in between each trial. Average score from three trials were used for data analysis. If the subject performed the technique incorrectly no score was recorded.² The subject performed the test on another day in order to practice pelvic tilt and perform the DLLT correctly. The subject had a rest for two minutes before moving to the 60s MSUT.

60s Maximal Sit-up Test for Core Power

For the 60s MSUT, the subject lay supine with knees flexed to 90° and hips flexed about 45°. Fingers were

interlocked behind the neck and the backs of the hands touched the floor (Appendix C7-Figure 9). The feet were together and another subject stepped on the subject's feet to stabilize the position. On the command "go", the subject began flexing the trunk to perform the sit up until the elbows touched to the thighs (Appendix C7-Figure 10) and then lowered the trunk back until the scapulae came into contact with floor without touching their head or hands to the floor for 60 seconds timed by a stopwatch. At 60 seconds, the researcher recorded the number of successful repetitions. Subjects performed one sit-up trial per testing session.¹

Warm-up 2: Dynamic Stretch

Prior to the kicking test, subjects performed a series of dynamic warm-up exercises selected from their soccer practice and those used in previous research.³ The warm-up consisted of two laps of jogging, 10 yards of hip external rotation, forward lunges, backward lunges, lateral squat, high knees, butt kickers, side shuffle, Carioca, A-skip, power skip, and straight leg kick followed by the leg swing to front/back and side to side in place. The subjects started with two laps of jogging from the start point, and

then were instructed dynamic warm up at the station where the cones were set up for the dynamic warm-up.³ After performing the leg swing by the fence, the subjects had kicking/passing warm-up with the partner for five minutes.^{11,12} Then the subjects were taken to the area where the kicking test took place.

Soccer Kicking Test

Soccer performance was evaluated with a dynamic soccer-style kick for maximal speed. Each subject was allowed to choose the distance of the run-up to a stationary ball as well as the type of kick (instep, toe kick, or shoelace). The subjects approached to the ball from the starting point, produced a counter movement swing with the kicking leg, and kicked the ball as hard as possible towards the radar gun. The researcher recorded the maximal speed using the radar gun. The subjects had two practice trials, and three test kicks. An average of the three test kicks was used for data analysis. The subject had 90 second rest in between each trial.

Hypothesis

The following hypothesis was investigated in this study: There will be a positive correlation among core power, core strength, core stability, and kicking velocity.

Data Analysis

An alpha level of ≤ 0.05 was used for all statistical tests. SPSS version 18.0 for Windows was used for all statistical analyses. The research hypothesis was analyzed using a Pearson Product Moment correlation to determine any relationship among core power, core strength, core stability and soccer kicking velocity.

RESULTS

The purpose of the study was to examine the relationship among core power, core strength, core stability, and athletic performance in college soccer athletes. Subjects were tested by using the RS, the 60s MSUT, the DLLT, and the soccer kicking test (SK). The RS was used to measure core stability, the DLLT was used to measure core strength, the 60s MSUT was used to measure core power, and the SK was used to measure maximal kicking speed.

Demographic Information

A total of 19 male subjects volunteered to complete this study. All subjects were physically active individuals participating in NCAA Division II soccer at California University of Pennsylvania. One subject's data was excluded from data analysis because he was unable to perform 60s MSUT due to pre-existing conditions, although actively participating in practice and games without problems. Table

1 presents demographic data for the 18 subjects that completed the study. Years of soccer experience was determined by active participation from age group to collegiate soccer.

Table 1. Demographic Information

	N	Minimum	Maximum	Mean	SD
Age (yrs)	18	18	23	20.39	1.614
Soccer experience (yrs)	18	8	20	14.94	2.920

SD = Standard Deviation

Hypothesis Testing

Hypothesis testing was performed by using data from the 18 subjects who completed all tests at an alpha level of ≤ 0.05 . Descriptive statistics for the RS, the DLLT, the 60s MSUT and the SK are shown in Table 2. The range of scores for the RS was from zero to three; three being the best possible score.⁴ The range of the DLLT was zero to 90; the degree from starting point (hip flexed to 90°) to ending point was used for data analysis. The 60s MSUT test was scored as maximal number of correct sit-ups within the 60-second time period.^{1,10} Higher numbers of repetitions

indicate better core power. For the SK, higher speeds indicated better kicking performance in this case.

Table 2. Descriptive statistics for RS, DLLT, 60s MSUT and SK

	N	Minimum	Maximum	Mean	SD
RS	18	2	3	2.39	0.502
60s MSUT	18	31	60	47.28	8.079
DLLT (Degrees)	18	26	63	37.39	8.991
SK (mph)	18	58	75	67.69	4.540

Hypothesis: There will be a positive correlation among the RS, the DLLT, the 60s MSUT and the SK, for core stability, core strength, core power and a maximum kicking velocity respectively. A Pearson Product Moment Correlation coefficient was calculated to examine the linear relationship among all four variables using a one-tailed test.

Conclusion: There were no significant correlations among the RS, the DLLT, the 60s MSUT and the SK, for core stability, core strength, core power and maximum kicking velocity (Table 3).

Table 3. Correlations among RS, DLLT, 60sMSUT and SK

		RS	DLLT	MSUT	SK
RS	Pearson Correlation		-.241	.001	-.091
	Sig. (1-tailed)		.168	.499	.360
DLLT	Pearson Correlation	-.241	1	.328	.348
	Sig. (1-tailed)	.168		.092	.078
MSUT	Pearson Correlation	.001	.328	1	.020
	Sig. (1-tailed)	.499	.092		.469
SK	Pearson Correlation	-.091	.348	.020	1
	Sig. (1-tailed)	.360	.078	.469	

Additional Findings

An additional Pearson Product Moment correlation was performed to examine the relationship among the RS, the DLLT, the 60s MSUT, and the Trunk Stability Push-up test (TSPU) completed as one of seven tests measured for the Functional Movement Screen (FMS) with a peer researcher, and is used to grade core stability. Unlike the RS, which requires multi-plane trunk stability during a combined upper and lower extremity motion, the TSPU assesses trunk stability during a closed-chain upper body movement.⁴ The subject was asked to perform a pushup with hands aligned under the top of the forehead for men. A possible score of three was given if the subject performed the push-up with the hands aligned with the top of the forehead correctly

without any compensation such as excessive movement in the lumbar spine or not lifting the body as a unit when performing this push-up. A score of two is given if the person is able to complete the push up with the hands aligned with the chin. If the requirements for a score of two are not met, then a score of a 1 is given. Descriptive statistics for the TSPU test are shown in Table 4.

A significant moderate low correlation between the TSPU and the SK was present ($r = .435$, $P = .036$) where the average score of the TSPU was 2.61 with a range of 2-3 (Table 5). Also, no correlations were reported for years of experience in the athletes (8-20 years) and any of the performance variables.

Table 4. Descriptive statistics for TSPU

	N	Minimum	Maximum	Mean	SD
TSPU	18	2	3	2.61	.502

Table 5. Correlations among TSPU, RS, DLLT, 60sMSUT, and SK

		TSPU	RS	DLLT	MSUT	SK
TSPU		1	.169	.073	-.059	.435*
			.252	.387	.408	.036
RS	Pearson Correlation	.169	1	-.241	.001	-.091
	Sig. (1-tailed)	.252		.168	.499	.360
DLLT	Pearson Correlation	.073	-.241	1	.328	.348
	Sig. (1-tailed)	.387	.168		.092	.078
MSUT	Pearson Correlation	-.059	.001	.328	1	.020
	Sig. (1-tailed)	.408	.499	.092		.469
SK	Pearson Correlation	.435*	-.091	.348	.020	1
	Sig. (1-tailed)	.036	.360	.078	.469	

*. Correlation is significant at the 0.05 level (1-tailed)

DISCUSSION

Discussion of Results

The main finding was that no significant correlations among the RS, the DLLT, the 60s MSUT and the SK, for core stability, core strength, core power and maximum kicking velocity were observed in NCAA Division II soccer athletes. While these findings are consistent with findings of previous studies,^{14,15} the recent research by Dendas¹ and Wagner³ has reported a relationship between core stability and athletic performance in American football athletes¹ and female soccer athletes³).

Nesser et al^{14,15} investigated the relationship between core stability and various strength and power variables in Division I football athletes¹⁴ and NCAA Division I female soccer athletes.¹⁵ The core stability was assessed using McGill Protocol that consists of back extension, trunk flexion, and left and right bridges in these studies.^{14,15} Performance variables in the study¹⁴ included three strength variables; one-repetition maximum (1RM) bench press, 1RM squat, and 1RM power clean, and four performance variables;

countermovement vertical jump, 20 and 40 yard sprints, and a 10 yard shuttle run. Data revealed a number of significant, but weak to moderate correlations between core strength/stability and strength and performance.¹⁴ The researchers¹⁴ concluded that increases in core strength does not contribute significantly to strength and power, and that training programs with emphasis on strength and power should not focus on core stability and strength.¹⁴ Nesser et al¹⁵ also investigated the relationships between core stability and various strength and power variables in NCAA Division I female soccer players. The researchers assessed core stability using the McGill protocol, two strength variables (1RM bench press and 1RM squat), and three performance variables (Countermovement vertical jump, 40 yard sprint, and a 10 yard shuttle run) in this study. According to their findings, no significant correlations among core strength, strength, and power were confirmed. Thus, the researchers¹⁵ concluded that core strengthening programs should not be the focus of strength and conditioning because increases in core strength will not contribute significantly to strength and power. Dendas¹ and Wagner³ successfully observed the relationship between the function of the core and athletic performance in a sports

specific manner. Dendas⁷ investigated the relationship between athletic performance and core stability in Division II football players where core power using Medicine Ball Explosive Sit-up Throw Test (MBESTT) and a 60 second maximum sit-up test with a built-in 30 second test, and core endurance using McGill protocol were used. Performance variables to investigate included 3RM for the power clean, back squat, and bench press, as well as vertical jump height, and 40m sprint time with a 20m split time.⁷ The findings suggested that the 60s maximum sit-up test was significantly correlated with the relative power clean (1.09 ± 0.17 ; $r = .836$), relative squat (1.64 ± 0.28 ; $r = .608$), relative bench press (1.24 ± 0.19 ; $r = .590$), vertical jump height (29.11 ± 3.70 in; $r = .721$), 40-m sprint time (5.26 ± 0.37 s; $r = -.680$), and 20-m sprint time (3.23 ± 0.27 s; $r = -.803$). Thus, Dendas' findings suggested that core power has a greater contribution to athletic performance in football players than isometric core stability.

On the other hand, Wagner's findings suggested that isometric core stability (ICS) has a greater contribution to soccer performance (standing kick and throw-in for maximum speed) than concentric functional core strength

(CFCS).³ According to the researcher,³ ICS test was used to evaluate the ability of the core to provide a stable base of support with use of a isokinetic dynamometer during movements of trunk flexion (TF) and bi-lateral rotation, while CFCS test was used to evaluate the ability of the core to produce and transfer forces to the limbs by performing the front abdominal power test (FAPT) and side abdominal power test (SAPT).¹⁵ This researcher found significant and meaningful correlations between isometric TF and throw-in ($r = 0.526$) and isometric left rotation (LR) and right footed kick ($r = 0.622$). Also, there were significant correlations between isometric right rotation (RR) and right footed kick ($r = 0.753$) and isometric TF and left footed ($r = 0.615$).¹⁵

Although the main finding in the current study did not support their findings and the question,^{1,3} which type of core function has a greater contribution to athletic performance, additional analysis supported Wagner's findings between trunk stability and athletic performance measured by kicking speed. Specifically, core stability measured by the TSPU was positively moderately correlated to kicking velocity as measured by the SK. Wagner³ identified the relationship between core fitness and tests

of soccer sport performance in female soccer players, and defined core fitness as "the combination of isometric core stability and concentric core strength to perform a task of sport performance."^{3(p8)} His finding suggested that isometric core stability has a greater contribution to soccer performance (standing kick and throw-in for maximum speed) than concentric functional core strength in female soccer athletes.³ The current additional finding supported that isometric core stability has a greater contribution to soccer performance when maximal effort is required.

Although the previous researchers^{1,3} assumed that selecting core tests that are specific to performance capabilities is a key to investigate the relationship between two variables successfully, the finding between the TSPU and the SK supported the idea that isometric core strength elicited a greater muscular activation due to a larger load placed on the core, which could have resulted in a greater correlation with tests of soccer athletic performance.³

Considering that the isometric core stability test used by Wagner³ has same characteristics of core function with the TSPU in the current study, the tests that measure the isometric core stability without dynamic limb movements

may be valid and reliable to assess core stability. Unlike the RS, which require multi-plane trunk stability during a combined upper and lower extremity motion, the TSPU assesses trunk stability during a closed-chain symmetrical upper body movement.⁴

As Sharrock et al² discussed in their literature, it would be appropriate to measure core function during dynamic movements in sports which require complex, explosive, and multilane movements. However, there is no gold standard used to measure core function, and no reliable and valid measurements that have been established in the previous literature.² The tests of the core function in the current study (RS, DLLT, and 60s MSUT) were selected due to existing reliability and/or validity, these tests did not have similar movement patterns of the specific athletic performance. Not only have these core tests have been widely used, but the reliability of the tests has been reported. The FMS has been reported to have an intraclass correlation coefficient (ICC) value of 0.98.⁵ Reliability for the timed sit-up tests have previously been established.^{1,10} Dendas reported that test-retest reliability coefficients for 60s timed sit-up test was statistically significant ($r = 0.862$).¹ Augustsson et al¹⁰ also reported

an ICC of 0.93 with a 95% confidence interval of 0.77.¹⁰ Sharrock et al reported that DLLT has been found to be reliable; the ICC for repeated measures of the DLLT was 0.98.⁷ From author's knowledge, the study⁷ is only one literature that has reported ICC of the DLLT. Sharrock et al suggested that "the DLL test is an appropriate way to measure core stability as it pertains to athletic function"¹⁶ based on evidence in previous literature, while Krause et al⁷ reported the DLLT has excellent intra-tester reliability as an assessment of core strength. The researcher⁷ reported an ICC of 0.98 that for repeated measures of the DLLT. Although the validity of the DLLT has not been shown in the previous literature,^{2,6-8} this test has been found to be reliable,⁷ and the DLLT has been used in several studies.^{2,6-8} Thus, the DLLT is a typical method to measure core strength.^{17,18} Prentice described DLLT as the Straight Leg Lowering Test (SLLT), and suggested that core strength can be assessed with using SLLT as well.¹⁷

However, we experienced difficulty assessing core strength with the use of a BP cuff during the DLLT when subjects had increased lumbar lordosis. According to procedures, the BP cuff is used to determine subject's ability of maintaining posterior pelvic tilt. A peer

researcher was needed to observe subject's pelvic movement to assess their core strength, while the researcher read the change of BP cuff in that case. Although all athletes were able to perform posterior pelvic tilt, some of them were not able to increase BP cuff pressure as described in the procedure (increase BP cuff to 40mmHg before lowering the legs.) The score of the DLLT was then determined by the point where the subjects keep posterior pelvic tilt.

While the selected core tests measured some aspect of core function in the current study, it appears that the test criteria were not sufficient to differentiate each core function. To seek the relationship between core function and athletic performance, future research is needed to establish valid and reliable core measurements first. It seems to be difficult to define core variables based on each core function since all core muscles work synergistically to provide stability. However, Wagner's³ and our additional finding suggested that tests used to measure isometric core stability may be valid and reliable to assess core stability. Further research is needed with larger number of subjects, elite/professional athletes in variety of sports, a greater variety of core tests, and more demographically diverse subjects.

Conclusions

While no significant correlations among the selected tests for core stability, core strength, core power and maximum kicking velocity in healthy Division II college male soccer athletes were reported, an additional test for core stability yielded different results. The significant moderate correlation between the push up test for core stability and kicking velocity indicates that isometric core stability/strength elicited a greater muscular activation due to a larger load placed on the core during a maximal kick. These findings support the current literature in that isometric core stability has a greater contribution to soccer performance measured by standing kick and dynamic style kick for maximum kicking velocity.³

Recommendations

Our findings suggested that it may be necessary to assess core stability with a test involving no limb movements (specifically of the upper and/or lower extremity) in order to identify contribution of the core to athletic performance. Only moderate relationships between core stability sports performance have been reported here and in previous research, further research is needed not only to establish validity and reliability of core tests, but also to quantify the relationship between core function and athletic performance. Our findings support the theory that the core musculature is the kinetic link between the lower and upper body and should directly influence any distal kinetic chain movement. Implications that the core has a significant role in providing a base of support for optimal lower extremity function, and the ability to produce and transfer force to the distal segments during a functional soccer task, specifically maximal kicking velocity could be used in future testing for injury prevention or performance enhancement.

Considering the complexity of the core musculature and its synergic function, however, it may not be important to quantify the relationship for the athletic trainers and allied health care professionals. Whether the relationship between core function and athletic performance is determined or not, it would be more beneficial to have the ability to assess athletes' various aspects of core function and performance, to train athletes with appropriate exercise selections/applications, and to prevent/rehabilitate athletic injury with the concept of kinetic chain, particularly when assessing for return to play. Application of a valid core stability test, such as the trunk stability push-up test (TSPU from the FMS) and other core stability tests involving no limb movements, may help to assess soccer kicking performance after lower extremity injuries.

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APPENDICES

APPENDIX A

Review of literature

REVIEW OF LITERATURE

The purpose of this review of literature is to overview previous studies examining core power and its effect on athletic performance. This literature review includes the following four sections: (1) Review of the Core, (2) Assessment of Core function, (3) Role of the Core in Athletic Performance, and (4) Summary of the research performed to date.

Review of the Core

The core has been identified as a key component for functional athletic performance in the field of sports science.¹⁻⁷ The core is referred as the region of the body that provides an adequate support for upper and lower extremity movements, during athletic performance.⁷ An efficient core provides optimum force production, as well as transfers and controls force and movement in the integrated functional athletic performance.^{3,4,7,8} The basic foundation of the core comes from more than 20 muscles that attach to the lumbo-pelvic-hip complex.^{7,9(p290)} Although some

researchers^{10,11} previously advocated the importance of a few core stabilizers, especially the transversus abdominis and multifidi, all core muscles work synergistically to provide stability and mobility of the spine in order for optimum athletic performance.^{7,9-11} Several researchers have attempted to explain the musculature of lumbo-pelvic-hip complex and its role in rehabilitation and athletic performance in their previous literature.^{7,9 (p295),12} However, the complexity and integrated function of the lumbo-pelvic-hip complex causes confusion regarding the definition of the core; differences among core stability, core strength, and core power; valid assessment of the core stability; and its application to functional athletic performance.¹⁻⁷ Therefore, it is very important to have an understanding of core anatomy and a clear definition of core strength, stability and power in order to assess the functional athletic performance.

Anatomy of the Core

The core is referred to as the "powerhouse," its where breathing and all the physical movements originate in Pilates exercise. The concept of core strength and stabilization was first addresses by Joseph Pilates who

created the Pilates exercise philosophy.¹³ Akuthota et al⁴ have also described the function of the core as being a "powerhouse," the center of the functional kinetic chain, that provides optimum force and power and initiates limb movement.⁴ The researcher⁴ also describe the core as a box that consists of core stabilizers; abdominal muscles in the front, paraspinals and gluteal muscles in the back, the diaphragm on the top, and the pelvic floor and the hip girdle muscles as the bottom. The core musculature works together synergically in order to support the "powerhouse" and provide optimum performance.

Bergmark originally introduced the concept of "global" and "local" core musculature in his literature in 1989.¹² According to Bergmark,¹² the "local" system consists of all the muscles that originate and insert at the vertebrae, with the exception of the psoas muscles. Local muscles are referred to as deep stabilizers and are responsible for the lumbar and thoracic stabilization. Global muscles are more superficial, are responsible for movement of the trunk, and transfers forces from the torso and the pelvis out to the extremities.^{4,7,12} Since Bergmark's classification of local and global system, several researchers have introduced the concept and attempted to explain the function of the lumbo-

pelvic-hip complex with some modifications in their studies.^{2,4,7} Dendas⁷ categorized the transverse abdominis and multifidus as primary local core stabilizers, and internal oblique, medial fibers of the external oblique, quadratus lumborum, diaphragm, pelvic floor muscles, iliocostalis and longissimus as secondary local core stabilizer. The rectus abdominis, lateral fibers of the external obliques, psoas major, and erector spinae were defined as the global core system based on Norris' study.¹⁴ Dendas also included all muscles that attach at the hip or cross the lumbo-pelvic region, such as the gluteals, hamstrings and quadriceps into the global system since the core consists of the musculature of the lumbar, pelvic, and hip regions contribute to spinal stability.⁹ Some researchers^{4,7,15} described the hip musculature as playing a significant role in transferring forces from the lower extremities to the pelvis and spine, and then out to the upper extremity. The lumbo-pelvic-hip complex also contributes to the piriformis and psoas major-iliacus complex that work as synergists and stabilizers of the core.^{4,6} These global core muscles are responsible for spinal orientation and control of external forces on the spine.¹ The large moment arms and long levers of these

muscles allow these global muscles to produce powerful movements and torque.^{5,7}

Core Stability

Although the term of the "core stability" has been very popular in the field of sports science, there is no clear definition of the term "core stability."⁷ It may be because that any musculoskeletal structures of the lumbo-pelvic-hip complex have been used to describe core stability, which include strength of hip and core musculature; core muscle endurance; maintenance of a particular pelvic inclination or of vertebral alignment; and ligamentous laxity of the vertebral column.⁶ Because core stability, core strengthening, and core power are terms that appear to be used interchangeably throughout literature,^{1,7,16} it is important to have a clear definition of core stability and its components including core strength, core endurance and core power.

Core stability can be defined as the ability of lumbo-pelvic-hip complex to stabilize the spine, which is produced by the coordinated efforts of the core musculature and its functions.^{5,7,12,17} Although the core stability is mainly maintained by the "local" core musculature, the

muscles that originate and insert at the vertebrae, with the exception of the psoas muscles, most core muscles, both the local and global stabilizers, must work together synergistically to achieve core stability.^{2,6} According to Tse et al, "the core musculature includes muscles of the trunk and pelvis that are responsible for maintaining the stability of the spine and pelvis and are critical for the transfer of energy from the larger torso to smaller extremities during many sports activities."¹⁸ Kibler et al defines core stability as "the ability to control the position and motion of the trunk over the pelvis to allow optimum production, transfer, and control of force and motion to the terminal segment in integrated athletic activities."¹⁹ According to Willson et al,⁶ core stability functions to effectively recruit the core musculatures and to provide a stable foundation for movements of the upper and lower extremities during athletic performance. Borghuis et al² suggested the role of sensory-motor control of core musculature is responsible for a precise balance between the amount of stability and mobility, compared with the role of strength or endurance of the core musculature. Therefore, appropriate muscle recruitment and timing has a

significant role in creating core stability as a base for all functions of core and extremities.

Finally, Dendas defined core stability as a foundation of all core functions, which is comprised of components including core strength, core power, balance, and coordination.⁷ In short, core stability primarily contributes to optimal neuromuscular efficiency in entire kinetic chain, transfer of force, control of upper and lower extremity in dynamic movement, and production of power.

Core Strength

When discussing the core, it is important to differentiate between core stability and core strength. These two terms are often used interchangeably not only in the literature but also in the practical field. Core stability and core strength differ based on their functions and involved musculature that are used.¹ Cholewicki et al²⁰ defined that core strength is more active control of spine stability achieved through the regulation of force in the surrounding muscles. According to Dendas,²¹ core strength was best described as "a necessity for core stability, meaning that there cannot be one without the other; the

core musculature has to possess both." Since the core works synergically to provide stability and mobility to the spine, core stability and core strength may be confused for one another in the literature and by practitioners.¹⁵

Core Endurance

Core endurance, a component of core stability, can be defined as the ability of the lumbo-pelvic-hip musculature to hold a core contraction for a prolonged time and/or perform repeated contractions over a period of time.^{7,22} Although core strength aids in producing force by maintaining intra-abdominal pressure,⁷ core endurance contributes more to length of time that a muscle or muscle group can hold a neutral stable position. Since core endurance also plays an important role in core stability and strength, it often causes the confusion regarding the definition of core endurance. Lehman¹⁷ has suggested that the core endurance influence to spinal stability is more than muscular strength due to the ability of local core musculature to stabilize the lumbar spine. Several researchers have also suggested that good core endurance reduces back pain.¹⁰⁻¹¹

Core Power

Power is referred as "the product of muscular force and the velocity of muscle shortening" in human biomechanical science.²² Dendas defined power as "the amount of mechanical work done over a certain amount of time" and core power as "explosive concentric contractions of the musculature over a certain amount of time against an object, such as throwing a weighted medicine ball."²³ The core power is commonly measured with use of medicine ball. The assessment includes the medicine ball toss using the overhead and reverse overhead throws. Dendas⁷ suggested that core power is also a component of core stability, which was measured by the medicine ball explosive sit-up throw test and maximum sit-ups in 30 and 60 seconds in the study.⁷ the researcher found a significant relationship between the core power measured with 60s and 30s maximum sit-up tests and athletic performance tested by the relative power clean, relative squat, relative bench press, vertical jump height, 40m sprint time, and 20m sprint time.⁷

Assessment of Core Function

Due to the complexity of the core musculature and its synergic function, the core cannot be assessed with one test or one aspect of core functions.⁷ Although several researchers have attempted to measure core stability and these components as they examined the relationships between core stability and performance,^{7,15-16,24-25} or effects of core training on performance,²⁶⁻³⁰ there is currently no gold standard recommended to assess core stability and its components, which include core strength, core endurance, and core power.^{1,7}

Common methods of core assessment have included isokinetic dynamometer for measures of strength and work, isometric exercises for measures of strength and endurance, and dynamic exercises for measures of strength and power.^{7,15} Isokinetic dynamometry, the Sahrmann test of core stability, and McGill protocol have been mainly used to assess function of the core in clinical or laboratory settings. Other measures using dynamic exercises such as timed sit-ups,⁷ front abdominal power,³¹ side abdominal power,³¹ and double leg lowering,³² were preferred in practical settings, especially in the field of strength and conditioning.

Reliability of core assessments has been established in previous studies using non-athletic populations^{31,33-35} and athletes.^{7,16,24,36-37} According to Baumgartner et al,³⁸ the reliability of most core stability tests was acceptable based on magnitude of the test-retest correlation coefficients. In order to assess the relationship between core and athletic performance, however, further research on validity and reliability of core assessments are needed because previous core assessments have been limited in regards to the sports and performance specificity, including the type of muscular contractions and movement speeds.⁷

Isokinetic Dynamometer for Strength and Work

The use of an isokinetic dynamometer is one of the standard methods of assessing core strength and work.¹⁵ In isokinetics, work is defined as torque multiplied by angular displacement or the area under the torque curve.^{10 (p152-153)} In other words, it is define as the amount of rotational force being produced. It allows researchers to measure three different strength variables (peak torque, total work, and average power) within one testing session.³⁹⁻⁴⁰ Wagner¹⁵ recently used isokinetic dynamometer

during movements of trunk flexion and bi-lateral rotation to assess isometric core strength. Although isokinetic machines have exhibited high reliability coefficients in the previous literature,^{35,38} it is still unknown whether the use of an isokinetic dynamometer is valid in assessing core strength and power to accurately measure force of the intended musculature.¹⁵

Sahrmann's Test for Core Stability

According to Faries and Greenwood, the Sahrmann core stability test is a measurement for the "ability of the core musculature to stabilize the spine with or without motion of the lumbo-pelvic-hip complex."⁴¹ The test consists of five levels with each level increasing in difficulty, progressing from a static position with activating transverse abdominals to positions that incorporate with lower extremity movement. The individual has to maintain the lumbar stabilization with a change of no more than 10 mmHg in pressure on a blood pressure cuff that is placed directly under individual's lumbar spine. Faries and Greenwood⁵ illustrated the Sahrmann assessment protocol as the following.

The level 1 begins in the supine with hip-flexed at 45° degrees and knee-flexed at 90°. The blood pressure cuff then is inflated to 40 mmHg, while the individual flatten out the back, in a drawing-in motion (hollowing), to stabilize the lumbar spine. This abdominal hollowing is the key component of the Sahrman core stability test. If performed correctly, the pressure blood pressure cuff does not change or slightly decrease from the initial 40 mmHg.⁵ At level one, the individual slowly raises one leg to 100° of hip flexion with comfortable knee flexion from supine, hook-lying position with abdominal hollowing. The opposite leg is brought up to same position. At level 2, the individual slowly lowers one leg until the heel contacts the ground from the hip flexed position, and then slides out the leg to full knee extension. The leg returns to the starting flexed position and then alternates the leg. At level 3, the individual performs the same motion as level 2 except the heel contact on ground. The subject is not allowed to contact both heels on ground as lowering the legs at level 3. At level 4, the individual slowly lowers both legs until both heels contact the ground from hip flexed position, and then slides out both legs to full knee extension. At level 5, the individual performs the same

motion as level 4 except heel contact. The subject is not allowed to contact both heels on ground as lowering the legs level 5. Although the Sahrman core stability test has widely used in the clinical setting with established reliability,⁴² its validity is currently unknown in available literature.⁷

McGill Test for Strength and Endurance

When measuring core stability and/or core strength in athletes, some researchers^{16,24,36-37} have assessed core with use of the McGill protocol.³⁴ The McGill protocol was originally established to assess core stability in patients with low-back pain by determining muscle endurance of the core stabilizer muscles.³⁴ This protocol consists of four isometric core endurance tests: trunk flexor test, trunk extensor test, and left and right lateral musculature test. The longer the person holds the position without movement correlates to strong core endurance. The trunk flexor test starts in a sit-up position at 60° from the floor with knees and hips flexed to 90°. The test ends when any part of the individual's back touches the jig that is placed 10 cm away from the back.²⁴ The trunk extensor test is evaluated with the upper body off the supporting bench with

the lower legs secured. The test ends when the upper body drops below the horizontal position from the supporting bench.²⁴ The lateral musculature test is evaluated in the side plank position. The person maintains the full side-bridge position with straight Legs. The person supports the torso on one elbow and on the feet while holding the hips off the floor. The test ends when the person loses the straight-back posture and/or the hip drops to the ground. Dendas⁷ discussed that there has not been reliability coefficients determined for the McGill protocol using football athletes, however, this protocol seemed to be valid as a widely used test to assess core endurance among non-athletic population. Durall et al³⁸ reported intraclass correlation coefficient (ICC) with the range from 0.89 to 0.92 for the McGill protocol in college gymnasts. Dendas reported that only two out of the four individual tests were considered to have "acceptable" reliability where test-retest reliability correlation coefficients of the trunk flexion ($r = 0.828, p = 0.000$) and Left flexion ($r = 0.742, p = 0.000$) were present.⁷ The researcher also found that left and right lateral musculature tests were related to one another ($r = 0.830, p = 0.000$).⁷

Double Leg Lowering Test for Core Strength

The DLLT has been commonly used to assess either core stability or core strength in previous literature.^{25,32,43-44} Sharrock et al suggested that "the DLL test is an appropriate way to measure core stability as it pertains to athletic function"⁴⁵ based on evidence in previous literature, while Krause et al³² reported the DLLT has excellent intra-tester reliability as an assessment of core strength. The researcher³² reported an ICC of 0.98 that for repeated measures of the DLLT. Although the validity of the DLLT has not been shown in the previous literature,^{25,32,43-44} this test has been found to be reliable,³² and the DLLT has been used in several studies.^{25,32,43-44} Thus, the DLLT is a typical method to measure core strength.^{11,13} Prentice described DLLT as the Straight Leg Lowering Test (SLLT), and suggested that core strength can be assessed with using SLLT as well.¹¹

In the current study, the modified DLLT will be used to measure core strength. The angle of the hip is measured with a goniometer will be taken the pressure of the blood pressure cuff drops below 20mmHg.^{43,46} This is unlike the double leg-lowering test, which takes a measurement at 40 mmHg. The angle of the hip interprets strength of core. The

lower the subject can lower the legs correlates to a stronger core.^{32,43-44} The modified DLLT test has shown to be reliable.⁴⁴

60s Maximal Sit Up Test for Core Power

The sit-up test is one of the most common tests used in assessing the core musculature in the practical setting.⁷ It has been used into many training programs as a traditional core exercise because this exercise effectively activates the abdominal and hip flexor muscles at the same time.⁷ According to Dendas,⁷ sit-ups activate mainly the "global" core muscles such as rectus abdominis and internal and external obliques, while minimally activate "local" muscles such as transverse abdominis, to ensure sufficient spinal stiffness.³⁴

Reliability for the timed sit-up tests have previously been established in both of young adults and athletes.^{7,35} Augustsson et al³⁵ examined the reliability of the maximum sit-ups and the 30-second sit-up test in their study. The researchers used ICC for analyses of the test/retest reliability calculated at 95% CI.³⁵ The researchers reported an ICC of 0.92 with a 95% CI of 0.77-0.98 for the maximal number of sit-ups and an ICC of 0.93 with a 95% CI of 0.77-

0.98 for the 30-second maximum sit-up test, suggesting that the tests are highly reliable for both muscular endurance and power testing in young active male and female.³⁵

Recently, Dendas used a test similar to the 60-second maximum sit-up, with a built in 30-second test, in order to assess core power in collegiate Division II football players.⁷ This test starts in the supine position with knees flexed to 90° and hips flexed about 45°. Subjects are required to elbows touch thighs on up portion and then lower the trunk back until the scapulae came in contact with ground, without touching their head or hands. The athlete moves quickly through the repetitive movement pattern. The 60-second maximum sit-up test, with a built in 30-second test, was found to have a high reliability coefficient ($r = 0.862$, $p = 0.000$).⁷ The test is scored as maximal number of correct sit-ups within the 60-second time period.^{7,47}

The Role of the Core in Athletic Performance

Over the past several years, the amount of literature regarding a correlation between core function and athletic performance has significantly increased. Although several

researchers previously showed the effect of core exercise participation on core stability,²⁷⁻³⁰ relatively few studies have attempted to quantify a correlation between the two variables.^{7,15-16,24-25} Regarding previous studies on the relationship between core and sport performance, researchers have suggested that there was little to no correlation between the two variables.^{16,24,48} According to Wagner,¹⁵ a possible reason for these findings was the failure to select appropriate testing methods. The researcher suggested that previous studies did not take into account the physiologic energy systems and movement specificity patterns required by the sport in selecting core assessment.¹⁵ Therefore, recent research^{7,15} has attempted to adapt specific physiologic characteristics and movement patterns of the core musculature into both the core assessment protocols and the sport performance tests.

Core Stability Exercise and Athletic Performance

Sato et al²⁶ investigated the effects of six weeks of participation in a core strengthening program on running kinetics, lower-extremity stability, and 5000 meter performance in runners. Although the researchers provided evidence of a significant effect on running time in the

experimental group after six weeks of training, the core stability test did not significantly influence ground force production and lower-leg stability functions. The researchers concluded that core strength training may be an effective training method for improving performance in runners due to the effect of effect on running time.²⁶ Stanton et al²⁷ examined the effect of a short-term Swiss ball training on core stability and running economy. The researchers assessed core stability using Sahrman's core test, and observed electromyographic (EMG) activity of abdominal and back muscles, VO₂max, and running economy. Since there were no significant differences observed for EMG activity of the abdominal and back muscles, treadmill VO₂max, running economy, or running posture, researchers concluded that Swiss ball training may positively affect core stability without concomitant improvements in physical performance.²⁷ Marshall and Desai²⁸ determined muscle activity of upper body, lower body, and abdominal muscles during advanced Swiss ball exercises with use of EMG analysis. The researchers concluded that performing more complicated Swiss ball exercises may reduce potential benefits due to the practical difficulty and risk. However,

this study provided evidence that advanced Swiss ball exercise provides a significant whole body stimulus.²⁸

Abt et al²⁹ also suggested that improved core stability and core endurance could promote greater alignment of the lower extremity when riding bicycle for extended duration due to the ability of the core to resist to fatigue. It was suggested that core fatigue resulted in altered cycling mechanics that might increase the risk of injury because the knee joint is potentially exposed to greater stress.²⁹

Core Stability and Athletic Performance

To the authors' knowledge, there were only five studies which have investigated the relationship between athletic performance and components of core stability core functions, which include core strength, core endurance, core power, and "core fitness."^{7,15-16,24-25}

The study by Nesser et al¹⁶ was the first study, to the author's knowledge, to examine the relationship between core stability and athletic performance in Division I football athletes. The core stability was assessed using McGill Protocol that consists of back extension, trunk flexion, and left and right bridges. Performance variables included three strength variables; one-repetition maximum

(1RM) bench press, 1RM squat, and 1RM power clean, and four performance variables; countermovement vertical jump, 20 and 40 yard sprints, and a 10 yard shuttle run. The collected data revealed that core stability is moderately related to strength and performance. The researchers¹⁶ concluded that increases in core strength do not contribute significantly to strength and power, and that training programs with emphasis on strength and power should not focus on core stability and strength.¹⁶

Nesser et al²⁴ also investigated the relationships between core stability and various strength and power variables in NCAA Division I female soccer players. The researchers assessed core stability using the McGill protocol (back extension, trunk flexion, and left and right bridges), two strength variables (1RM bench press and 1RM squat), and three performance variables (Countermovement vertical jump, 40 yard sprint, and a 10 yard shuttle run). According to their findings, no significant correlations among core strength, strength, and power were confirmed. The researchers concluded that core strengthening program should not be the focus of strength and conditioning because increases in core strength will not contribute significantly to strength and power.²⁴

Sharrock²⁵ examined the relationship between a core stability test and tests of performance using the double-leg lowering test as a measure of core strength/stability collegiate athletes in a variety of sports. Performance tests included the forty yard dash, the T-test, vertical jump, and a medicine ball throw. Although correlational data results showed a fair to weak relationship between the DLLT as a measure of core stability and the medicine ball throw, no significant correlations between abdominal strength and the T-test ($r = 0.052$), forty-yard dash ($r = 0.138$), and the vertical jump ($r = -0.172$) were reported.³⁰

Recently, two research groups^{7,15} investigated the relationship between core stability and athletic performance in a sports specific manner. These researchers assumed that selecting core tests specific to performance capabilities is a key to investigating the relationship between two variables successfully. By estimating the tests of core stability that has similar movement patterns of the specific athletic performance, researchers were able to analyze the core muscular contributions in dynamic movement. Wagner¹⁵ and Dendas⁷ successfully observed the relationship between the function of the core and athletic performance; although their conclusions were conflicted within the

context of core stability and its effect on athletic performance.

Dendas⁷ investigated the relationship between athletic performance and core stability in Division II football players where core power using Medicine Ball Explosive Sit-up Throw Test (MBESTT) and a 60 second maximum sit-up test with a built-in 30 second test, and core endurance using McGill protocol were used. Performance variables to investigate included 3RM for the power clean, back squat, and bench press, as well as vertical jump height, and 40m sprint time with a 20m split time.⁷

The findings showed that there was a significant relationship between athletic performance and 60 second and 30second maximum sit-up tests, and the McGill trunk flexion test. The 60s maximum sit-up test was significantly correlated with the relative power clean ($r = 0.836$), relative squat ($r = 0.608$), relative bench press ($r = 0.590$), vertical jump height ($r = 0.721$), 40-m sprint time ($r = -0.680$), and 20-m sprint time ($r = -0.803$). The MBESTT was only significantly correlated to the absolute bench press ($r = 0.496$). Although Dendas⁷ hypothesized that MBESTT represented the contribution of the core power, scores on the MBESTT were not related to scores on any of the other

measures of core stability in the study, the researcher concluded that most of the core stability measures had acceptable field-based test reliability.

Wagner¹⁵ identified the relationship between core fitness and tests of soccer sport performance in female soccer players. The researcher defined core fitness as "the combination of isometric core stability and concentric core strength to perform a task of sport performance."⁴⁹ According to the researcher, isometric core strength was used to evaluate the ability of the core to provide a stable base of support with use of a isokinetic dynamometer during movements of trunk flexion and bi-lateral rotation, while concentric functional core strength was used to evaluate the ability of the core to produce and transfer forces to the limbs by performing the front abdominal power test (FAPT) and side abdominal power test (SAPT).¹⁵ The researcher compared these two core tests with the soccer kick and throw-in to see which core function played a greater role in soccer athletic performance. The researchers assessed isometric core strength while they assessed concentric functional core strength. The researchers concluded that the isometric core strength correlated more strongly with tests of soccer sport

performance than concentric functional core strength, as opposed to other previous studies and their own hypothesis.¹⁵ The researcher explained the results that "the isometric tests had a much larger load placed on them, which elicited a greater muscular activation and could explain why there was a greater correlation with tests of soccer sport performance."^{21(vi)} Wagner's finding suggested that isometric core stability has a greater contribution to soccer performance (kicking and throw-in) than concentric functional core strength. Although both researchers^{7,15} have established valid assessments of core and athletic performance, their findings leaves the question, which type of core function has a greater contribution to athletic performance?

Core in Soccer Kicking

Theoretically, the core musculature links the lower and upper body in the kinetic chain and directly influences the control and force production of the kicking motion.¹⁵ In approaching a soccer ball for a kick, the core musculature helps to stabilize the spine and produce maximum force into the ball by which the core musculature co-contract and increase intra-abdominal pressure.

The soccer kick significantly depends on various factors including the strength of musculature of lower extremity, the distance of the kick from the goal, the type of kick used, the air resistance, the rate of rapid movement of knee flexion and extension, and any other biomechanical factors.⁵⁰ Kellis et al⁵⁰ examined research findings on the biomechanics of soccer kick performance and identified weaknesses of present research. The researchers also summarized previous studies of muscle activation during the kick. According to Kellis et al,⁵⁰ previous researchers have examined muscle activation patterns of the iliopsoas, rectus femoris, vastus lateralis, vastus medialis, biceps femoris, gluteus maximus, semitendinosus, and tibialis anterior during the kick with use of EMG.

Dorge et al⁵¹ examined the EMG activity of hip flexion, knee extension and ankle plantarflexion moments (N·m) during soccer kicking. The researchers observed a high activation of iliopsoas during the backswing phase in the soccer kicking. The findings suggested a high activation of the iliopsoas during the beginning of the kicking which was followed by a high activation of the rectus femoris during backswing. In turn, high activation of vastus lateralis was observed during forward swing phase.⁵⁰⁻⁵¹ The researchers

also suggested that the EMG activity levels correspond to the proximal-to-distal pattern of segmental angular velocities for kick performance. Although there are a few studies that examined muscle activation patterns during the soccer kick,⁵⁰ the muscles examined were mostly lower extremity and hip flexors; no literature was found regarding the activation of abdominal muscles and other core musculature. According to the researcher's knowledge, only one previous study exists that examined the relationship between kicking speed and core measures.¹⁵

Summary

In summary, various reasons exist as to why previous research has not been able to firmly establish the role that the core plays in sport performance. It can be mainly because the complexity and integrated function of the lumbo-pelvic-hip complex causes confusion regarding the definition of the core, differences among core stability, core strength, and core power, valid assessment of the core stability, and/or its application to functional athletic performance.¹⁻⁷ Although several researchers previously showed the effect of core exercise participation on core

stability,²⁶⁻³⁰ relatively few studies have attempted to quantify a correlation between the core function and athletic performance.^{7,15-16,24-25} As mentioned in Wagner's study,¹⁵ a possible reason for these findings was the failure to select appropriate testing methods. Thus, the literature suggests that further research should focus on the specific physiologic characteristics and movement patterns of the core musculature when choosing the core assessment protocols and the sport performance tests. Apparently, core function can be associated with upper or lower extremity movement as long as those movements are similar to the specific athletic performance.^{7,15}

APPENDIX B

The Problem

STATEMENT OF THE PROBLEM

The correlation between core stability and athletic performance has not been determined in the available literature. Although several researchers have attempted to quantify the relationship between core stability/strength and functional performance, recent researchers suggested that further research is needed to investigate important components of core stability and the measurement of core stability in relation to athletic performance.^{7,25}

Therefore, the primary purpose of this study was to examine the relationship the primary purpose of this study is to examine the relationship among core power, core strength, core stability, and athletic performance in college soccer athletes. It is important to examine the correlation to assess core power and its effect on athletic performance because core power is an integrated component of core stability, strength and endurance among dynamic movement.

In addition to the lack of current scientific evidence to support the correlation between core and athletic performance, a valid core assessment has not established yet. Therefore, the secondary purpose of this study is to

establish a valid assessment of core. It would be beneficial to clarify the definition of core power, as a component of core stability, and its effect on performance in the field of sports science.

Definition of Terms

The following definitions of terms were defined for this study:

- 1) Core power - the combination of isometric core stability and concentric core strength to perform a task of sport performance that needs to produce maximum speed and/or strength.¹⁵
- 2) Core stability - the ability to control the position and motion of the lumbo-pelvic-hip complex to allow optimum production, transfer, and control of force and motion to the terminal segment in integrated athletic activities.^{3,15}
- 3) Core strength - the ability of the musculature to generate force through contractile forces and intra-abdominal pressure.¹⁵
- 4) Dynamic balance - the ability to maintain equilibrium or the center of gravity with proper body alignment in motion.⁵²

- 5) Functional balance - the ability to maintain dynamic balance for optimal extremity function, producing and transferring force to the distal segments during dynamic movement.
- 6) Work - torque multiplied by angular displacement.^{10 (p152-153)} In other words, it is the area under the torque curve where the torque curve is torque against angular displacement.¹⁰

Basic Assumptions

The following are basic assumptions of this study:

- 1) The subjects will be honest when they complete their demographic sheets.
- 2) The subjects will perform to the best of their ability during testing sessions and adhere to the pre-test conditions
- 3) All tests and procedures are valid and reliable as previously determined in the literature.

Limitations of the Study

The following is a possible limitation of the study:

The results in this study may be only applicable to Division II men's soccer players.

Significance of the Study

The purpose of the study was to examine whether the core has a significant role in providing a base of support for optimal lower extremity function and the ability to produce and transfer force to the distal segments during a functional soccer task, specifically maximal kicking velocity. This study may be able to provide not only a better explanation of the relationship between the core and sport performance, but also a better concept of core stability that is a base of all core functions. It may be able to provide better idea of preventing and rehabilitating athletic injury with the concept of kinetic chain. It will also guide future studies that improve training and sport performance with use of core training.

APPENDIX C

Additional Methods

APPENDIX C1

Informed Consent Form

A Correlation Among Core Stability, Core Strength,
Core Power, and Kicking Velocity in Division II
College Soccer Athletes– Informed Consent

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California University
of Pennsylvania

Informed Consent Form

1. *Atsuko Takatani*, who is a Graduate Athletic Training Student at California University of Pennsylvania, has requested my participation in a research study at California University of Pennsylvania. The title of the research is *a correlation among core stability, core strength, core power, and kicking velocity in Division II college soccer athletes*.
2. I have been informed that the purpose of this study is to examine the relationship between core function and athletic performance in NCAA Division II collegiate soccer athletes. I understand that I must be 18 years of age or older to participate. I understand that I have been asked to participate along with actively practicing and competing in the varsity men's soccer team at California University of Pennsylvania.
3. I have been invited to participate in this research project. My participation is voluntary and I can choose to discontinue my participation at any time without penalty or loss of benefits. My participation will involve 3 core tests and 1 performance test. The three core tests are core power test using 60 second maximum sit-up test, core strength test using the double leg lowering test, and core stability test using the Rotatory Stability test. Performance testing will involve dynamic soccer-style kick for maximal speed. I will be tested after completing the Functional Movement Screen (FMS) as my warm-up. The Rotatory Stability test, included in the FMS, which will be assessed by a peer researcher who is a certified FMS specialist, will be recorded as part of my core stability data. My participation in this study will consist of an orientation meeting with a practice trial of each test on Day 1 and two meeting days for testing on Day 2 (core tests) and Day 3 (kicking test). All of the testing will be conducted on in the Phillipsburg soccer complex. All of the core testing will be conducted in the training room on Day 2 and performance testing will be conducted at the soccer field on Day 3, for approximately 20-30 minutes on each of the two days for each subject.
4. I understand there are foreseeable risks or discomforts to me if I agree to participate in the study. With participation in a research program such as this there is always the potential for unforeseeable risks as well. The risk is no more than normal physical activity that collegiate athletes would be exposed during soccer practice or performance. There is limited risk involved with core testing and maximum soccer kicking which may include muscle soreness or strain. I will perform warm-up prior to core testing and performance testing to prepare for the performance testing and minimize associated risks. Any injuries that may occur during the core and performance testing can be treated at the athletic training room at Phillipsburg soccer

A Correlation Among Core Stability, Core Strength, Core Power, and Kicking Velocity in Division II College Soccer Athletes– Informed Consent | Page2

complex provided by the researcher, Atsuko Takatani, a certified athletic trainer from California University of Pennsylvania.

5. I understand that, in case of injury, I can expect to receive treatment or care in Hamer Hall's Athletic Training Facility. This treatment will be provided by the researcher, Atsuko Takatani, a certified athletic trainer. Additional services needed for prolonged care will be referred to the attending staff at the Downey Garofola Health Services located on campus.

6. There are no feasible alternative procedures available for this study.

7. I understand that the possible benefits of my participation in the research is to help determine whether the core has a significant role in providing a base of support for optimal lower extremity function and the ability to produce and transfer force to the distal segments during a functional soccer task, specifically maximal kicking velocity. This study will be able to provide not only a better explanation of the relationship between the core and sport performance, but also a better concept of core stability that is a base of all core functions. Results may also guide future studies that improve training and sport performance with use of core training.

8. I understand that the results of the research study may be published but my name or identity will not be revealed. Only aggregate data will be reported. In order to maintain confidentiality of my records, Atsuko Takatani will maintain all documents in a secure location on campus and password protect all electronic files so that only the student researcher and research advisor can access the data. Each subject will be given a specific subject number to represent his or her name so as to protect the anonymity of each subject.

9. I have been informed that I will not be compensated for my participation.

10. I have been informed that any questions I have concerning the research study or my participation in it, before or after my consent, will be answered by:

Atsuko Takatani, MA, ATC
STUDENT/PRIMARY RESEARCHER
tak6094@calu.edu
724-518-1064

Rebecca Hess, PhD
RESEARCH ADVISOR
hess_ra@calu.edu
724-938-4359

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Core Power, and Kicking Velocity in Division II
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11. I understand that written responses may be used in quotations for publication but my identity will remain anonymous.

12. I have read the above information and am electing to participate in this study. The nature, demands, risks, and benefits of the project have been explained to me. I knowingly assume the risks involved, and understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefit to myself. In signing this consent form, I am not waiving any legal claims, rights, or remedies. A copy of this consent form will be given to me upon request.

13. This study has been approved by the California University of Pennsylvania Institutional Review Board.

14. The IRB approval dates for this project are from: NN/NN/NN to MM/MM/MM.

Subject's signature: _____ Date: _____

Witness signature: _____ Date: _____

Appendix C2

Subject Information/Individual Data Collection Sheet

Subject Information/Data collection Sheet

Subject # _____

Date _____

Date of Birth (Age): _____ (____) Position: _____

Type of kick used: Toe kick / Top of the foot / In-step (Please circle one)Kicking leg: Right / Left Year of soccer experience: _____

RS* Score (Right)	RS 2 Score (Left)	RS Final Score	
60s sit-ups # 1			
DLLT angle 1	DLLT angle 2	DLLT angle 3	AVG
kicking Velocity 1	kicking Velocity 2	kicking Velocity 3	AVG

APPENDIX C3

Institutional Review Board -
California University of Pennsylvania



California University
of Pennsylvania

Proposal Number
Date Received

PROTOCOL for Research Involving
Human Subjects

Institutional Review Board (IRB) approval is required before beginning any research and/or data collection involving human subjects

(Reference IRB Policies and Procedures for clarification)

<i>Project Title</i> <u>A CORRELATION AMONG CORE STABILITY, CORE STRENGTH, CORE POWER, AND KICKING VELOCITY IN DIVISION II COLLEGE SOCCER ATHLETES</u>	
<i>Researcher/Project Director</i> <u>Atsuko Takatani</u>	
<i>Phone #</i> <u>724-518-1064</u>	<i>E-mail Address</i> <u>tak6094@calu.edu</u>
<i>Faculty Sponsor (if required)</i> <u>Dr. Rebecca Hess</u>	
<i>Department</i> <u>Health Science</u>	
<i>Project Dates</i> <u>January 1st, 2012 to December 31st, 2012</u>	
<i>Sponsoring Agent (if applicable)</i> <u>N/A</u>	
<i>Project to be Conducted at</i> <u>California University of Pennsylvania</u>	
<i>Project Purpose:</i> <input checked="" type="checkbox"/> <i>Thesis</i> <input type="checkbox"/> <i>Research</i> <input type="checkbox"/> <i>Class Project</i> <input type="checkbox"/> <i>Other</i>	
Keep a copy of this form for your records.	

Please attach a typed, detailed summary of your project AND complete items 2 through 6.

1. *Provide an overview of your project-proposal describing what you plan to do and how you will go about doing it. Include any hypothesis(es) or research questions that might be involved and explain how the information you gather will be analyzed. For a complete list of what should be included in your summary, please refer to Appendix B of the IRB Policies and Procedures Manual.*

The purpose of the present study is to examine the relationship among core power, core strength, core stability, and athletic performance in college male soccer athletes. A correlational design will be used to determine whether core stability (the Rotatory Stability test), core strength (the Double Leg Lowering test) and power (the 60s Maximum Sit-Up test) are related to soccer performance (kicking speed). The instruments used in this study are a Subject Information Sheet/ Data Collection Sheet, the Rotary Stability Test (RS), the 60s Maximum Sit-Up test (60s MSUT), the Double Leg Lowering test (DLLT) utilizing a blood pressure cuff and 360° universal goniometer, and the soccer kicking test utilizing a JUGS™ radar gun. All equipment is included in Appendix A.

Demographic information will be collected on a Subject Information/Data Collection Sheet (Appendix B). The survey form included questions regarding: (a) date of birth (age); (b) type of kick used; (c) kicking leg; (d) years of soccer experience.

The Rotatory Stability Test (RS) is one of seven tests used to test functional movement by the Functional Movement Screen (FMS), and will be used to grade core stability. The FMS is an assessment tool comprised of 7 different movements to identify asymmetry and dysfunctions of movement pattern within the body. This RS test consists of multi-plane trunk stability during a combination of asymmetric upper and lower extremity movement, which requires proper neuromuscular coordination and energy transfer through the trunk (Appendix C1). Not only the FMS has been widely used, but the reliability of the FMS has been established (1). The ranges of scores on the FMS are from zero to three; three being the best possible score (2). A score of three is given if the subject performs the movement of RS correctly without any compensation (Appendix C1_Figure 4). A score of two is given if the person is able to complete the movement with compensation (Appendix C1_Figure 5). If the requirements for a score of two are not met, then a score of a 1 is given (Appendix C1_Figure 6). If there is pain with the movement, a final score of a zero will be given for the RS.

The modified Double Leg Lowering Test (DLLT) will be used to grade core strength (Appendix C2). The test is adopted from Zingaro's study (3). The lower the subject can lower the legs correlates to a stronger core (3-5). The degree from starting point (hip flexed to 90°) to ending point will be used for data analysis. A blood pressure cuff will be used to measure the pressure under the back during the DLLT. A 12-inch, 360° degree universal goniometer will be used to measure the angle of hip flexion during the core strength testing. The angle of the hip from 90° of hip flexion will be measured with a goniometer will be taken when the pressure of the blood pressure cuff drops below 20mmHg (3). This is unlike the double leg-lowering test, which takes a measurement at 40 mmHg. This test has been found to be reliable; the ICC for repeated measures of the DLLT was 0.98 (4). Core strength will be interpreted by the hip angle at the time of pressure change where a greater angle will indicate greater core strength. Average score of three trials will be used for data analysis (3). The lengthy in depth directions of the test are described in Appendix D.

Core power will be measured by the 60s Maximum Sit-Up test (60s MSUT) (Appendix C3). The 60s MSUT was adopted from similar tests described by Dendas (6). Each up-down cycle counted as a successful repetition of the sit-up. The subject have to flex the trunk up until the elbows touch the thighs and then lower the trunk back until the scapulae came in contact with ground for the successful sit-up. The test is scored as maximal number of correct sit-ups within the 60-second time period (6). Higher numbers of repetitions indicate better core power. Subjects will only perform one sit-up trial per testing session. Reliability for the timed sit-up tests has previously been established (6,7). Dendas reported that test-retest reliability coefficients for 60s timed sit-up test was statistically significant ($r = 0.862$) (6). Augustsson et al also reported an ICC of 0.93 with a 95% confidence interval of 0.77 (7). The lengthy in depth directions of the test are described in Appendix D.

Prior to kicking assessment, the subjects will perform a series of dynamic warm-up exercises adapted from Wagner's study (dynamic stretch)(8) and studies by Sedano et al (kicking/passing warm-up)(9,10). The warm-up will consist of 2 laps of jogging, 10 yards of forward lunges, backward lunges, lateral squat, high knees, butt kickers, side shuffle, Carioca, A-skip, and power skip. This warm-up was adapted from Wagner's study (8). The subjects will have kicking/passing warm-up with another subject for 5 minutes (9,10). Soccer performance will be evaluated with a dynamic soccer-style kick for maximal speed. The speed of a dynamic instep or shoelace kick while attempting to kick a dead ball as hard as possible will be used to seek the dynamic stability of the core in the current study (8). The maximum kicking velocity (meters per second, m/s) will be assessed with use of the JUGS™ radar gun (Jugs Sports, Tualatin, OR), which will be placed behind the soccer goal. The ball will be placed 5 m from where the ball was struck (9, 10). The radar gun will be fixed on a tripod located at 50 cm high and perpendicular to the direction of launch (9,10). The radar gun is a good instrument to measure soccer kicking velocity (9). According to Sedano et al, the speed of soccer kicking measured by a radar gun and the measurement protocol was validated by a photogrammetry system (9). A value of $R_{xy} = 0.998$ was obtained in this study (9). Sedano et al also showed a positive correlation ($R_{xy} = 0.994$, $p < 0.05$) between the maximal kicking speeds registered by the radar gun and those recorded by the high speed video camera with use of the protocol (10). The JUGS™ radar gun has a reported accuracy of ± 0.4 display unit and range of speeds of 40-200kph (11). Using a radar gun to measure the soccer kicking velocity of the ball has been reported to be reliable (10). The radar gun will be calibrated by manufacture instruction prior to the study. A standard size five soccer ball will be used for the test. Higher speeds will indicate better kicking performance in this case. The subjects will have 2 practice trials. The 3 kicks after the practice trials will be recorded. The lengthy in depth directions of the test are described in Appendix D.

Once approved by the Institutional Review Board at California University of Pennsylvania, preliminary research will be performed prior to beginning the research study. The researcher will conduct trials with the core tests; the 60s MSUT and the DLLT, and the soccer kicking test. The researcher will conduct the preliminary testing as described in the lengthy in depth directions (Appendix D). The researcher will be familiar with the equipment including; blood pressure cuff; 360° universal goniometry and JUGS™ radar gun (Appendix A). These preliminary trials will be conducted on two physically active students within the same age-range as the desired subjects. Preliminary testing will also help to determine a time frame for testing sessions and to identify any modifications that will be made to the testing procedures. The study will take place over a 3-day period which will consist of an orientation meeting with a practice trial of each test on Day 1 and two meeting days for testing on Day 2 and Day 3. Orientation and testing will be conducted at the Phillipsburg soccer complex at California University of Pennsylvania.

On Day 1, the researcher will have a meeting with all potential subjects and explain the concept of the study and offer the Informed Consent Form (Appendix E) in order for them to understand the requirements and risks of involvement in the study. Qualifications for the subjects (mentioned in the subject section), requirements, testing date (approximately 7 days later), and approximate time frame for entire study, 20 minutes on each of the two testing days, will also be announced. Then the subjects, who meet the qualifications, will have a practice session for all core tests. All subjects, who meet the qualifications, will be asked to participate in the rest of the study. Day 2 consists of a warm up using the FMS, measurement of two core assessments. Prior to the core testing session, the subjects will perform the FMS assessed by a peer researcher who is a certified FMS specialist. The following testing will be performed in the following order; Core stability test (Rotatory Stability test as a part of the FMS); Core strength test (DLLT); Core power test (60s MSUT). Day 3 consists of a series of dynamic warm ups and soccer performance assessment (Soccer kicking test).

The following 7 tests in the FMS will be conducted by a peer researcher who possesses the FMS certification. The assessment variables include: (1) Deep Squat; (2) Hurdle Step; (3) In-line Lunge; (4) Shoulder mobility; (5) Active Straight Leg Raise; (6) Trunk Stability Push Up; (7) Rotatory Stability. Scores of the RS will be used as the assessment of core stability in the current study.

For the RS, the subject will be in a quadruped position with shoulders and hips at 90° relative to the torso with the FMS kit, a 2x6 in board (Appendix A, Figure 1), parallel to the spine in between the hands and the knees. The ankles will be in a dorsiflexed position. The subject will then flex the shoulder while extending

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the same-side hip and knee, and then slowly bring the elbow to the same-side knee while remaining in line over the board. For a score of a 3 on the RS, the subject must perform the task correctly using the same-side leg and arm while keeping the torso parallel to the FMS kit board and keeping the elbow and knee in line with the FMS kit board (Appendix C1_Figure 4). A score of a 2 is given, the subject performs a diagonal pattern using the opposite shoulder and hip in the same manner as for a score of a 3 (Appendix C1_Figure 5). The knee and opposite elbow must make contact over the FMS kit. If the requirements for a score of a 2 are not met, then a score of a 1 is given (Appendix C1_Figure 6). If there is pain with the movement, a final score of a zero will be given for the RS test. The researcher views the movement from the side of the subject. After completing the FMS, the subjects will move to the core testing session. All subjects will perform the core tests in the following order; DLLT; 60s MSUT.

The DLLT begins with the athlete in a supine position. A blood pressure cuff will be placed beneath the umbilicus. Once the cuff is placed in a correct position, the subject will flex his hips into 90° with full knee extension and arms laid along the side of the body with hands palm down on the field (Appendix C2_Figure 7). However, the knees may be flexed slightly to reduce tension on the hamstrings, which will allow subjects to flex their hips to 90°. The goniometer will be placed at the hip joint. The stationary arm will be placed parallel to the mid axillary line of the torso (parallel to the table) and the moveable arm will be parallel to the longitudinal axis of the femur (3). The athlete will be instructed to relax the abdominal muscles to 20 mmHg and told to 'flatten out the back,' in a drawing-in motion, to stabilize the lumbar spine and increase the pressure of the cuff to 40 mmHg (3). Then the legs will be slowly lowered, maintaining the posterior pelvic tilt until the pressure of the cuff drops below 20mmHg (Appendix C2_Figure 8). The subject's legs will be held by the researcher once the pressure of the cuff gets to below 20mmHg or when this pelvic position can no longer be maintained. Then the goniometer measurement of hip joint will be taken while being held the legs so that the athlete does not have to keep contraction of the abdominal muscles and hold the leg position during the goniometer measurement. The subject will perform the test three times with one minute rest in between each trial. Average score from three trials will be used for data analysis. Athletes will have a rest for two minutes before moving to the 60s MSUT.

For the 60s MSUT, the subject lie supine with knees flexed to 90° and hips flexed about 45°. Fingers are interlocked behind the neck and the backs of the hands will touch the field (Appendix C3_Figure 9). The feet will be together and another subject will step on the subject's toes to stabilize. On the command "go", the subject will begin flexing the trunk to perform the sit up until the elbows touch the thighs (Appendix C3_Figure 10) and then lower the trunk back until the scapulae come into contact with ground without touching their head or hands to the ground for 60 seconds timed by a stopwatch. At 60 seconds, the researcher will record the number of successful repetitions. Subjects will only perform one sit-up trial per testing session (6). After the core test, the subject will be taken to the soccer field for warm-up and kicking test.

Prior to kicking test, the subjects will perform a series of dynamic warm-up exercises selected from their soccer practice and those used in previous research (8). The warm-up will consist of 2 laps of jogging, 10 yards of forward lunges, backward lunges, lateral squat, high knees, butt kickers, side shuffle, Carioca, A-skip, and power skip. The subjects start with 2 laps of jogging from the start point, and then will be instructed dynamic warm up at the station where the cones are set up for the dynamic warm-up. The subjects will have kicking/passing warm-up with another subject for 5 minutes (9,10). Then the subjects will be taken to the area where the kicking test will take place.

Soccer performance will be evaluated with a dynamic soccer-style kick for maximal speed. Each subject is allowed to choose the distance for their run-up to a stationary ball as well as the type of kick (instep or shoelace). The subject will approach to the ball from the starting point, produce a counter movement swing with the kicking leg, and kick the ball as hard as possible towards the radar gun. The researcher records the speed using the radar gun. The subjects will have 2 practice trials. Then 3 kicks after the practice trials will be recorded. The subject will have 90 second rest in between each trial. The average of three kicks will be used for data analysis.

My hypothesis is that there will be a positive correlation among core power, core strength, core stability, and peak kicking velocity. An alpha level of < 0.05 will be used for all statistical tests. SPSS version 18.0 for Windows will be used for all statistical analyses. The research hypothesis will be analyzed using a Pearson Product Moment correlation to determine any relationship among core power, core strength, core stability and soccer kicking velocity.

References

1. Minick K, Kiesel K, Burton L, Taylor A, Plisky P, and Butler R. Interrater reliability of the Functional Movement Screen. *J Strength Cond Res.* 2010;24(2): 479-486.
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 10. Sedano S, Vaeyens R, Philippaerts R, Redondo J, De Benito A, Cuadrado G. Effect of lower-lomb plyometric training on body composition, explosive strength, and kicking speed in female soccer players. *J Strength Cond Res.* 2009;23(6):1714-1722.
 11. Jugs [package insert]. Tualatin, OR: JUGS Sports Inc.
2. *Section 46.11 of the Federal Regulations state that research proposals involving human subjects must satisfy certain requirements before the IRB can grant approval. You should describe in detail how the following requirements will be satisfied. Be sure to address each area separately.*
- a. *How will you insure that any risks to subjects are minimized? If there are potential risks, describe what will be done to minimize these risks. If there are risks, describe why the risks to participants are reasonable in relation to the anticipated benefits.*

The risk of injury is minimal because soccer players are used to kicking and performing core exercises. However, the researcher's knowledge of a proper warm-up before testing will minimize these risks further. Additionally, all subjects will have passed a preseason physical conducted by the team physician. In the event of an injury, care will be provided by the researcher, a certified athletic trainer. If additional care is needed the subject will be referred to the Health Center. All information will remain confidential through the use of subject numbers and no names on data collection sheets.

6

- b. *How will you insure that the selection of subjects is equitable? Take into account your purpose(s). Be sure you address research problems involving vulnerable populations such as children, prisoners, pregnant women, mentally disabled persons, and economically or educationally disadvantaged persons. If this is an in-class project describe how you will minimize the possibility that students will feel coerced.*

The subjects will be volunteer male student athletes from California University of Pennsylvania's (NCAA Division II) Men's soccer team (n~20). The subjects will be of the same training level within their team and had have had some familiarity with the testing protocols; core training and soccer style kicking as a part of their soccer experience. The subjects will need to be actively participating and competing in the varsity soccer team at the time of testing.

- c. *How will you obtain informed consent from each participant or the subject's legally authorized representative and ensure that all consent forms are appropriately documented? Be sure to attach a copy of your consent form to the project summary.*

The subjects will be given time to read over and sign the informed consent form on the orientation meeting day.

- d. *Show that the research plan makes provisions to monitor the data collected to insure the safety of all subjects. This includes the privacy of subjects' responses and provisions for maintaining the security and confidentiality of the data.*

The subjects will be given a subject number for collection of all data. All data sheets will be stored in a locked filing cabinet in the Graduate Athletic Training Program Director's office. Only the student researcher and faculty advisor will have access to the data.

3. *Check the appropriate box(es) that describe the subjects you plan to use.*

<input checked="" type="checkbox"/> <i>Adult volunteers</i>	<input type="checkbox"/> <i>Mentally Disabled People</i>
<input checked="" type="checkbox"/> <i>CAL University Students</i>	<input type="checkbox"/> <i>Economically Disadvantaged People</i>
<input type="checkbox"/> <i>Other Students</i>	<input type="checkbox"/> <i>Educationally Disadvantaged People</i>
<input type="checkbox"/> <i>Prisoners</i>	<input type="checkbox"/> <i>Fetuses or fetal material</i>
<input type="checkbox"/> <i>Pregnant Women</i>	<input type="checkbox"/> <i>Children Under 18</i>
<input type="checkbox"/> <i>Physically Handicapped People</i>	<input type="checkbox"/> <i>Neonates</i>

4. *Is remuneration involved in your project?* *Yes* or *No*. *If yes, Explain here.*
5. *Is this project part of a grant?* *Yes* or *No* *If yes, provide the following information:*
Title of the Grant Proposal _____
Name of the Funding Agency _____
Dates of the Project Period _____
6. *Does your project involve the debriefing of those who participated?* *Yes* or *No*
If Yes, explain the debriefing process here.

Approved, September 12, 2005 / (updated 02-09-09)

7. *If your project involves a questionnaire interview, ensure that it meets the requirements of Appendix ___⁷ in the Policies and Procedures Manual.*

California University of Pennsylvania Institutional Review Board
Survey/Interview/Questionnaire Consent Checklist (v021209)

This form MUST accompany all IRB review requests

Does your research involve ONLY a survey, interview or questionnaire?

YES—Complete this form

NO—You MUST complete the “Informed Consent Checklist”—skip the remainder of this form

Does your survey/interview/questionnaire cover letter or explanatory statement include:

- (1) Statement about the general nature of the survey and how the data will be used?
- (2) Statement as to who the primary researcher is, including name, phone, and email address?
- (3) FOR ALL STUDENTS: Is the faculty advisor’s name and contact information provided?
- (4) Statement that participation is voluntary?
- (5) Statement that participation may be discontinued at any time without penalty and all data discarded?
- (6) Statement that the results are confidential?
- (7) Statement that results are anonymous?
- (8) Statement as to level of risk anticipated or that minimal risk is anticipated? (NOTE: If more than minimal risk is anticipated, a full consent form is required—and the Informed Consent Checklist must be completed)
- (9) Statement that returning the survey is an indication of consent to use the data?
- (10) Who to contact regarding the project and how to contact this person?
- (11) Statement as to where the results will be housed and how maintained? (unless otherwise approved by the IRB, must be a secure location on University premises)
- (12) Is there text equivalent to: “Approved by the California University of Pennsylvania Institutional Review Board. This approval is effective nn/nn/nn and expires mm/mm/mm”? (the actual dates will be specified in the approval notice from the IRB)?
- (13) FOR ELECTRONIC/WEBSITE SURVEYS: Does the text of the cover letter or explanatory statement appear before any data is requested from the participant?
- (14) FOR ELECTONIC/WEBSITE SURVEYS: Can the participant discontinue participation at any point in the process and all data is immediately discarded?

**California University of Pennsylvania Institutional Review Board
Informed Consent Checklist (v021209)**

This form MUST accompany all IRB review requests

Does your research involve ONLY a survey, interview, or questionnaire?

YES—DO NOT complete this form. You MUST complete the “Survey/Interview/Questionnaire Consent Checklist” instead.

NO—Complete the remainder of this form.

1. Introduction (check each)

(1.1) Is there a statement that the study involves research?

(1.2) Is there an explanation of the purpose of the research?

2. Is the participant. (check each)

(2.1) Given an invitation to participate?

(2.2) Told why he/she was selected.

(2.3) Told the expected duration of the participation.

(2.4) Informed that participation is voluntary?

(2.5) Informed that all records are confidential?

(2.6) Told that he/she may withdraw from the research at any time without penalty or loss of benefits?

(2.7) 18 years of age or older? (if not, see Section #9, Special Considerations below)

3. Procedures (check each).

(3.1) Are the procedures identified and explained?

(3.2) Are the procedures that are being investigated clearly identified?

(3.3) Are treatment conditions identified?

4. Risks and discomforts. (check each)

(4.1) Are foreseeable risks or discomforts identified?

(4.2) Is the likelihood of any risks or discomforts identified?

(4.3) Is there a description of the steps that will be taken to minimize any risks or discomforts?

(4.4) Is there an acknowledgement of potentially unforeseeable risks?

(4.5) Is the participant informed about what treatment or follow up courses of action are available should there be some physical, emotional, or psychological harm?

(4.6) Is there a description of the benefits, if any, to the participant or to others that may be reasonably expected from the research and an estimate of the likelihood of these benefits?

(4.7) Is there a disclosure of any appropriate alternative procedures or courses of treatment that might be advantageous to the participant?

5. Records and documentation. (check each)

(5.1) Is there a statement describing how records will be kept confidential?

(5.2) Is there a statement as to where the records will be kept and that this is a secure location?

(5.3) Is there a statement as to who will have access to the records?

6. For research involving more than minimal risk (check each),

- (6.1) Is there an explanation and description of any compensation and other medical or counseling treatments that are available if the participants are injured through participation?
- (6.2) Is there a statement where further information can be obtained regarding the treatments?
- (6.3) Is there information regarding who to contact in the event of research-related injury?

7. Contacts.(check each)

- (7.1) Is the participant given a list of contacts for answers to questions about the research and the participant's rights?
- (7.2) Is the principal researcher identified with name and phone number and email address?
- (7.3) FOR ALL STUDENTS: Is the faculty advisor's name and contact information provided?

8. General Considerations (check each)

- (8.1) Is there a statement indicating that the participant is making a decision whether or not to participate, and that his/her signature indicates that he/she has decided to participate having read and discussed the information in the informed consent?
- (8.2) Are all technical terms fully explained to the participant?
- (8.3) Is the informed consent written at a level that the participant can understand?
- (8.4) Is there text equivalent to: "Approved by the California University of Pennsylvania Institutional Review Board. This approval is effective nn/nn/nn and expires mm/mm/nn"? (the actual dates will be specified in the approval notice from the IRB)

9. Specific Considerations (check as appropriate)

- (9.1) If the participant is or may become pregnant is there a statement that the particular treatment or procedure may involve risks, foreseeable or currently unforeseeable, to the participant or to the embryo or fetus?
- (9.2) Is there a statement specifying the circumstances in which the participation may be terminated by the investigator without the participant's consent?
- (9.3) Are any costs to the participant clearly spelled out?
- (9.4) If the participant desires to withdraw from the research, are procedures for orderly termination spelled out?
- (9.5) Is there a statement that the Principal Investigator will inform the participant or any significant new findings developed during the research that may affect them and influence their willingness to continue participation?
- (9.6) Is the participant is less than 18 years of age? If so, a parent or guardian must sign the consent form and assent must be obtained from the child
 - Is the consent form written in such a manner that it is clear that the parent/guardian is giving permission for their child to participate?
 - Is a child assent form being used?
 - Does the assent form (if used) clearly indicate that the child can freely refuse to participate or discontinue participation at any time without penalty or coercion?
- (9.7) Are all consent and assent forms written at a level that the intended participant can understand? (generally, 8th grade level for adults, age-appropriate for children)

California University of Pennsylvania Institutional Review Board
Review Request Checklist (v021209)

This form **MUST** accompany all IRB review requests.
 Unless otherwise specified, **ALL** items must be present in your review request.

Have you:

(1.0) FOR ALL STUDIES: Completed ALL items on the Review Request Form?

Pay particular attention to:

(1.1) Names and email addresses of all investigators

(1.1.1) FOR ALL STUDENTS: use only your CalU email address)

(1.1.2) FOR ALL STUDENTS: Name and email address of your faculty research advisor

(1.2) Project dates (must be in the future—no studies will be approved which have already begun or scheduled to begin before final IRB approval—NO EXCEPTIONS)

(1.3) Answered completely and in detail, the questions in items 2a through 2d?

2a: NOTE: No studies can have zero risk, the lowest risk is “minimal risk”. If more than minimal risk is involved you **MUST**:

i. Delineate all anticipated risks in detail;

ii. Explain in detail how these risks will be minimized;

iii. Detail the procedures for dealing with adverse outcomes due to these risks.

iv. Cite peer reviewed references in support of your explanation.

2b. Complete all items.

2c. Describe informed consent procedures in detail.

2d. NOTE: to maintain security and confidentiality of data, all study records must be housed in a secure (locked) location **ON UNIVERSITY PREMISES**. The actual location (department, office, etc.) must be specified in your explanation and be listed on any consent forms or cover letters.

(1.4) Checked all appropriate boxes in Section 3? If participants under the age of 18 years are to be included (regardless of what the study involves) you **MUST**:

(1.4.1) Obtain informed consent from the parent or guardian—consent forms must be written so that it is clear that the parent/guardian is giving permission for their child to participate.

(1.4.2) Document how you will obtain assent from the child—This must be done in an age-appropriate manner. Regardless of whether the parent/guardian has given permission, a child is completely free to refuse to participate, so the investigator must document how the child indicated agreement to participate (“assent”).

(1.5) Included all grant information in section 5?

(1.6) Included ALL signatures?

(2.0) FOR STUDIES INVOLVING MORE THAN JUST SURVEYS, INTERVIEWS, OR QUESTIONNAIRES:

(2.1) Attached a copy of all consent form(s)?

(2.2) FOR STUDIES INVOLVING INDIVIDUALS LESS THAN 18 YEARS OF AGE: attached a copy of all assent forms (if such a form is used)?

(2.3) Completed and attached a copy of the Consent Form Checklist? (as appropriate—see that checklist for instructions)

(3.0) FOR STUDIES INVOLVING ONLY SURVEYS, INTERVIEWS, OR QUESTIONNAIRES:

- (3.1) Attached a copy of the cover letter/information sheet?
- (3.2) Completed and attached a copy of the Survey/Interview/Questionnaire Consent Checklist? (see that checklist for instructions)
- (3.3) Attached a copy of the actual survey, interview, or questionnaire questions in their final form?

(4.0) FOR ALL STUDENTS: Has your faculty research advisor:

- (4.1) Thoroughly reviewed and approved your study?
- (4.2) Thoroughly reviewed and approved your IRB paperwork? including:
 - (4.2.1) Review request form,
 - (4.2.2) All consent forms, (if used)
 - (4.2.3) All assent forms (if used)
 - (4.2.4) All Survey/Interview/Questionnaire cover letters (if used)
 - (4.2.5) All checklists
- (4.3) IMPORTANT NOTE: Your advisor's signature on the review request form indicates that they have thoroughly reviewed your proposal and verified that it meets all IRB and University requirements.
- (5.0) Have you retained a copy of all submitted documentation for your records?

Project Director's Certification
Program Involving HUMAN SUBJECTS

The proposed investigation involves the use of human subjects and I am submitting the complete application form and project description to the Institutional Review Board for Research Involving Human Subjects.

I understand that Institutional Review Board (IRB) approval is required before beginning any research and/or data collection involving human subjects. If the Board grants approval of this application, I agree to:

1. Abide by any conditions or changes in the project required by the Board.
2. Report to the Board any change in the research plan that affects the method of using human subjects before such change is instituted.
3. Report to the Board any problems that arise in connection with the use of human subjects.
4. Seek advice of the Board whenever I believe such advice is necessary or would be helpful.
5. Secure the informed, written consent of all human subjects participating in the project.
6. Cooperate with the Board in its effort to provide a continuing review after investigations have been initiated.

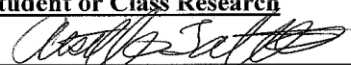
I have reviewed the Federal and State regulations concerning the use of human subjects in research and training programs and the guidelines. I agree to abide by the regulations and guidelines aforementioned and will adhere to policies and procedures described in my application. I understand that changes to the research must be approved by the IRB before they are implemented.

Professional Research

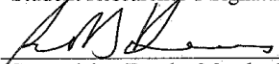
Project Director's Signature

Department Chairperson's Signature

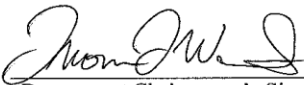
Student or Class Research



Student Researcher's Signature



Supervising Faculty Member's
Signature if required



Department Chairperson's Signature

ACTION OF REVIEW BOARD (IRB use only)

The Institutional Review Board for Research Involving Human Subjects has reviewed this application to ascertain whether or not the proposed project:

1. provides adequate safeguards of the rights and welfare of human subjects involved in the investigations;
2. uses appropriate methods to obtain informed, written consent;
3. indicates that the potential benefits of the investigation substantially outweigh the risk involved.
4. provides adequate debriefing of human participants.
5. provides adequate follow-up services to participants who may have incurred physical, mental, or emotional harm.

Approved [_____]

Disapproved

Chairperson, Institutional Review Board

Date

**Institutional Review Board
California University of Pennsylvania
Morgan Hall, Room 310
250 University Avenue
California, PA 15419
instreviewboard@calu.edu
Robert Skwarecki, Ph.D., CCC-SLP, Chair**

Dear Atsuko Takatani:

Please consider this email as official notification that your proposal titled "A Correlation Among Core Stability, Core Strength, Core Power, and Kicking Velocity in Division II College Soccer Athletes" (Proposal #11-043) has been approved by the California University of Pennsylvania Institutional Review Board as submitted.

The effective date of the approval is 2-28-2012 and the expiration date is 2-27-2013. These dates must appear on the consent form .

Please note that Federal Policy requires that you notify the IRB promptly regarding any of the following:

- (1) Any additions or changes in procedures you might wish for your study (additions or changes must be approved by the IRB before they are implemented)**
- (2) Any events that affect the safety or well-being of subjects**
- (3) Any modifications of your study or other responses that are necessitated by any events reported in (2).**
- (4) To continue your research beyond the approval expiration date of 2-27-2013 you must file additional information to be considered for continuing review. Please contact instreviewboard@calu.edu**

Please notify the Board when data collection is complete.

Regards,

**Robert Skwarecki, Ph.D., CCC-SLP
Chair, Institutional Review Board**

Certificate of Completion

The National Institutes of Health (NIH) Office of Extramural Research certifies that **Atsuko Takatani** successfully completed the NIH Web-based training course "Protecting Human Research Participants".

Date of completion: 06/26/2011

Certification Number: 705147

Appendix C4

Pictures: Equipment



Figure 1. FMS 2x6in board



Figure 2. Blood Pressure Cuff and 360° universal goniometer for the Double Leg Lowering Test



Figure 3. JUGS™ radar gun

Appendix C5

Pictures: Rotary Stability Test (RS)

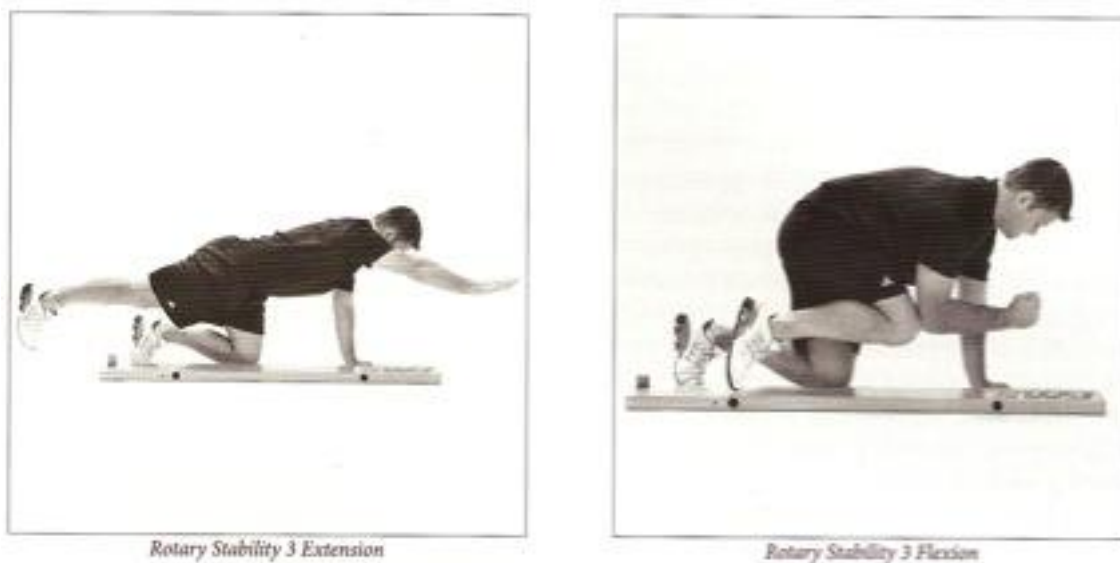


Figure 4. Rotary stability given score 3

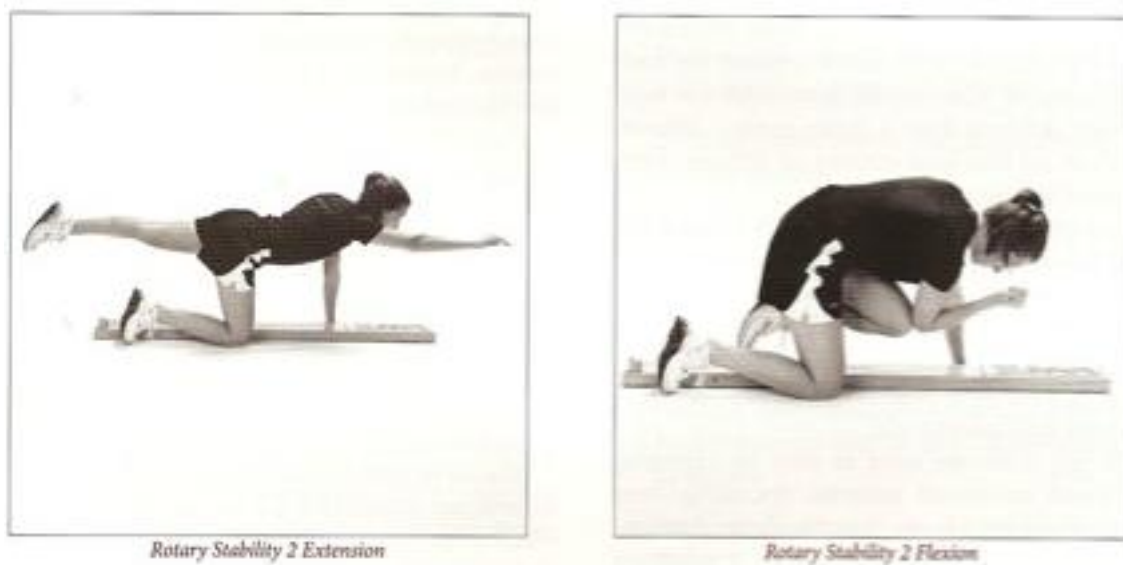


Figure 5. Rotary stability given score 2

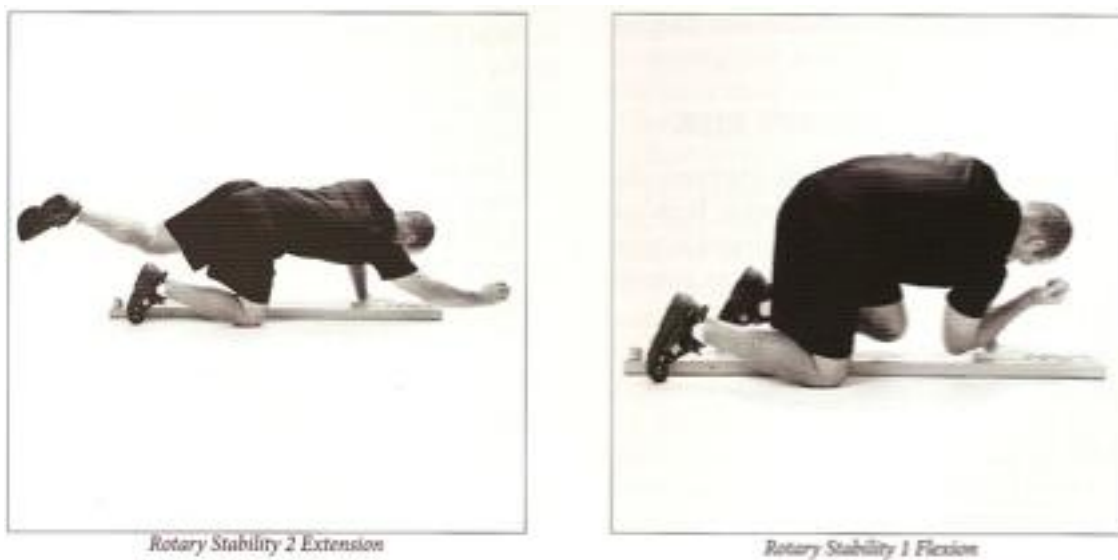


Figure 6. Rotary stability given score 1

Appendix C6

Pictures: Double Leg Lowering Test



Figure 7. Double Leg Lowering Test - Starting Position



Figure 8. Double Leg Lowering Test

Appendix C7

Pictures: 60s Maximal Sit Up Test



Figure 9. 60s Maximal Sit Up Test - Starting position



Figure 10. 60s Maximal Sit Up Test

Appendix C8
Testing Directions

Double Leg Lowering Test

1. The researcher finds the subject's Posterior Superior Iliac Spine (PSIS) and places the blood pressure (BP) cuff on the back while the client sits straight on the floor
2. "Lay spine on the floor."
3. The BP cuff is placed beneath the umbilicus
4. "Maintain the legs in full extension, or slightly bended, and then flex hips to 90°."
5. "Relax the abdominal muscles"
(The BP cuff is at 20 mmHg.)
6. "On the 'Flatten out his back' command, try to keep your belly button towards the table."
7. "Flatten out your back"
"Slowly lower the legs towards the floor, with squeezing the core and keeping knee extension."
8. The subject's legs will be held once the BP cuff drops below 20mmHg.
9. The hip angle is then measured with a goniometer to determine the angle.

(Adapted from Prentice, 2004 and Zingaro, 2008)

60-s Maximum Sit-up

1. "Lay spine on the floor with knee flexion to 90° and hip flexion to 45°."
2. To another subject: "Step on the subject toes."
3. "Interlock fingers behind head, but do not pull on neck."
4. "On 'Go' command, quickly perform sit-ups."
5. "Make sure elbows touch thighs on up portion."
6. "Lower trunk down to floor, let upper back touch floor."
7. "Make sure hands and head DO NOT touch floor."
8. "Quickly perform as many sit-ups (i.e., up-down cycles) as possible."
9. "Ready, Go."

(Adopted from Dendas, 2010)

Dynamic Warm-up

1. Jogging
 - Take 2 laps around the field
2. Hip External Rotation
 - Open hips, externally rotate hips and step to 45° with skipping motion
 - repeat with opposite leg
3. Forward lunges
 - Step backward into lunge with right foot and contract right glute
 - Twist your trunk and take your left elbow towards the outside of the right knee
 - Push off with left foot and step forward into lunge
4. Backward lunges
 - Step backward into lunge with right foot and contract right glute
 - Twist over the front leg by taking right elbow to the outside of the left knee
 - Reverse the twist back to neutral and return to standing position by pulling through with left hip flexor, and immediately step into lunge with other leg
 - Continue for prescribed number of repetitions
5. Lateral squat
 - Shift your weight to the right, bending your right knee and keeping your left knee straight
 - Turn to the back, shift your weight to the left, bending your left knee and keeping your right knee straight
6. High knees
 - Run 10 yards by alternately lifting your knees towards chest as high as possible
 - Move your legs as quickly as possible
7. Butt kickers
 - Pull one ankle up toward butt alternately in running 10 yards

8. Side shuffle
 - Begin in an athletic ready position with feet hip width apart.
 - Shuffle sideways towards the other side of corn.
9. Carioca
 - Cross one leg over the other as you move sideways
 - The shuffle goes side to side without crossing the legs
10. A-skip
 - Skip for 10 yards, jump up as high as you can on each skip
 - Swing your arms in opposition to your legs
11. Power skip
 - Skip for 10 yards, jump up and forward as much as you can on each skip
 - Swing your arms in opposition to your legs
12. Straight Leg kick
 - Stand tall, kick leg up in front and reach for the toes
 - Alternate legs while walking forward
13. Leg Swing (front/back and side)
 - Hold onto fence for support
 - Swing one leg front and back for 15 sec and alternate
 - Swing one leg side to side for 15 sec and alternate
14. Passing/kicking ball to partner for 5 minutes

Kicking test

- 2 practice trials
 - 3 trials for records
- Free to choose the type of your kicking and distance of the run-up to the dead ball
 - Kick the ball towards the radar gun as hard as you can
 - Repeat the trials after 90 seconds rest

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Abstract

Title: A CORRELATION AMONG CORE STABILITY, CORE STRENGTH, CORE POWER, AND KICKING VELOCITY IN DIVISION II COLLEGE SOCCER ATHLETES

Researcher: Atsuko Takatani

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Date: May 2012

Research Type: Master's Thesis

Context: Recent studies suggest that further research is needed to investigate important components and measurement of core stability in relation to athletic performance. The correlation between core stability and athletic performance has not been determined in the available literature.

Objective: The purpose of this study was to examine the relationship among core power, core strength, core stability, and athletic performance in college soccer athletes.

Design: A descriptive correlational design was used to determine a relationship among core power, core strength, core stability, and athletic performance in college soccer athletes.

Setting: The testing was performed in a controlled soccer field setting by the researcher.

Participants: Eighteen Division II college male soccer athletes volunteered this study that were actively participating practice without any limitations.

Interventions: Each subject was tested on two days. All subjects were tested by using the Rotatory Stability test (RS), the 60s Maximum Sit-Up

test (60s MSUT), the Double Leg Lowering test (DLLT), and the soccer kicking test (SK). The RS was used to measure core stability, the DLLT was used to measure core strength, the 60s MSUT was used to measure core power, and a dynamic soccer-style kick (SK) was used to measure maximal kicking speed.

Main Outcome Measures: RS score, 60s MSUT score, DLLT score, and SK score were computed from all test trials and correlation was examined among all four variables. Existing data on TSPU scores were additionally used for trunk stability.

Results: There were no significant correlations among the RS, the DLLT, the 60s MSUT and the SK, for core stability, core strength, core power and maximum kicking velocity in healthy Division II 18 college soccer athletes. A significant moderate low correlation between the TSPU and the SK was present ($r = .435$, $P = .036$).

Conclusion: Trunk stability and kicking velocity appears to be moderately related in healthy Division II collegiate athletes. The core tests that measure the isometric core stability without dynamic limb movements may be valid and reliable to assess core stability.

Word Count: 363