CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

THE RELATIONSHIP BETWEEN PERFORMANCE OF HIGH INTENSITY INTERMITTENT EXERCISE AND AEROBIC AND ANAEROBIC CAPACITIES

A thesis submitted in partial fulfillment of the requirements
For the degree of Master of Science in Kinesiology

By

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May 2012
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DEDICATION

I would like to dedicate this thesis to my family. To my beautiful wife for her generous love and support during this challenging time in my life, the sacrifices you made, and your dedication to supporting me even though it meant you had to do more than your share is what true love is all about. To my children Grace, Anneliese, and Kieran who kept me grounded in what matters most when I desperately needed it.
ACKNOWLEDGEMENTS

I would first like to thank my thesis committee, which is comprised of Dr. Sean Flanagan, Dr. Steven Loy, and Dr. Ben Yaspelkis for their support and guidance. I would also like to thank my Graduate Coordinator Dr. Victoria Jaque for her reliable support in this process. I would especially like to thank my thesis chair, Dr. Sean Flanagan for his dedication and commitment of his time to helping me complete this project. I would also like to thank the participants from College of the Canyons for their commitment to performing in theses physically demanding tests. Thank you all very much for your contributions, without your knowledge and guidance this would not have been possible.
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ABSTRACT

THE RELATIONSHIP BETWEEN PERFORMANCE OF HIGH INTENSITY INTERMITTENT EXERCISE AND AEROBIC AND ANAEROBIC CAPACITIES

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Introduction: Competitive soccer is characterized by high-intensity intermittent exercise (HIIE) interspersed with intervals of submaximal work, performed over a prolonged period of time (90 minutes). Due to the unpredictable, intermittent nature of the sport it is challenging to understand the athletes’ soccer specific energy requirements. Although the relationship between aerobic capacity and performance in HIIE has been widely studied, research examining the relationship between anaerobic capacities and HIIE is limited. Purpose: The purpose of this study was to examine the relationship between high intensity intermittent exercise (HIIE) and anaerobic power, anaerobic endurance, and aerobic capacity. Participants: Thirty one soccer players were recruited from College of the Canyons, a community college in southern California. Participants were recruited from the men’s and women’s soccer programs. Participants include 19 female and 12 male soccer players.
The 12 male participants were 19 ± 1 years old, 177.6 ± 6.0 cm tall, and weighed 73.6 ± 6.0 kg. The 19 female participants were 18 ± 1 years old, 161.9 ± 5.1 cm tall, and weighed 59.3 ± 7.3 kg. Methods: Participants completed five performance-based tests over a period of two days. The Yo-Yo Intermittent Recovery Test Level 1 (YYIRT1), which assesses HIIE, was measured using cones, audio player and YYIRT1 sound track. The 1.5 mile run, which was used to estimate aerobic capacity, was performed on a track and timing was assessed with a stop watch. The 300 yard shuttle is a measure of anaerobic endurance and was performed using cones and timing was assessed with a stop watch. The 40 yard sprint, used to measure anaerobic power, was assessed using cones and a digital timing system. All tests were performed as recommended by the National Strength and Conditioning Association (NSCA), from least fatiguing to most fatiguing. Correlation analysis was run against all subjects as well as between sexes.

Data Analysis: Pearson’s product moment coefficient of correlation was used to determine a relationship between the performance measures of the YYIRT1, 1.5 mile run, 300 yard shuttle, and 40 yard sprint. Backward multiple-regression to determine the relationship between the YYIRT1 and a combination of the 300 yard shuttle, 40 yard sprint and 1.5 mile run within gender groups. Results: No significant relations were found for male subjects in this study. Female subjects however, produced significant correlations between HIIE and aerobic capacity (r = -.706, p<.05), and HIIE and anaerobic endurance (r = -.724, p<.05). No significant relationship was found between HIIE and anaerobic power (r = -.366, p>.05). Through multiple regression analysis between HIIE and aerobic capacity, anaerobic endurance and anaerobic power for female subjects, our
results suggest that the coefficient of determination for inclusion of all three predictors was 56%. For male subjects, no significant results were found.

With the exclusion of anaerobic power, a decrement of $r = .001$ was seen. Further exclusion of aerobic capacity reduced the coefficient of determination by 3%. The results suggest that anaerobic endurance may account for the majority of variance of the three measures when compared to HIIE. **Conclusion:** Results suggest that anaerobic endurance and aerobic capacity are both important measures for performance in the YYIRT1 for female athletes. However, anaerobic endurance may be more closely related to the demands of HIIE than aerobic capacity. Additionally data was collected in four different performance tests for male and female junior college athletes. These measures create a baseline for coaches within this special population to create programs to address fitness needs of their athletes.
CHAPTER 1: INTRODUCTION

Competitive soccer is characterized by high-intensity intermittent physical activity interspersed with intervals of submaximal work, performed over a prolonged period of time (90 minutes). Energy from aerobic pathways provides the majority of energy for players, due to the length of a soccer match (Stolen, Chamari, Castagna, Wisloff, & Krustrup, 2005; Bangsbo, 1994; Chamari et al., 2005), while improved anaerobic capacities have been shown to increase the amount of sprints performed during a match (Reilly, Durst, Clarke, 2008; Mohr, Krustrup, Bangsbo, 2003). It has been shown that top-class players perform more high-intensity running, sprinting, and cover more distance in the course of a soccer match than moderate players (Reilly et al., 2008; Mohr, et al.Krustrup, Bangsbo, 2003). It was shown that top-class players covered 5% more distance, performed 28% more high intensity running and 58% more sprinting. Top-class players in the study were recruited from professional teams that were ranked in the top 10 in the world according to official FIFA rankings. Moderate players were recruited from professional teams that were not ranked in the top 20 (Mohr et al., 2003).

Due to the unpredictable, intermittent nature of the sport it can be challenging for coaches to accurately test their athletes’ soccer specific fitness levels. The Yo-Yo intermittent recovery test level 1 (YYIRT1) however, has been shown to be a valid and reliable tool to test an athlete’s ability to repeatedly perform high-intensity exercise (Krustup et al., 2003), which has been suggested to be the best measure of endurance performance in soccer (Bangsbo, Iaia, Krustrup, 2008).
The extent to which the YYIRT1 taxes each energy system has not clearly been defined, but many researchers have demonstrated that there is a significant relationship between VO₂max and performance of the YYIRT1 (Castagna, Impellizzeri, Rampinini, D’Ottavio, & Manzi, 2008; Bangsbo et al., 2008; Rampinini, Sassi, Azzalin, Castagna, 2010). Bangsbo (1994) estimates that aerobic metabolism contributes 90% of the energy production during a soccer match. Bangsbo et al., (2008) states that the YYIRT1 stimulates the aerobic system maximally and focuses on the ability to repeatedly perform aerobic high intensity work, suggesting anaerobic contribution is limited (Bangsbo et al., 2008; Rampinini et al. 2010). In stark contrast, Fox & Mathews (1974) suggests the percentage of ATP contribution from aerobic metabolism during a match is less than 20%. The estimated contribution of each energy system proposed by these authors was not measured during a match, but highlights the discrepancy in literature and the lack of a clear understanding of the physical demands.

It was the objective of this study to examine the practical relationship between the YYIRT1 and common field tests for aerobic capacity, anaerobic endurance, and anaerobic power. The 40 yard sprint was selected for its reliance on the phosphagen system, familiarity and longtime popularity as a predictor of anaerobic power output (Powers & Howley, 2009). The 300 yard shuttle was selected because of its similarity in movement patterns to soccer, its reliance on fast glycolysis, and its predictive ability of anaerobic endurance (Jones, 1991). The 1.5 mile run was selected for its reliance on aerobic pathways and moderately high correlation with VO₂max (Powers & Howley, 2009).
Although the tests do not directly measure efficiency or complete reliance of a particular energy system, they are practical means of testing activities that rely heavily on a particular metabolic pathway. Therefore, in the present study we attempted to infer a relationship between energy systems and performance in the YYIRT1 from the correlation between results of the different protocols. I hypothesize that anaerobic endurance will be highly correlated and anaerobic power and aerobic capacity will be moderately correlated with HIIE.
CHAPTER 2: LITERATURE REVIEW

The transition of the sport of soccer into the realm of professional enterprise has led clubs to explore a variety of different training techniques to develop a competitive advantage. By virtue of the relative importance of fitness, researchers have found it useful to study the activity patterns and the physical demands of soccer. A player’s level of fitness will determine their ability to meet the demands of the game and ultimately determines the player’s potential to contribute to the match. Time-motion analysis has been used to observe the activity patterns of low, intermediate, high, and elite level teams. It has been suggested that a team’s level of play has a positive correlation with the ability of the players to perform repeated high-intensity exercise (Bangsbo, 1994).

Research indicates top-class players performed more high-intensity running, sprinted more, and covered more distance in the course of a soccer match than moderate players (Reilly et al., 2008). Time-motion analysis supports these findings. One study determined that the total distance covered in a match was 5% more for top-class players than moderate level players, the amount of high-intensity running during a match was 28% more, and the distance covered when sprinting was 58% more for top-class compared to moderate players (Mohr, 2003).

It was also demonstrated that an improvement in a player’s VO2max and running economy of 5ml/kg/min and 7% respectively, increased the player’s involvement with the ball and increased the number of sprints and distance covered during a match (Helgerud, Engen, Wiloff, & Hoff, 2001).
Rampinini et al (2009) has shown that the number of short passes by teams, diminished in the second half compared to the first half. The decrease in the number of passes between halves is indicative of the occurrence of fatigue (Impellizzeri et al, 2008). This is supported in findings by Rampinini et al (2008) that demonstrated a deterioration in short passing ability, as measured by the Loughborough Soccer Passing Test (LSPT), was correlated to a player’s physical fitness, as measured by the Yo-Yo Intermittent Recovery Test (YYIRT1).

Lees and Davies study (as cited in Reilly et al. 2008), found that diminished coordination in the fatigued state led to a poor impact position of the foot on the ball and a lower velocity of the ball. Lyons, Yahya, & Nevill, (2006) further strengthen the argument showing short passing ability diminished following 1 minute of alternating split squats. Research suggests better conditioned teams are more capable of meeting the physical demands of soccer and more likely to be successful in a soccer match than less conditioned teams.

**Physical Demands of Soccer**

The physical demands of soccer are characterized by variability and unpredictable intermittent work (Nicholas, Nuttall, & Williams, 2000). Due to the nature and length of a soccer match, soccer relies heavily on the aerobic energy system but is played near the anaerobic threshold (Stolen et al., 2005). Although research suggests the aerobic energy system is responsible for the majority of energy during a match (Stolen et al., 2005; Krstrup, Mohr, Ellingsgaard, & Bangsbo, 2005; Bangsbo, 1994; Chamari et al., 2005), the anaerobic system is probably more critical to the outcome of the game (Wragg, Maxwell, Doust, 2000). Energy from anaerobic metabolism is used during times of short
sprints, jumps, tackles, and jousts. These are the critical moments in the game, when sprinting faster, jumping higher, or tackling harder can be the difference between winning and losing.

Match analysis of a competitive Danish team reported elite female soccer players changed movement activities approximately 1,460 times in a 90 minute match, approximately every 4 seconds. On average 26 sprints and 125 high intensity runs were made with an average duration of 2.3 seconds. The players covered an average distance of 10.3km. The match breakdown consisted of players walking 44% of the time, running at low intensity for 34% of the time, standing 16% of the time, and sprinting 5% of the time (Krustrup, 2005).

Physical activity patterns in a soccer match is supported by match analysis of Australian International women soccer players by Hewitt, Engen, Wisloff, & Hoff, (2001). Despite analogous activity pattern data, Hewitt et al., (2001) found the total distance covered was reported to be 9.1km on average, 1.2km less than Krustrup (2005) (Hewitt, 2001). Scott & Durst (2007) also came to a similar conclusion to the breakdown of physical activity patterns during match analysis of 30 international elite women soccer players. He found the players covered approximately 12km (Scott, 2007). All three researchers came to a similar conclusion to the time spent performing physical activity, but varied on distance covered.

The discrepancy in distance covered may be contributed to differences in level of competition, playing schemes, and positions of the players analyzed. Research by Andresen, Krustrup, Mohr, (2007) supports this idea, finding international players cover more distance than national league players. Performing match analysis on the same 11
players during their International matches and their National League matches, Andresen (2007) determined the same players, playing the same positions, covered an average of one third of a kilometer more during their International Matches. The results also indicate that when players played on their International teams they performed more high-intensity running than with their National League teams (Andresen, 2007). This is important because high-intensity running has been shown to occur during the critical moments in games that highly impact winning and losing (Wrag, 2000). The distance covered in a match is also important because it has been shown to be a determinate of physical match performance (Krustrup, 2005).

**Energy Needs**

To meet the demands of soccer, energy must be produced using both aerobic and anaerobic metabolism. The length of the match will require ATP production from the oxidative system. The phosphagen system will provide ATP for short sprints, tackles and jousts. Fast glycolysis will provide energy for repeated sprints and high intensity running. The intermittent nature of the sport combined with the length of a match will require energy contributions from a combination of oxidative, glycolytic and phosphagen systems.

**Aerobic Metabolism**

Aerobic ATP production occurs in the mitochondria and involves two metabolic pathways, the Krebs cycle and the electron transport chain. The two metabolic pathways cooperate to produce ATP. The Krebs cycle’s function is to oxidize carbohydrates, fats, and proteins. In order for the Krebs cycle to be activated, acetyl CoA must be formed. Acetyl CoA can be formed from the breakdown of carbohydrates, fats, or proteins. When
acetyl CoA enters the Krebs cycle it combines with oxaloacetate to form citrate and then encounters a series of reactions which induces the complete oxidation of acetyl CoA into hydrogen and carbon dioxide. The released hydrogen combines with coenzymes NAD and FAD, which serve as electron transporters (Powers & Howley, 2009). Every turn of the Krebs cycle produces 3 molecules of NADH and 1 molecule of FADH to enter the electron transport chain.

The reduced electron carries NADH and FADH transfer their electrons to the first and second cytochrome respectively. As the electrons travel down the cytochrome chain H⁺ is pumped from inside of the mitochondria across the inner mitochondrial membrane resulting in an accumulation of H⁺ between the inner and outer mitochondrial membranes. The H⁺ diffuses back into the inner compartment through special channels. This movement of H⁺ activates ATP synthase which catalyzes the reaction to phosphorylate ADP to form ATP (Powers & Howley, 2009).

**Anaerobic Metabolism**

**Phosphagen System**

The ATP-PCr System, also known as the phosphagen system, is the simplest and most rapid method of producing ATP (Powers & Howley, 2009). ATP production by the phosphagen system can occur in the presence of oxygen, but it is not required. Therefore, the phosphagen system is considered anaerobic (Wilmore & Costill, 2004). ATP is produced by coupling Pᵢ with ADP. This reaction is catalyzed by the enzyme creatine kinase. Creatine kinase acts on phosphocreatine (PC) to separate Pᵢ from creatine. The energy released is then used to couple Pᵢ with ADP producing ATP. This process is a
rapid, one-enzyme reaction, and doesn’t rely on any special structures within the cell (Wilmore, 2004).

The phosphagen system provides energy for high intensity exercise bouts lasting less than 5 seconds. The production of energy for extended periods of time is likely limited by the depletion of PC. Muscles store small amounts of PC, thus the total number of ATP that can be formed is limited. During times of recovery from exercise, PC is reformed but requires ATP (Powers & Howley, 2009).

**Glycolytic System**

The glycolytic system produces ATP anaerobically through the breakdown of glucose or glycogen via glycolysis. Glycolysis occurs in the sarcoplasm of the muscle cell and requires 12 enzymatic reactions to complete the breakdown of glucose to lactic acid producing a net gain of 2 ATP (Wilmore & Costill, 2004). Glycolysis consists of 2 phases, each phase comprising of 5 reactions. The first 5 reactions are considered “the energy investment phase,” where 2 ATP must be used to form sugar phosphates, 1 ATP if glycolysis begins with glycogen. The second phase is considered “the energy generation phase,” where 4 ATP are produced for a net gain of 2 ATP, 3 if glycolysis begins with glycogen (Powers & Howley, 2009).

Glycolysis and the ATP-PC system produce the majority of energy at the onset of high-intensity exercise (Wilmore & Costill, 2004). In general, the first 60s of high-intensity exercise relies on anaerobic metabolism for approximately 70% of energy needs. However, glycolysis does not produce large amounts of ATP, but with the combined action of the ATP-PC system, the muscles can generate force even without the presence of oxygen.
Ultimately, glycolysis produces pyruvic acid which is converted to lactic acid in the absence of oxygen. Lactic acid accumulation in the muscle can increase from 1 mmol.kg to 25 mmol/kg in an all-out sprint (Wilmore & Costill, 2004). This acidification of the muscle fibers impairs glycolytic enzyme function, thus impeding glycolysis. Another result of the acidification of the muscle fibers is the decrease in the fibers’ calcium binding capacity, which hinders muscle contraction (Wilmore & Costill, 2004).

**Lactate Threshold**

Lactate Threshold is characterized by a dramatic increase in blood lactic acid levels during exercise (Powers & Howley, 2009) and is typically represented as a percentage of VO$_2$max. It has been suggested that the anaerobic threshold, also known as the lactate threshold, is the point of increasing reliance on anaerobic metabolism (Powers & Howley, 2009). The rate of lactate removal appears dependent on lactate concentration, type of recovery, and aerobic capacity (Stolen et al., 2005), although aerobic capacity is highly debated.

Stolen argues lactate removal will be greater in aerobically trained individuals because of improved aerobic response and enhanced phosphocreatine regeneration (Stolen et al., 2005). Stolen’s argument is supported by research suggesting endurance training improves lactate clearance capacity and increases lactate threshold (Evertsen, Medbo, & Bonen, 2001). In contrast to this view, other researchers have reported that endurance training had no impact on lactate clearance capacity (Mayes, Hardman, Williams 1987; Slawinski, Demarle, Koralsztein, Billat, 2001.)
Energy System Contribution to Match Performance

There is controversy in the literature concerning the importance of each energy system for physical performance during a soccer match. Most research however suggests that soccer is highly dependent on aerobic metabolism to meet the energy cost of a match (Stolen et al., 2005; Krstrup et al., 2005; Bangsbo, 1994; Chamari et al., 2005). Bangsbo (1994) estimates that aerobic metabolism contributes 90% of the energy production during a soccer match. In direct contrast, Fox & Mathews (1974) suggests the percentage of ATP contribution from aerobic metabolism during a match is less than 20%. Despite an unclear view of the energy demands of soccer, research is heavily geared toward aerobic interval training to improve performance, giving less regard to anaerobic training methods.

Helgeruld et al. (2001) showed that an improvement in VO$_2$max by 10.8% increased distance covered in a match by an average of 1716m, increased the number of involvements with the ball by 24%, and increased the number of sprints performed per player by 100%. Helgeruld et al. also suggests that endurance training for soccer, more than a training regimen aimed to improve LT only, should emphasize improving VO$_2$max, and in turn, improve LT. The importance of aerobic fitness for soccer players has been widely studied and confirmed through descriptive, cross-sectional, and training studies (Castagna, Impellizzeri, Chamari, Carlomagno, & Rampinin, 2006).

A less studied area is that of anaerobic endurance training for soccer players. Benefits of anaerobic endurance training for improving match performance in soccer players has not been well documented. Despite the lack of research committed to this area, there is research that indicates an anaerobic interval training program can
significantly increase VO₂max and anaerobic endurance, as well as increase enzymatic activities associated with glycolysis such as phosphofructokinase, lactate dehydrogenase, and glycogen phosphorylase (Parra, Cadefau, Rodas, Amigo, & Cusso, 2000; Bompa & Haff, 2009). Research by MacDougall et al. (1998) supports these findings showing an increase in glycolytic and oxidative muscle enzyme activity, maximum short term power output, and VO₂max after 7 weeks of sprint interval training.

Recovery

The ability to recovery from short bouts of high intensity exercise is critical for success in sports such as soccer. It has proven very difficult to provide an accurate assessment of each energy system’s contribution due the intermittent nature of the sport however. Notably, there is much debate over the relationship between aerobic capacity and recovery from anaerobic bouts of exercise.

The argument that aerobic capacity is an important determinant in recovery from high-intensity intermittent exercise (HIIE) is primarily based on the idea that when individuals work at the same percentage of VO₂max, trained individuals will consume more oxygen than untrained individuals because of their higher VO₂max. It is argued that increased reliance on oxidative pathways during HIIE spares the reliance on glycolytic pathways and an increased oxidative capacity at the start of the recovery period results in a greater potential for fast EPOC (Tomlin & Wenger, 2001). Tomlin & Wenger (2001) demonstrated that female soccer players with high aerobic power (HAP) attained similar peak power to female soccer players with low aerobic power (LAP), but the HAP group consumed more oxygen and showed a smaller percentage decrement over 10 sprints. The results indicate that the increased aerobic capacity may result in less
reliance on anaerobic glycolysis (Tomlin & Wenger, 2001). Additionally, Balsom, Gaitanos, Ekblom, & Sjodin, (1994) demonstrated that by decreasing oxygen availability during high intensity intermittent exercise using a hypobraric chamber, individuals consumed less oxygen, accumulated more lactate and showed larger power decrements than they experienced under normal conditions. This study showed that an increase in oxygen availability increased the reliance on aerobic pathways and in turn spared anaerobic glycolysis.

In direct contrast, Cooke, Petersen, & Quinney (1997) states aerobic capacity alone is a poor predictor for recovery from high-intensity exercise. Further, Cooke’s research concluded that individuals with the same VO$_2$max showed vastly different recovery rates, and individuals with a dramatically different VO$_2$max showed similar recovery rates (Cooke et al., 1997). Supporting research from Bell, Snydmiller, Davies, & Quinney (1997) asserts metabolic recovery from HIIE is not related to various measurements of aerobic fitness. Bell et al. (1997) points out that there does appear to be a difference in recovery between trained and untrained groups, but there does not appear to be a relationship between aerobic fitness and recovery from HIIE between trained athletes.

There has been much debate over the relative importance of each energy system for physical performance during a soccer match. Anecdotal evidence suggests that many players, coaches and strength and conditioning experts employ aerobic fitness tests to predict match performance, although the relationship between aerobic capacity and anaerobic recovery has yet to be clearly defined. Often soccer players are encouraged to train aerobically to enhance metabolic recovery, with the success being determined by a
change in VO$_2$-max despite clear evidence of the benefit (Cooke et al. 1997). Thus, the purpose of this study is to examine the relationship between HIIE and aerobic capacity, anaerobic endurance and anaerobic power. The research hypothesis is that anaerobic endurance will have a high correlation to the HIIE as measured by the YYIRT1. The second hypothesis is that aerobic capacity and anaerobic power will both be moderately correlated with HIIE.
Participants

Thirty-one soccer players were recruited from College of the Canyons, a community college in southern California. Participants were recruited from the men’s and women’s soccer programs. Nineteen female and twelve male soccer players participated in the study. The participants were selected for their familiarity with the testing protocol and ability to perform the physical demanding work.

Male players selected represent an average performance level for California Community College Athletic Association (CCCAA) men’s soccer. The Men’s team failed to make playoffs and finished the season ranked 34 of 67 teams. The female players selected represent a high performance level for CCCAA women’s soccer. The Women’s team qualified for playoffs and finished ranked 11 of 83 teams. Male participants had recently finished their intercollegiate season the week before testing and were practicing two times per week and performing resistance training two times per week. Female participants had recently finished their regular season and were training five times per week as they prepared for play-offs.

Sample Characteristics

Thirty one community college soccer players participated in this study, 12 male and 19 female. The 12 male participants were 19 ± 1 years old, 177.6 ± 6.0 cm tall, and weighed 73.6 ± 6.0 kg. The 19 female participants were 18 ± 1 years old, 161.9 ± 5.1 cm tall, and weighed 59.3 ± 7.3 kg.
Participant Screening

Prior to the beginning of the study, verbal and written explanation of the experimental design and potential risks of the study were expressed. All participants signed an Experimental Subjects Bill of Rights and consent form indicating they understood the purpose of the study, testing procedures and risks of the study and were willing to participate. The study was reviewed and approved by the California State University, Northridge Standing Advisory Committee for the protection of Human Subjects (SACPHS) prior to data collection. Participants were informed that participation was voluntary and participation would not impact playing time, or any other role on the team. Participants were required to complete a Physical Activity Readiness Questionnaire (PAR-Q; see appendix) form to determine if they were healthy enough for physical activity. To be considered for the study, participants must have answered “no” to all questions on the PAR-Q form. No potential participants answered “yes” to any of the questions on the PAR-Q form, therefore none were excluded.

Materials

The YYIRT1 was performed on an artificial turf field using an audio player, YYIRT1 soundtrack and cones. The 1.5 mile run (2,414 meters) was performed on a 400m tack and was timed with a stop watch. The 300 yard shuttle run (274.3 meters) was performed on an artificial turf field. The distance was marked using cones and time was recorded using stop watches. The 40 yard sprint (36.6 meters) was marked using cones and timing was done using the Brower Timing Systems, Speed Trap 2 (Draper, Utah) digital timing system.
Procedure

The study examined the relationship between the YYIRT and three common field tests for aerobic capacity, anaerobic endurance, and anaerobic power. All participants performed a sport specific group warm-up which included 4x40 meters jogging followed by dynamic stretching movements. Testing was performed over the course of two days and consisted of the Yo-Yo Intermittent Recovery Test (YYIRT1), 1.5 mile run (2,414 meters), 300 yard shuttle run test (274.3 meters), and 40 yard sprint (36.6 meters). Testing was done in the order recommended by the National Strength and Conditioning Association (NSCA). Day 1 consisted of the 40 yard sprint test (36.6 meters), and YYIRT. Day 2 consisted of the 1.5 mile run (2,414 meters) followed by the 300 yard shuttle run test (274.3 meters) (Baechle & Earle, 2008). Elapsed time between the 1.5 mile run (2,414 meters) and 300 yard shuttle run (274.3 meters) was 20 minutes to allow for recovery. Following completion of testing a five minute cool down was performed consisting of slow jogging, walking and stretching.

Yo-Yo Intermittent Recovery Test

The YYIRTL1 was used to assess performance of high intensity intermittent exercise. The YYIRT1 tests an athlete's ability to repeatedly perform intense intermittent exercise over time (Sayers, & Binkley, 2008). The test was conducted on an artificial turf football field. It can be considered an aerobic-anaerobic, soccer specific field test (Castagna, et al., 2006). The test is performed to a standardized sound track and consisted of 2x20m running at a progressively increasing speed. The amount of time to complete each stage progressively decreased, therefore participants were required to increase their speed each level in order to complete each progressing stage. There was a 10s active recovery rest interval between repetitions. The test was over when the
participant has twice failed to complete a stage in the allotted time. The YYIRT1 has been shown to be significantly correlated with high-intensity running during a soccer match (Krustrup et al., 2003). Performance measurements were recorded in total distance ran before participant failed to complete two stages. Distances calculations are performed by the YYIRT1 iPhone app.

**1.5-Mile Run (2,414 meters)**

The 1.5 mile run (2,414 meters) is a field test used to estimate aerobic capacity. It has been shown to have a strong correlation with VO$_2$max (ACSM, 2010). The test requires the participant to complete 1.5 miles (2,414 meters) in the shortest amount of time possible. The participants were informed of the purpose of the test, and the importance of finding the best pace to cover the distance in the shortest time possible. All subjects were previously exposed to and familiar with the 1.5 mile test (2,414 meters). The test was conducted on a track and a stop watch was used to record time.

**300 Yard Shuttle (274.3 meters)**

The 300 yard shuttle run (274.3 meters) test was used to evaluate the subjects' anaerobic endurance. It is considered “An excellent test of anaerobic lactic endurance capacity” (Jones, 1991). The testing was conducted on an artificial turf football field. The test requires subjects to run maximally 25 yards (22.8 meters), turn and sprint back to the start line continuously for a total of 6 times, which equals 300 yards (274.3 meters). Subjects were informed of the purpose of the test, and the importance of finishing in the shortest amount of time possible. After completion of the first 300 yards (274.3 meters), the time was recorded and a 5 minute clock was started for the rest interval. After 5 minutes rest the subjects were required to complete the test again. After
completion of the second trial the time was again recorded. The times of the two trials
were averaged to give the subject's score (Gillam, 1983).

40 Yard Sprint (36.6 meters)

The 40-yard sprint test (36.6 meters) was conducted using a digital timing system
to eliminate human error. The testing was conducted on an artificial turf football field. A
gate made of two cones was placed at the start and at 40 yards (36.6 meters) from the
start. The subjects placed their trail foot on a trigger pad to engage the timing system.
When the subject’s foot disengaged the trigger pad the time began. The time to reach 40
yards (36.6 meters) was recorded to the nearest 10th of a second.

Statistical Analysis

Pearson’s product moment coefficient of correlation was used to determine a
relationship between the performance measures of the YYIRT1, 1.5 mile run (2,414
meters), 300 yard shuttle (274.3 meters), and 40 yard sprint (36.6 meters). Correlation
was considered low for r values of .5-.7, moderate for .7-.89, and high for r value greater
than .9. A stepwise backward multiple-regression was used to determine the relationship
between the YYIRT1 and a combination of the 300 yard shuttle (274.3 meters), 40 yard
sprint (36.6 meters) and 1.5 mile run (2,414 meters) within sexes.
CHAPTER 4: RESULTS

Performance Outcomes

The detailed performance outcomes for male and female subjects in this study are shown in Table 4.1. Male participants performed significantly better than female participants. Pearson’s product moment correlation coefficient of the 4 different testing protocols for all subjects showed significant correlations between all measures and is found in Table 4.2. However, this may be misleading as significant results were not produced among any measures when we accounting for sex.

Table 4.1: Performance Outcomes Soccer Athletes by Sex

<table>
<thead>
<tr>
<th>Sex</th>
<th>1.5 mile run (sec)</th>
<th>YYIRT1 (m)</th>
<th>300 yard shuttle (sec)</th>
<th>40 yard sprint (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>640.67 ± 27.28</td>
<td>1663 ± 386</td>
<td>63.72 ± 2.17</td>
<td>5.23 ± 0.17</td>
</tr>
<tr>
<td>Female</td>
<td>681.00 ± 63.50</td>
<td>962 ± 284</td>
<td>68.89 ± 2.53</td>
<td>5.96 ± .20</td>
</tr>
</tbody>
</table>

Table 4.2: Pearson’s Correlation Coefficients among Measures for All Subjects

<table>
<thead>
<tr>
<th>YYIRT</th>
<th>Run 1.5 miles</th>
<th>300 yard shuttle</th>
<th>Run 40 yards</th>
</tr>
</thead>
<tbody>
<tr>
<td>YYIRT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run 1.5 miles</td>
<td>-.532*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run 300 yards</td>
<td>-.831*</td>
<td>.709*</td>
<td></td>
</tr>
<tr>
<td>Run 40 yards</td>
<td>-.720*</td>
<td>.470*</td>
<td>.789*</td>
</tr>
</tbody>
</table>

*significant at (p < .05)
Correlation

Table 4.3 shows Pearson’s product moment coefficient of correlation of the YYIRT1 for male and female subjects separately. Female subjects produced significant correlations between the YYIRT1 and the 1.5 mile run and the 300 yard shuttle run. No significant relationship was found between the YYIRT1 and the 40 yard sprint. For male subjects, no significant correlation was found between the YYIRT1 and the 1.5 mile run, the 300 yard shuttle run, or the 40 yard sprint.

<table>
<thead>
<tr>
<th></th>
<th>Run 1.5 miles</th>
<th>300 yard shuttle</th>
<th>Run 40 yards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>.153</td>
<td>-.546</td>
<td>-.032</td>
</tr>
<tr>
<td>Female</td>
<td>-.706*</td>
<td>-.724*</td>
<td>-.366</td>
</tr>
</tbody>
</table>

*significant at (p < .05)

The results of the step-wise, backward multiple-regression within sexes is found in Table 4.4. For male subjects, no significant results were found. For female subjects, the R value for inclusion of all three predictors was .747. With the exclusion of the 40 yard sprint, a decrement of .001 was seen. Further exclusion of the 1.5 mile run reduced the coefficient of determination by 3%. The results suggest that the 300 yard shuttle run accounts for the majority of the variance among the 3 performance tests.
Table 4.4  Multiple Regression by Gender for the YYIRT1

<table>
<thead>
<tr>
<th>Predictors</th>
<th>YYIRT1 Male</th>
<th></th>
<th>YYIRT1 Female</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R²</td>
<td>Sig</td>
<td>R²</td>
<td>Sig</td>
</tr>
<tr>
<td>1.5 mile run, 300 yard shuttle, 40 yard sprint</td>
<td>.381</td>
<td>.256</td>
<td>.558*</td>
<td>.006</td>
</tr>
<tr>
<td>1.5 mile run 300 yard shuttle</td>
<td>.379</td>
<td>.117</td>
<td>.556*</td>
<td>.002</td>
</tr>
<tr>
<td>300 yard shuttle</td>
<td>.546</td>
<td>.066</td>
<td>.524*</td>
<td>.000</td>
</tr>
</tbody>
</table>

*significant at (p < .05)
CHAPTER 5: DISCUSSION

The primary purpose of this study was to examine the relationship among high intensity intermittent exercise (HIIE) and anaerobic power, anaerobic endurance, and aerobic capacity. This was accomplished by examining the relationship among three common performance-based tests and performance in the YYIRT1 (HIIE). In this study we used the 40 yard sprint (anaerobic power), 300 yard shuttle (anaerobic endurance) and the 1.5 mile run (aerobic capacity) because of their popularity among coaches and trainers, and the subjects’ familiarity with these tests. The secondary purpose of this study was to examine the same relationship between sexes.

The YYIRT performance for male subjects in this study (1663 ± 386m) was lower than observed performance of amateur soccer players (1827 ± 292m) (Rampinini, 2010) and sub-elite male soccer players (1846 ± 91m) (Bravo et al., 2006). The YYIRT1 performance for female subjects in this study (962 ± 284m) was lower than observed performance of U20 elite female soccer players (1278 ± 80m), but similar to moderately trained women team sport athletes (958 ± 368m) (Sirotic & Coutts, 2007). It is important to point out that testing was performed at or near the end of the season for both male and female subjects. It has been shown that during and the end of the season YYIRT1 performance on average decreases (Bangsbo et al., 2008).

The 300 yard shuttle run performance for male subjects in this study (63.72 ± 2.17s) was slower than values reported for 18 elite male soccer players before and after an 8 week intervention (56.99 ± 1.64s and 55.74 ± 1.63s, respectively) (Sporis, Ruzic, & Leko, 2008). Results were also slower than those reported in trained teenage basketball cadets (57.00 ± 3.09s) (Trinic, Markovic, & Heimer, 2001). Female subjects’ values
(68.89 ± 2.53s) in this study were slower than male subjects. Values were also slightly slower than previously reported values of NCAA Division I basketball players (65.05 ± 13.77s) (Schaal, 2011).

The 40 yard sprint performance for male subjects in this study (5.23 ± .17s) was slower than reported values for two test groups of NCAA Division III football players before and after intervention (4.95 ± .17s and 4.89 ± .18s, respectively) (Hoffman, Cooper, Wendell, & Kang, 2004). Results were also slower than reported values for experienced NCAA Division I soccer players before and after intervention respectively (5.06 ± .24s) (4.87 ± .16s) (Cressey, West, Tiberio, Kraemer, & Maresh, 2007). Female subjects’ 40 yard sprint time in this study (5.96 ± .20s) was slightly slower than reported values of DI female soccer players (5.8 ± .40s) (Nesser & Lee, 2009).

The 1.5 mile run performance for male subjects in this study (641 ± 27s) was slower than that reported in male military recruits of approximately the same age (598 ± 30s) pre-intervention and (564 ± 24s) post intervention (Clarkson et al., 1999). Recruited university students also performed better (594 ± 66s) (George, Vehrs, Allsen, Fellingham, & Fisher, 1993) than the current study’s male participants. Mean time for male subjects is equivalent to the 70-75th percentile value for ACSM’s maximal aerobic power based on performance times in the 1.5 mile run (Kaminsky, 2010). Performance for female subjects in this study (681 ± 63s) was slower than male subjects and that reported of female British cadets after a 40 week commissioning course (639 ± 41s) (Rayson, Harwood, & Nevill, 1999). However results were faster than values reported for that of recruited university students (750 ± 78s) (George et al., 1993). Mean time for female subjects is equivalent to the 85-90th percentile value for ACSM’s maximal aerobic power based off performance time in the 1.5 mile run (Kaminsky, 2010).
The hypotheses in the present study was that anaerobic endurance would be highly correlated with the amount of HIIE performed in the YYIRT1, and the 40 yard sprint test and the 1.5 mile run would both be moderately correlated. A moderate correlation was found between the HIIE and anaerobic endurance when including data from both sexes (r=-.831, p<.05). The data did not support the hypothesis of a high correlation, but results did produce a common variance of 69% compared to 52% and 28% for the anaerobic power and aerobic capacity, respectively. A moderate correlation was found between HIIE and anaerobic power (R=-.720, P<.05). The data supports the hypothesis of a moderate correlation between measures. To the best of this researcher’s knowledge, no data exist comparing anaerobic power and anaerobic endurance to HIIE. A low correlation was found between HIIE and aerobic capacity (r=-.532, p<.05). The data does not support the hypothesis of a moderate correlation. The common variance between HIIE and aerobic capacity (28%) is similar to that found by (Castagna et al., 2006) of 21%, but much lower than previous findings of 59% (Castagna et al., 2008).

In the present study we found that sex was a significant predictor of performance, so the relationship between performance tests within sexes was examined. Correlation analysis for male subjects determined that there was no significant correlation between any tests. Findings that HIIE was not significantly related to aerobic capacity is supported by findings from (Castagna et al.,2006), but contrasts with that reported by (Krustrup et al., 2003) who found a correlation coefficient of (r=0.71, p<.05) between the YYIRT1 and VO2max.

For female subjects only, we found a moderate correlation between the HIIE and anaerobic endurance (r= -.724, p<.05) with a common variance of 52%. A moderate correlation was also found between the HIIE and aerobic capacity (r=-.706, p<.05).
Previous research reports that the YYIRT1 and VO$_2$max share a common variance of 59% (Castagna et al., 2008). Similarly, it was shown that The YYIRT1 is moderately correlated with VO$_2$max ($r=0.71$). However this data was collected from male subjects (Impellizzeri, Rampinini, Marcora, 2005). No significant correlation was found between the YYIRT and the 40 yard sprint for female subjects.

A step-wise, backward multiple-regression was used to determine the relationship between the YYIRT1 and a combination of the 300 yard shuttle, 40 yard sprint and 1.5 mile run within gender groups. For male subjects we did not produce any significant predictive ability. For female subjects the coefficient of correlation for inclusion of all three predictors was ($r=0.747$, $p<.05$). With the exclusion of the 40 yard sprint the correlation only decreased by .001 ($r=0.746$, $p<.05$). Further exclusion of the 1.5 mile run left us with only the 300 yard shuttle and a correlation of ($r=0.724$, $p<.05$). Based on analysis of the backward multiple regression it appears that aerobic capacity and anaerobic power may not be as strong of an indicator as anaerobic endurance for performance in HIIE in moderately trained female athletes. This conclusion is not supported by previous finding by Bansbo et al., 2008 who states that the YYIRT1 stimulates the aerobic system maximally and focuses on the ability to repeatedly perform aerobic high intensity work, suggesting anaerobic contribution is limited (Bangsbo et al., 2008; Rampinini et al. 2010). However, it has been suggested that anaerobic contribution during the YYIRT1 was greater in amateur soccer players compared to professional soccer players (Rampinini et al.,2010).

Findings in this study were produced under circumstances that have limitations. One of the limitations of this study was the use of field tests to measure aerobic capacity, anaerobic endurance, and anaerobic power. Although these field tests were selected
because of their familiarity to soccer players and coaches, they can only estimate physiological aspects of performance. Some factors that may contribute to performance of these tests include running economy, motivation, competitiveness, nutritional intake and timing, temperature, testing surface, and the assumption that the participant is performing at 100% of their ability.

Another limiting factor of this study was that the subjects only performed each test one time. Although they had performed these tests throughout the year and were familiar with them, we only performed final testing measurements one time per test. Having only one set of data for each test, we were not able to measure the reliability of the tests within this particular sample population.

In conclusion, the results suggest that anaerobic endurance and aerobic capacity are both significantly correlated with performance in the YYIRT1 for female athletes. However, anaerobic endurance appeared to be slightly more related to the demands of HIIE than aerobic capacity. Although a significant relationship was found, neither aerobic capacity nor anaerobic endurance was shown to be strong predictors for performance of HIIE. Similarly, through step-wise backward multiple regression the results indicate that performance of HIIE cannot be predicted from a combination of aerobic and anaerobic capacities. Consequently, for practical applications, it may be more efficient for coaches to train and test soccer players using interval training and HIIE, and limit continuous conditioning exercises. This type of training can improve anaerobic and aerobic performances while being specific to the activity patterns of the sport.
REFERENCES


APPENDIX

Physical Activity Readiness Questionnaire (PAR-Q)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their physician before they start becoming more physically active. Please complete this form as accurately and completely as possible.

<table>
<thead>
<tr>
<th>PAR-Q FORM</th>
<th>Please mark YES or NO to the following:</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>NO</td>
</tr>
</tbody>
</table>

| Has your doctor ever said that you have a heart condition and recommended only medically supervised physical activity? | ☐ ☐ |
| Do you frequently have pains in your chest when you perform physical activity? | ☐ ☐ |
| Have you had chest pain when you were not doing physical activity? | ☐ ☐ |
| Have you had a stroke? | ☐ ☐ |
| Do you lose your balance due to dizziness or do you ever lose consciousness? | ☐ ☐ |
| Do you have a bone, joint or any other health problem that causes you pain or limitations that must be addressed when developing an exercise program (i.e. diabetes, osteoporosis, high blood pressure, high cholesterol, arthritis, anorexia, bulimia, anemia, epilepsy, respiratory ailments, back problems, etc.)? | ☐ ☐ |
| Are you pregnant now or have given birth within the last 6 months? | ☐ ☐ |
| Do you have asthma or exercise induced asthma? | ☐ ☐ |
| Do you have low blood sugar levels (hypoglycemia)? | ☐ ☐ |
| Do you have diabetes? | ☐ ☐ |
| Have you had a recent surgery? | ☐ ☐ |

If you have marked YES to any of the above, please elaborate below:

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

Do you take any medications, either prescription or non-prescription, on a regular basis? Yes/No
What is the medication for?
How does this medication affect your ability to exercise or achieve your fitness goals?

______________________________________________________________________________
______________________________________________________________________________

Please note: If your health changes such that you could then answer YES to any of the above questions, tell your trainer/coach. Ask whether you should change your physical activity plan.
I have read, understood, and completed the questionnaire. Any questions I had were answered to my full satisfaction.

Print Name: _________________________________Signature: _________________________________ Date: __________