2013

Reactive agility, core strength, balance, and soccer performance

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REACTIVE AGILITY, CORE STRENGTH, BALANCE,

AND SOCCER PERFORMANCE

A Masters Thesis Presented to the Faculty of the

Graduate Program in Exercise and Sport Sciences

Ithaca College

In partial fulfillment of the requirements for the degree

Master of Science

by

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May 2013

Ithaca College

School of Health Science and Human Performance

Ithaca, NY

CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Thesis of

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submitted in partial fulfillment of the requirements for the degree of Master of Science in the Department of Exercise and Sport Sciences at Ithaca College has been approved.

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ABSTRACT

The purpose of this study was to determine if female soccer player balance, reactive agility, and core strength were related to soccer performance in skill tests and in coach appraisal. Fourteen subjects (*n* = 14), between the ages of 19 and 22 years, that had played or were current members of a Division III Varsity soccer team completed a series of three balance tests, a reactive agility test, a speed test, two core strength tests, and two soccer skill tests. The team's coach filled out two ratings consisting of a coach ranking and player skill appraisal. The first involved ranking each player from 1 to 14, with 1 being the top player. The second part was an appraisal that included a Likert-type scale grading of each player on physical ability, technical ball skill, and field sense. These components were summated into a "total" performance score. Physical fitness components of balance, speed and agility, core strength, and soccer skill tests were correlated with coach appraisal using Spearman Rho correlations. Physical fitness components were also correlated with each other using Pearson correlations. The results indicated that balance on the right foot, as measured by the Balance Error Scoring System (BESS) was strongly related to player performance indicated by the coach ranking and individual scoring of each performance component. Although no other balance or fitness components related to better performance in soccer skills test or in coach appraisal, some other inter-variable relationships may be meaningful. Balance on the right foot was related to reactive agility when cutting to the left, and also to speed. Similarly, balance on the left foot was found to be related to reactive agility when cutting to the right. In addition, the slalom dribble test used was highly related to coach rating of technical ball

skill, giving validation to the slalom dribble test in Division III female soccer players. Balance, as measured by the BESS, may be a valuable predictor of soccer performance in females. Future studies with a longitudinal design are needed to further examine the impact of balance on soccer performance.

DEDICATION

This thesis is dedicated to my parents, Bonnie and Greg, and grandmother, Margaret, for their constant physical, emotional, and financial support throughout my educational career and life.

ACKNOWLEDGEMENTS

I would like to thank Dr. Gary Sforzo for his patience, guidance, and encouragement with this project.

I would like to thank Dr. Jeffrey Ives for his deep insight into the subject matter, encouraging me to figure things out on my own, and full access to his lab.

I would like to thank Dr. Deborah King for writing the DPSI program and allowing me full access to her lab.

I would like to thank Samantha Grassi for assisting me with data collection.

I would like to thank Coach Mindy Quigg for supporting my efforts and encouraging her athletes to work with me.

I would like to thank my subjects for their time and participation in this study.

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Chapter 1

INTRODUCTION

The current literature centered around improving athletic performance suggests connections between balance, core strength, agility, and speed. However, no study has examined the interrelationships among these performance measures and their potential for talent identification in female soccer players or determined if they are associated with more proficient play. It is apparent that certain sports (e.g., gymnastics), require high levels of balance ability. Other sports require postural control coupled with fine motor skills (e.g. archery, rifle shooting). However, in many sports the connection between balance ability, reactive agility, core strength, and performance on the field seems clear but has not been closely evaluated. One study examining differences between soccer ability levels demonstrated that agility and speed are the most discriminating factors between elite and subelite males (Reilly, Williams, Nevill, & Franks, 2000). Soccer is the most popular sport in the world, but little is known about how dynamic balance relates to critical field tasks, such as agility, speed, and technical skill with the ball. Whenever an athlete makes contact with the ball, they are not only balancing on the opposing leg but they are coordinating their core and limbs in a precise way to send the ball in a desired direction.

Recently, core strength has gained much attention as a potentially important sport-specific ability (Saeterbakken, Van Den Tillaar, & Seiler, 2011; Scibek, Guskiewicz, Prentice, Mays, & Davis, 2001; Stanton, Reaburn, & Humphries, 2004). It is believed that core strength improves postural control and postural control improves balance (Cosio-Lima, Reynolds, Winter, Paolone, & Jones, 2003; Morris, 1999). Core strength, stability, and endurance are important in any movement because the core musculature attaches to and controls the limbs. Core activation is required prior to completing most any athletic movement. Research has shown positive correlations between core stability and measures of total body strength (power clean) and speed (20-yd, 40-yd sprint) in football players (Nesser, Huxel, Tincher, & Okada, 2008). In soccer, athletes are sprinting, jumping, and cutting throughout the match. Core stability and strength may play a role in enhancing these movements and, therefore, overall soccer ability.

Agility involves moving laterally and changing direction quickly and is most obvious in sports such as football, tennis, basketball, soccer, and baseball, and is why higher-level athletes include agility training in their programs. Balance interventions with athletes have improved measures of athletic performance including agility (slalom course, shuttle run), and vertical jump height (Malliou et al., 2004; Šalaj, Milanović, & Jukić, 2007; Yaggie & Campbell, 2006). This suggests that improved balance, or underlying postural control, may elicit an improved rate of force development in the muscles (Hyrsomallis, 2011). Reactive agility is a component of agility involving movement in response to a stimulus. Reactive agility is not well-studied even though it is highly applicable to most field sports, where direction change and movement in response to field circumstances is paramount.

In addition to balance, agility, and core strength, soccer performance is dictated by many sport skill components (e.g., endurance, speed, power, and technical ball skill). The growing field of strength and conditioning emphasizes training and improvement for each of these components. Training for improved cardiovascular endurance is known to not only improve maximum oxygen uptake, but also running economy, distance covered during a game, number of total sprints, and number of contacts with the ball (Helgerud, Engen, Wisloff, & Hoff, 2001). Likewise, resistance training, coupled with speed training, has demonstrated improvements in one-repetition maximum squat, 30 m dash time, and two types of vertical jumps (Kotzamanidis, Chatzopoulos, Michailidis, Papaiakovou, & Patikas, 2005). Both of these studies sought to improve soccer ability by training specific skill and fitness components.

Several studies have attempted to identify components of successful soccer performance in athletes. However, the relationship between balance, core strength, reactive agility, and soccer skill is yet to be examined in female soccer players. If a relationship between balance ability, core strength, reactive agility, and soccer skills exists, coaches may be well advised to consider training programs emphasizing these components of performance.

Statement of Purpose

The purpose of this study was to examine if balance, core strength, and reactive agility are related to soccer skill.

Research Question

Do balance, core strength, and reactive agility relate to performance in skill-based soccer tests and predict success in soccer?

Hypothesis

The hypotheses for this study are:

1. Balance ability, core strength, and reactive agility will each be positively correlated with specific soccer skill tests in Division III (DIII) female players.
2. Balance, core strength, and reactive agility will each be positively correlated with coach assessment of DIII female players.

Scope of the Problem

The average DIII female soccer player does not incorporate balance training into her pre-season program. Core strength may be trained but not specifically targeted, while reactive agility is a new concept that has not been evaluated in soccer players. Each of these fitness components may make an important contribution to soccer skill, yet they are generally overlooked during training. Most studies based on balance training have shown that it can decrease injury (Mandelbaum et al., 2005) and improve agility and speed (Kean, Behm, & Young, 2006; Myer, Ford, Palumbo, & Hewett, 2005; Šalaj, Milanović, & Jukić, 2007; Yaggie & Campbell, 2006). Core stability has been shown to increase performance measures related to strength and speed. Reactive agility is known to be an indicator of performance in other field sports (Gabbett & Benton, 2009). Determining the importance of balance, core strength, and reactive agility to soccer performance should be of great interest to coaches and players alike. Strength and conditioning professionals, in particular, will be very interested to learn of the results of this work which might lead them to consider implementing balance, core, and reactive agility training for female soccer players.

Assumptions of the Study

For the purpose of this study, the following assumptions are made:

1. The subjects are representative of typical college-aged female DIII soccer players.
2. Dynamic balance tests are valid indicators of core strength and balance ability.

Definition of Terms

The following terms are operationally defined for the purpose of this investigation:

1. Balance: Ability to maintain center of gravity within the base of support; an outcome of postural control.
2. Dynamic Balance: Ability to maintain balance under conditions of movement.
3. Kinesthesia: Ability to recognize one’s own body, limb positions, and movements.
4. Postural Control: Maintaining the desired core position by stabilizing the spine with the surrounding musculature; allows for improved balance and biomechanical alignment.
5. Agility: Ability to quickly change direction; ability to quickly stop and redirect movement.
6. Core: Musculature surrounding the lumbopelvic region that attaches the upper and lower extremities.
7. Reactive Agility: Direction change done in response to a stimulus.
8. Core Strength: The core musculature ability to elicit forceful contractions.

9. Core Stability: 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.
10. Experienced Soccer Players: Soccer players who have played at least one year at the varsity collegiate level.

Delimitations

The delimitations of this study were as follows:

1. Only Ithaca College DIII experienced, female soccer players were used as subjects.
2. Balance was measured using the Star Excursion Balance Test (SEBT) and the Dynamic Postural Stability Index (DPSI).
3. The dribbling test and passing test were done in a gymnasium.
4. The reactive agility test took place inside and required athletes to change direction based on a contrived stimulus.
5. The test of core endurance involved holding several plank positions with the feet on a bench rather than the floor.
6. The test of core power involved launching a medicine ball as far as possible from a supine position.
7. A coach assessment of all athletes was used to discriminate between athletes' performance.

Limitations

The limitations of this study were as follows:

1. The results may only apply to Division III collegiate soccer players.
2. The tests used to assess balance may be specific and not easily applicable to measuring dynamic balance during soccer play.
3. The skill tests may only display isolated soccer skill ability and not be generalizable to overall soccer ability.
4. The reactive agility and core tests have never been used in soccer players before and may not represent the best indications of these skills in soccer players.
5. Coach appraisal may be subject to bias.

Chapter 2

REVIEW OF LITERATURE

Introduction

Soccer is the world's most popular sport and many studies have attempted to define the characteristics of successful soccer players (Franks, Williams, Reilly, & Nevill, 2000; Reilly, Williams, Nevill, & Franks, 2000;Williams & Reilly, 2000). Not only does this information help coaches when designing training programs, but it also provides information as to who may be most successful in a given position. Though most of these studies examined specific athletic components among elite male players, not one has investigated the relationships between balance ability, core strength, reactive agility, and skills tests in non-elite female soccer players. This review of pertinent literature will examine: 1) measures of soccer performance; 2) physiology of balance; 3) physiology of the core; 4) core stability vs. core strength; 5) balance and core; 6) balance, agility, and speed; 7) reactive agility; 8) balance and soccer; 9) core and performance; 10) core and soccer; and 11) performance and injury differences between male and female soccer players.

Measures of Soccer Performance

Research shows that many athletic ability components directly relate to improved soccer ability. Elite players demonstrate higher levels of speed, acceleration, agility, power, anaerobic endurance, aerobic fitness, technical skill, and anticipation (Franks, Williams, Reilly, & Nevill, 2000; Reilly, Williams, Nevill, & Franks, 2000; Williams & Reilly, 2000). Of these athletic components, however, agility and speed account for most of the difference seen between elite and sub-elite male soccer players (Reilly, Williams, Nevill, & Franks, 2000). Performing the slalom dribbling course with and without the ball, only the test with the ball produced a significant difference between elite and subelite players suggesting that agility coupled with technical ball skill is most predictive of elite performance (Nicolaire, Correa, & Bohme, 2010). Reilly et al. (2000) tested elite male soccer players and found marked positional differences between players. Midfielders and defensive players had better aerobic endurance (i.e., V02max) and also performed better in intermittent running activities. Midfielders, however, were found to have lower strength values than other players.

Positional characteristics are not as apparent for Division I female college soccer players. Investigators took several measurements including body height, weight, acceleration, speed, agility, and estimated aerobic endurance. Although no significant differences were found between position on any of the tests, they found that fullbacks and midfielders tended to be taller and heavier. In addition, keepers and fullbacks tended to score slower times on the speed and agility tests, suggesting they were slower than midfielders and forwards (Vescovi, Brown, & Murray, 2006). This raises the question, are there other discriminating characteristics for success in soccer in addition to the components that have already been tested? Is it possible that balance ability, core strength, and reactive agility might play a role?

Physiology of Balance

Soccer requires balance when contacting the ball on one foot, coming down from a heading opportunity, or when evading an opponent. The process of balancing is complex and requires specific coordination of the core and limbs. Balance is defined as an ability to maintain the center of gravity within the base of support (Yaggie &

McGregor, 2002). In sport, the center of gravity is constantly changing and at times is at the edge of the base of support. To maintain balance, the brain receives feedback from various systems including visual, vestibular, and somatosensory (Hryosomallis, 2011).

Of these three feedback systems, it is believed that the somatosensory plays the most important role (Eisen, Danoff, Leone, & Miller, 2010). The somatosensory system provides feedback from nerves in ligaments and joint capsules, skin, and muscle tissue. Proprioception is part of this system and relays specific feedback regarding joint position and motion (Hyrosomallis, 2011). These feedback systems constantly receive input to allow for smooth movements when challenged to complete a specific complex neuromuscular movement (Nashner, 1997). Athletes must not only be able to balance effectively but must perform during movements requiring dynamic balance. Field sport athletes rarely hold a static balanced position during competition but most sport-specific movements require losing contact with the ground surface or maintaining stability while catching, kicking, throwing, or contacting an object.

Several potential mechanisms exist to explain ability to improve balance, most of which involve the improved functioning of the nervous system or strengthening of the core (Bliss & Teeple, 2005; Taube, Gruber, & Gollhofer, 2008). Taube et al. (2008) suggested that "balance training may lead to neural adaptations at the spinal and supraspinal level that suppress reflex activity." This suppression may improve muscle co-contraction properties and result in more stable joints, allowing for better balance. The nervous system also learns how to most effectively coordinate various contractions while the core maintains posture. Davlin (2004) found that athletes have superior dynamic balance compared to nonathletes. He hypothesized this could be due to repeated high levels of physical activity and the constant stimulation of the nervous system. Other researchers have suggested that experience in sport or activity improves balance but visual input is not as important as the increased involvement of other components of postural control. If the visual system requires less feedback, then feedback from other systems will have greater priority (Chapman, Needham, Allison, Lay, & Edwards, 2008). Elite athletes also have better static balance due to a better awareness of body axis and the position of the head in relation to the body (Paillard, Bizid, & Dupui, 2007). It seems that balance improvements may be partially due to neural adaptations but also may be due to increased core strength.

Physiology of the Core

The core consists of the musculature surrounding the lumbopelvic region. These muscles are either directly or indirectly attached to the spinal column and connect the upper and lower extremities (Vleeming, Pool-Goudzwaard, Stoeckart, Van Wingerdenm, & Snijders, 1995). Panjabi (1992) stated that core stability is controlled by the passive spinal column, active spinal muscles, and the neural and feedback subsystem. The neural and feedback subsystem includes proprioceptors in the tendons, ligaments, muscles, and the nervous system. These three interdependent systems combine to allow movements enabling the dynamic activities seen in daily living. This idea can also be applied to sport. Most athletic movements begin with the core musculature and then continue to the limbs. Several muscles (latisimuss dorsi, pectoralis major, hamstrings, quadriceps, and iliopsoas) attach to the core and are directly involved in throwing, kicking, and running. Stabilizing muscles (upper and lower trapezius, hip rotators, glutei) also attach to the core (Kibler, Press, & Sciascia, 2006). Not only has the lumbopelvic region shown to be involved in core rotation and load transfer from the lower body, but also in core stability (Bliss & Teeple, 2005; Vleeming et al., 1995).

Core Strength vs. Stability

Currently, many studies do not distinguish between core strength and stability despite the clear differences. Researchers have defined 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" (Kibler, Press, & Sciascia, 2006). Meanwhile, core strength is defined as, "the ability of the musculature to produce force through contractile forces through intra-abdominal pressure" (Faries & Greenwood, 2007). Elite level athletes must be able to produce powerful movements while maintaining core stability in dynamic environments.

Balance and Core

Although soccer involves great use of the lower limbs, the core must be strong and coordinated to allow for optimal force production. The greatest amount of force in any movement can only be produced when core mechanics are optimized (Oliver, 2009). Researchers proposed that improved balance could decrease the amount of musculature involved in stabilization, allowing more muscles to contribute to force production in a given movement (Kean, Behm, & Young, 2006). Other researchers (Cosio-Lima, Reynolds, Winter, Paolone, & Jones, 2003) found that training the core on unstable surfaces increased erector spinae muscle EMG activity and static balance ability compared to those completing abdominal and back exercises on the floor. Instability training stressed the core musculature more than floor exercises and led to neural adaptations that directly related to static balance ability. In summary, current research proves the potential impact of core strength on balance ability.

Balance, Agility, and Speed

Agility refers to the ability to quickly change direction. Whenever the body changes direction the center of gravity moves around and to the edges of the base of support. This relationship between agility and balance is supported in several research studies of balance training in athletes. Malliou et al. (2004) implemented a four week balance program with skiiers and showed that the balance intervention group performed significantly better than a control in downhill slalom agility. Yaggie & Campbell (2006) employed balance training in recreationally active subjects and demonstrated significant improvements in a timed shuttle run. Other researchers (Šalaj, Milanović,, & Jukić, 2007) also found significant improvements in agility following balance training in physical education students. In summary, it seems clear that improved balance will likely improve agility.

Speed includes the ability to produce force rapidly and is closely related to the quickness and balance required in agility. Hockey players showed that maximum skating speed correlated with 40 yard dry land sprint time and also with balance ratio on a wobble board (Behm,Wahl, Button, Power, & Anderson, 2005). Balance is important in hockey because of the amount of weight and force being distributed onto a narrow blade. Their results suggested that if a player is better balanced, then he is more powerful in his skating speed. Other research related to sprinting showed that speed was not only predicted by the amount of force applied to the ground, but also by the direction of the force (Morin, Edouard, & Samozino, 2011). This suggests that the ability to distribute force from the foot, in the most effective direction, correlates to improved speed. Balance begins in the foot with the ability to stabilize and move efficiently, which is dependent on proprioceptive ability and technique. Therefore, balance and speed may well be related. However, the connection between balance and reactive agility has not yet been investigated.

Reactive Agility

Agility, as defined by Sheppard and Young (2005), refers to a "rapid whole body movement with change of velocity or direction in response to a stimulus". This new definition addresses a physical part of agility in addition to a cognitive aspect involved with rapid decision making. Other researchers term this "reactive agility" (Gabbett & Benton, 2009). Although athletes typically train speed and changing direction, they may not always practice responding to the position of the ball or an oncoming player during these drills. Since reactive agility is a new form of training and testing, there is no information provided in the literature that specifically applies to soccer. Limited research has been done with rugby players.

Investigators tested elite and subelite Australian rugby players to see if reactive agility could be an important indicator of performance. A recently validated test of reactive agility was used (Sheppard, Young, Doyle, Sheppard, & Newton, 2006). Researchers demonstrated a significant difference between rugby players of differing ability in several areas of performance including movement time, decision making time, and response accuracy (Gabbett & Benton, 2009). Rugby is similar to soccer in that athletes must constantly anticipate and react accordingly to the changing field dynamics. Sheppard and Young (2005) provided an example of reactive agility and how it could relate to soccer players when stating, "agility could describe a soccer player who rapidly accelerates or decelerates in a straight line to evade an opponent, as this action is not pre-planned, would be in response to the movements of the opposing player and is an open skill." A closed skill, as are most current agility drills with cones and hurdles, provide no stimulus for which the athlete must respond and adjust.

Balance and Soccer

Recently, researchers have identified balance ability in soccer players as an important aspect of performance (Paillard et al., 2006). The last few years have shown increasing numbers of balance studies with these athletes. One of the driving factors behind this research is the unilateral nature of the sport when contacting the ball. Paillard et al. (2006) tested several national and regional players and found significant differences in balance ability between the groups. Not only did national players perform better in normal unilateral balance tasks, but also in tests of dynamic balance. This discrepancy between levels of play supports the idea that balance ability should be considered an individual component of soccer ability. Other researchers have also demonstrated better unilateral balance in soccer players when compared to untrained subjects, basketball players, and swimmers (Matsuda, Demura, & Nagasawa, 2010; Matsuda, Demura, & Uchiyama, 2008).

Kubo and Nishikawa (2010) tested balance ability in the kicking and pivoting legs of professional soccer players. Significant asymmetrical differences between legs existed only in forwards, but not other positions. Conversely, other researchers have found no significant difference between balance ability in opposing legs (Matsuda, Demura, & Nagasawa, 2010). Sidaway et al. (2007) investigated kicking ability and how it relates to postural control. Female and male soccer players were asked to kick a ball as hard as possible under three conditions of varying instability. In the most stable condition players grasped a nearby railing, and in the least stable they held onto nothing. They found that the grasp condition, where they had the most postural control, elicited a significantly higher ball velocity. These findings suggest that improved postural control could directly relate to improved ball velocity when kicking.

Core and Performance

Currently, the relationship between core strength and dynamic performance has not been clearly established. Many researchers have inferred this relationship because of core activation prior to moving any limb. Improved core stability is hypothesized to create a stronger foundation for greater force production in extremities (Lehman, 2006).

Studies implementing core training programs have demonstrated improvements in performance tests, but few have demonstrated improved performance on the field. Researchers implemented a six-week core training program with swimmers in efforts to improve 100-yard sprint performance, however, the only improvement documented was in upper body power. Core stability improvement did not translate into swimming faster (Scibek, Guskiewicz, Prentice, Mays, & Davis, 2001). Investigators have also looked at the effect of core stability and running economy (Stanton, Reaburn, & Humphries, 2004). This study revealed no significant differences in running performance after core training. However, they suggested the results could have been different if athletes performed core exercises while in a running-like position that emphasized power and strength rather than stabilization.

It is still unclear whether improved core strength can actually translate to improved athlete performance. In only one study was an improvement of skill performance documented (Saeterbakken, Van Den Tillaar, & Seiler, 2011). These researchers implemented a core-stability training program with female handball players and demonstrated significant increases in throwing velocity when compared to a control group.

The results of these studies give an ambiguous picture of the relationship between core training, balance, and on-field performance. However, researchers have not yet conducted core training that focuses on developing strength and power, which is more important in certain sports than stability.

Core and Soccer

The core seems to play an important role in soccer. The core stabilizes through every agile movement, every kick, and every landing. Sprinting and kicking are known to be related to core strength, for example, the glutei stablize the trunk and allow for powerful forward movements of the leg (Putnam, 1993). Therefore, the core stabilizes during every shot and pass. Investigators looked at soccer players and untrained subjects to see the effects of unexpected perturbations on core stability. They found that soccer players required less time than recreationally active people to activate the various core muscles and less postural sway in response to a change in surface stability. This suggests that these muscles are important and incorporated in soccer (Borghuis, Lemmick, & Hof, 2011).

The kicking motion also requires core rotation to generate torque. Researchers demonstrated that maximum foot velocity in kicking is more highly related to hip flexor muscle activation than knee extension (Zattara, & Bouisset, 1988). The hip flexor muscles directly attach to the core musculature, suggesting core strength and power in this area produce a faster movement in the distal limbs.

Performance and Injury Differences Between Male and Female Soccer Players

Few studies have investigated the differences between male and female soccer players. In one study, both genders displayed significant differences between elite junior and professional players in the cardiovascular endurance and agility tests (Mujika, Santisteban, Impellizzeri, Castagna, 2008). However, only professional females performed better on vertical jump height when compared to elite juniors. Significant differences in a dribbling test only existed between professional and elite junior players, rather than between males and females (Mujika, Santisteban, Impellizzeri, Castagna, 2008). The results of this study suggest that some differences exist in predicting performance between male and female soccer players.

According to the literature, females have a two-three fold greater chance of tearing their ACL and sustain these tears at a younger age (Walden, Hägglund, Werner, & Ekstrand, 2011). Females are known to have different knee kinematics, in stop-jump tasks, that may increase their likelihood of ACL tear in comparison to their male counterparts (Chappell, Yu, Kirkendall, & Garrett, 2002). It is apparent that differences exist between male and female soccer players based on performance measures and injury rates.

Summary

Although a plethora of current research on soccer players exists, some questions about performance indicators still exist. Dynamic balance has been assessed in soccer players and has shown to be an important measure of performance in elite males (Paillard et al., 2006). Improved core strength has shown mixed results in improving athletic ability (Saeterbakken et al., 2011; Scibek et al., 200; Stanton, 2004), but has shown to impact balance ability (Cosio-Lima, Reynolds, Winter, Paolone, & Jones, 2003). Balance and agility have shown to be related as well (Maillou, 2004; Šalaj, Milanović, & Jukić, 2007; Yaggie & Campbell, 2006), but these components have never been examined in soccer female players, particularly at the subelite (DIII) level. These components could be directly related to soccer ability and be valuable for talent assessment.

Chapter 3

METHODS

Soccer requires many athletic components coming together to be a successful player. Previously, many training programs focused on improved cardiovascular endurance and ball skill. However, the growing field of strength and conditioning reveals that other athletic components are important to soccer players and are highly discriminative between elite and subelite players. The tests implemented in this study will provide information on athletes' balance, core strength, reactive agility, and will provide insight into possible relationships between these components and soccer skill. This chapter explains the research methodology and contains sections: 1) subjects; 2) measurements and instrumentation; 3) procedures; and 4) statistical analysis.

Subjects

After receiving approval from the Human Subjects Review Committee, the head coach of the women's soccer team was contacted and asked for permission to meet with the players and discuss possible participation in the study. A recruitment flyer was distributed to convey the basic idea of the study (Appendix A). All athletes at the meeting interested in participating signed a contact sheet with name, email address, and phone number to receive further details. If players were unable to attend the meeting, the coach provided their email address.

The researcher followed up with interested participants and supplied information about the study. Athletes self-reported were excluded if they had suffered a lower extremity injury, concussion within the last 12 weeks, or if they suffered from any visual or vestibular problems that could affect performance. These guidelines were included in the informed consent. The subjects in this study only consisted of Division III female soccer players. Subjects were chosen on the basis of access, convenience, and availability. All participants were at least eighteen years of age and signed an informed consent form (Appendix B) prior to participation. After completing the informed consent document, subjects were reminded that they could voluntarily remove themselves at any point during the study.

Measurements and Instrumentation

Athletes completed three tests of balance, two tests of core strength, one sprint test, two skills tests, and a reactive agility test. Test order was adjusted to allow for maximal performance on each test. The results from the balance, core, and agility tests were compared with scores on skill tests and a coach appraisal of ability.

Static balance was assessed with the single leg Balance Error Scoring System (BESS). A variation of the BESS test recently developed (Hunt, Ferrara, Bornstein & Baumgartner, 2009) was used because researchers have established a high inter-tester reliability (intraclass correlation coefficients = .78 to .96), its wide use in the previous literature, and because it has shown to be a potential replacement for assessing balance when a forceplate based system is not available (Riemann, Guskiewicz, & Shields, 1999). This provided insight to static balance ability with and without the visual system.

The Star Excursion Balance Test (SEBT), as described by Gribble and Hertel (2003), was used to assess dynamic balance. Leg length of each athlete was measured to partially account for variability seen in this test. The SEBT is described as having a high intratester reliability (intraclass correlation coefficients = .81 to .96)(Hertel, Miller, & Denegar, 2000). Researchers believe it is an accurate test based on its sensitivity to screening lower extremity injuries even though it has not been validated (Olmstead, Carcia, Hertel, & Schultz, 2002). This test was chosen because few tests of dynamic balance have been researched in terms of reliability and validity, ease and convenience, and it only requires a tape measure. It provides information about balance ability from a more dynamic perspective than the BESS.

The Dynamic Postural Stability Index (DPSI) was chosen because of its minimal standard error of measurement (SEM), reliability, and application to soccer in terms of running and jumping. In a study evaluating the test's effectiveness and efficacy, the SEM was very low (.03) and the reliability between sessions was extremely high (.96) (Wikstrom, Tillman, Smith, & Borsa, 2005). The DPSI requires landing one-footed on a forceplate (AMTI model # OR6-6, Watertown, MA) that measures anterior-posterior sway, medial-lateral sway, and vertical ground reaction force. This test provides dynamic balance data and mimics movement often seen in soccer when a player lands from a jump.

The Front Abdominal Power Test (FAPT) was used because of a high intraclass correlation coefficient (ICC = .95)(Cowley & Swensen, 2008). According to Cowley and Swensen (2008), this test demonstrates good test-retest reliability and no learning effect, making it easy to administer. In this test, athletes launch a medicine ball as far as possible from a supine position with the knees bent at 90°. A measuring tape is used to record distance. This test gives information about core power, or ability to rapidly produce force.

The 'Bunkie' test (Appendix C) was chosen as another core measure because it has recently gained attention in the clinical and sport setting (Bassett & Leach, 2011; de Witt & Venter, 2009). It was chosen based on its simplicity and correlation with quantitative tests suggesting validity (Brumitt, 2010). The Bunkie test requires the athlete to perform a series of eight planks for 20 seconds each, and a stop watch is used to record time during administration. This test provides information about athletes' core endurance.

The 10-yard sprint was chosen to assess speed because it is widely used in the literature. The protocol was used by Cressey, West, Tiberio, Kraemer, and Maresh (2007) and involves two timing gates (SmartSpeed Timing Gate System, Burbank, CA) placed 10 yards apart. The sprint was self-initiated.

The tests to assess soccer skill included a dribbling and passing test. The dribbling test, developed by Reilly and Holmes (1983) uses five cones with athletes timed while dribbling between them (Appendix D). The reliability coefficient is between .92 and .95 (Reilly & Holmes, 1983). The validity coefficient is considered moderate between .38 and .69 (Reilly & Holmes, 1983). The Loughborough soccer passing test (LSPT) was developed by Ali et al. (2007) and demonstrated good reliability (r = .73), and a ratio of limits agreement between .92 and .96. Athletes complete 16 passes against 4 different colored targets as quickly as possible while being timed with a stopwatch (Appendix E).

Skills tests are often used by coaches to rank players and give some insight to soccer specific abilities.

Researchers recently developed a reactive agility test (RAT) that demonstrates good reliability (r = .91) and construct validity. Construct validity was based on non-parametric tests correctly distinguishing between nonathletes, subelite, and elite rugby players (Veale, Pearce, & Carlson, 2010). To complete the RAT, athletes move through a series of gates between 2 and 5 m apart in response to a lighting system (Appendix E) (SmartSpeed Timing Gate System, Burbank, CA). This test measures how agile and quick an athlete is and how well they move in response to a stimulus.

Lastly, the coach was given two forms to fill out to describe each athlete's ability. One form included a report to rank order the most talented to the least talented player, and a percentage ranking of each player in comparison to former players of the same position (Appendix F). The other form included a Likert-type scale scoring physical ability, technical skill, and field sense for each athlete (Appendix G).

Procedures

After giving informed consent, participants completed four test sessions when it was conducive to their schedules. The first session included vertical jump height, BESS, and the SEBT. Subjects were also familiarized with the FAPT at the end of the first testing session but no data were collected. The second session of assessments included the FAPT and the DPSI. The third session included the RAT and the Bunkie Core test. The fourth session included the skills tests of dribbling and passing. Tests were grouped based on minimizing potential fatigue that could impact performance in subsequent tests. The test order was the same for all athletes.

Anthropometric Measures

Anthropometric measurements were taken prior to any warm up and included height, weight, and bilateral leg length. Athletes wore sport shorts, a t-shirt, and no shoes for these measurements. Height was recorded with a stadiometer to the nearest .5 cm. Weight was recorded to the nearest .10 kg on a balance scale. Leg length was measured while supine with a tape measure from the anterior superior iliac spine to the center of the medial malleolus. Prior to any further testing, athletes were taken through a 3 min warm-up that included three minutes of jogging, dynamic stretches, and footwork exercises. The following dynamic stretches and footwork exercises were used; walking lunges, high knees, sumos, butt kicks, quad pulls, tin soldiers, carioca, and lateral shuffles.

Maximum Vertical Jump

Within 5 min of the warm-up, the first test administered was a maximum vertical jump (VJ) because it is a necessary precursor to completing the DPSI. Prior to jumping, reach height was recorded with a stadiometer to the nearest centimeter. Athletes were required to stand flat footed facing the wall with both arms above their heads and to reach as high as they could with one hand on top of the other. A tape measure was placed along the wall to record the height. This value was then subtracted from the vertical jump height reached (Yaggie & McGregor, 2002). Subjects were instructed how to do a countermovement vertical jump correctly. Each athlete completed three trials with a 1-2 min break between attempts. The maximum of three jumps was used for analysis and to determine each athlete's designated jump height for the DPSI. Jump height was recorded using a Vertec device (model # 22550). A Vertec has vanes (measuring .5 in increments) that athletes move with their hands at the apex of their jump.

Balance Error Scoring System

Following a 5 min break, a modified BESS was administered (Hunt, Ferrara, Bornstein, & Baumgartner, 2009; Riemann, Guskiewicz, & Shields, 1999). The unstable surface used was an Airex foam balance pad (model # 2350, Sins, Switzerland) and the stable surface was the vinyl flooring in the lab. A single-led stance with the contralateral limb at about 90º of knee flexion was used to evaluate balance on both limbs separately. All conditions were done on firm ground and on the foam pad. Both conditions, under stable and unstable conditions, were performed three times following one practice trial. Athletes were instructed to place both hands on their iliac crests and to close their eyes once they felt balanced and to make immediate adjustments if they began to lose their balance. Timing began when their eyes closed and each condition lasted for 20 s. During each condition one error point was recorded for the following reasons; opening their eyes, taking hands off the iliac crest, touching down with the contralateral limb, stepping or moving with the stance foot or feet, lifting the forefoot or the heel, moving the hip into more than 30º of flexion or abduction, and remaining out of position for more than 5 s (Riemann, Guskiewicz, & Shields, 1999). The error scores were summed for each limb separately with trials on both foam and firm surface.

Star Excursion Balance Test

Following another 5 min break, the SEBT was administered. An asterisk-shaped grid was taped on the floor with each section between the lines measuring 45º. Participants were asked to stand in the middle with one foot planted while reaching out as far as possible with the other leg to all 8 lines. The athlete quickly touched the ground with the most distal part of their foot and then quickly returned to a two-legged stance. All distances were recorded with measuring tape from the center for the grid to the point of contact. The marks were immediately erased after being recorded. All participants were required to keep their hands on their waists throughout the test. Athletes practiced moving in each direction six times to minimize a learning effect and then waited 5 min before testing. Trials were discarded or repeated for the following reasons; if the researcher thought the subjects reach foot was in contact with the ground too long, moved his or her foot from the center of the grid, or if they were unable to maintain balance on the support leg. All athletes completed a total of three trials on the nondominant leg, rested 5 min, and then completed three more on the dominant leg. The trials for each leg were averaged. Athletes then rested for 10 min before completing the DPSI.

Dynamic Postural Stability Index

Subjects began the DPSI in a standing position 70 cm away from a force plate (AMTI model # OR6-6, Watertown, MA). They were instructed to jump up and touch a flag above them marking 50% of their previously recorded maximum vertical jump height. Either hand could be used. They were instructed to land on the force plate with one foot and maintain balance for 5 s with the head upright. Once they felt balanced, they were asked to put their hands on their hips. Subjects were allowed as many practice trials as they wanted in order to feel comfortable. Once they felt comfortable, they rested 2 min before recording data. Recordings of anterior-posterior and medial-lateral sway and vertical ground reaction force were recorded for the first 3 s to determine the time to stabilization (TTS). This was defined as the moment the athlete felt balanced and was displayed by placing both hands on their iliac crests. Sways measure the movement forwards and backwards, left and right, and body weight respectively. An algorithm was incorporated to find each subject's time to stabilization (Wikstrom, Tillman, Smith & Borso, 2005). This DPSI algorithm was a composite of both sways and the vertical ground reaction force and was sensitive to change in all three planes. Subjects completed three successful trials with 2 min of rest in between each jump. The average of these trials was used. Data was discarded and repeated for the following reasons: if the subject lost balance and touched the floor with the contralateral limb, if a short additional hop or movement occurred on the forceplate after landing, and excessive swaying of the trunk, arms, or contralateral limb that almost caused the subject to step off the force plate.

Front Abdominal Power Test

The core test to assess power (Cowley & Swensen, 2008) required the athlete to explode from a supine position and throw a medicine ball as far as possible. An open space of 10 m by 3 m was required to perform these tests. In both tests their feet were flat and at the end of the mat underneath them. The FAPT began with the athlete laying supine with a 2-kg medicine ball over head and knees flexed at 90º. Subjects were instructed to flex their trunks in a sit-up motion and launch the medicine ball as far as possible. All participants were given as many practice trials as needed, with rest periods, until they performed the movement correctly. They then performed each test three times with 2 min rest between trials. The mean of the three trials was calculated. Distance was calculated to the nearest 0.5 cm by measuring the distance where the ball landed from the subject's right toe.

The Bunkie Core Test

The Bunkie core test assesses core stability and endurance (de Witt & Venter, 2009). A variation of this test was used (Bassett & Leach, 2011). Participants performed eight different plank positions with their feet on a bench for 20 s. The plank was performed from the elbows, and they were placed directly below the shoulder. The bench measured between 25 and 30 cm high, adjusted for each athlete so that their shoulders and feet on the bench were at the same height. The athletes were allowed to try each position to familiarize for 5 s, but no longer as to avoid fatigue. The plank series is located in Appendix C. During each test, participants were given two warnings if they fell out of the correct position. Time was stopped if they could not return to a neutral position after the second warning, or if they fell out of position a third time. After the time stopped, they were asked to go into the next plank position. If the subject maintained the position correctly for 20 s, they moved immediately to the next phase. The order of the planks positions is located in Appendix C. Athletes' aggregate time for all trials was recorded, even if they did not complete the entire 20 s.

10-yard Sprint

The 10-yd sprint (Cressey, West, Tiberio, Kraemer, & Maresh, 2007) required athletes to sprint between two sets of timing gates (SmartSpeed Timing Gate System, Burbank, CA). Subjects began from their preferred position but had to have their front toe within 1 inch of the starting line between the first set of gates. Following two warm-up trials, they completed three trials with 3 min of rest between each. The fastest of the three trials was taken for analysis.

Dribbling Test

The dribbling task (Reilly and Holmes, 1983) had participants dribble a soccer ball back and forth between a straight line of five cones. A diagram is located in Appendix D. The five cones were spaced at 6, 3, 6, and 6 ft, respectively. The player began 9 ft away from the first cone and on reaching the last cone, then turned and returned through the cones. Timing was recorded with timing gates (SmartSpeed Timing Gate System, Burbank, CA). Players were allowed one practice run through the cones. The aggregate time of four trials was used with a rest period of 5 min between each trial. Testing aides were located on either side of the cones to return the ball in case the player lost control. If a player lost control beyond the testing aides, the trial was discarded.

Loughborough Soccer Passing Test (LSPT)

The LSPT required a rectangular set up with four different colored targets, .6 m x .3 m in size, supported by a standard size gymnasium bench (Ali et al., 2007). A diagram is located in Appendix E. Standard size gymnasium benches were not available, but two 45-lb Olympic plates placed behind the targets provided a stable surface. A piece of sheet metal (0.1 m x 0.15 m) was hung vertically in the middle of the target areas. The metal was only hung to the top of the target so that it hung loosely. When hit, a distinct noise could be could be heard. This provided positive audible feedback. The total area of the test area was 12 m x 9.5 m. The athlete stood inside two overlapping rectangles, one measuring 2.5 m x 1 m and one surrounding that measuring 2.5 m x 4 m. The rectangles were marked with tape on the ground and cones at every corner. The area in between these rectangles was considered the passing zone. The first ball began in the center of the inner designated rectangle. Subjects were told what color to pass to first and timing began as soon as the ball rolled out of the athlete's rectangle. Athletes were required to complete a total of 16 passes (8 short and 8 long) as quickly as possible.

The order of passes was randomly picked from four possible trial orders, determined prior to the study. One researcher would call out the color of the next target to pass to as the athlete was completing the prior pass. The time was stopped when the last pass made contact with the target. The other researcher would add penalty seconds for errors made. Errors included 5 s for missing the target completely or passing to the wrong target; 3 s for missing the target area (0.6 x 0.3 m); 3 s for handling the ball; 2 s for passing the ball from outside the designated area; 2 s for hitting any of the cones with a ball; and 1 s for every additional second over the designated time of 43 s. Players received a deduction of 1 s if they hit the 10 cm metal strip directly in the middle of the target. Research helpers stood near the designated passing area rectangle with balls in hand so that the athlete could perform the next task immediately. Athletes were allowed one practice trial prior to the test. Each participant performed two trials with the mean score used. A 5-min rest period was required between each trial.

Reactive Agility Test

The RAT was originally designed to be used with rugby players (Sheppard & Young, 2006). No practice trials were allowed for this test because of its high inter-trial variability that simulates a game. The athlete was told to face the tester and stand on a marked line with 3 m between the tester and athlete. Timing gates were placed 1 m after the starting line and 5 m to the left and right of the participant. A diagram of this set up is in Appendix E. The subject began behind the timing gate because timing begins on the movement of the athlete. The athlete moved forward and reacted to the lighting system. Timing stops when the athlete triggers a light in the gate to the left or right side (SmartSpeed Timing Gate System, Burbank, CA). The system randomly displayed one of two possible scenarios for the athlete to react to with each scenario requiring short steps of about .5 m. The two scenarios are listed:

1. Step forward and change direction to the left.
2. Step forward and change direction to the right.

There were two trials for each scenario for every athlete. Athletes sprinted forward on the testers command and were instructed to recognize the scenario as soon as possible by changing direction and sprinting through the designated timing gate according to the lighting system. Trial time was recorded with a digital timing system to the nearest .01 s. Each trial was followed by a rest time of approximately two minutes. A total of four trials, two trials of each condition, were completed and the mean of each condition was calculated.

Statistical Analysis

Pearson correlations were run between each performance measurement (i.e., BESS, SEBT, DPSI, FAPT, Bunkie, RAT, and 10-yd sprint) and skills tests (i.e., LSPT, and Dribbling Test). Spearman Rho correlations were run between coach ranking for each player and all performance and soccer skill tests. For analysis, the ranking excluded the ranking of players from 1 to 14 but included the percentage of ability in comparison to former athletes of the same position. The total score summed the coach ranking of 1 to 5 for each variable of physical ability, field sense, and technical ball skill. Alpha tests were run on all balance tests separately to establish internal consistency between different items or subcategories within the same test. This ensures that all parts of the test are measuring the same variable. All descriptive statistics are located in the Results section. A p value of .05 was set at the level of significance.

Chapter 4

RESULTS

The purpose of this study was to examine if reactive agility, core strength, and balance ability were related to soccer skills and on-field performance as determined by coach appraisal. It was also of interest to examine inter-variable relationships in Division III female soccer players. This chapter will present descriptive statistics and correlational analyses with data organized by dependent variable: 1) BESS; 2) SEBT; 3) DPSI; 4) FAPT; 5) Bunkie Core Test; 6) 10-yd. sprint; 7) RAT; 8) slalom dribble; 9) LSPT, and 10) Coach Appraisal Outcomes (TECH, FIELD, PHYS, TOTAL).

Although 15 subjects were initially recruited, only 14 completed the study with one being injured outside of data collection. Participants' height ranged from 157.1 cm to 178 cm (*M* = 166.5, *SD* = 5.8) and weight ranged from 127 lbs to 172 lbs (*M* = 141.7, *SD* = 12.1). Athletes were DIII female soccer players whose age ranged from 19 years to 22 years (*M* = 20.4, *SD* = 1.1). Table 1 provides participants' information.

Descriptive Statistics

The BESS (Table 2) had a large range of scores among athletes with composite scores ranging from 12 to 60. Scores between the right and left side were not significantly different (t (26) = .962, p = .345). Only two participants were considered left foot dominant. The SEBT (Table 2) showed no significant differences between the nondominant and dominant foot (t (22.815) = -.661, p = .515). The highest score was achieved when stabilizing on the nondominant foot. The DPSI (Table 2) showed the

Table 1

Description of Participants

Measure	Mean	Standard Deviation	Range
Height (cm)	166.5	5.8	19-22
Weight (lbs)	141.7	12.1	151.7-178
Age (yrs)	20.4	1.1	127-172
MVJ (inches)	17.1	1.5	15.2-20.3

Note. MVJ = Maximum Vertical Jump Height

Table 2

Descriptive Statistics for Balance Tests

Test	Right M±SD	Left M±SD	Total M±SD	Range Right|Left
BESS (Stable) (error scores)	4.9 ± 4.2	3.4 ± 4.1		0-15|0-13
BESS (Unstable)	15.0 ± 6.7	13.8 ± 5.7		4-23|7-23
BESS Composite	19.9±10.1	17.2±8.5	37.1±17.7	12-60
	Dominant M±SD	Nondominant M±SD		Dominant|Nondominant
SEBT (cm)	704.5±8.5	713.8±43.7		659.57-747.42|663.70-790.61
DPSI (units)	0.3579±.026	0.3555±.032		.3139-.4138|.2996-.3958

Note. BESS= Balance Error Scoring System; SEBT = Star Excursion Balance Test; DPSI = Dynamic Postural Stability Index lowest and highest scores on the nondominant foot. However, on average scores between the dominant (*M* = .3593) and nondominant side (*M* = .3555 were not statistically different (t (26) = .310, *p* = .759).

For core tests, the FAPT (Table 3) showed a minimum and maximum score differing by over 100 cm. The Bunkie Core test (Table 3) had a lowest score at 147 total seconds and many scores reached a high of 160 s. More than half of the participants completed the test entirely to 160 s, suggesting that this test may not have challenged these athletes enough.

Speed and agility tests are reported in Table 4. The 10 yd sprint mean was 2.02 s, ranging from 1.89 to 2.28 s. The RAT test was measured when cutting to the left (*M* = 2.43 s) and to the right (*M* = 2.44 s). There were no significant differences between the right and left scores (t (26) = .474, *p* = .640).

Descriptive statistics for the soccer skill tests are shown in Table 5. The LSPT had a mean of 78.18 s (*SD* = 14.08). The slalom dribble had a mean of 46.39 s (*SD* = 4.46).

Correlation Analyses

Variables were grouped into categories measuring balance, speed and agility, and core stability and power. Pearson correlations were run between performance measurements and skills tests. After running correlations on all parameters, several relationships were found to exist between variables. Spearman Rho correlations were run between coach ranking and all performance and soccer skill tests. For coach ranking,

Table 3

Descriptive Statistics for Core Tests

Test	Mean	Standard Deviation	Range
Bunkie Core (s)	158.2	3.5	147.0-160.0
FAPT (cm)	461.5	60.6	432.0-532.3

Note. Bunkie Core Test units = seconds; FAPT = Front Abdominal Power Test

Table 4

Descriptive Statistics for RAT and 10 yd Sprint

Test	Mean	Standard Deviation	Range
RAT – Right (s)	2.44	0.17	2.19-2.75
RAT – Left (s)	2.43	0.14	2.18-2.70
10-yd Sprint (s)	2.02	0.01	1.89-2.28

Note. RAT = Reactive Agility Test

Table 5

Descriptive Statistics for Soccer Skill Tests

Test	Mean	Standard Deviation	Range
LSPT (s)	78.18	14.08	61.89-118.49
Slalom Dribble (s)	46.39	4.46	39.75-55.60

Note. LSPT = Loughborough Soccer Passing Test scoring excluded the ranking of players from 1 to 14 but included the percentage of ability in comparison to former athletes of the same position. The total score summed the coach ranking of 1 to 5 on each variable of physical ability, field sense, and technical ball skill.

The following correlation tables are broken up into groups of balance correlations, speed and agility correlations, and core correlations. Table 6 presents relationships between the balance tests and soccer performance measures. Several of the BESS variables were significantly related to coach appraisal of performance (i.e., RANK and TOTAL). No significant relationships existed between the balance tests and soccer skill tests (i.e., LSPT and Slalom Dribble) suggesting that balance may not play a large role in these assessments.

Table 7 displays correlations for balance tests, with speed and agility tests, and with core tests. The SEBT-ND, which was on the left foot except two cases, correlated with the RAT-R (r = .664, p = .013). The BESS-R significantly correlated with the 10 yard sprint (r = .550, p = .042) and the RAT-L (r = .542, p = .045). The BESS-L correlated with the RAT-R (r = .545, p = .044) and RAT-L (r = .763, p = .002). It is interesting to note that better balance, as measured by the BESS, on one foot was consistently related to better agility when likely cutting on the same foot as measured by

Table 6

Correlation of Balance Tests and Soccer Performance

	RANK	TOTAL	TECH	PHYS	FIELD	LSPT	SLALOM
BESS-R	-.767**	-.763**	-.736**	-.614*	-.651*	-.058	.436
BESS-L	-.535*	-.446	-.449	-.290	-.408	-.150	-.067
BESS-RU	-.546*	-.544*	-.521	-.522	-.501	-.373	.131
BESS-LU	-.210	-.318	-.359	-.280	-.282	-.288	-.171
BESS-T	-.564*	-.589*	-.612**	-.497	-.517	-.282	-.282
DPSI-D	.262	.176	.385	-.072	-.033	-.353	-.477
DPSI-ND	.414	.329	.452	.145	.170	-.186	-.299
SEBT-D	.141	.200	-.005	.260	.205	.235	-.150
SEBT-ND	-.166	-.229	-.378	-.174	-.123	.404	.198

Note. BESS-R = Balance Error Scoring System on Right Foot; BESS-L = Balance Error Scoring System on Left Foot; BESS-RU = Balance Error Scoring System on Right Foot on Unstable Surface; BESS-LU = Balance Error Scoring System on Left Foot on Unstable Surface; BESST = Balance Error Scoring System Total Score; DPSI-D = Dynamic Postural Stability Index on Dominant Foot; DPSI-ND = Dynamic Postural Stability Index on Nondominant Foot, SEBT-D = Star Excursion Balance Test on Dominant Foot; SEBT-ND = Star Excursion Balance Test on Nondominant Foot; RANK = Rank of Player in Relation to Other Players; PHYS = Coach Ranking on Physical Ability; TECH = Coach Ranking on Technical Ball Skill; FIELD = Coach Ranking on Field Sense; TOTAL = Composite of PHYS + TECH + FIELD, LSPT = Loughborough Soccer Passing Test; SLALOM = Slalom Dribble
All correlations with RANK, TOTAL, TECH, PHYS, FIELD are Spearman Rho Correlations
All correlations with LSPT and SLALOM are Pearson Co. Correlations
*p<.05, **p<.01

Table 7

Correlation of Balance Tests with Speed and Agility, Core Stability and Core Strength Tests

	10-yd	RAT-R	RAT-L	Bunkie	FAPT
BESS-R	.550*	.161	.542*	-.123	.138
BESS-L	.364	.545*	.763**	.031	.184
BESS-RU	.056	.105	.382	.007	-.005
BESS-LU	-.143	-.176	.118	.022	.301
BESS-T	.189	.146	.485	-.013	.170
DPSI-D	-.300	.307	-.262	-.098	-.028
DPSI-ND	-.208	.529	.093	.049	.145
SEBT-D	-.265	-.211	.022	.177	.278
SEBT-ND	-.278	.644*	-.280	-.034	-.168

Note. BESS-R = Balance Error Scoring System on Right Foot; BESS-L = Balance Error Scoring System on Left Foot; BESS-RU = Balance Error Scoring System on Right Foot on Unstable Surface; 10-yd = 10 Yard Sprint; BESS-LU = Balance Error Scoring System on Left Foot on Unstable Surface; BESST = Balance Error Scoring System Total Score; DPSI-D = Dynamic Postural Stability Index on Dominant Foot; DPSI-ND = Dynamic Postural Stability Index on Nondominant Foot; SEBT-D = Star Excursion Balance Test on Dominant Foot; SEBT-ND = Star Excursion Balance Test on Nondominant Foot; 10 yd = 10 yard sprint; RAT-R = Reactive Agility to the Right, RAT-L = Reactive Agility to the Left; Bunkie = Bunkie Core Test; FAPT = Front Abdominal Power Test
All Correlations are Pearson Correlations
*p<.05, **p<.01

the RAT. The relationships between speed/agility and balance measured with the BESS and SEBT are interesting and merit consideration. However, the DPSI failed to relate to any other variable.

The balance variable inter-relationships comprise Table 8. The BESS-R correlated with the BESS-L (r = .803, p = .001), the BESS total composite score (BESS-T) (r = .833, p = .000), and on the right foot on the unstable surface (BESS-RU) (r = .699, p = .005). The BESS-RU also correlated with the BESS-L (r = .758, p =.002), the BESS-LU (r = .655, p = .011), and the BESS-T (r = .927, p = .000). Lastly, the BESS-T correlated with the BESS-L (r = .867, p = .000) and BESS-LU (r = .792, p = .001). All BESS tests combined established a high level of internal consistency (α = .827). The DPSI on the left and right leg were highly correlated (r = .671, p = .009) and also had a high level of internal consistency (α = .784). The SEBT on the dominant (SEBT-D) and nondominant (SEBT-ND) legs were significantly correlated (r = .620, p = .018) and had high level of internal consistency (α = .730). No balance tests correlated with one another, suggesting that they were independent tests that may have aspects of balance.

Table 9 displays the relationships between the speed and agility tests with soccer performance. No significant correlations were found between any coach appraisal variable and speed or agility variable. Similarly, no significant correlations existed between the soccer skill tests and any speed or agility variables. According to these data, speed and agility do not significantly correlate well with soccer performance in Division

Table 8

Inter-Correlations of Balance Tests

	1	2	3	4	5	6	7	8	9
1. BESS-R									
2. BESS-L	.803**								
3. BESS-RU	.699**	.758**							
4. BESS-LU	.461	.503	.655**						
5. BESS-T	.833**	.867**	.927**	.792**					
6. DPSI-D	-.303	-.056	.206	.077	.000				
7. DPSI-ND	.051	.422	.311	.339	.335	.661*			
8. SEBT-D	-.201	.002	-.064	.513	.093	-.144	.093		
9. SEBT-ND	-.089	-.288	-.087	.281	-.030	.093	-.378	.620*	

Note., 1. BESS-R = Balance Error Scoring System on Right Foot ; 2. BESS-L = Balance Error Scoring System on Left Foot; 3. BESS-RU = Balance Error Scoring System on Right Foot on Unstable Surface; 4. BESS-LU = Balance Error Scoring System on Left Foot on Unstable Surface; 5. BESST = Balance Error Scoring System Total Score; 6. DPSI-D = Dynamic Postural Stability Index on Dominant Foot; 7. DPSI-ND = Dynamic Postural Stability Index on Nondominant Foot; 8. SEBT-D = Star Excursion Balance Test on Dominant Foot; 9. SEBT-ND = Star Excursion Balance Test on Nondominant Foot
All Correlations are Pearson Correlations
*p<.05, **p<.01

Table 9

Correlation of Speed and Agility Tests and Soccer Performance

	RANK	TOTAL	TECH	PHYS	FIELD	LSPT	SLALOM
10 yd	-.360	-.285	-.203	-.463	-.033	.179	.389
RAT-R	-.101	.102	.184	.101	.002	-.083	-.014
RAT-L	-.524	-.327	-.449	-.145	-.196	.095	.303

Note. 10 yd = 10 yard sprint; RAT-R = Reactive Agility to the Right; RAT-L = Reactive Agility to the Left; RANK = Rank of Player in Relation to Other Players; PHYS = Coach Ranking on Physical Ability, TECH = Coach Ranking on Technical Ball Skill; FIELD = Coach Ranking on Field Sense; TOTAL = Composite of PHYS + TECH + FIELD, LSPT = Loughborough Soccer Passing Test; SLALOM = Slalom Dribble
All correlations with RANK, TOTAL, TECH, PHYS, and FIELD are Spearman Rho Correlations
All correlations with LSPT and SLALOM are Pearson Correlations

III women's soccer players.

Correlations between the core tests and soccer performance are found in Table 10. The only significant relationship found was between a coach appraisal (i.e, FIELD) and the Bunkie core test. There is no apparent explanation for this significant relationship between soccer field sense and core stability. No other significant relationships existed between core tests and soccer performance measures. Correlations between core and speed and agility tests are presented in Table 11. No significant relationships were found between these variables. Finally, correlations between the soccer skill tests and coach appraisals are found in Table 12. The coach ranking of technical ball skill correlated with the SLALOM (r = .593, p = .026), indicating that coach perceptions of technical ball skill were well supported by laboratory test of dribbling.

The coach individual player ranking (RANK) and coach total score (TOTAL) given to each player based on the summation of physical ability (PHYS), field sense (FIELD), and technical ball skill (TECH) were highly correlated (r = .937, p = .000). The rank score also correlated with PHYS (r = .685, p = .007), TECH (r = .912, p= .000), and FIELD (r = .829, p = .002). This was expected based on the large correlation seen in the total of the scores (TOTAL). PHYS also correlated with TECH (r = .700, p = .005), indicating that players who are coach ranked as having better physical ability typically also had better technical ball skill ranking. FIELD was also associated with TECH (r = .712, p = .004), demonstrating that players who were ranked as having better field awareness were also ranked as having better technical ball skill. These results can be seen in Table 13.

Table 10

Correlation of Core Tests with Soccer Performance

	RANK	TOTAL	TECH	PHYS	FIELD	LSPT	SLALOM
FAPT	.114	.082	.014	.109	.106	.084	.248
BUNKIE	.359	.371	.301	.093	.576*	.167	-.023

Note. FAPT = Front Abdominal Power Test; BUNKIE = Bunkie Core Test; Rank = Rank of Player in Relation to Other Players; PHYS = Coach Ranking on Physical Ability; TECH = Coach Ranking on Technical Ball Skill; FIELD = Coach Ranking on Field Sense; TOTAL = Composite of PHYS + TECH + FIELD; LSPT = Loughborough Soccer Passing Test; SLALOM = Slalom Dribble
All correlations with RANK, TOTAL, TECH, PHYS, and FIELD are Spearman Rho Correlations
All correlations with LSPT and SLALOM are Pearson Correlations
*p < .05

Table 11

Correlation of Speed and Agility with Core Tests

	FAPT	Bunkie
10 yd.	.105	.031
RAT-R	.144	.070
RAT-L	-.032	.147

Note. 10 yd = 10 yard sprint: RAT-R = Reactive Agility to the Right; RAT-L = Reactive Agility to the Left; FAPT = Front Abdominal Power Test; Bunkie = Bunkie Core Test
All correlations are Pearson Correlations

Table 12

Correlation of Soccer Skill Tests and Coach Appraisal

	RANK	TOTAL	TECH	PHYS	FIELD
LSPT	.230	.220	-.019	.217	.466
SLALOM	-.439	-.418	-.593*	-.275	-.181

Note. LSPT = Loughborough Soccer Passing Test; SLALOM = Slalom Dribble; Rank = Rank of Player in Relation to Other Players; PHYS = Coach Ranking on Physical Ability; TECH = Coach Ranking on Technical Ball Skill; FIELD = Coach Ranking on Field Sense; TOTAL = Composite of PHYS + TECH + FIELD
All correlations are Spearman Rho Correlations
*p<.05, **p<.01

Table 13

Inter-correlation of Coach Appraisals

	RANK	PHYS	TECH	FIELD	TOTAL
RANK					
PHYS	.685**				
TECH	.912**	.700**			
FIELD	.829**	.504	.712**		
TOTAL	.937**	.806**	.931**	.859**	

Note. RANK = Rank of Player in Relation to Other Players; PHYS = Coach Ranking on Physical Ability; TECH = Coach Ranking on Technical Ball Skill; FIELD = Coach Ranking on Field Sense; TOTAL = Composite of PHYS + TECH + FIELD
All correlations are Spearman Rho Correlations
* p < .05, ** p < .01

Chapter 5

DISCUSSION

The purpose of this study was to determine if soccer player balance, reactive agility, and core strength were related to soccer performance in skill tests and in coach appraisal. These physical performance measures were taken over the course of four testing days during the off-season for a DIII collegiate women's soccer team. It was hypothesized that athletes who performed better on tests assessing balance, reactive agility, balance, and core strength would also perform better on soccer skills tests and in coach appraisal. The hypothesis that better performance on balance, reactive agility, and core tests would be associated with performing better on skill tests was not supported. The hypothesis that better performance on balance, reactive agility, and core tests on improved performance was partially supported. This chapter will focus on the hypothesized outcomes, relationships between variables, and how these results compare to current literature. Discussion of reactive agility test (RAT), speed, balance, core power, and their relationships to soccer performance measures are found below.

Researchers investigating the RAT suggested this test might discriminate performance in field sports with a constant change in game dynamics (Sheppard & Young, 2005). However, the present study failed to find the RAT to be indicative of ability in DIII female collegiate soccer players. The average RAT time in the present study was slightly greater than times found in a group of high school athletes. However, these findings may not be easily compared because the researcher's initiated movement rather than athlete direction being dictated by a lighting system as in the current study (Gabbett, Sheppard, Pritchard-Peschek, Leveritt, & Aldred, 2008). The automated lighting system used presently probably allowed for greater precision and explains the overall scoring differences between studies. A video system, which actually projects images of athletes to assess reactive agility, may provide a novel method of measuring RAT and may allow discrimination of performance or ability level among athletes (Henry, Dawson, Lay, & Young, 2011). Future research should investigate the video system with various field athletes, such as soccer and field hockey. This video system could be used not only to evaluate reactive agility but may also be useful for training and improving reactive agility. Perhaps the use of a person or image, rather than lights, would have yielded better results in the present study. Further research should look into improving reactive agility at the elite and subelite levels in soccer players to see if results would parallel those found in rugby players (Sheppard & Young, 2005). It is also possible that RAT differences could be seen between DI and DIII soccer players.

The 10 yd sprint was also not related to improved soccer performance. Results from the current study evaluating speed in female soccer players were very similar to others (Bullis, van Boxtel, Harnell, Ostrowski, Holzem, 2007). Following a dynamic warm-up, they found that the female soccer players displayed an average of 1.98 s with a standard deviation of .06 s. Their coefficient of variation (CV) was .03 while the current study displayed CV = .05, showing that this test is very consistent. These results indicate that perhaps the 10 yd sprint is too short of a test to be related to performance measures in DIII collegiate players. Researchers (Bullis, van Boxtel, Harnell, Ostrowski, Holzem, 2007) actually referred to this test as the 10-yd acceleration test, suggesting that it only measures an ability to accelerate rather than speed. Maximal speed may be more important in soccer players. Other researchers investigating sprinting (Buchheit, Simpson, Peltola, & Mendez-Villanueva, 2012) found that two or three 10-m splits should be used when assessing maximal velocity. In addition, they found that older players with greater acceleration also reached maximal sprinting speed later in the 40-m dash compared to those with a lower acceleration. This suggests that greater acceleration may not result in reaching maximal sprinting speed over a shorter distance. This could be due to subtle differences in running mechanics or changes in acceleration between splits. Future research should include this protocol in assessing speed in female collegiate soccer players and speed relationship with player performance.

Balance is known to discriminate ability between national and regional male soccer players (Paillard et al., 2006). The balance tests implemented in this study involved static and dynamic balance tests. Compared to a previous study using the BESS in DI female soccer players, the mean amount of error scores in the present study's DIII players was greater and may suggest that DI players have better balance (Logan, 2007). In addition, the present study did not include the tandem stance, which would have accounted for additional error scores. The BESS, on the right leg specifically, was shown to be highly related to soccer performance measured by coach appraisal. It cannot be concluded from this correlational analysis that balance ability on the right foot causes better performance. However, better athletes as ranked and scored by the coach tended to have better balance. These results might suggest balance training should be considered a potentially important component of fitness in female soccer players. Improving balance in these athletes may also elicit improvements agility and speed (Malliou et al., 2004;

Šalaj, Milanović, & Jukić, 2007; Yaggie & Campbell) while reducing the likelihood of injury (Verhagen et al., 2004; Chasan, 2012). Although the BESS scores were related to better performance on the field in the coach's opinion, BESS did not correlate well with either soccer skill test. These findings suggest that balance ability may not be clearly related to performance in dribbling and passing. A relationship between balance and speed was supported in the present study with the strong correlation (r = .550) displayed between the BESS-R and 10 yd sprint. The BESS-R was also strongly related (r = .542) to the RAT-L, probably because when athletes move to the left they likely push off their right foot. Therefore, it is conceivable that right leg balance ability can predict and affect agility, speed, and soccer performance in DIII women's soccer players. A balance training study in female soccer players is warranted in the future.

The SEBT did not mimic BESS results and showed no relationship to soccer performance ability. Although it is widely used in the literature to assess dynamic balance, maybe the SEBT is more appropriate for a clinical setting. However, present SEBT scores were less than those found in a similar study with female DI soccer players. Perhaps there is a difference between ability levels that the SEBT discriminates but more research is needed to prove this result (Logan, 2007). The SEBT was previously used to compare balance ability between gymnasts, soccer players, and basketball players, and no differences were found in balance ability (Bressel, Yonker, Kras, & Heath, 2007). However, other studies using stabilometers in gymnasts and soccer players have found differences (Davlin, 2004), suggesting the SEBT may distinguish balance ability with a ceiling effect limiting its use in higher level athletes. In the present study, the SEBT on the nondominant foot was also related to RAT-R. Similarly to the BESS-R and the RAT-L relationship, the balance ability on what was most often the left foot was related to agility to the right side. Again, this suggests that balance ability and agility are inter-related and it is conceivable that training one can lead to improvements in the other.

The last balance test, the DPSI, was implemented because of its potential relationship to actual soccer game play. However, no relationship was found between the DPSI and soccer performance measures in the present study. One previous article reported the effects of different landing positions of the foot and found that slight differences in foot position may alter sway in various planes, thereby altering the DPSI score (Wikstrom, Tillman, Schenker, & Borsa, 2008). In addition, unsuccessful and failed trials were not taken into account in the present protocol and these values could have provided additional information (Wikstrom, Tillman, Smith, & Borsa, 2005). Sell (2012) recently looked at DPSI relationship with static single-leg stance and found no correlation between the two. The author suggested differences exist in these abilities and that more challenging measures of dynamic postural stability may be more appropriate for identifying injury risk in physically active adults (Sell, 2012). It may be that the DPSI is more appropriate for identifying injury risk rather than identifying performance ability.

Core strength, as measured by the FAPT, showed no correlation with any other variables, suggesting that core strength may be a unique variable whose relationship to performance in DIII female (subelite) soccer players is difficult to ascertain. One study (Wagner, 2010) comparing isometric core strength, or core stability, to the FAPT in collegiate female soccer players supports that two limitations of this test might exist: (1)

muscular involvement of the shoulder, elbow, and wrist; and (2) release height and angle of the ball. Wagner contends that taller players who release the ball from a greater height will project the ball further when all else is equal. Wagner found a mean score of 160 cm in the FAPT, while the present study's had a very different average of 461.5 cm. This suggests that the protocol of this test is difficult to perfect and scores vary radically even between athletes of the same sport. Another recent study (Nikolenko, Brown, Coburn, Spiering, & Tran, 2011) looked at the relationship between the FAPT and sports performance as measured by a 40-yd dash, shuttle run, vertical jump, and 1-RM back squat. The only significant correlation they found was between the FAPT and the 1-RM back squat (r = .652). The authors concluded that this test may not be appropriate in assessing core power because it was unrelated to all other variables that are indicative of sports performance. They justify this by suggesting that the FAPT may target the trunk flexors, which are also highly recruited in the back squat and could explain the relationship between the tests. Although the trunk flexors may be activated in the other tests, the specific muscle movements and actions seen in the FAPT may not be specific to the role the core muscles play in the other tests.

Results from the present study generally support previous findings of core strength and its lack of significance to sports performance (Nesser & Lee, 2009; Scibek et al., 2001). Perhaps more sport-specific tests measuring core power and strength would be more appropriate to demonstrate the importance of core fitness. Alternatively, core fitness may not be a critical element in soccer player performance.

The Bunkie core test was also unrelated to all soccer performance measures with the exception of 'field sense' as ranked by the coach. There is no apparent or plausible explanation for this correlation between core stability and field sense suggesting that this result may simply be a statistical anomaly due to a small sample size. The Bunkie test was implemented as a measure of improved core stability in gymnasts and runners (Bassett and Leach, 2011; de Witt and Venter, 2009), but no prior study has related the Bunkie to sports performance. Core stability relationship with soccer performance is not clear with many studies finding conflicting results (Nesser et al., 2008; Nesser & Lee, 2009; Stanton, Reaburn, & Humphries, 2004; Tse et al., 2005). Most studies evaluating core stability involve isometric tests of various positions, similarly to the Bunkie Test. However, the entire Bunkie test was completed by only 9 of 14 participants. Wagner (2010) found that the core played a greater role in providing a stable base of support in soccer players rather than a mechanism by which to transfer and produce force. He found significant relationships between isometric core strength and improved ability on various skills including throw-ins and kicking velocity. However, the isometric test involved a maximal voluntary contraction of the core using a harness attached to a dynamometer. This may be a better test and could be used in the future when measuring core stability in female soccer players.

The present study found no relationship between better performance in core power or stability and soccer performance. However, the relationship between improved core stability and decreased likelihood of injury cannot be ignored (Borghuis, Lemmick, & Hof, 2008; Hibbs, Thompson, French, Wrigley, & Spears, 2008). It is possible that the players with better core stability may be at a decreased likelihood of injury, thereby displaying better performance in the long run.

The slalom dribble test showed no relationship to any other soccer performance variable, aside from technical ball skill in the coach rating. This test is established and it has known validity and reliability (Reilly & Holmes, 1983). The significant correlation ($r = .534$; $p < .05$) between the test and the coach ranking suggests a nice agreement between a laboratory test and expert opinion. Previously, Reilly & Holmes (1983) validated the slalom test by comparing teenage boys' dribbling ability to a subjective scoring of soccer ability. The present study supports these findings providing expert validation of the slalom test. Although this test shows great reliability, it is possible that it is not as game-like as more recently developed slalom dribble courses. In this test, the athlete is simply dribbling around cones in a straight line with minimal space between the cones. Another study (Stone & Oliver, 2009), evaluating a similar age group as the present study, incorporated a more complex slalom course where participants had to dribble around cones that were angled to one another. They also had to change direction with the ball twice and dribble straight. Perhaps such a test would be more useful in finding differences in soccer ability due to the increased complexity and more game-like maneuvers in experienced players.

Passing test scores (LSPT) were not related to any other variable. It was expected that this test might correlate with a coach's rating of technical ball skill or perhaps field sense. However, technical ball skill includes other variables aside from directing and passing potentially giving the LSPT a weak relationship with coach appraisal. The original use of this passing test included elite and subelite players (Ali et al., 2007). On average, elite players were able to complete the test in 43.6 s and subelite players in 52.5 s. They were also involved in a regular training schedule. The LSPT test developers found that the largest differences between the groups were due to the difference in error scores accrued, rather than the gross time to complete the circuit. They also found that although the test was valid and reliable, reliability was greater at the elite level (Ali et al., 2007). They found this to be the case when assessing elite and nonelite female players as well (Ali, Foskett, & Gant, 2008). The mean performance time for our group of DIII female collegiate players was much greater than previously seen at 78.2 s, suggesting that the LSPT should be repeated in DIII soccer players to see if this time is typical for this level of athlete. Participants in the LSPT accrued various amounts of error scores, which likely contributed to the large range of scores seen in performance. Most participants also missed the target entirely at least one time, causing lag time between participants receiving a new ball. The participant was instructed not to chase far after the ball because this would have measured other variables, such as fetching ability, in addition to passing ability. If the ball stopped close to the boundaries, the same ball was retrieved. This could not be controlled if the ball went across the gymnasium. Perhaps these athletes would have benefitted from discarded trials as to solely measure passing ability. In other words, logistics of the LSPT might account for score variation as much as, or more than, player ability. Establishing a good passing test is important to evaluating soccer skill. More work should be done on the LSPT to make it easy to administer with all levels of skill. It is possible that this test would reveal differences between the DI and DIII levels on performance in general.

In summary, most tests of agility, speed, balance, and core power showed no relationship to better soccer performance. However, some of the relationships discovered were meaningful. A consistent relationship between balance, agility, and speed was apparent. Specifically, balance on one foot was associated with agility in the other direction. Female players who displayed better static balance on the right foot were rated as being the best players by the coach. This might be useful information for strength and conditioning coaches. At least one assessment of balance (i.e., BESS) positively related to coach appraisal of soccer ability. Though not overwhelming, balance may be an important fitness component to the female DIII soccer player. Future studies should be conducted to see if improvements in balance can lead to improved soccer skill.

Chapter 6

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

Summary

Although researchers have identified several athletic components for success in soccer, most research has investigated important parameters in elite players. In these studies, agility and speed, and balance are identified as predictors of success. Differences in gender, and lack of research on DIII female soccer players, provides an issue worthy of study. Therefore, the purpose of this study was to determine if athletic components of balance, reactive agility and speed, core strength, and core stability were related to better performance on soccer skill tests and performance as defined by coach appraisal. Fourteen subjects from a women's DIII soccer team performed three tests of balance, one test of reactive agility, one test of speed, two tests of core strength, and two soccer skill tests over four days. Coach appraisal included a ranking of each player individually in relation to teammates and a total score using a Likert-type scale assessing technical ball skill, physical ability, and field sense. Pearson correlations were run between tests of athletic skill (i.e., balance, speed, agility, core) and tests of soccer skill (i.e., slalom dribble and passing test). In addition, Spearman Rho correlations were determined for all variables with coach appraisal scores. Significant relationships ($p < 0.05$) were found between balance and performance as indicated by the coach appraisal, balance and reactive agility and speed, and the coach's ranking of technical ball skill and performance in the slalom dribble test. Analysis revealed that most tests of balance, speed and agility, and core strength were not related to improved performance on soccer skill tests or coach appraisal. It appears that balance, when measured by the BESS, is related to soccer performance. Further research, with more powerful designs, should look deeper into this relationship.

Conclusions

Based upon the analysis of data collected in the present study the following conclusions can be made:

1. In DIII female soccer players, balance (as measured by the BESS) is positively related to performance as assessed by coach appraisal.
2. In DIII female soccer players, balance, agility, and speed display some inter-relationship, though it is not clear if development of one leads to better performance in another.
3. The slalom dribble test appears valid for use in DIII female soccer players as supported by coach assessment of technical ball skill.
4. It is unclear if improving balance in DIII female soccer players, through a training program, will lead to improved soccer performance.

Recommendations

Based upon the results collected in the present study, the following recommendations are made for future research:

1. Further research should be performed to see if improving balance leads to improved performance in DIII female soccer players.
2. Further research should be performed to see if the LSPT should be modified for use in DIII female soccer players.
3. Further research should be performed with athletes with varying degrees of balance, most likely based on sport, to see if the DPSI is an accurate indication of dynamic balance ability in a wide group or if the test has application limitations.

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APPENDICES

Appendix A

SUBJECT RECRUITMENT FLYER

Research Study Announcement

Dynamic balance, reactive agility, and core strength in male and female soccer players

The Graduate Program of Exercise and Sport Sciences and Ithaca College is looking for intercollegiate soccer players that are at least eighteen years of age to participate in a study to look at dynamic balance, reactive agility, and core strength and how it relates to selected skill tests and performance. Each athlete will perform a series of nine tests related to dynamic balance ability, core endurance and power, reactive agility, a dribbling test, and a passing test. In addition, the basic anthropometric measurements of height, weight, and leg length. Total time for the study will be around two hours over two separate days, suggesting a total time commitment of between three and four hours. These days of testing will be selected based on participant's schedule and what times work for them personally. This could change slightly based on the number of participants. Also, the soccer coaches will be asked to rate soccer players' ability in comparison to the other athletes and in relation to other players of the same position that they have coached in the past. There may be minimal fatigue involved with the soccer specific skills tests and core endurance tests, but it should reside quickly. If at any point in time during the study you feel discomfort or wish to leave, you have the option to remove yourself from the study. Non-participation in the study or removing yourself will have no effect with your placement on the soccer team. This is voluntary participation. For all those who do participate, a cash raffle of $25, $20, and $15 will be conducted at the end of the study.

For more information, contact:

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Appendix B

INFORMED CONSENT FORM

"Dynamic balance, reactive agility, and core strength in male and female soccer players"

Purpose of the Study

The purpose of this study was to examine if balance, core strength, and reactive agility in soccer players correlates with specific tests of skill. In addition, to determine if balance, core strength, and reactive agility are potential talent identification factors based on expert appraisal.

Benefits of the Study

The results of this study could reveal that dynamic balance, core strength, and reactive agility are important skills and predictive of performance in soccer. Based on the findings, coaches may consider implementing these components into your training program. As a participant, you may get insight to your own personal ability in several athletic performance measures. All participants will also have three chances to win cash rewards in a raffle.

What You Will Be Asked To Do

Participants will have basic anthropometric measurements done including height, weight, and leg length. You will be asked to perform a total of ten performance tests that will challenge your athletic ability. The first will measure your maximum vertical jump height. Two tests of dynamic balance will be used and two tests evaluating core endurance and core power will be used. The core endurance test will involve holding plank positions for a given amount of time and the core power test will involve launching a medicine ball as far as possible. The speed test will involve a 10-yard sprint. The reactive agility test will require you to go through a series of two gates as quickly as possible and the skills tests will include one dribbling test and one passing test. You will have access to all of this information following data collection. If you have sustained a lower extremity injury or concussion within the last two months, you will not be eligible for participation.

In addition, we will give your coaches a questionnaire for him or her to rate your performance in comparison to the other current players on your team and in relation to other past players in your position. The coach information will be provided confidentially and no one, not even you, will be able to see the information your coach provides. Your total time commitment will involve two weekend days and each day will require around two hours of testing. If testing can be done during the week or on weekends, and is conducive to your schedule, that can be arranged as well.

Risks

In reality, a risk of serious injury is minimal. As an athlete you are familiar with maximal effort tests. They are challenging but tiring and may carry some risk of injury. If any injury should occur, the athlete will be escorted to the health center on campus or to an urgent care facility. More than likely, you will feel some fatigue, especially following the core endurance test and the skills tests. This fatigue should subside relatively quickly.

Compensation for Injury

If you suffer an injury that requires any treatment or hospitalization as a direct result of this study, the cost for such care will be charged to you. If you have insurance, you may bill your insurance company. You will be responsible to pay all costs not covered by your insurance. Ithaca College will not pay for any care, lost wages, or provide other financial compensation.

If You Would Like More Information about the Study

Please contact the primary investigator, Kaitlin Dolan, to receive more information about this study or to receive an abstract of the results. She can be reached at (585)749-0601. You may also contact Dr. Gary Sforzo at sforzo@ithaca.edu for additional information.

Withdrawal from the Study

If you feel uncomfortable at any time, you are free to withdraw from the study without any questions being asked of you and without it affecting your standing on the soccer team. If you remove yourself from the study, none of your data or information will be used.

Confidentiality of the Data

All data acquired about you during the study will remain confidential. All hard data will be kept with the primary investigator, Kaitlin Dolan, and she will not allow others to see it. Computer data will only refer to a numerical code, which be assigned by the primary investigator while entering data. Results may be used educationally for scholarly publications and presentations, but you will never be referred to or identified by name.

Participant's Statement

I have read the above and I understand its content. I agree to participate in this study. I acknowledge that I am 18 years of age or older. I have received a copy of this consent for my own records.

____

Print Name (Participant)

________________________________ ______________________

Signature (Participant) Date

Appendix C
BUNKIE CORE TEST

Test Phase	Leg Position	Fascial Line
Supine Plank	Right Leg Raised Left Leg Raised	Posterior Fascial Line
Prone Plank	Right Leg Raised Left Leg Raised	Anterior Fascial Line
Side Plank, Feet Above Bench	Right Leg Raised Left Leg Raised	Lateral Fascial Line
Side Plank, Foot Below Bench	Right Leg Raised Left Leg Raised	Medial Fascial Line

Appendix D

DRIBBLING TEST

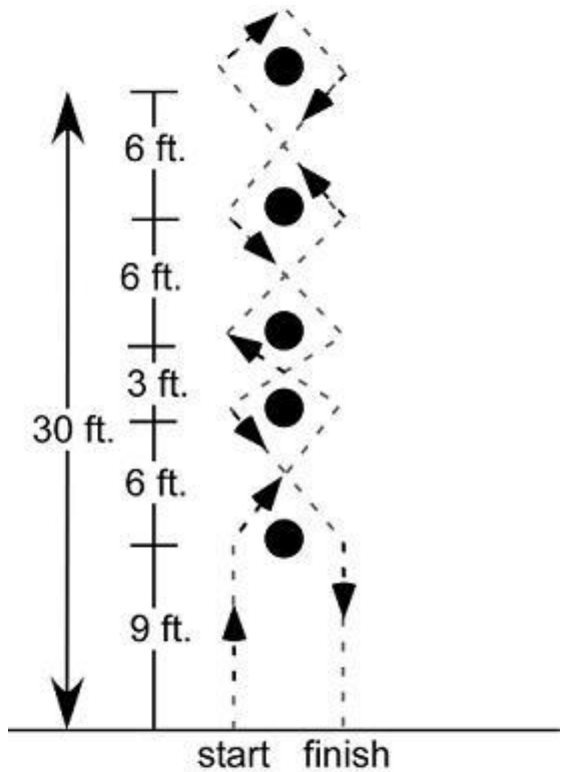


Image (Reilly & Holmes, 1983) Retrieved From: Electronic Delivery through Ithaca College interlibrary loan services

<u>Appendix E</u>

LOUGHBOROUGH SOCCER PASSING TEST

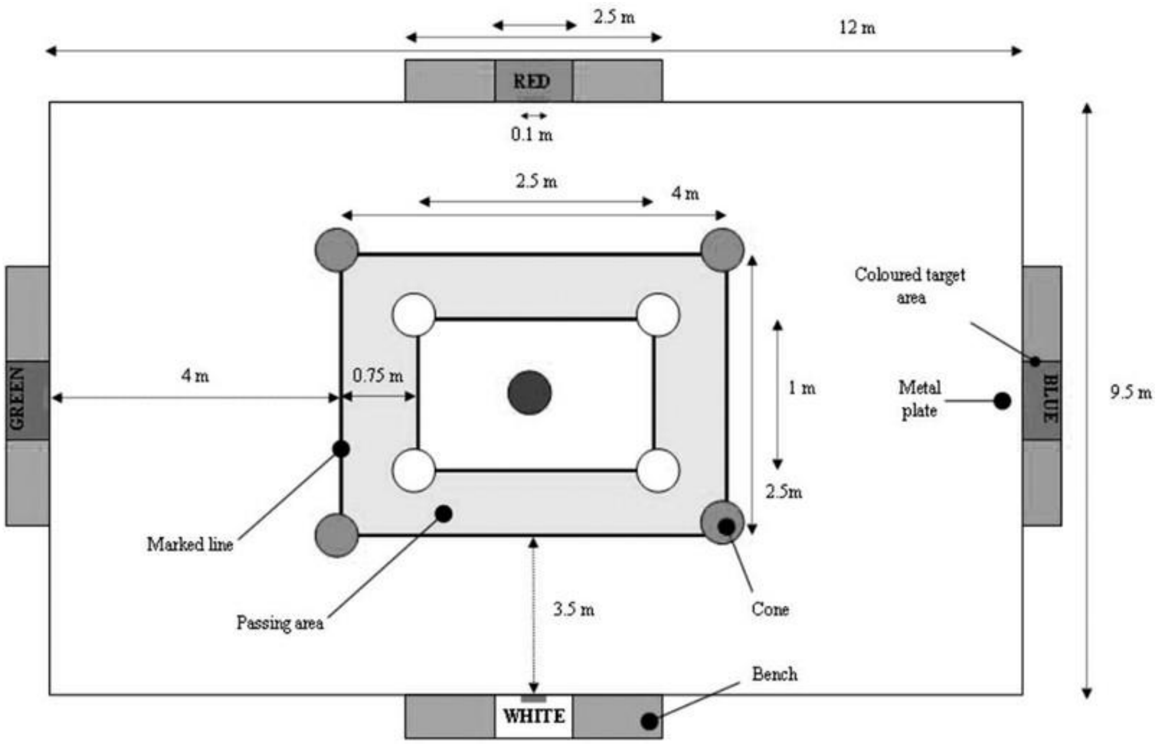
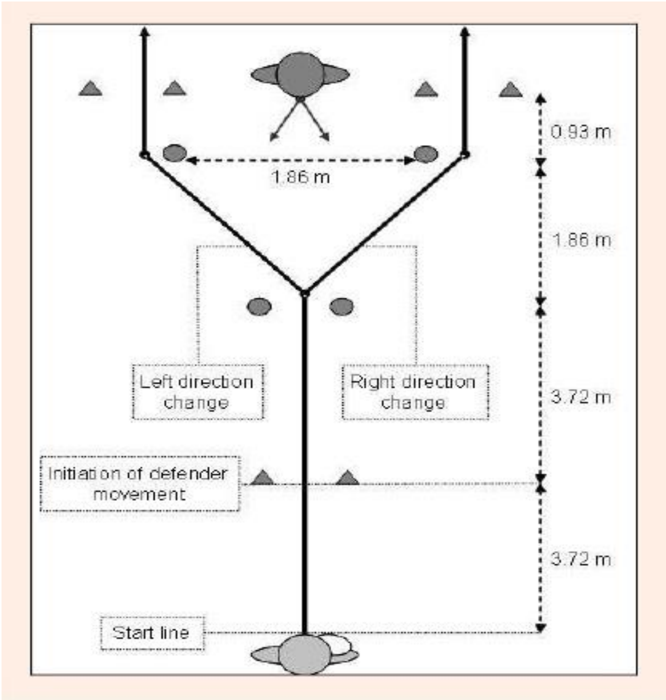


Image (Ali et al., 2007) Retrieved From: https://www.thieme-connect.de/media/sportsmed/200811/t0705sm01.jpg

<u>Appendix E</u>
REACTIVE AGILITY TEST



Note. The area designating a 'tester' between the two final gates was not included in this study because the lighting system served as the 'tester', and two sets of timing gates were placed where the participant started and prior to the arrows indicating direction change. Dimensions were those used by Sheppard, Young, Doyle, Sheppard, & Newton (2006) rather than those in the image.

Image Retrieved From: https://dc261.4shared.com/doc/_JYZkRDQ/preview002.png

Appendix F

COACH RATING QUESTIONNAIRE – LIKERT-TYPE SCALED ABILITY

For each athlete, you will grade them on a scale of 1-5 in three categories.

1 – Poor, 2 – Below Average, 3 – Average, 4 – Good, 5 – Excellent

The three categories will include:

1. **Physical Ability (endurance, speed, power, agility, aggression)**
2. **Technical Ball Skill (dribbling, passing, receiving, redirecting)**
3. **Field Sense (decision making, field awareness, leadership)**

SUBJECT NUMBER	PHYSICAL ABILITY	TECHNICAL BALL SKILL	FIELD SENSE
1			
2			
3			
4			
5			
6			
8			
9			
10			
11			
12			
13			
14			
15			

Appendix G

COACH'S RATING QUESTIONNAIRE – RANKING

For this ranking, simply rank each player 1(the 'best') to 14(the 'worst').Then rank them with a percentage in relation to other players of the same position. Your players will not have access to nor will they ever see this information.

RANK ON TEAM (1-14)	PLAYER NAME	RANK IN RELATION TO FORMER PLAYERS OF SAME POSITION (0-100%)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		

Appendix H

RAW DATA

Subject	Slalom	LSPT	10yd	RAT-L	RAT-R	FAPT	Bunkie
1	39.75	80.55	1.92	2.28	2.31	457.0	160
2	51.06	91.58	2.28	2.70	2.59	532.3	157
3	44.03	69.58	2.02	2.18	2.19	482.0	158
4	46.60	82.28	1.89	2.39	2.28	587.0	160
5	53.51	118.49	2.02	2.42	2.40	446.3	160
6	45.27	79.13	2.05	2.51	2.56	493.3	160
8	47.96	70.29	1.98	2.34	2.46	506.3	147
9	46.08	81.58	1.92	2.54	2.39	394.3	157
10	40.42	68.52	1.98	2.37	2.30	386.7	156
11	55.59	77.47	2.05	2.40	2.25	444.0	160
12	45.55	61.89	2.08	2.49	2.43	458.3	160
13	43.95	75.61	2.01	2.42	2.57	353.8	160
14	44.30	74.33	2.08	2.39	2.66	434.0	160
15	45.47	63.29	1.95	2.65	2.75	485.0	160

Subject	SEBT-D	SEBT-ND	BESS - R	BESS - L	BESS - RU	BESS - LU	BESS TOTAL
1	689.41	676.22	1	1	14	9	25
2	698.61	686.64	15	12	23	17	67
3	700.53	730.31	7	2	19	23	51
4	765.50	758.64	1	1	13	21	36
5	731.87	779.75	2	0	7	8	17
6	695.04	670.73	0	1	4	7	12
8	672.30	688.75	4	1	11	9	25
9	715.75	759.35	8	5	17	19	49
10	747.42	790.61	3	3	18	17	41
11	667.37	735.65	9	3	16	10	38
12	701.20	683.33	5	2	16	13	36
13	659.57	686.52	2	1	17	8	28
14	711.83	683.69	3	3	6	11	23
15	707.16	663.70	9	13	29	21	72

Appendix H Cont.

Subject	DPSI - ND	DPSI – D	MVJ	Rank #	Phys	Tech	Field	Total
1	0.361133	0.365833	19	100	5	5	5	15
2	0.3436	0.335733	15.6	70	3	3	4	10
3	0.3786	0.3775	16.4	85	3	4	4	11
4	0.3538	0.374667	16.5	90	4	4	5	13
5	0.3578	0.340633	15.4	85	4	4	5	13
6	0.327433	0.334533	17.4	90	5	5	5	15
8	0.361267	0.3827	18	80	4	4	3	11
9	0.339667	0.3278	20.3	75	4	3	3	10
10	0.3272	0.3466	17.7	80	4	4	4	12
11	0.299633	0.3139	15.5	75	3	3	4	10
12	0.3337	0.3499	17.5	50	3	3	3	9
13	0.355067	0.413767	17.1	80	3	4	4	11
14	0.395833	0.377133	15.2	90	4	5	5	14
15	0.4434	0.3889	17.3	80	4	4	4	12

Note. Slalom = Slalom Dribble; LSPT = Loughborough Soccer Passing Test; 10 yd = 10 yd sprint; RAT-L = Reactive Agility to the LEFT; RAT-R = Reactive Agility to the Right; FAPT = Frot Abdominal Power Test; Bunkie = Bunkie Core Test; SEBT-D = Star Excursion Balance Test on the Dominant Foot; SEBT-ND = Star Excursion Balance Test on the Nondominant Foot; BESS-R = Balance Error Scoring System on the Right Foot; BESS-L = Balance Error Scoring System on the Left Foot; BESS-RU = Balance Error Scoring System on the Right Foot on Unstable Surface; BESS-LU = Balance Error Scoring System on the Left Foot on Unstable surface; BESS-TOTAL = Balance Error Scoring System Composite Score; DPSI-ND = Dynamic Postural Stability Index on the Nondominant Foot; DPSI-D = Dynamic Postural Stability Index on the Dominant Foot; MVJ = Maximum Vertical Jump Height; Rank # = Percentage Score from Coach Appraisal; Phys = Physical Ability; Tech = Technical Ball Skill; Field = Field Sense; Total = Phys + Tech + Field