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Field and Laboratory Assessments of Muscular Power in Female NAIA Soccer Players

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Field and Laboratory Assessments of Muscular Power in Female

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Table of Contents

Contents Page

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Tables

Figures

Abstract

The primary purpose of the investigation was to determine the most closely related assessment between the agility t-test, countermovement vertical jump, fly-in 40-yard dash, lower limb length, and percent body fat when correlated to kicking power as measured by the Tendo FitroDyne Powerlizer. The study also aimed to form a prediction model based on all of the independent variables that could be used to predict soccer-specific kicking power. The study included 21 female soccer players (19 $\pm$ 0.92 years) from Saint Gregory's University (n=11) and Oklahoma City University (n=10). The best score from the Tendo, agility t-test, countermovement vertical jump, and fly-in 40-yard dash was recorded for each participant. The percentage of body fat was determined using skinfold calipers and limb length was measured on the dominant kicking leg. A Pearson's correlation coefficient was used to identify relationships between kicking power and each of the independent variables. A backward multiple regression was administered in order to determine the independent variables that were able to best predict kicking power. The results from the Pearson's indicated that a significant relationship exists between kicking power and percent body fat (r = 0.630, p = .001) and limb length (r = 0.418, p = .047) while no significant relationships exist between kicking power and each of the field assessments of lower limb power. The backward multiple regression results indicate that limb length and percent body fat are the best predictors of kicking power. The primary investigator concluded that although the correlations between kicking power and limb length and %BF were significant, the field assessments of lower limb power were not correlated to kicking power indicating that the Tendo may not have effectively measured the instep soccer kick.

Chapter One: Introduction

Jumping, sprinting, jogging, kicking, and quick changes in direction are a few of the diverse movements required by lower extremity muscles while participating in a soccer competition (Malliou, Ispilidis, Beneka, Taxidaris, & Godilias, 2003). Having the ability to perform each of these dynamic movements requires the participant to recruit much of their lower limb strength and power. When assessing performance in soccer athletes, lower limb power has shown to be a vital tool (Pereira, Pereira, Thiebaut, Sampalo-Jorge, & Machado, 2009). Muscular power contributes to every aspect of soccer; however the most accurate soccer-specific field measure of lower limb power has yet to be determined. The purposes of physical performance field tests are aimed at improving the players' overall competition performance. With increases in lower limb power, soccer players will be at an advantage in striking, have the ability to jump higher in order to beat an opponent for an aerial ball, and win the ball when tackling an opponent in a one verses one challenge (Castagna, Impellizzeri, Chamari, Carlomagno, & Rampinini, 2006).

If coaches knew each of their athletes kicking power, an appropriate training program could then be implemented to improve each player individually. The athlete would benefit from the individualized training program as well. The increase in lower limb muscular power would assist the athlete's instep ball striking ability. Ball striking ability does not simply mean the athlete would be able to obtain a more powerful shot, but also possess the ability to perform firm, accurate passes. The countermovement vertical jump, agility t-test, and fly-in 40-yard dash are valid tests of soccer-specific lower limb power however, knowing the assessment that is the most closely correlated to kicking power would be beneficial to coaches and athletes at all levels (Pauole, Madole, Garhammer, Lacourse, & Rozeneks, 2000).

Currently, the most often used tests of lower limb power in the soccer community are the 20m multistage shuttle run (Aziz, Yau, & Chuan, 2005), the one repetition maximum (1RM) squat (Wisloff, Castagna, Helgerud, Jones, & Hoff, 2004), and the Wingate Anaerobic Power Test (Thomas, Plowman, & Looney, 2002). Each one of these tests is a valid measure of either aerobic or anaerobic power. However, these assessments are not directly related to the skills and movements needed to perform in a soccer match. Soccer-specific, physical performance field tests are the most important factors that can be evaluated outside of the game situation (Malliou et al., 2003). The field tests that seem the most applicable to soccer are the countermovement vertical jump, agility t-test, and fly-in 40-yard dash. Each one of these tests are directly associated with movement patterns involved in soccer performance. These field tests are also valid and reliable measures of lower limb power (Sassi et al., 2009). The vertical jump measures the explosive force generated from the legs, which is a frequent movement performed in soccer (Pereira et al., 2009). The agility t-test involves speed movements and four changes in direction in order to assess the athlete's ability to quickly react and change direction during match play (Sassi et al., 2009). The fly-in 40-yard dash measures the athlete's ability to accelerate to full speed as quickly as possible. Normal assessments of the 40-yard dash perform stationary starts. Conversely, the fly-in 40-yard dash is more closely related to the type of movement pattern performed by a soccer player. The fly-in 40-yard dash allows the participant 10 yards to gain momentum.

A more precise method of measuring leg power in a laboratory setting is achieved by using the Tendo FitroDyne Powerlizer (Tendo). Although the Tendo is a valid and reliable measurement of power, it is an expensive piece of equipment that is not likely to be included in the typical soccer coach's budget (Jennings, Viljoen, Durandt, & Lambert, 2005). If the most closely correlated field test to kicking power measured by the Tendo between the countermovement vertical jump, agility t-test, and fly-in 40-yard dash was known, it could be used as an alternate way to measure lower limb power that is directly related to the movements required of a soccer player. Obtaining a field test that is an inexpensive measure of lower limb power would be of great interest to coaches when designing a proper training program.

Hypotheses

The Tendo has not yet been used to assess the soccer-specific movement of a full range of motion dominant leg, instep soccer kick. The primary investigator aimed to validate the Tendo as an assessment of soccer-specific lower limb power. Pauole and colleagues (2000) determined that the 40-yard dash and agility t-test were strongly correlated ($r = .73$, $p < 0.05$) when the participants were female collegiate athletes. Other studies have determined that the relationship between these tests of lower limb power are also correlated, but not as strongly ($r = .34$ – $r = .57$; Sassi et al., 2009). It was hypothesized by the researcher that the agility t-test will have the strongest correlation with the Tendo, because this test most closely imitates the movements required of a soccer player. It is hypothesized that a positive relationship will exist between kicking power and the vertical jump, while a negative relationship will occur between kicking power and both the agility t-test and the fly-in 40-yard dash time.

The study also looked at the correlation between the participant's kicking power and the length of their lower limb, and body composition. It was hypothesized that the participants who have a lower percent body fat or longer lower limbs will have an advantage in being able to generate more power during a maximal effort instep soccer kick. The investigation aimed to develop a model that could be used to predict Tendo kicking power based on the three field tests, limb length, and percent body fat. It was hypothesized that the agility t-test and percent body fat would provide the best model to predict Tendo kicking power.

Limitations/Delimitations

The delimitations of the study were the use of female, soccer athletes, who compete at the National Association of Intercollegiate Athletics (NAIA) Division 1 level. The study was limited because the Tendo has yet to be used to determine soccer-specific kicking power. The current study obtained 21 participants. The small sample size made it more difficult for the researcher to find significant correlations between the variables. Although, a significant correlation of $r = .73$ was found between the 40-yard dash and the agility t-test when assessing female collegiate athletes (Pauole, Madole, Garhammer, Lacourse, & Roxenek, 2000), the study indicates that in order to find a significant relationship between the assessments using power analysis, 11 participants were needed. It is believed that even though the current study provided almost two times the amount of participants needed to find significance, the process still proved to be difficult due to the extra assessments included. The study was also limited in that the participants may not have put forth full exertion on each assessment, causing the data to be inaccurate.

Variables

The independent variables for the research project were the three field assessments (countermovement vertical jump, fly-in 40-yard dash, and the agility t-test), lower limb length, and body composition, while the dependent variable was instep kicking power. The instep kick is an essential component when determining soccer performance. This type of kick is used when the player needs to advance the ball a great distance or if a player is attempting a long range shot on goal. An increase in the amount of strength and power would allow the athlete to advance the ball further and more accurately. The researcher assumes that the chosen field tests were the most accurate assessments with regard to soccer-specific movements preformed by female soccer athletes.

Operational Definitions

Dominant leg: Dominant leg was chosen by the athlete based on the leg the athlete prefers to kick with in order to achieve the greatest amount of ball velocity and control (Manolopoulos, Papadopoulos, & Kellis, 2004).

Instep soccer kick: The type of soccer kick where the player approaches the ball at a 45-60° angle after taking two approach steps, places their non-kicking foot adjacent to the ball with toe pointing in the direction intended for the ball to travel, hyperextends the hip of kicking leg with strong plantar flexion of the kicking foot and then immediately flexes the hip and swings through the motion. The player will then strike the ball with the laces of the shoe as hard as they can and land on their kicking foot. During this motion the arms are usually abducted and the head is steady and looking at the ball, both causing the body to achieve balance while all body weight is shifted to the non-kicking leg (Manolopoulos, Papadopoulos, & Kellis, 2004).

Fly-in 40 yard dash: A field assessment intended to allow the athlete 10 yards of preparation steps prior to beginning the 40 yard dash test. This type of assessment is beneficial to soccer athletes because it mimics the movements during competition. Soccer players are constantly in motion and it is unlikely that the player would sprint 40 yards without multiple preparation steps.

Striking the ball: A term used to describe when a player is kicking the ball in order to achieve the greatest amount of power.

Purpose

The primary purpose of the investigation was to determine the most closely related field assessment between the agility t-test, countermovement vertical jump, and fly-in 40-yard dash, when correlated to kicking power measured by the Tendo FitroDyne Powerlizer. If these relationships were known, coaches may be able to assess the lower-limb power of their soccer athletes using an inexpensive and easily administered field assessment. The secondary purpose of the investigation was to determine the correlation between kicking power and dominant leg length and body composition. The final purpose was to form a model based on the independent variables that could be used to predict soccer-specific kicking power.

Chapter Two: Literature Review

The requirements of a soccer athlete are to accelerate, decelerate, and change directions in response to the opposition's movements or the change in direction of the ball (Campo et al., 2009). In order to achieve successful status as a soccer player, the player needs to possess a great amount of muscular power, as power will allow the athlete to achieve the required soccer-specific movements. Examining and understanding the lower-limb power measurement could assist athletes, coaches, and athletic trainers in selecting and treating athletes in their specific sport (Shetty, 2002). Lower-limb muscular power can be developed through plyometric or running programs when performed by soccer athletes (Campo et al., 2009). Before improvements can be made to a soccer athlete's muscular power, the initial lower-limb power of the athlete needs to be assessed. The ultimate aim of muscular power field assessments is to obtain information that can be used to help improve the players' overall soccer competition performance. Therefore, this review aims to explore effective ways to gain soccer-specific explosive power, discuss the validity, reliability and soccer specificity of current field assessment techniques, and justify the use of the Tendo laboratory assessment as a method of measuring lower-limb kicking power.

The development of explosive power in soccer athletes is not improved through simply performing Olympic power lifts alone (BenEliyahu, 1996). Although these types of power gaining exercises are very beneficial, they lack the effectiveness of targeting the specific types of functional soccer related movements. If a soccer athlete is attempting to achieve improvements during competition, the coach needs to develop a training program that aims to increase aerobic and anaerobic endurance, vertical jump ability, and power (BenEliyahu, 1996). Increasing explosive soccer-related power can be achieved by performing plyometric and agility running drills. Plyometric and agility drills enhance the athlete's ability to quickly change direction on the field. These types of drills are used when a coach's aim is to improve explosive power and endurance, simultaneously.

Campo et al. (2009) suggests that kicking is the most important skill performed by soccer players. The effectiveness of a kicker during soccer play derives from the individual's ability to possess neuromuscular coordination, be able to perform maximal strength of the muscles involved in the kick, and control the rate of force development (Campo et al.). Campo and colleagues aimed to determine the effects that a 12-week plyometric training program would have on the explosive strength and kicking speed in 20 female soccer players. These players were divided into a plyometric group and a control group. Both groups performed normal soccer training sessions; the plyometric group performed plyometric training three days a week in addition to normal daily training. The plyometric training program consisted of jumping hurdles, performing horizontal jumps, and drop jumps in stands. The participants' explosive strength was assessed via the countermovement vertical jump, while kicking speed was assessed using hyperfrequency radar. The results indicated that after the plyometric training program, the plyometric group indicated significant ($p < 0.05$) increases in both vertical jump height and kicking speed. The researchers concluded that performing a plyometric training program is an effective way to increase soccer kicking speed and explosive strength (Campo et al.). The importance of possessing a broad knowledge base containing various ways of assessing soccer-specific muscular power is apparent, but it is equally important to know the types of training programs that will assist in the development and improvement of explosive power in female soccer athletes.

Although plyometric training has been shown as a beneficial way to increase explosive muscular power in soccer athletes, Rahimi and Behpur (2005) suggest that the coupled effect of a plyometric training program combined with a weight training program will demonstrate greater increases in power than when either one of the programs are performed individually. The researchers recruited 48 male college age students, which were divided into four groups. The divisions included a plyometric training group (n=13), a weight training group (n=11), a combined plyometric and weight training group (n=14), and a control group (n=10). Each of the training groups performed the designated training program two days per week for six weeks. The researchers used the vertical jump, 50-yard run, and one repetition maximum squat as the assessment tools for determining lower-limb muscular power (Rahimi & Behpur, 2005). The plyometric training protocol consisted of two days per week of training that included various forms of jumping. The weight training protocol included lower body strengthening exercises only. The plyometric and weight training protocol included both of the previous programs combined. The researchers concluded that no significant differences occurred between the pre- and post-power assessments from the plyometric program or the weight training program. Conversely, the combined training program produced significant ($p < 0.05$) improvements in the participants muscular power when using the three mentioned assessments (Rahimi & Behpur).

This study provides useful information that includes a detailed program that has been successfully used to increase muscular power of the lower body. Although, it did not include soccer athletes, the plyometric training programs are similar to those performed in previous studies involving soccer athletes, providing indications that this type of training would be beneficial in a soccer setting. Manolopoulos, Papadopoulos, and Kellis (2006) reported similar findings while examining the effects that a 10-week resistance (strength), plyometric (explosive power), and soccer-specific training program had on instep soccer kick. The researchers found that significant ($p < 0.05$) improvements occurred in soccer kick performance during post training program assessments (Manolopoulos, Papadopoulos, & Kellis).

In a study aiming to compare the differences between NCAA Division I football players and basketball players, the investigators gathered data including height, weight, percent body fat, vertical jump, 40-yard dash, bench press, and squat strength (Berg & Latin, 1995). The researchers determined that overall, football players weigh more than basketball players and have a higher body fat percentage. The study found significant ($p < 0.05$) differences between all variables except vertical jump and 40-yard dash (Berg, & Latin). The investigation is important because it provides insight as to how important it is that elite athletes to have increased amounts of lower-limb muscular power.

When attempting to develop or increase muscular power in soccer athletes, it is necessary to determine each athlete's current muscular power ability. BeEliyahu (1996) suggests that the performance assessments needed prior to inclusion in a power, endurance, and speed training program are the one-mile run, 300-yard shuttle run, vertical jump, and the 40-yard dash. Although there are currently enumerable power assessments, the most often used assessments in a soccer-specific setting are the 20 meter (20m) multistage shuttle run, Wingate Anaerobic Power test, one repetition maximum (1RM) squat, vertical jump, agility t-test, and the 40-yard dash. Each of these assessments is considered a soccer-specific power test and used most frequently because they directly mimic the skills needed to successfully perform in a soccer competition.

In a study involving the 20m multistage shuttle run the researchers aimed to assess the validity and sensitivity of the test and the correlation it had with the 20m all-out-sprint and vertical jump. The research study involved professional soccer players from 16 various soccer clubs in Singapore. The researchers found that the assessment was reliable when the test was administered on the same participants twice within the same week. The results indicated no significant difference between the two assessments. The intraclass reliability between the two trials was .97 ($p < 0.01$). The assessment for sensitivity involved a 20m multistage shuttle run performed prior to training and one performed five weeks post training. The results indicated that the participants performed significantly better on the five week post-training assessment than on the pre-training assessment ($p < 0.001$). The 20m multistage shuttle run showed weak correlations with both the vertical jump ($r = -.18$, $p < 0.05$) and 20m all-out-sprint ($r = -.01$, $p < 0.05$). The assessment was found to be significantly valid and reliable (Aziz, Yau, & Chuan, 2005). Although the 20m multistage shuttle run was significantly reliable and valid, it was weakly correlated to the vertical jump when assessing soccer players, thus concluding that the test is a better assessment of aerobic endurance than muscular power.

A study aiming to monitor the fitness variations throughout a competitive season in a professional Asian soccer league, the researchers included the 20m multistage shuttle run. The primary reason for inclusion of the 20m multistage shuttle run was to assess the participants' maximal aerobic power. In order to assess the participants' lower limb explosive power, the vertical jump was included in the research (Aziz, Newton, Tan, & Teh, 2006). Although the 20m multistage shuttle run is an extremely soccer-specific assessment, a study performed by Pelham and Holt (2001) used the shuttle run as an assessment for determining maximum aerobic capacity. The 20m multistage run is a very widely accepted soccer assessment; however, the previous studies provide evidence that the shuttle run is not an accurate assessment of muscular power (Aziz, Yau, & Chuan, 2005). The results of the study suggest that when comparing the shuttle run test to a 2-mile run the correlation was $r = .89$ $p < 0.05$, indicating a strong relationship between the shuttle run and the 2-mile run (Pelham & Holt). Due to the strong correlation, the shuttle run assessment is seen as a better indicator of a soccer athlete's muscular endurance and aerobic capacity.

Wisloff, Castagna and colleagues (2004) conducted a study aiming to determine if a correlation existed between 1RM half squat strength when compared to the 30 meter (30m) sprint and vertical jump. The researchers used 17 international soccer players as the participants. The results indicated that a strong relationship existed between the half squat and the 30m sprint ($r = .71$, $p < 0.01$) and vertical jump height ($r = .78$, $p < 0.02$). The half squat is a highly correlated assessment to multiple power measures, but does not mimic the movements required during a soccer competition (Wisloff, Castagna, et.al.). A similar study conducted by Wisloff, Helgerud, and Hoff (1998) viewed the relationship between the 1RM squat as an assessment of muscular strength and the vertical jump as an assessment of muscular power. This study included 29 male soccer players from two Norwegian elite division teams. A moderate, significant correlation ($r = .61$, $p < 0.01$) was found between the muscular strength and muscular power of elite soccer players (Wisloff, Helgerud, & Hoff, 1998).

The Wingate anaerobic power test is a 30 second maximal effort test on a cycle ergometer. Thomas and colleagues (2002) determined that this was seen as the criterion measure of anaerobic work capacity primarily because prior research has shown that non-cycling athletes perform at higher levels than cyclists. This assessment has been seen as the criterion measure of anaerobic work capacity in soccer players because the researchers determined that, at the time, there was a lack of valid running criterion tests that mimic the movements involved in a soccer match (Thomas, et al., 2002). Currently alternate assessments have been seen as more accurate measures of soccer-specific lower-limb power.

The Wingate anaerobic test was used to assess the peak power, mean power and explosive power of 145 elite athletes, sports including; boxing, wrestling , hockey, volleyball, handball, basketball and soccer. The study determined that volleyball and basketball players perform the greatest amount of peak power of all measured sports (Popadic, Jelena, Otto, Grujic, & Nikola, 2009). It could be assumed that both of the sports that performed the greatest peak power are accustomed to performing small bouts of high intensity exercise on a small playing surface that could allow for multiple rest periods. The Wingate assessment of anaerobic power mimics this type of exercise. Although each of those sports does not specifically mimic the cycling movement, the training patterns are similar.

As previously stated, the purposes of physical performance field tests are aimed at improving the players' overall competition performance. There are multiple ways to assess power in female soccer players, although when assessing power, it is more beneficial to the athlete if the assessment can be directly related to the movements involved in their preferred sport. If the field test is not a direct assessment of the movements performed by the athlete during normal competition or practice, the assessment is not as effective as possible. Soccer-specific physical performance field tests are the most important factors that can be evaluated outside of the game situation (Malliou et al., 2003). Sport-specific field assessment will provide the coach and the player with the information needed to assist in the enhancement of the player's ability to perform during a competition.

The assessments of lower limb muscular power that most mimic the movement patterns performed by a soccer player are the countermovement vertical jump, agility t-test, and the fly-in

40-yard dash. Each of these assessments has been determined as being a reliable and valid tool for assessing lower-limb muscular power. The vertical jump measures the explosive force generated from the legs, which is a frequent movement in soccer and a very useful index (Pereira et al., 2009). The vertical jump requires the athlete to put forth the maximum amount of muscular force in the shortest amount of time. Thus, the vertical jump does not require a significant amount of aerobic energy. The vertical jump assessment requires explosive leg power in order for the participant to reach peak height. The agility t-test involves speed movements and four changes in direction in order to assess the athlete's ability to quickly react and change direction during match play. The agility t-test is designed to measure the leg speed, leg power, and agility of soccer athletes (Sassi et al., 2009). The agility t-test evaluates the participant's ability to change direction without losing speed and while maintaining balance. The fly-in 40-yard dash measures the athlete's ability to accelerate to full speed as quickly as possible. Normal assessments of the 40-yard dash begin with stationary starts. The fly-in 40-yard dash allows the participant 10 yards to gain momentum prior to performing a maximal effort sprint. Conversely, the fly-in 40-yard dash is more closely related to the type of movement pattern performed by a soccer player during competition.

Each of these three field assessments measuring soccer-specific lower limb power (vertical jump, 40-yard dash, agility t-test) in female college aged students has been correlated among one another in a study conducted by Pauole and colleagues (2000). All assessments were significantly correlated at $p < 0.05$. The greatest correlation was found between the agility t-test and the 40-yard dash ($r = .73$). The agility t-test was moderately correlated to the vertical jump ($r = .55$). The 40-yard dash and the vertical jump were also moderately correlated ($r = .55$). These studies concluded that all assessments are measures of leg speed and leg power. These tests are all very easily administered, require minimal equipment, and can be used for athletes at all levels of sports participation (Pauole, et al.). This study is important because it provides information indicating that the three assessments chosen for the current study possess moderate to high correlations among each other, potentially indicating that these assessments are all measurements of muscular power in female soccer players.

Sassi et al. (2009) attempted to assess the correlation among a modified agility t-test and the vertical jump, the 40-yard dash, and the 10 meter (10m) sprint in college aged men and women. The researchers had previously determined a moderate correlation between the agility t-test and each of the mentioned assessments. The only difference between the agility t-test and the modified agility t-test is that the modified t-test is half of the distance between each cone. The modified agility t-test would be a beneficial assessment for sports that are performed on a smaller playing surface. The researchers found the strongest correlation among female participants between the modified agility t-test and all assessments. All assessments were correlated at a 95% confidence interval. The modified t-test showed moderate correlations with the vertical jump (r = .47) and a slight correlation with the 10m straight sprint (r = .34). The agility t-test is an easily modified assessment that has been found to be reliable (Sassi et al.).

The countermovement vertical jump and the squat jump were both involved in a study aiming to validate these jumps as assessments of explosive power in the lower body. The squat jump was found to produce r = .97 intraclass reliability, while the countermovement jump produced r = .98 intraclass reliability (Markovic, Dixdar, Jukic, & Cardinale, 2004). Both jumps were correlated with the explosive power factor and the countermovement vertical jump showed the highest relationship (r = .87, $p < 0.05$). This research indicates that the countermovement vertical jump is a valid field test for estimating the explosive power of the lower body

(Markovic, et al., 2004). Not only is the countermovement vertical jump a better representation of the movements involved during on-field soccer play, this study also provides information suggesting that the countermovement vertical jump is a more valid assessment for lower limb explosive power when compared to the squat jump.

Stockbrugger and Haennel (2001) conducted a study evaluating the validity and reliability of a medicine ball throw as an assessment of explosive power. The criterion measure of explosive power that the medicine ball throw was correlated with was the countermovement vertical jump. The researchers recruited 20 sand volleyball players to be as the participants in the current study. Each player performed three attempts of each assessment. A Pearson's product moment correlation coefficient was used, and determined a strong, significant relationship ($r = .90$, $p < 0.01$) existed between the medicine ball throw and the countermovement vertical jump (Stockbrugger & Haennel). Both the medicine ball throw and the countermovement vertical jump were found to possess strong test-retest reliability, $r = .99$ and $r = .99$, respectively (Stockbrugger & Haennel). The current study is important as it provides more evidence suggesting the reliability of the countermovement vertical jump as an assessment of explosive lower-limb power.

The vertical jump has been seen as a valid and reliable assessment of lower limb muscular power (Markovic, et al., 2004). The countermovement vertical jump height was correlated to the soccer-specific kicking movement which can be assessed using an isokinetic knee extension. The isokinetic knee extension machine was programmed to measure the kicking motion of the dominant striking leg from 180° to full extension. A moderate, significant correlation ($r = .60$, $p = 0.05$) was found between the countermovement vertical jump and the knee extension (Malliou et al., 2003). Although the isokinetic knee extension machine allows for a soccer-specific movement that mimics a soccer kick, the machine is limited to only measuring the movement from the knee to the ankle. An actual soccer kick is a multi-joint movement that involves the hip, knee, and ankle. Thomas, Fiatarone, and Fielding (1996) were able to find a moderate correlation between the double leg press and the vertical jump ($r = .58$, $p < 0.004$). The researchers concluded that the significant relationship that occurred between the double leg press and the vertical jump performance was used as a way of validating the double leg press as a valid field assessment of lower-limb power.

The 40-yard dash has been seen not only as a valid and reliable assessment of lower-limb muscular power, but also as an important assessment for measuring power in athletes. The National Football League analyzes the differences between the performance scores in drafted and nondrafted players at the combine each year. From the 2004 combine, Sierer, Battaglini, Mihalik, Shields, and Tomasini (2008) found that among all six performance assessments, the 40-yard dash ($p < 0.001$) and the vertical jump ($p < 0.003$) showed the greatest significant difference between drafted and nondrafted combine players (Sierer et al., 2008). The study provides evidence as to how important the 40-yard dash and vertical jump are in assessing the muscular power and performance of athletes.

The three soccer-specific field assessments that have been determined by the primary investigator as providing the greatest validity and reliability of measuring lower-limb muscular power are the countermovement vertical jump, agility t-test, and the fly-in 40-yard dash. This project aims to determine which of these assessments is the most highly correlated to an actual soccer instep kick. The primary investigator will also be measuring the limb length of the dominant kicking leg and the percentage of body fat for each of the participants. The Tendo will be the laboratory assessment used to determine each participant’s maximal ball striking power.

The Tendo has yet to be used as a direct measurement of soccer kicking ability, but it has been determined to be a valid and reliable laboratory assessment of lower-limb muscular power (Jennings et al., 2005). Jennings and colleagues suggest that when the Tendo is attached to resistance training equipment the production of muscular power can be calculated. The two power movements assessed for the Tendo reliability were the squat jump and the biceps curl. The results suggest that an intraclass correlation of $r = .97$ at a 95% confidence level was seen with regard to both of the power movements (Jennings et al.). The primary investigator of the project recognizes that the Tendo FitroDyne is lacking in evidence suggesting its validity as a measure of soccer-specific kicking power. Although the Tendo is lacking in this evidence the primary investigator justifies its usage, because the tether of the Tendo will be set up in a way that will measure the full range of a maximal effort soccer kick. The tether on the Tendo can easily be attached to a barbell, exercise plates, or the athlete.

The Tendo FitroDyne is a relatively new assessment tool used for measuring power. Although the assessment is not currently a highly used assessment, the primary investigator was able to provide evidence supporting the use of the Tendo FitroDyne as a valid and reliable assessment of lower-limb muscular power. Rhea, Perterson, Oliverson, Ayllon, and Potenziano (2008) were aiming to determine the effectiveness of a new type of training modality in 40 male and female college age participants. It is suggested that the new training method will assist in improving lower limb reactive power. In order to determine the differences among the group using the new training method and the group performing traditional plyometric power gaining programs, the Tendo FitroDyne was used to measure the lower body power of the participants before and after the 12-week exercise programs (Rhea, Peterson, Oliverson et al., 2008). The same type of study was performed in a younger age group to determine if the same new training method would produce similar results in a high school setting. The researchers used the Tendo as the instrument to assess the lower limb power of high school athletes before and after the training programs. Similar to the previous study the increases in power favored the new method training group (Rhea, Peterson, Lunt, & Ayllon, 2008). In both of the previous studies the Tendo was used to accurately assess the lower-limb power of the participant's by simply placing the tether of the Tendo on the barbell while the participant performed a squat. As demonstrated in the previous studies, the Tendo is easily attached to equipment, and just as easily could be attached to the participant. The population used in the studies provides evidence that the Tendo FitroDyne is an effective way to assess the lower-limb power in the type of participants needed for the current study.

The Tendo has also been used in a study aiming to determine the relationship between myosin heavy chain and the velocity and force characteristics of muscle fibers. The Tendo was used as the way of measuring the force and velocity of the 1RM peak power in five well-trained female participants (Schilling et al., 2002). The Tendo FitroDyne is starting to become more widely used in the literature as a way of assessing muscular power of the lower body using various techniques.

Not only is the Tendo used as an assessment for measuring lower body power, it is very diverse in that multiple investigations have also used the Tendo as an instrument to measure the muscular power of the upper body. There is a great importance placed on the upper body strength and power of Division I college football players. In an investigation attempting to determine the effects of a seven-week heavy elastic band strength training program and a weighted chain program when each were correlated to the maximal power bench press exercise, the Tendo was the instrument used to assess the muscular power of the upper body (Ghigiarelli et al., 2009). The Tendo was attached to the barbell while each participant performed their 1RM bench press.

The Tendo FitroDyne Powerlizer has been used in this the study to examine the lower-limb muscular power produced in each set of three back squats. The authors were aiming to determine the difference between two groups while performing back squats (Rhea & Kenn, 2009). The first group experienced three minutes of rest between the sets, while the second group rested for two and a half minutes and then performed 30 seconds of dynamic squats on an iTonic vibration platform. The vibration platform is suggested to enhance the participant's strength and power development. According to the calculation of peak power based on the Tendo FitroDyne, the group that produced significantly ($p < 0.05$) greater improvements was the whole body vibration group (Rhea & Kenn, 2009).

Jennings and colleagues (2005) performed a study aiming to assess the reliability of the Tendo FitroDyne as a measure of muscular power. The FitroDyne was attached to a bar during a squat jump exercise and three trials were performed. The correlation between the FitroDyne and the maximal power measurements of the squat jump produced a very strong, significant ($r = .97$, $p = 0.05$) relationship. The intraclass correlation among all trials performed using the FitroDyne ranged between $r = .95$ and $r = .98$. The authors concluded that the muscular power of the lower body can be assessed using the Tendo FitroDyne. (Jennings et al.). It was also concluded that the Tendo can be easily adapted to a variety of movement patterns.

When attempting to develop or assess any type of performance variable in an athletic situation it is crucial to recognize that the athlete will obtain the greatest amount of gains or have the opportunity to perform better if the program or assessment is functional to the athletes preferred sport. Choosing soccer-specific movement assessments that exhibit valid and reliable results will allow the athletes to perform movements that are familiar and natural. Due to the adaptability of the Tendo, this piece of equipment will allow the athletes to perform the most natural movement used in their specific sport.

Chapter Three: Methodology

The primary purpose of the investigation was to determine the most closely related assessment between the agility t-test, countermovement vertical jump, fly-in 40-yard dash, lower limb length, and percent body fat when correlated to kicking power as measured by the Tendo FitroDyne Powerlizer. When these relationships are known, coaches may be able to assess the lower limb power of their soccer athletes using an inexpensive and easily administered assessment.

Participants

The study consisted of 21 National Association of Intercollegiate Athletics (NAIA) college soccer players aged 18 to 24 years. All participants were trained, female college soccer players, completing at least one or more seasons as a college athlete. Written permission (Appendix A) from team coaches was granted in order to recruit the Saint Gregory's University and Oklahoma City University women's soccer players as participants for the investigation. Written consent from the participants based on the requirements of the University of Central Oklahoma Institutional Review Board (Appendix C) was obtained prior to the onset of the study. The primary investigator has previously obtained a certificate of completion from the National Institutes of Health office for successfully completing a course on Protecting Human Research Participants (Appendix D). Each participant previously performed a routine physical allowing participation in the soccer season.

Instruments and Procedures

Lower Limb Kicking Power.

Lower limb kicking power was measured by using the Tendo FitroDyne Powerlizer (Sorinex, Slovak Republic). Before the administrator began the assessment the participant's weight in kilograms was determined. The participant's weight in kilograms was then entered into the Tendo Weightlifting Analyzer handheld (Figure 1). The Tendo cord was attached to the participant's dominant kicking leg at the shoelace. A soccer ball was placed in alignment with the Tendo. The cord allowed the participant one preparation step prior to striking the ball (Figure 2). Each participant was instructed to strike the ball as hard as possible and follow through the entire motion. Each participant performed five trials, with one minute of rest between each trial. During the entire movement the Tendo Weightlifting Analyzer measured multiple segments of the movement and calculated the peak power and the average power in watts. The peak power represented the participant's fastest measurement recorded throughout the entire movement. The average power represented the average output of power during all of the movements recorded throughout the entire movement. The average power was used for statistical analysis.

The Tendo was used to determine initial lower-limb power. Each participant was assessed on the Tendo five times with one minute of rest between each movement. The best of the five was used for statistical analysis. Each of the following assessments was correlated to the Tendo in order to detect the strength of the relationship. For the agility t-test, the fly-in 40-yard dash, and the countermovement vertical jump the participants performed three trials on each assessment. The best score from each of the assessments was used for statistical analysis. Each participant was allotted two to five minutes of rest between all trials. The assessments were measured in one day with sufficient rest time between trials to allow the participants to regain muscle strength. The three-site skinfold measurement and lower limb length were the first tests completed on testing day.

Countermovement Vertical Jump.

The countermovement vertical jump was measured using the Vertec apparatus (Jump USA, Sunnyvale, California) which determined the participants' vertical jump in inches (Figure 3). The Vertec consists of vanes that are blue, red, and white. Each red vane is positioned exactly six inches apart, while the white vanes are one inch apart and the blue vanes are also one inch apart. The vanes on the Vertec alternate white and blue, indicating one half inch between one white vane and one blue vane. Depending on the color reached, these vanes were used to measure how high the participant jumped. The Vertec contains four red vanes, which allowed the participants to jump a maximum of 24 inches before a readjustment to the Vertec was required. The participants were allowed to choose the hand in which they wished to use while they jumped.

Prior to the onset of jumping, the participant was instructed to stand directly underneath the Vertec and fully extend the chosen arm straight above their head. The Vertec was adjusted in order to allow the participant's fingertips to be touching the bottom vane on the apparatus. Once the Vertec was properly adjusted and all vanes are aligned, the participant was ready to begin the countermovement jump. With both feet planted firmly on the floor the participant was allowed to take one preparation step and then exploded upward attempting to move the highest vane they could reach. Immediately following the jump the administrator determined the number of inches jumped using the color coded system of the vanes on the Vertec. The participant was allowed three trials, with one minute of rest between each trial. The highest countermovement vertical jump from the three trials was used for statistical analysis.

Fly-in 40-yard Dash.

Both the fly-in 40-yard dash and the agility t-test were measured using the Brower Timing System (Brower Timing Systems, Salt Lake City, Utah). The Brower Timing System allowed for accurate time measurements of both field assessments.

The 40-yard dash was measured outside on the campus of the University of Central Oklahoma using a measuring wheel. The Brower Timing System consists of four tripods. Two tripods were placed on either side of the starting line. The other two tripods were placed at the end of the 40 yards approximately five yards apart on the end line. Once the participants passed through the plane between the tripods at the starting line the time started, and once they passed through the plane at the finish line the time stopped. Participants started a light jog and began sprinting once they passed through the starting line. The time in seconds displayed on the handheld device for the amount of time in which it took each participant to complete the fly-in 40 yard dash. Three trials were performed by each participant and the best of the trials was used for statistical analysis. The participants rested approximately 3-5 minutes between each trial.

Agility t-test.

The Brower Timing System was also used as the measurement instrument for the agility t-test. The agility t-test assessment was set up on an indoor basketball court at the University of Central Oklahoma. The measuring wheel was used to determine the length of five yards between each cone and ten yards between the first and second cone. The first cone was the start and finish point. The Brower Timing System was placed at both sides of the start/finish line and timing started after the plane is crossed the first time and stopped when the timing system plane was crossed a second time. The participant's began at the start/finish cone, and at their discretion sprinted 10 yards forward to the second cone, touched the second cone and sprinted to the left five yards to the third cone. After touching the third cone, the participant's sprinted to the forth cone, back to the second cone, and then sprinted though the start/finish line again. The shape of the four cones resembled the letter "T" (Figure 4). Each participant performed the assessment three times and the best time was used for statistical analysis. The participant rested for one minute between each trial.

Percent Body Fat.

The tool used to assess each participants subcutaneous body fat was a Lange skinfold caliper (JohnsonDiversey Equipment, Cambridge, Maryland). Prior to assessment the testing tool was properly calibrated. The skinfold measurements were assessed on the right side of the participant's body. All measurements were taken directly on the participant's skin. The calipers were placed perpendicular to the skinfold, one centimeter away from the finger and thumb pinch. The pinch was maintained throughout the reading and the measurement was determined within two seconds. Each measurement was performed twice at each site within. If the retest was not within two millimeters the administrator continued the process until two accurate measurements were obtained. Between each measurement ample time was allotted for the participant's skin to regain normal texture. This was accomplished by rotating through all measurements before retesting each site.

In order to assess the body composition of each participant a three-site skinfold measurement was taken. The three-sites measured were the triceps, suprailiac, and thigh. The anatomical site that was used to measure the triceps was halfway between the acromion and olecranon processes on the posterior side of the upper arm. This was a vertical fold. The suprailiac was a diagonal fold taken superior to the iliac crest at its' natural angle on the anterior axillary line of the body. The thigh measurement was a vertical fold taken at the midline between the patella and inguinal crease on the anterior side of the upper leg. According to the ACSM Guidelines for Exercise Testing (2010) the female, three-site formula for the mentioned sites is body density = 1.099421 - 0.0009929 (sum of three skinfolds) + 0.0000023 (sum of three skinfolds)^2 - 0.0001392 (age). After that calculation, each participant's body density was entered into the population specific percent body fat equation, fat= (5.01/Db)-4.57. The skinfold measurement was taken prior to all power assessments. The participants were informed prior to assessment day not to exercise within three to four hours prior to participation and to not apply lotion to the skin immediately prior to the assessments.

Lower Limb Length.

In order to measure the length of the participant's dominant kicking leg, a retractable measuring tape (Prestige Medical, Northridge, California) was used. The administrator started by placing the end of the measuring tape at the anterior superior iliac spine (ASIS) of the pelvis and measured from that point down to the lateral malleolus of the ankle. Each measurement was performed twice in order to ensure accuracy. The average of the two measurements was used for statistical analysis.

Statistical Design and Analysis

A Pearson product moment correlation was conducted to analyze the correlation between kicking power and each of the mentioned field tests along with limb length and percent body fat. For the current research project the alpha level was set at 0.05. The researcher had an increased chance of making a Type 1 error, due to the fact that multiple statistical tests were conducted. A backward multiple regression was conducted in order to determine which combination of independent variables best predicted kicking power performed using the Tendo. The backward multiple regression analysis places all independent variables into the model and removes them one by one if they are shown to significantly weaken the dependent variable. This process continues until all non-contributing variables are eliminated and only the useful independent predictor variables remain. The results from a backward multiple regression are expressed in a R^2 value. The multiple R value represents the amount of the variability of the dependent variable that can be accounted for by the independent variables.

Chapter Four: Results

The primary objective of the investigation was to examine the magnitude and significance of the correlation between lower limb kicking power, assessed using the Tendo and three field assessments of power. The three field tests used were the agility t-test, countermovement vertical jump and the fly-in 40-yard dash. The secondary purpose was to determine if a relationship existed between kicking power and lower limb length, measured on the dominant kicking leg and kicking power and percent body fat. Body composition, limb length, self-reported height, weight and age were also recorded. The final purpose was to form a model based on the independent variable that could be used to predict soccer-specific kicking power.

The study included 21 participants, 18 to 24 years (19.00 ± 0.92 years), from the Saint Gregory's University (*n* = 11) and Oklahoma City University (*n* = 10) varsity women's soccer teams. The participants were 134.00 ± 21.15 pounds and had a mean percent body fat (%BF) of 27.30 ± 6.36%. The mean limb length for all participants was 34.00 ± 1.83 inches. The mean kicking power was 2852 ± 1079 watts. The participants completed the fly-in 40-yard dash in 5.51 ± 0.54 seconds and the agility t-test in 10.63 ± 0.72 seconds. The participants jumped 19.00 ± 3.11 inches on the countermovement vertical jump. Descriptive statistics and basic demographic information for the participants is shown in Table 1.

Table 1

Descriptive Statistics for Participants

Variables	M ± SD	Skewness	SE_{SKEW}	Kurtosis	SE_{KURT}	Minimum	Maximum
Weight (lbs)	134 ± 21.15	.73	.47	1.98	.92	92	194
Age (yrs)	19 ± 0.92	.36	.47	-.47	.92	18	21
%BF	27.3 ± 6.36	.64	.47	-.49	.92	17.5	40.2
Limb (in)	34 ± 1.83	-.79	.42	.59	.82	30	38
Power (W)	2852 ± 1079	.47	.48	.66	.94	877	5558
40yd (sec)	5.51 ± 0.54	.60	.48	-.59	.94	4.69	6.67
T-test (sec)	10.63 ± 0.72	.51	.50	.60	.97	9.46	12.44
CMVJ (in)	18 ± 3.11	.58	.48	-.07	.94	13.5	25.5

Note. SE_{SKEW} = Standard Error of the Skewness; SE_{KURT} = Standard Error of the Kurtosis; %BF = Percent Body Fat; Limb = Limb Length; Power= kicking power; 40yd = Fly-in 40-yard dash time; T-test = Agility t-test time; CMVJ= Countermovement Vertical Jump.

Kicking Power and Field Tests

It was hypothesized by the researcher that the agility t-test would have the strongest correlation with kicking power, because this test most closely imitates the movements required of a soccer player. In order to determine if significant relationships exist between variables, a Pearson's product correlation coefficient was conducted. The results from the tests are displayed in Table 2. It was determined that no significant correlation existed between kicking power and any of the field tests. Although the agility t-test demonstrated a small to moderate, positive relationship (r = .356) it was not significant (p = 0.113). The fly-in 40-yard dash (r = .099, p = 0.652) and the countermovement vertical jump (r = -.022, p = 0.992) held no correlation with kicking power.

The results from the current study indicated that a significant correlation existed between each of the field tests when related to each other. A moderate, negative correlation was demonstrated between the countermovement vertical jump and the agility t-test (r = -.580, p = 0.006) and the fly-in 40-yard dash (r = -.651, p = 0.001). This indicates that better performance on the countermovement vertical jump may result in less time taken to complete the agility t-test and the fly-in 40-yard dash. It was also shown that the agility t-test and the fly-in 40-yard dash demonstrate a moderate, positive correlation (r = .671, p = 0.001). Indicating that a faster time on the fly-in 40-yard dash may correspond with a faster agility t-test time.

Kicking Power, Limb Length, and Body Composition

It was hypothesized that the participants who have a lower %BF would have a more powerful kick. It was also hypothesized that participants with longer lower limbs would have an advantage in being able to generate more power during a maximal effort instep soccer kick. The current study looked at the correlation between the participants's kicking power, lower limb length, and body composition. The results from the tests are displayed in Table 2. The results indicated that %BF has a moderate, significant, positive relationship (r = .630, p = 0.001) when correlated to kicking power. This correlation indicates that the greater the %BF the greater the kicking power. When limb length is correlated to kicking power the results indicated that a moderate, significant, positive relationship (r = .418, p = 0.047) exists. The positive correlation between limb length and kicking power signifies that having longer lower limbs may allow an individual to generate greater kicking power. Percent body fat and lower limb length were the only two assessments that had significant correlations to kicking power. Figure 5 and Figure 6 respectively display scatter plots of these two significant correlations.

Table 2

Results from Pearson's Correlation Coefficient

Variables	%BF	Limb	Power	40yd	T-test	CMVJ
%BF	---	-.017	.630**	.558**	.708**	-.334
Limb	-.017	---	.418*	-.401	-.042	.298
Power	.630**	.418*	---	.099	.356	-.022
40yd	.558**	-.401	.099	---	.671**	-.651**
T-test	.708**	-.042	.356	.671**	---	-.580**
CMVJ	-.334	.298	-.022	-.651**	-.580**	---

Note. %BF = Percent Body Fat; Limb = Limb Length; Power = kicking power; 40yd = Fly-in 40-yard dash; T-test = Agility t-test; CMVJ= Countermovement Vertical Jump.
* $p < 0.05$. ** $p < 0.01$.

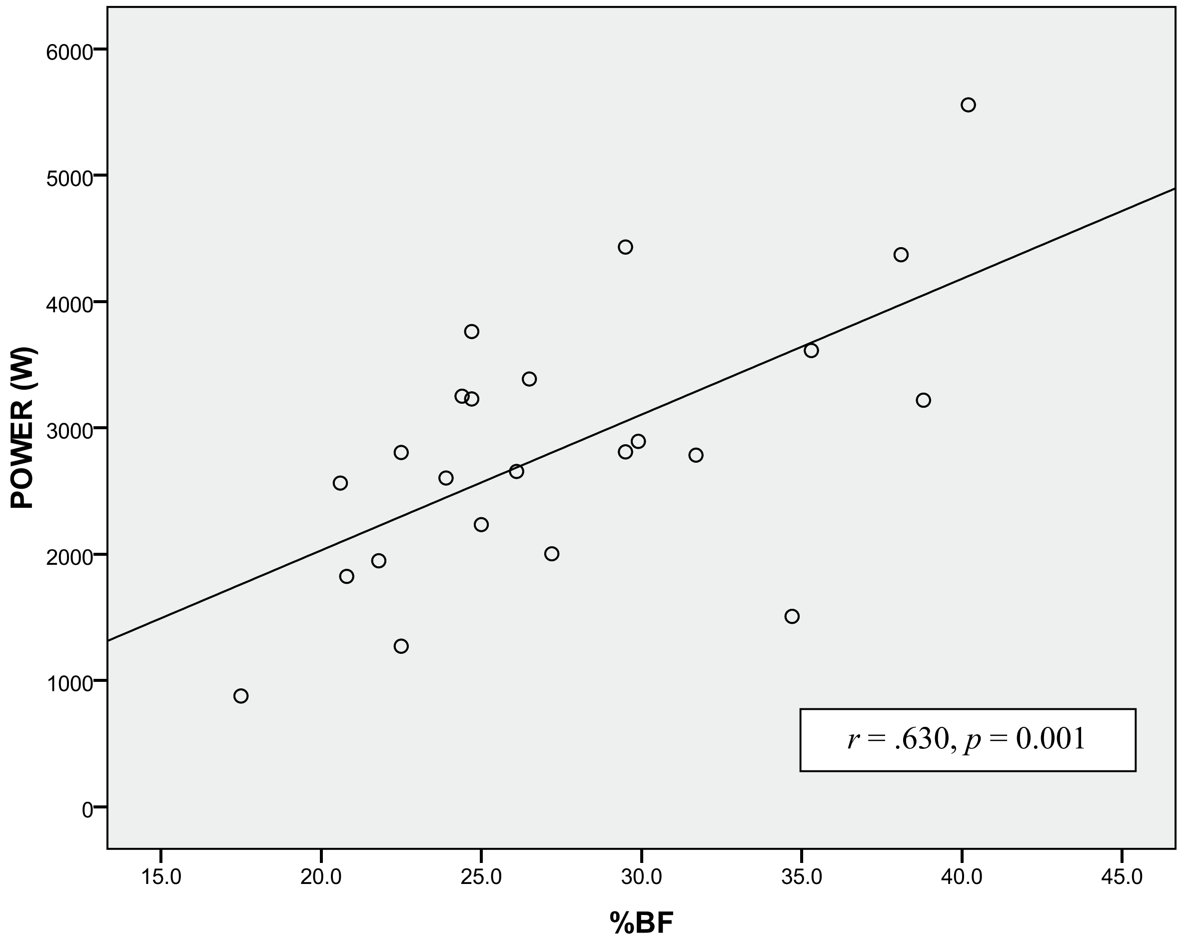

Figure 5. Scatter plot displaying the relationship between percent body fat and kicking power.

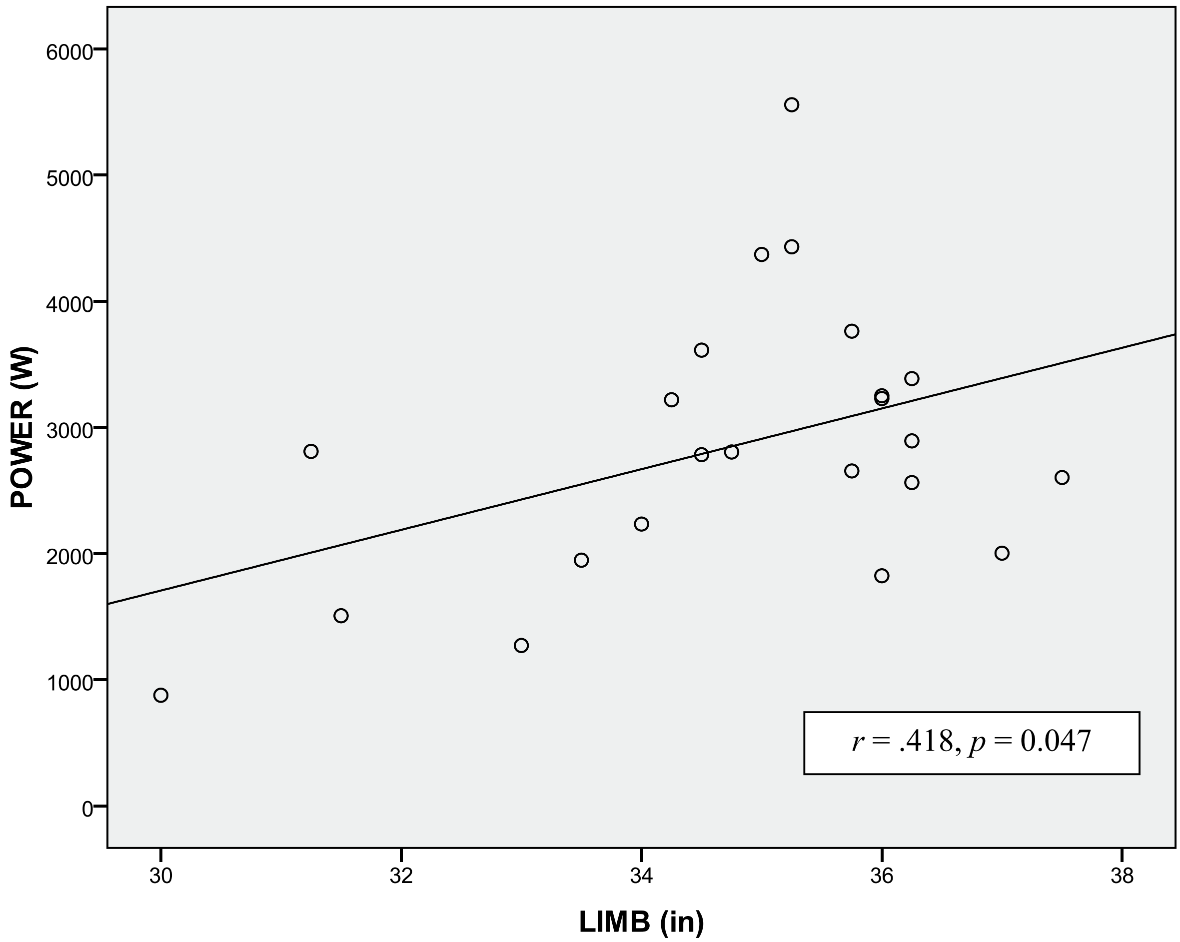

Figure 6. Scatter plot displaying the relationship between limb length of the dominant kicking leg and kicking power.

Backward Multiple Regression

The final purpose of the current investigation was to develop a model that could be used to predict kicking power from the three field tests, limb length, and percent body fat. A backward multiple regression analysis was used to identify the variables that would best predict kicking power. This process entered all independent variables into the model to be used as predictors of the dependent variable. One by one the independent variables were removed if it significantly weakens the model. This process continued until all non-contributing variables were eliminated and only the useful predictor independent variables remained. The results from the backward multiple regression are presented in Table 3.

It was hypothesized that the agility t-test and percent body fat would provide the best model to predict kicking power. The results from the backward multiple regression indicated that limb length and percent body fat were the best predictors of kicking power. When considering all independent variables as predictors of kicking power the R^2 value was 0.644. This value means that 64% of the variability of the dependent variable can be accounted for by the independent variables.

The first independent variable that was removed from the prediction analysis was the agility t-test. When this variable was removed it did not greatly reduce the R` value (R^2 = 0.643) indicating that this variable did not add significance to the prediction model. Although the agility t-test had a moderate non-significant relationship with kicking power, its contribution to the model was overlapped by limb length and %BF. The countermovement vertical jump was eliminated in Model 3 and provided a R^2 value of 0.627. The last independent variable that was eliminated from the prediction model was the fly-in 40-yard dash. Each of the removed variables was seen to significantly weaken the prediction model which provided a R^2 value of 0.608. The two variables that added the greatest amount of prediction to the model were limb length and %BF.

The interpretation of these results indicates that all independent variables provide 64% variability, while using only limb length and %BF can still predict 61% of the variability in kicking power. As seen in Table 3 limb length and %BF were the only two variables that significantly contributed to the prediction model throughout the elimination process. Even though the value of the multiple R was reduced by eliminating all but two of the variables, the variables that were removed were shown to significantly weaken the prediction model.

Table 3

Results from Backward Multiple Regression

	Tendo Kicking Power			
Variables	Model 1 B	Model 2 B	Model 3 B	Model 4 B
Constant	-4512.180	-4910.216	-6993.684	-9918.708
T-test	-0.053			
CMVJ	-0.196	-0.182		
40yd	-0.286	-0.304	-0.182	
Limb	0.467*	0.456*	0.439*	0.512**
%BF	0.716**	0.692**	0.692**	0.600**
R^2	0.644	0.643	0.627	0.608
F	5.424**	7.205**	9.513**	13.933**

Note. %BF = Percent Body Fat; Limb = Limb Length; 40yd = Fly-in 40-yard dash; T-test = Agility t-test; CMVJ= Countermovement Vertical Jump.
* $p < 0.05$. ** $p < 0.01$.

Chapter Five: Discussion

The primary objective of the current investigation was to examine the magnitude and significance of the correlation between lower limb kicking power, assessed using the Tendo FitroDyne Powerlizer, and three field assessments of performance. The three field tests used were the agility t-test, countermovement vertical jump, and the fly-in 40-yard dash. The secondary purpose was to determine if a relationship existed between kicking power and lower limb length, measured on the dominant kicking leg and kicking power and percent body fat. The final purpose of the investigation was to develop a model that could be used to predict Tendo kicking power from the three field tests, limb length, and percent body fat.

Results from the study suggested that no significant correlation was found between kicking power and each of the three field tests (CMVJ: $r = -.022$, $p = 0.922$; 40yd: $r = .099$, $p = 0.652$; T-test: $r = .356$, $p = 0.113$). Each of the three field tests were chosen strictly because they possess strong soccer specificity, as they mimic the movements required during competition or performance. Although each of these four tests (countermovement vertical jump, agility t-test, fly-in 40-yard dash, and Tendo) is a valid and reliable assessments of lower limb power (Markovic, et al., 2004, Sassi et al., 2009, Pauole, et al., 2000, Jennings et al., 2005) the results from the current study suggest that the Tendo was not an accurate assessment of kicking power.

Field Test Relationship

While no significant correlation was demonstrated between the field assessments and kicking power, the findings from the current study are congruent with existing literature when correlating the three field assessments of power to each other. In a study performed by Pauole and colleagues (2000), the agility t-test was found to be a valid and reliable assessment of leg power, leg strength, and agility. These three characteristics are considered essential components for successful performance in sports activities (Pauole et. al.). In this study Pauole and colleagues found moderate to strong significant relationships between the agility t-test time, countermovement vertical jump, and 40-yard dash time. These findings suggest that all three field assessments are good indicators of leg power.

The results from the current study indicated that a significant correlation exists between each of the field tests when related to each other. A moderate, negative correlation was seen between the countermovement vertical jump and the agility t-test (r = -.580, p = 0.006) and the fly-in 40-yard dash (r = -.651, p = 0.001). This suggests that better performance on the countermovement vertical jump may result in less time taken to complete the agility t-test and the fly-in 40-yard dash. It was also shown that the agility t-test and the fly-in 40-yard dash demonstrate a moderate, positive correlation (r = .671, p = 0.001), indicating that a faster time on the fly-in 40-yard dash may correspond with a faster agility t-test time.

Kicking Power and the Field Tests

It was hypothesized that the agility t-test would have the strongest correlation with power as measured by the Tendo. This hypothesis was in agreement with the findings on the current study. Although it was non-significant, of the three field tests, the agility t-test did have the strongest correlation with kicking power (r = .356, p = 0.113). It was also hypothesized that a positive relationship would exist between kicking power and the vertical jump, while a negative relationship would exist between kicking power and both the agility t-test time and the fly-in 40-yard dash time. The reasoning behind this assumption was that the participants that had greater kicking power would also be able to complete the timed assessments faster. In a study performed by Dorge and colleagues (2002) the researchers suggest that a basic instep soccer kick requires maximum power from the activation of lower limb muscles. The researchers indicated that a greater amount of lower limb power and strength may assist in producing a stronger instep soccer kick.

Previous literature indicates that the Tendo is easily adapted to various pieces of equipment and can accurately measure lower limb power (Jennings et al., 2005; Rhea, Peterson, Lunt, & Ayllon, 2008). In each of these findings the tether of the Tendo was attached to a barbell and a single plane resistance training movement, such as a squat. In order to properly perform an instep soccer kick the individual must combine an approach step, arm movement for balance, incorporate stabilizing muscles in the abdominals, and engage most of the muscles and joints in the lower body. Although the tether of the Tendo can easily be attached to resistance equipment and result in accurate power measurements, the results from the current study suggest that attaching it to the human body and performing multi-plane dynamic movements does not produce dependable results of power.

Kicking Power and Limb Length

The present study also investigated the relationship between kicking power and limb length of the dominant kicking leg. It was hypothesized that the participants who have longer limbs would have an advantage in being able to generate more power during a maximal effort instep soccer kick. The results from the study were in agreement with the hypothesis and demonstrated a moderate positive relationship between kicking power and limb length ($r = .418$, $p = 0.047$). This correlation indicates that greater length in the lower limbs is associated with greater kicking power. This correlation may be due to the mechanical advantage that exists as a longer limb would correspond with a greater force arm of the lever system.

Kicking Power and Percent Body Fat

A possible correlation between kicking power and %BF was also examined in the present study. The primary investigator hypothesized that a negative relationship would exist between the two variables, meaning that greater kicking power would come from the individuals with a lower percent body fat. It was determined that kicking power assessed using the Tendo and %BF produced a moderate, significant positive correlation ($r = .630$, $p = 0.001$). This correlation indicates that the higher %BF that an individual has, the more kicking power they will be able to produce.

Although a greater percent body fat was shown to produce more kicking power, previous literature and the current study reiterate the assumption that the Tendo might not be the most accurate way to assess a dynamic movement of an instep soccer kick. Since kicking power measured using the Tendo was not significantly correlated with the field assessments that are all measuring lower limb power (Pauole et. al., 2000), it could be justified that a greater percent body fat would not be the most effective way to produce soccer specific lower limb power. Increased percent body fat was significantly related to two out of the three field assessments but these correlations were coupled with poorer performance on each of the tests. The results from the Pearson's correlation in the current study indicated that %BF had a moderate significant positive correlation with the fly-in 40-yard dash ($r = .558$, $p = 0.006$) and agility t-test ($r = .708$, $p < 0.000$). Meaning that greater %BF produced significantly worse performance on field assessments of lower limb power. This further justifies that a better method of assessing lower limb kicking power is needed to accurately measure an instep soccer kick that is more applicable to soccer specific movements.

Limitations

After completion of the thesis procedure, some methodological limitations were identified. Previous literature indicated that the Tendo is easily attached to various types of equipment (e.g. a barbell or dumbbell); therefore it was hypothesized that the Tendo would accurately measure kicking power when attached to the foot of the participant performing an instep kick. After statistical analysis it was determined that the Tendo was unable to be validated as an accurate assessment to directly measure kicking power. This became a limitation for the current study considering that measuring power of a soccer kick was paramount to the aims of this study.

It was intended that all data collection be collected in an indoor facility. Another limitation was presented due to the fact there was a lack of area in the testing facility to accommodate the fly-in 40-yard dash. Since there was a lack of available space to perform the fly-in 40-yard dash at the indoor facility, the assessment was performed outside. Data was collected on two separate days for the two collegiate teams who participated in the study. The different weather conditions during testing could be considered a limitation.

Post data collection it became apparent that there was a difference in the ability level of the two collegiate soccer teams. Although the teams are in the same division and regularly compete against each other, the performance on the assessments was noticeably different even though no statistical comparison was conducted. The difference in scores on the assessments could be seen as an additional limitation to the current study since a more similar group was intended.

Multiple Kinesiology and Exercise Science undergraduate students from the University of Central Oklahoma that were proficient in the assessments performed in the study were recruited to assist with the data collection process. The assessments that had consistent technicians throughout the data collection process were limb length, body composition and kicking power, all other assessments were conducted by two different sets of undergraduate Kinesiology students. Although the students were proficient and the assessments are easily administered this method could have resulted in variation of the results.

Recommendations for Future Studies

The results from the backward multiple regression indicated that percent body fat and limb length were the best predictors of lower limb kicking power. Based on the usage of the Tendo assessment and the non-significant correlations that were found between this assessment and each of the field tests, discovering that limb length and %BF were significantly correlated and could be used to predict Tendo kicking power is logical. These two measurements had the greatest correlation with kicking power (limb length: $r = .418$, %BF: $r = .630$). In order to determine the most appropriate soccer specific field assessment of lower limb power it would be suggested that finding a better way to assess specific components of the soccer kick would be more beneficial when assessing soccer athletes.

The Tendo is an accurate assessment of lower limb power (Jennings et al., 2005) but was seen to not be congruent with kicking power. Although kicking is considered the most important skill performed by soccer athletes (Campo et. al., 2009), there are other components that need to be considered when assessing soccer kicking performance. The Tendo was unable to assess the accuracy of the kick or the balance, technique, and control of the participant. The machine only measured the raw power behind the kick. It was hypothesized that the participants that performed better on the field assessments measuring lower limb power would in turn have a more powerful instep soccer kick. Therefore, a more in depth assessment of soccer kicking performance would potentially provide strong correlations to the chosen field assessments.

As previously stated, there are several other components to consider when assessing soccer kicking performance. One recommendation would be to attempt to control for other aspects of the kick while still using the Tendo to assess power. One way this could be achieved is by incorporating a target so the participants would have to aim in order to help in identifying not only kicking power but also accuracy. This small adjustment may better allow for the participants that appear to be more skilled in a competition setting to perform better (i.e. have a more powerful soccer kick). Incorporating accuracy into the Tendo assessment might help make the assessment a better indicator of soccer kicking power and performance.

Future studies may be done in order to determine an accurate way to directly measure soccer-specific kicking power including as many of the necessary components involved in the kick that reflect a players ability. If an assessment was found that better represents an instep soccer kick, future studies may be better equipped to determine which of the field assessments is best for measuring soccer kicking ability. It would also be recommended that more participants be recruited in order to allow for injuries or various other issues that could arise while planning a study with a large amount of data collection.

It is also recommended that future studies add male participants to the investigation or participants from a different division other than the NAIA (i.e. Division 1). Including more skilled soccer players may change the outcome of the current research study. It would also be suggested to conduct a study that looked at the differences between the kicking power of soccer athletes that play at different positions on the soccer field.

Conclusions

The results from the current study demonstrate that strong significant correlations exist between the countermovement vertical jump, the agility t-test, and the fly-in 40-yard dash suggesting that these three assessments are measuring the same thing. When attempting to correlate kicking power to each of these assessments the primary investigator assumed that the Tendo would be able to accurately measure this dynamic movement. Although these correlations were significant, the field assessments of lower limb power were not correlated to kicking power indicating that the Tendo may not have effectively measured the instep soccer kick. The significant findings of the correlations and the backward multiple regression indicated that limb length and %BF both hold a moderate, positive relationship to kicking power and are the best indicators of kicking power measured using the Tendo. It is concluded that the Tendo does not accurately measure kicking power in soccer players. The Tendo has been shown effective when measuring the lower limb power of a single plane motion (e.g. squat)(Jennings et. al., 2005) but future studies are needed to determine a power assessment for a multi-plane dynamic movement such as an instep soccer kick.

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Figure 1. A picture of the various pieces of the Tendo FitroDyne Powerlizer

Figure 2. An example of how the Tendo FitroDyne was used to assess the instep soccer kick.

Figure 3. An example of the Vertec Apparatus, used to assess vertical jump height.

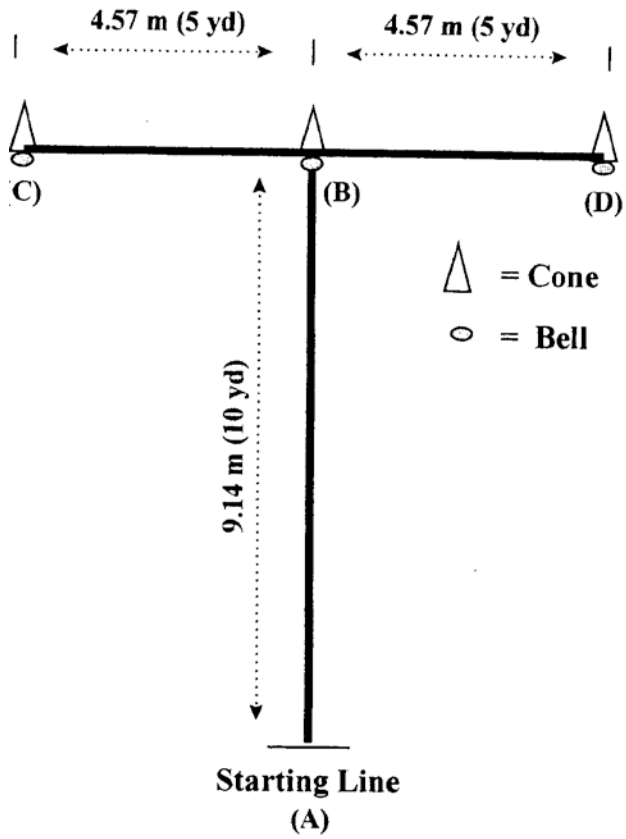

Figure 4. A diagram of an agility t-test.

Appendices

Appendix A

Written Permission

To Whom it May Concern:

I, Coach Paul McNally, give permission to Kara Nimz, a graduate student at University of Central Oklahoma, to recruit the members of my soccer team for her thesis study.

If there are any problems or questions, please feel free to either contact myself or Kara, as we can help you.

Thanks,

Paul McNally

Women's Soccer Coach

St. Gregory's University

pkmcnally@stgregorys.edu

(816) 616-5256 cell phone

(405) 878-5341 office

To Whom it May Concern:

I, Coach Brian Harvey, give permission to Kara Nimz, a graduate student at University of Central Oklahoma, to recruit the members of my soccer team for her thesis study.

If there are any problems or questions, please feel free to either contact myself or Kara, as we can help you.

Thanks,

Brian Harvey

Women's Soccer Coach

Oklahoma City University

bharvey@okcu.edu

(405) 208-5165 office

Appendix B

Institutional Review Board Approval

UNIVERSITY OF Central Oklahoma

November 16, 2010

IRB Application #: 10165

Proposal Title: Field and Laboratory Assessments of Muscular Power in Female NAIA Soccer Players

Type of Review: Initial-Expedited

Investigators:

Ms. Kara Nimz
Dr. Gregory Farnell
Department of Kinesiology and Health Studies
College of Education and Professional Studies
Campus Box 189
University of Central Oklahoma
Edmond, OK 73034

Dear Ms. Nimz and Dr. Farnell:

Re: Application for IRB Review of Research Involving Human Subjects

We have received your revised materials for your application. The UCO IRB has determined that the above named application is APPROVED BY EXPEDITED REVIEW. The Board has provided expedited review under 45 CFR 46.110, for research involving no more that minimal risk and research category 7.

Date of Approval: 11/16/2010
Date of Approval Expiration: 11/15/2011

If applicable, informed consent (and HIPAA authorization) must be obtained from subjects or their legally authorized representatives and documented prior to research involvement. A stamped, approved copy of the informed consent form will be sent to you via campus mail. The IRB-approved consent form and process must be used. While this project is approved for the period noted above, any modification to the procedures and/or consent form must be approved prior to incorporation into the study. A written request is needed to initiate the amendment process. You will be contacted in writing prior to the approval expiration to determine if a continuing review is needed, which must be obtained before the anniversary date. Notification of the completion of the project must be sent to the IRB office in writing and all records must be retained and available for audit for at least 3 years after the research has ended.

It is the responsibility of the investigators to promptly report to the IRB any serious or unexpected adverse events or unanticipated problems that may be a risk to the subjects.

On behalf of the UCO IRB, I wish you the best of luck with your research project. If our office can be of any further assistance, please do not hesitate to contact us.

Sincerely,

Jill A. Devenport, Ph.D.
Chair, Institutional Review Board
Director of Research Compliance, Academic Affairs
Campus Box 159
University of Central Oklahoma
Edmond, OK 73034
405-974-5479
jdevenport@uco.edu

Appendix C

Informed Consent

UNIVERSITY OF CENTRAL OKLAHOMA

INFORMED CONSENT FORM

Research Project Title: Field and Laboratory Assessments of Muscular Power in Female NAIA Soccer Players

Researcher (s): Kara Nimz

A. Purpose of this research: The purpose of the investigation is to determine the most closely related field assessment between the agility t-test, countermovement vertical jump, and fly-in 40-yard dash, when correlated to the Tendo FitroDyne Powerlizer which will be used to measure soccer kicking power. The Tendo FitroDyne Powerlizeris a computer based assessment of leg power. The secondary purpose is to determine if limb length, body, composition, or years competing at the NAIA level effect kicking power.

B. Procedures/treatments involved: Each participant will be attached to the Tendo FitroDyne. The Tendo is an instrument that is used to assess lower-limb muscular power. The participants will have the tether of the Tendo attached to their dominant kicking foot. They will be asked to strike a soccer ball as hard as they possible can for ten repetitions. Each participant will be asked to preform each of the following assessments four times, the countermovement vertical jump, agility t-test, and fly-in 40-yard dash. The countermovement vertical jump will require the participant to take one preparation step prior to jumping as high as possible. The agility t-test will require the participant to preform a four direction all-out sprint that is a total of 40 yards. The fly-in 40-yard dash will allow the participant 10 yards of preparation prior to preforming a maximal effort 40 yard sprint. Each participant's height and weight will be determined using a digital scale. Each participant's limb length will be measured using a tape measurer and their body composition will be assessed using the three site skinfold caliper formula. All data collection will take place at the UCO Wellness Center.

C. Expected length of participation: The assessments will be taken over a two day period.

D. Potential benefits: The results of the current study will not be given to the participant or coaches to provide direct benefit, howevera general benefit to society will be that coaches would then have an easy to administer, accurate assessment that will provide them with the kicking power of their soccer athletes.

E. Potential risks or discomforts: All tests would fall under the intensity used during their practices. Proper stretching and warm-up will be preformed prior to beginning the assessments which will minimize the risk for muscle soreness. Once all tests are finished for the day the participants will be instructed to cool down and stretch again. This will help eliminate any delayed muscle soreness that might occur. UCO is not liable for any injuries that occur. Personal physicians are to be contacted in the case of an injury.

F. Medical/mental health contact information (if required): Participants are instructed to contact their personal physician if they experience any discomfort or injury.

G. Contact information for researchers and UCO IRB: Kara Nimz, daytime phone 405.620.4499, PI email knimz2@uco.edu or Dr. Greg Farnell e-mail:gfarnell@uco.edu or Dr. Devenport with the IRB office at the University Of Central Oklahoma (974-5497).

H. Explanation of confidentiality and privacy: The collected data will only be diseminated as aggregate data. The paper data will be shredded and the electronic data will be erased off of the flash drive and emptied into the computers recycle bin, where it will then be deleted off of the hard drive completely. The data will be kept for one year following completion of the study. All data will be destroyed at this time.

I. Assurance of voluntary participation: Your decision to participate or not participate in the study is completely voluntary. You will not experience any negative consequences based on your decision of participation. You should also understand that you may discontinue participation at any time without consequence.

APPROVED
NOV 16 2010
UCO IRB

APPROVAL
NOV 15 2011
EXPIRES

AFFIRMATION BY RESEARCH SUBJECT

I hereby voluntarily agree to participate in the above listed research project and further understand the above listed explanations and descriptions of the research project. I also understand that there is no penalty for refusal to participate, and that I am free to withdraw my consent and participation in this project at any time without penalty. I acknowledge that I am at least 18 years old. I have read and fully understand this Informed Consent Form. I sign it freely and voluntarily. I acknowledge that a copy of this Informed Consent Form has been given to me to keep.

Research Subject's Name: _____

Signature: ______________________________ Date _____

Appendix D

Protecting Human Research Participants Certificate of Completion

Certificate of Completion

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

Date of completion: 08/26/2009

Certification Number: 272248

Appendix E

Thesis Summary Document

Previous assessments used to measure lower limb kicking power in soccer athletes do not mimic the movement patterns performed by the athlete during competition. There are a limited number of studies that have attempted to determine the most accurate way to assess lower limb kicking power in soccer players. An assessment is most beneficial when accurately measuring an athletic skill or movement when the movement patterns of the assessment mimics those required of the athlete. The purpose of the current study was to determine which field assessment of lower limb power is most closely correlated with an instep soccer kick.

When assessing performance in soccer athletes, lower limb power has shown to be a vital component (Pereira, Pereira, Thiebaut, Sampalo-Jorge, & Machado, 2009). Soccer-specific physical performance field tests are the most important factors that can be evaluated outside of the game situation (Malliou et al., 2003). The field tests that seem the most applicable to soccer are the countermovement vertical jump, the agility t-test, and the fly-in 40-yard dash. Each one of these tests are directly associated with movement patterns involved in soccer performance. These field tests are also valid and reliable measures of lower limb power (Sassi et al., 2009).

A more precise method of measuring leg power in a laboratory setting is achieved by using the Tendo FitroDyne Powerlizer (Tendo). The Tendo is an easily attachable assessment tool that has been shown to measure lower limb power (Rhea & Kenn, 2009) and is considered a valid and reliable measurement of power (Jennings, Viljoen, Durandt, & Lambert, 2005). However it is an expensive piece of equipment that is not likely to be included in the typical soccer coach's budget. If the most closely correlated field test to the Tendo between the countermovement vertical jump, the agility test, and the fly-in 40-yard dash was known, this field test could be used as an alternate way to estimate lower limb power that is directly related to the movements required of a soccer player.

The primary purpose was to determine the most closely related power assessment between the agility t-test, the countermovement vertical jump, and the fly-in 40-yard dash when correlated to the Tendo FitroDyne Powerlizer. An additional aim of the study was to determine if a relationship existed between lower limb length and percent body fat when correlated to the Tendo. A Pearson's correlation coefficient was used to examine the relationships between the kicking power and each of the independent variables. A backward multiple regression was administered in order to determine which independent variables were able to best predict kicking power.

The results from the current study indicate that no significant relationship exists between kicking power and the countermovement vertical jump (r = -.022, p = 0.992), the fly-in 40-yard dash (r = .099, p = 0.652) or the agility t-test (r = .356, p = 0.113). However, a significant positive relationship was found between kicking power and lower limb length (r = .418, p = 0.047) and percent body fat (r = .630, p = 0.001). The results from the backward multiple regression indicate that the best predictors of kicking power are lower limb length and percent body fat.

Although no significant correlation exists between kicking power and each of the assessments of soccer specific power, significant correlations were found among all of the field tests indicating that all of the assessments were measuring lower limb power. This suggests that the Tendo may not have effectively measured the instep soccer kick. The Tendo has been shown effective when measuring the lower limb power of a single plane motion (e.g. squat) (Jennings et. al., 2005) but future studies are needed to determine a power assessment for a multi-plane dynamic movement such as an instep soccer kick. It is concluded that the Tendo does not accurately measure kicking power in soccer players.