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The Relationship Between Yo-Yo Intermittent Recovery Testing Ability and 20-meter Sprint Times in NCAA Division I Men's and Women's Collegiate Soccer Players

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by

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ABSTRACT

The Relationship Between Yo-Yo Intermittent Recovery Testing Ability and 20-meter Sprint Times in NCAA Division I Men's and Women's Collegiate Soccer Players

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The purpose of this study was to determine the relationship between Yo-Yo intermittent recovery testing ability and 20-meter sprint times in NCAA Division I men's and women's collegiate soccer players. Results show no significant ($p = >0.05$) relationship between the distance covered in the Yo-Yo IR1 test and 20-meter sprint times in the female players and a significant correlation between the two tests in the male players ($r = -0.33$). A non-significant relationship between the tests in female players may be due to greater variation in the total distance covered during the Yo-Yo IR1 test and small variation in 20-meter sprint times. The inclusion of speed and resistance training may be beneficial in developing the anaerobic speed reserve in female collegiate soccer players, leading to improvement in the Yo-Yo IR1 test performance. Improving the sprinting capabilities of male collegiate soccer players may also improve Yo-Yo IR1 test performance.

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Chapter 1. Introduction

Collegiate soccer at the Division I level is physiologically demanding in terms of the total distance covered and the amount of high intensity running, and sprints performed during a game for both male and female competitors. Male collegiate soccer players cover approximately 8,900 – 9,900 meters per match and perform 1,300 – 1,900 meters of high intensity running and 200 – 400 meters of sprinting (Curtis et al., 2018). Likewise, female players cover distances of approximately 9,000 meters per match, with 300 - 1,000 meters of that being high-speed running and 200 – 600 meters of sprinting (Alexander, 2014; Sausaman, 2019).

Collegiate soccer coaches are continuously monitoring and assessing their players physical readiness throughout the season through various testing procedures. Field-based test are also commonly used by soccer coaches as a means of establishing match performance benchmarks for playing standards and positional roles, assessing the effectiveness of training programs and for constructing collective and individual training prescriptions (Deprez et al., 2014; Haugen & Seiler, 2015; Krustrup et al., 2003). Over the last decade, maximum oxygen uptake tests (VO_2 max), the Leger shuttle-run test and the 12-minute running test were regularly used to assess the aerobic capacities of soccer players (Bangsbo et al., 2008). The maximal oxygen uptake test is regarded as gold standard when it comes to measuring aerobic fitness (Castagna et al., 2006). However, this type of test is typically performed on a treadmill in a laboratory setting, therefore failing to represent practical and realistic sporting environments. The test is also time consuming, requires trained personnel and expensive equipment, and is neither appealing to athletes (Castagna et al., 2006; Castagna et al., 2010; Gumusdag et al., 2013; Mirkov et al., 2008).

More recently, the Yo-Yo intermittent recovery test level 1 (Yo-Yo IR1) has been recognized as a more soccer-specific test due to its intermittent nature and practicality. Numerous studies have observed relationships between Yo-Yo IR1 test performance and match performance variables. Krustrup et al. (2003) observed a significant correlation between the Yo-Yo test performance and the amount of high intensity running (>15 km·h-1) during a soccer match in thirty-seven professional male soccer players ($r = 0.71$, $p < 0.05$). Performances in the Yo-Yo IR1 test was also correlated to the total amount of high-speed running, sprinting and total distance during a game ($r = 0.58$ and $r = 0.53$ [$p < 0.05$] respectively). Similarly, Krustrup and Bangsbo (2001) demonstrated a strong correlation between Yo-Yo IR1 test performance and the amount of high intensity running during a game in twenty-seven top class referees ($r = 0.75$, $p < 0.001$). A significant correlation ($r = 0.81$) between Yo-Yo IR test performance and high intensity running in elite female soccer players during the final playing moments of each half of a match has also been observed (Krustrup et al., 2005).

Sprinting is regarded as one of the most important actions during a soccer match, playing a fundamental role in ball possession, transitional play and goal scoring opportunities (Lockie et al., 2019). A sprint is said to occur every 60-180 seconds during a match, covering distances between 10-20 meters and lasting 2-4 seconds (Andrzejewski et al., 2013; Haugen & Seiler, 2015; Keir et al., 2013; TaŞkin, 2008). Notable sprint distances during competitive matches have been established in numerous studies, with average distances between 200 and 1,200 meters (Andrzejewski et al., 2013). These values constitute to ~1-12% of the total distances covered per game (Andrzejewski et al., 2013; TaŞkin, 2008). Due to the importance and relevance of sprinting actions in soccer, measuring maximal linear speed outputs over certain distances is

routine practice for some soccer coaches as a means of evaluating the sprinting capabilities of their players (Buchheit et al., 2012)

Maximal linear sprint output tests and the Yo-Yo IR1 are a popular testing battery among soccer coaches and have shown to be valid and reliable means of evaluating repeated high intensity running ability and maximal speed outputs in soccer players (Altmann et al., 2019; Bangsbo et al., 2008). The Yo-Yo IR1 test requires participants to gradually increase their speed in accordance with the increasing speed levels of the test. Therefore, it may be appropriate to hypothesize that linear speed may contribute to Yo-Yo IR1 performance. Few studies have properly investigated the relationship between Yo-Yo IR1 test performance and maximal linear outputs amongst soccer players, therefore more research is warranted in this area.

Statements of Purpose

The primary purpose of the current study is to examine the relationship between Yo-Yo IR1 testing ability and 20-meter sprint times in NCAA Division I men's and women's collegiate soccer players.

Assumptions

1. All subjects attempted to sprint as fast as possible during the 20-meter sprint test.
2. All subjects attempted to reach the highest level possible during the Yo-Yo IR1.
3. The timing gates used for data collection were accurate and reliable.
4. All subjects rested prior to the testing sessions.

Limitations

1. There was no way to determine if subjects were performing to the best of their ability.

2. Any potential findings from the current study cannot be assumed for other populations.

Chapter 2. Review of the Literature

Introduction

Soccer is recognized as one of the most popular sports in the world (Haugen & Seiler, 2015). The game provides playing opportunities for female and male participants, ranging from the youth, to club, and college to professional and national level. Although much of the emphasis at the youth level is enjoyment and participation, the physicality of the game becomes of an importance as players advance through the levels of play.

The game involves technical and tactical components but relies heavily on the physiological capabilities of the players (Gumusdag et al., 2013). The game has been largely characterized as intermittent, involving periods of high intense activity (sprinting, high intensity running, changes in direction, jumping and tackling), combined with active recovery over a prolonged period of time (Alexander, 2014; Bangsbo et al., 2008; Castagna et al., 2006; Krustrup et al., 2003; Markovic & Mikulic, 2011).

Recently, there has been a growing interest within the research concerning the physical demands of collegiate men's and women's soccer (Alexander, 2014; Curtis et al., 2018; Sausaman, 2019). This research is of particular value to college coaches, as it plays an important role in the training construct of their players. Over the last decade, numerous laboratory and field tests have been developed, allowing coaches to evaluate and monitor their players physical parameters. This review of the literature will provide a brief overview of the physical demands of Division I collegiate men's and women's soccer and will examine the development of laboratory and field tests within the sport. Of particular interest will be the Yo-Yo intermittent recovery test (Level 1) and maximal linear speed output tests. Special attention will be paid to the relationship between the two field tests.

Collegiate Soccer

Collegiate soccer at the Division I level in the United States is governed by the NCAA (National Athletic Association). The game consists of 90-minutes (two, 45-minute halves) of regular playing time, with a 15-minute rest interval separating the two halves. If a winner is not determined in regular playing time, there is potential for a further two, 10-minute periods, with two-minutes of intermission. This portion of extra playing time is discontinued if a team successfully scores the winning goal. In addition, the clock is stopped for events such as injuries, card issuance and when goals are scored (until play resumes). In some instances, athletes competing in NCAA collegiate soccer can play in over 25 matches per season (~15-weeks) and play up to three games per week (Curtis et al., 2018).

Male Physical Demands

Advancements in technology have allowed for some men's and women's Division I programs to monitor and assess their athletes physical, technical, and tactical performance during training sessions and competition (Haugen & Seiler, 2015). This enables efficient qualitative analysis of positional activity profiles and match demands at the college level. Recently, Curtis et al. (2018) explored the physical demands of 18 male NCAA Division I soccer players over the course of 24 competitive season games. Global Positioning System (GPS) devices (Catapult Sports, Melbourne, Australia) sampling at 10 Hz were used in data collection. High-speed running and sprinting were categorized; >14.40 $km \cdot h^{-1}$, >21.6 $km \cdot h^{-1}$, respectively. On average, players covered a total distance of 8,900 – 9,900 m per match. Of that distance, players completed 1,300 – 1,900 m of high intensity running, approximately 15-20% of total match distance. More specifically, central midfield players covered the greatest distance (9,941 ± 2,140 m), when compared with defenders (8,985 ± 2,158 m), wide midfielders (9,593 ± 2,290 m) and

forwards (8,948 ± 2,005 m). Central midfield players also generated the highest average speeds per match (97 ± 20 m·min^{-1}), closely followed by wide midfielders (94 ± 22 m·min$^{-1)}$. Defenders and forwards produced similar high average speeds, 87 ± 20 m·min^{-1} and 87 ± 19 m·min^{-1}, respectively. However, wide midfielders demonstrated the largest sprint distances (391 ± 145 m) and high-speed running distances (1,915 ± 611 m), with respect to defenders (214 ± 113 m, 1,328 ± 369 m), central midfielders (201 ± 83 m, 1,837 ± 579 m) and forwards (329 ± 147 m, 1,721 ± 498 m).

Female Physical Demands

Sausaman (2019) conducted a similar study with 23 female NCAA Division I collegiate soccer players over four successive seasons. Data collection was obtained through Global Positioning System (GPS) devices (Catapult Sports, Melbourne, Australia) sampling at 10 Hz. Sausaman (2019) reported that players, on average, covered 9,486 ± 300 m per match, with 1,014 ± 118 m of that being high-speed running (>15 km/hr). This accounts for ~10.7% of the match total distance being played at high speeds. Furthermore, sprint distances (> 18 km/hr), regardless of playing position were shown to be 428 ± 70 m. This equates to 4.5% of match distance covered by sprints, representing 42% of high-speed running during a match. Upon closer analysis of position specific demands, attacking players were responsible for accumulating a greater total distances (~9,882 m) in comparison with midfield (~9,536 m) and defending (~9,039 m) players. Attacking players also covered larger high speed running distances (~1,333 m) than defenders (~868 m) and midfielders (~840 m). Additionally, greater sprint distances were observed in attacking players (~633 m), than those witnessed in defenders (~385 m) and midfielders (~267 m).

In a dissertation, Alexander (2014) explored the physical demands of each position within the women's college game. Although a considerably smaller sample size was used, Alexander's (2014) findings co-inside with the results of Sausaman's (2019) study. Alexander (2014) observed 6 division I female soccer players during the entirety of a competitive season (17 matches). Global Positioning System (GPS) devices (Catapult Sports, Melbourne, Australia) were used in the data collection process. Each player represented a different position within the game; central defender, fullback, central defensive midfielder, wide midfielder, central attacking midfielder and forward. The overall average distance covered by players in each position was 9,058 ± 840 m per match. The central defensive midfielder covered the greater distance during a match (947.4 ± 577.9 m), followed by the forward (695.0 ± 401.6 m), wide midfielder (9500.4 ± 847.0), fullback (9306.2 ± 367.8 m), central attacking midfielder (9236.1 ± 491.3 m) and lastly, the central defender (8041.2 ± 371.0 m). The forward player demonstrated the largest high speed running distances (>15 km/h) at 797.0 ± 102.8 m, closely followed by the full back and wide midfielder at 762.2 ± 93.6 m and 688.7 ± 170.1 m, respectively. At the latter end of the scale was the central defensive midfielder (576.8 ± 162.9 m), central attacking midfielder (423.9 ± 102.8 m), with the central defender accumulating the least amount of distance at high running speeds during a match (334.3 ± 58.9 m). Overall and independent of playing position, 80% of match total distance was performed at low intensity (< 15.0 km·h-1), with 10 ± 2% of match total distance completed at high speed. On average, central players (central defensive midfielder and central defender) completed 8% of their total distance at high running speeds per game. Whereas the full back and wide midfielder covered 12.6 – 14.5% at high speed. Furthermore, the forward player produced the greatest sprinting distances (>18 km/h) at 614.0 ± 207.9 m, closely accompanied by the fullback (559.3 ± 119.1 m) and wide midfielder (519.6 ± 160.2 m). The

central attacking midfielder and central defender covered sprinting distances of 323.7 ± 115.4 m and 279.8 ± 66.3 m, respectively. Lastly, the central defensive midfielder covered the least sprinting distance per match at 270.9 ± 97.4 m

The findings from the scientific literature mentioned in this section of the review is evident of the conclusions made by Alexander (2014). That is, the physical demands of collegiate soccer are subject to playing position, match tactics, competition level and sex. It is also important to note that the standard and demands of play can vary, even at the Division I level within the men's and women's game. Despite soccer being a male dominated sport in much of the world, there is a disproportion in the literature concerning the physical demands of the men's game at the college level. In the United States especially, there is increasing popularity in women's soccer with greater media coverage, fan support and funding. This contributes to the growing interest in athlete monitoring and subsequent research within the women's game. Nevertheless, the available literature exploring the physical demands of men's and women's Division I soccer, provides valuable insight into the physical requirements associated with this level of play.

Development of Field Tests

As more literature relating to the physical requirements of the game emerge, soccer coaches are becoming increasingly involved in monitoring and evaluating their players physical performance. Testing strategies have been developed and implemented for the purpose of assessing soccer related fitness and the effects of training programs. Match performance benchmarks for playing standards and positional roles can also be established from such tests (Deprez et al., 2014; Haugen & Seiler, 2015). Furthermore, testing guides the construction of collective and individual training prescriptions, aids in talent identification and indicates

development at the youth levels (Deprez et al., 2014; Haugen & Seiler, 2015; Krustrup et al., 2003).

There has been much debate among soccer practitioners and scientist concerning the validity, reliability and practicality between laboratory and field-based tests. For an extensive period of time, traditional tests such as the Leger shuttle-run test, the 12-minute running test and maximum oxygen uptake tests (VO_2 max) have been used to evaluate the aerobic capacity of athletes (Bangsbo et al., 2008). Some of these tests tend to be continuous and linear, therefore, failing to relate to the intermittent nature of sports such as soccer (Castagna et al., 2010; Sparks et al., 2016). The VO_2 max test is typically performed on a treadmill in a laboratory setting. The test is time consuming, requires trained personnel and expensive equipment, and is neither appealing to athletes or represents practical and realistic sporting environments (Castagna et al., 2006; Castagna et al., 2010; Gumusdag et al., 2013; Mirkov et al., 2008).

In the literature concerning physical match demands at the college level (Alexander, 2014; Curtis et al., 2018; Sausaman, 2019), it is recognized that men's and women's college soccer consists primarily of low intensity running with bouts of high-speed running and sprinting. Therefore, it is logical to incorporate these components of the game into testing procedures. Due to the intermittent nature of numerous sports and the impracticality of lab-based testing in team sports, the Yo-Yo intermittent recovery test level 1 (Yo-Yo IR1) was introduced. Sprinting ability also plays an important role in soccer performance and success. Therefore, maximal linear sprint output testing over certain distances has become of popular interest for soccer coaches. Timing gates and GPS are normally used in this type of testing. The Yo-Yo IR1 and maximal sprint output tests are commonly used in conjunction by coaches to evaluate

repeated high intensity running ability and maximal speed outputs at the collegiate, professional and international level.

Measuring Performance

Yo-Yo Intermittent Recovery Test Level 1

The series of Yo-Yo intermittent recovery tests were created and introduced by Jens Bangsbo and associates during the 1990's. The introduction of these tests came following questionable relevance, specificity, and practicality of VO_2 max testing in intermittent sports (Deprez et al., 2014; Haugen & Seiler, 2015). The Yo-Yo intermittent recovery test level 1 measures the ability to repeatedly perform high intense exercise with limited opportunity to recover (Schmitz et., 2018). The test consists of 2 x 20-meter shuttle runs, with a 10 second period of active recovery between each shuttle run (Bangsbo et al., 2008; Sánchez-García et al., 2018). The test begins with four running bouts between 10-13 $km \cdot h^{-1}$ (0–160 m), before the tests speed increases to 13.5–14 $km \cdot h^{-1}$ for the following seven running bouts (160– 440 m). For the remainder of the test, the speed gradually increases in 0.5 $km \cdot h^{-1}$ increments after every eight running bouts (Krustrup et al., 2003).

Bangsbo et al. (2008) examined the data collection from published, unpublished and observational studies, in which the validity and reproducibility of the Yo-Yo IR1 in soccer was evaluated. The article discusses findings associated with Yo-Yo IR1 test performances amongst various groups, as well as in relation to seasonal changes, VO_2 max testing and match performance. With regards to test performances amongst various groups, Mohr et al. (2003) demonstrated that top-class soccer players performed 11% ($p < 0.05$) better on the Yo-Yo IR1 test than moderate players (2.26 + 0.08 vs 2.04 +0.06 km, respectively). The Yo-Yo IR1 performances of the players was also compared with computerized time–motion analyses from

the competitive season. The results showed that top-class players performed 28% more high intensity running and 58% ($p < 0.05$) more sprinting than the moderate players (2.43+ 0.14 vs 1.90+ 0.12 km and 0.65 +0.06 vs 0.41+ 0.03 km, respectively). Similar findings were reported for female soccer players, whereby top-elite players performed better in the Yo-Yo IR1 test compared to moderate-elite and sub-elite players; 1600, 1360 and 1160, respectively (Bangsbo et al., 2008).

Seasonal changes in Yo-Yo IR1 test performance have been observed in male and female soccer players. Male soccer players have been seen to improve Yo-Yo IR1 performance by 25% during pre-season testing (Krustrup et al., 2003). However, different results were observed in a study preparing female national under 20's for a World Cup. The team progressively improved Yo-Yo IR1 scores over a one-year period, with progression in scores suggested to be a result of an increased focus in fitness related training (Tunstall [unpublished study]; Bangso et al., 2008). Furthermore, improvements in Yo-Yo IR1 test performances (12-25%) have been detected after a 6-7-week training period in male sub-elite and elite soccer players (Ferrari et al., 2006; Ferrari [dissertation], 2006; Krustrup et al., 2003). Additionally, improvements in performance have been observed amongst elite (31%) and top-class (35%) male soccer referees after a 12- and 68-70-week training duration, respectively (Krustrup & Bangsbo, 2001; Weston et al., 2004).

Physical differences amongst playing positions have been reflected in Yo-Yo IR1 test performances. Numerous studies have demonstrated that central defenders and attackers do not perform as well as fullbacks and midfielders during the test (Krustrup et al., 2005; Krustrup et al., 2003; Mohr et al., 2003). Mohr et al. (2003) demonstrated that differences in physical parameters associated with playing position correspond to performance in the Yo-Yo IR1 test. Findings showed that fullbacks, attackers and midfield players covered more total distance in

high intensity running during a match than defenders. Furthermore, fullbacks and attacking players covered greater sprinting distances than midfielders and defenders. As expected, fullbacks and midfielders covered the greatest distance during the Yo-Yo IR1, in comparison to defenders and attackers (2.21+ 0.04 and 2.23 +0.10 vs 1.91 +0.12 and 1.99+ 0.11 km, respectively).

Maximal oxygen uptake tests are regarded as gold standard when it comes to measuring aerobic fitness (Castagna et al., 2006). Krustrup et al. (2003) reported significant correlations between the Yo-Yo IR1 and VO_2 max testing. Conversely, interindividual difference were demonstrated between Yo-Yo IR1 and VO_2 max performance. Subjects who obtained VO_2 max results of 48–49 mL·min-1 ·kg-1, displayed a range of Yo-Yo IR1 performances (1560 - 2200 m). Therefore, it is suggested that the Yo-Yo IR1 test is greater sensitive measure in reflecting changes in performance and the ability to perform repeated intense exercise than VO_2 max testing (Krustrup et al., 2003).

There is a limited amount of research examining the relationship between Yo-Yo IR test results and match performance (Bangsbo et al., 2008). However, some studies have demonstrated the relationships between Yo-Yo IR test performance and high intensity activity during a game. Krustrup et al. (2005) found a significant correlation ($r = 0.81$) between Yo-Yo IR test performance and high intensity running in elite female soccer players during the final playing moments of each half of a match. In a similar study concerning elite players, Krustrup et al. (2003), observed a significant correlation between the Yo-Yo test performance and the amount of high intensity running (>15 km·h-1) during a soccer match in thirty-seven professional male soccer players ($r = 0.71$, $p < 0.05$). Performances in the Yo-Yo test was also correlated to the total amount of high-speed running, sprinting and total distance during a game ($r = 0.58$ and $r =$

0.53 [$p < 0.05$] respectively). Krustrup and Bangsbo (2001) also demonstrated a positive relationship between Yo-Yo IR1 test results and match performance in twenty-seven male top-class referees. Performance in the Yo-Yo IR1 was strongly correlated with high-intensity running during a game ($r = 0.75$, $p < 0.001$). Additionally, the referees saw a 31% improvement in Yo-Yo IR1 test scores after a 12_week training period, accompanied by a 23% increase in the amount of high intensity activity during a game, and a decrease in the reduction of high intensity running near the end of competition. Lastly, the referees who had the greatest improvements in the Yo-Yo IR1, saw the largest increase in high intensity exercise during matches ($r = 0.77$) as a result of training.

Krustrup et al. (2003) measured the reproducibility of the Yo-Yo IR1 test. Minimal difference was observed in the distance covered in two Yo-Yo IR1 testing sessions. The two-testing sessions were separated by a week. The distance covered in the first and second test being 1867 ± 72 and 1880 ± 89m (n = 13 [CV = 4.9%]), respectively. The test-retest reliability of the Yo-Yo IR1 was also measured by Thomas et al. (2006). Active subjects were used in the study and the results demonstrated a CV of 8.7% and a strong correlation coefficient of $r = 0.95$ ($p < 0.01$).

Within the literature it is evident that the Yo-Yo IR1 test has the ability to discriminate between playing level and position. The test can also effectively detect changes in seasonal performance. Furthermore, the Yo-Yo IR1 can more sensitively measure training-induced changes in performance, better than VO_2 max testing. Most importantly, the test correlates strongly to physical match parameters and has shown strong reproducibility despite the physical and psychological stress of the test.

Maximal Speed Output Tests

Sprinting is regarded as one of the most important actions during a soccer match, playing a fundamental role in ball possession, transitional play and goal scoring opportunities (Lockie et al., 2019). A sprint is said to occur every 60-180 seconds during a match, covering distances between 10-20 meters and lasting 2-4 seconds (Andrzejewski et al., 2013; Haugen & Seiler, 2015; Keir et al., 2013; TaŞkin, 2008). Notable sprint distances during competitive matches have been established in numerous studies, with average distances between 200 and 1,200 meters (Andrzejewski et al., 2013). These values constitute to ~1-12% of the total distances covered per game (Andrzejewski et al., 2013; TaŞkin, 2008). The qualitative analysis of sprinting variables within the research are subject to sex differences and dependent upon match substitution (minutes played), playing position, level of play, match duration, tactical approach, training experience, monitoring methods and the classification of sprinting.

Due to the importance and relevance of sprinting in soccer, assessing maximal linear speed outputs over certain distances is routine practice for some soccer coaches as a means of evaluating the sprinting capabilities of their players (Buchheit et al., 2012). A review of the literature by Altmann et al. (2019) reported that linear sprint testing is a valid means of distinguishing between playing level (Cometti et al., 2001; Cotte & Chatard, 2011; Djaoui et al., 2017; Haugen et al., 2012; Haugen et al., 2013; Kobal et al., 2016; Mujika et al., 2009; Nikolaidis et al., 2016; Rebelo et al., 2012), drafted vs non-drafted (Vescovi, 2012), starters vs nonstarters (Risso et al., 2017; Silvestre et al., 2006a; Silvestre et al., 2006b) and competitive vs non-competitive (Ferro et al., 2014). Results showed that higher level players were faster than lower-level players when comparing professional and amateur players (trivial to large ES). Professional women's soccer players who were drafted demonstrated faster sprint times than

those that were not drafted (small to moderate ES). Furthermore, starters outperformed non-starters in Division I men's soccer and professional female soccer (small to moderate ES). Lastly, male competitive soccer players were faster than non-competitive (small to moderate ES).

Altmann et al. (2019) also highlighted the validity of maximal linear speed tests in relation to match performance variables, referring to studies conducted by Silva et al. (2013) and Djaoui et al. (2017). Silva et al. (2013) investigated the training status and match activity of male professional soccer players over the course of a season and described the relationship between time-motion analysis variables and sprint speed. Sprint testing was measured at 5 and 30-meters, and time motion variables such as high intensity running, and sprint distance were calculated through video capture and determined in five-minute intervals. The peak distance covered in high intensity running in a five-minute period was reported, which represented the five minutes in which the most distance was covered at high intensity during a game. Results showed that performances in the 30-meter sprint test moderately correlated with high intensity running during the third and fourth 15-minute periods of a match (r = -0.47 and r = -0.58, respectively). Furthermore, 30-meter sprint times demonstrated moderate-strong correlations with sprint distances covered in the first (r = -0.45), second (r = -0.72), first and fourth (combined) half of a match (r = 0.48), as well as sprint distance during all matches (r = 0.65). Sprint times at the 5-meter interval also moderately correlated with high intensity running during the third and fourth 15-minute periods of a match (r = -0.67 and r = -062, respectively). Sprinting distance during the first to fourth half of a game and sprinting distance during all matches moderately correlated to 5-meter sprint performance (r = -0.56 – -0.62).

Djaoui et al. (2016) compared the maximal sprinting speed attained during match play of professional and elite amateur soccer players. Subjects performed a 40-meter sprint test to assess individual maximal sprint speed, that was then compared to their match activity for analysis. The study found no differences in maximal sprint speed with level of play but did find a moderate correlation ($r = 0.52$, $p = 0.05$) between individual maximal sprint test and maximal sprint speed during a match. Overall, the review illustrates that within the literature, linear sprint tests up to 40 meters have acceptable validity (construct and criterion) and reliability to assess linear sprinting skills in soccer players.

Comparison of Field Tests

Yo-Yo Intermittent Recovery Test & Sprint Tests

The structure of the Yo-Yo IR1 requires participants to moderately increase their speed in accordance with the increasing speed levels of the test. Therefore, it may be fair to hypothesize that linear speed may contribute to Yo-Yo IR1 performance. Few studies have properly investigated the relationship between Yo-Yo IR1 test performance and maximal linear outputs amongst soccer players. Ingebrigtsen et al. (2014) studied the relationships between field performance tests in fifty-seven high-level male soccer players competing regularly in three of the highest levels of Norwegian soccer. Results showed a moderate correlation between 20- and 35-meter sprinting and Yo-Yo IR1 performance ($r = -0.289$ and -0.321, respectively [$p \leq 0.05$]).

Gumusdag et al. (2013) investigated the Yo-Yo intermittent recovery test as an assessment of aerobic-anaerobic fitness and game-related endurance in soccer. The study used twenty-five male professional soccer players who competed for the same club team. Players completed various tests (VO_2 max testing, Yo-Yo IR1, Hoff dribbling test, maximal vertical jump & 30-meter sprint) and a Bonferroni Post Hoc test was used to compare test performances.

The level of statistical significance was set at $p < 0.05$. The findings demonstrate a moderate correlation between 30-meter sprint time and the Yo-Yo IR1 ($p = 0.002$). However, a weak correlation was discovered in relation to 10-meter sprint time ($p = 0.12$).

Sánchez-García et al. (2018) explored the relationship between sprint ability and endurance capacity in twenty-three experienced and trained soccer referees. The referees completed the 40-meter sprint, followed by the Yo-Yo IR1, with 8-minutes of rest between each test. Two 40-meter sprint trials were performed and the trial with the best time and maximum velocity was used in analysis. Findings from the study show that the distance covered during the Yo-Yo IR1 moderately correlates to the velocity reached in the 40-meter sprint test ($r = 0.40$, $p < 0.05$).

More recently, Lockie et al. (2019) examined the relationship between the Yo-Yo IR2 test and other soccer related field tests. Twenty-one Division I female collegiate soccer players were used in the study. Within the study, Yo-Yo IR1 performances (distance covered) and sprint times were correlated. Sprint times were assessed at 0-5, 0-10 and 0-30-meters. Results showed that Yo-Yo IR1 performances did not significantly correlate with sprint times at 0-5, 0-10 or 0-30-meters ($r = 0.05$, $r = 0.17$, $r = 0.27$, respectively [$p \leq 0.05$]).

Summary

There is a limited amount of literature that specifically focuses on the relationship between Yo-Yo IR1 performance and maximal linear sprint outputs. The majority of the literature available briefly investigates the relationship in addition to the realm of the studies. There is also a disproportion within the literature with regards to female subjects. Furthermore, the literature mainly consists of professional male soccer players and referees. To the author's

knowledge, there is only one study involving Division I collegiate female soccer players. In addition, most of the studies use small samples sizes. Therefore, it is difficult to establish whether there is a true relationship between the two field-based tests at the Division I female and male college level. As more research pertaining to the physical demands of collegiate soccer is conducted, more college coaches will seek to regularly assess their players physical capabilities via field-based testing to determine whether their players can impact the game. Subsequently, there will be greater opportunity at the Division I college level to assess the relationships between endurance and speed-based tests, as further research in this area is warranted.

Chapter 3. The Relationship Between Yo-Yo Intermittent Recovery Testing Ability and 20-meter Sprint Times in NCAA Division I Men's and Women's Collegiate Soccer Players.

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Abstract

The purpose of this study was to determine the relationship between Yo-Yo intermittent recovery testing ability and 20-meter sprint times in NCAA Division I men's and women's collegiate soccer players. Results show no significant ($p = >0.05$) relationship between the distance covered in the Yo-Yo IR1 test and 20-meter sprint times in the female players and a significant correlation between the two tests in the male players ($r = -0.33$). A non-significant relationship between the tests in female players may be due to greater variation in the total distance covered during the Yo-Yo IR1 test and small variation in 20-meter sprint times. The inclusion of speed and resistance training may be beneficial in developing the anaerobic speed reserve in female collegiate soccer players, leading to improvement in the Yo-Yo IR1 test performance. Improving the sprinting capabilities of male collegiate soccer players may also improve Yo-Yo IR1 test performance.

Introduction

Soccer involves technical and tactical components but relies heavily on the physiological capabilities of the players (Gumusdag et al., 2013). The game is characterized as intermittent, involving periods of high intensity activity (sprinting, high intensity running, changes in direction, jumping and tackling), combined with active recovery over a prolonged period of time (Alexander, 2014; Bangsbo et al., 2008; Castagna et al., 2006; Krustrup et al., 2003; Markovic & Mikulic, 2011). Male collegiate soccer players cover approximately 8,900 – 9,900 meters per match and perform 1,300 – 1,900 m of high intensity running and 200 – 400 meters of sprinting (Curtis et al., 2018). Likewise, female players cover distances of approximately 9,000 meters per match, with 300 - 1,000 meters of that being high-speed running and 200 – 600 meters of sprinting (Alexander, 2014; Sausaman, 2019). Due to the physiological demands of collegiate soccer, athletes should be exposed to various fitness components in training such as aerobic capacity, aerobic power, speed, speed endurance, strength, power, and agility. Therefore, when assessing the match readiness and preparation of collegiate soccer players, coaches should utilize appropriate, valid and reliable fitness tests (Sayers et al., 2008).

Field-based tests are commonly used by soccer coaches as an means of establishing match performance benchmarks for playing standards and positional roles, assessing the effectiveness of training programs and for constructing collective and individual training prescriptions (Deprez et al., 2014; Haugen & Seiler, 2015; Krustrup et al., 2003). Traditional assessments in soccer have included the maximum oxygen uptake tests (VO_2max), the Leger shuttle-run test and the 12-minute running test to assess the aerobic capacities of soccer players (Bangsbo et al., 2008). However, due to the questionable relevance of such tests, the Yo-Yo IR1 test was developed and applied to soccer, as it specifically reflects the intermittent nature of the

sport (Bangsbo et al., 2008; Deprez et al., 2014; Haugen & Seiler, 2015). Significant correlations have been observed between Yo-Yo IR1 test performance and the amount high intensity running, sprinting and the total distance covered during a match (Bangsbo, 2001; Krustrup et al., 2003; Krustrup &; Krustrup et al., 2005).

Sprinting is regarded as one of the most important actions during a soccer match, playing a fundamental role in ball possession, transitional play and goal scoring opportunities (Lockie et al., 2019). A sprint is said to occur every 60-180 seconds during a match, covering distances between 10-20 meters and lasting 2-4 seconds (Andrzejewski et al., 2013; Haugen & Seiler, 2015; Keir et al., 2013; TaŞkin, 2008). Assessing maximal linear speed outputs over certain distances is routine practice for some soccer coaches as a means of evaluating the sprinting capabilities of their players (Buchheit et al., 2012). Significant correlations have been demonstrated between performances in maximal linear sprint tests and maximal sprint speed, high intensity running and sprinting distances performed during a match (Djaoui et al., 2016; Silva et al., 2013).

The Yo-Yo IR1 and maximal linear sprint output tests are a popular testing battery among soccer coaches and have shown to be valid and reliable means of evaluating repeated high intensity running and maximal speed outputs in soccer players (Altmann et al., 2019; Bangsbo et al., 2008). The Yo-Yo IR1 test requires participants to gradually increase their speed in accordance with the increasing speed levels of the test. Therefore, it may be fair to hypothesize that linear speed may contribute to Yo-Yo IR1 test performance. Few studies have properly investigated the relationship between Yo-Yo IR1 test performance and maximal linear outputs amongst soccer players. Moderate correlations between the distance covered during the Yo-Yo IR1 test and maximal linear sprint times (20-40 meters) have been observed in high-level

and professional male soccer players, and experienced match officials (Gumusdag et al., 2013; Ingebrigtsen et al., 2014; Sánchez-García et al., 2018). To the authors knowledge, there is only one outstanding study that briefly examines the relationship between Yo-Yo IR1 test performance and maximal linear sprint distances in Division I female collegiate soccer. Lockie et al. (2019) found no significant correlation between Yo-Yo IR1 test performance and sprint times at 0-5, 0-10 or 0-30-meters ($r = 0.05$, $r = 0.17$, $r = 0.27$, respectively [$p \leq 0.05$]).

There is a limited amount of research specifically focusing on the relationship between Yo-Yo IR1 test performance and maximal linear sprint outputs. The majority of the available literature briefly investigates the relationship in addition to the realm of the studies. If a relationship between Yo-Yo IR1 test performance and maximal linear sprint output is established, this could provide collegiate soccer coaches with a better interpretation of Yo-Yo IR1 and linear speed test results. Furthermore, coaches will be able to obtain better understanding of training preparation and match readiness. Thus, the aim of this study was to determine the relationship between Yo-Yo IR1 testing ability and 20-meter sprint times in NCAA Division I men's and women's collegiate soccer players.

Methods

Experimental Design

Over the course of nine years, pre-season testing sessions were conducted prior to the Fall competitive season for male and female soccer players. Testing sessions occurred outside, on a grass surface at the beginning of August. The temperature ranged from 75 to 85°F. Players were advised to avoid heavy training during the days preceding the testing session. The players performed a standardized dynamic warm-up prior to the testing session. The warm-up consisted of ~10 minutes of non-fatiguing mobilization and activation exercises, including dynamic

stretching, sprint mechanics and progressive sprints. Players performed the Yo-Yo IR1 test after the 20-meter sprint assessment. Players were provided adequate time to prepare for the Yo-Yo IR1 test.

Participants

Sixty-nine NCAA Division I female soccer players (freshmen, *n* = 19; sophomores, *n* = 10; juniors, *n* = 23; seniors, *n* = 16, graduates, *n* = 1; age: 19.9 ± 1.25 [age range, 19-23]; body mass (BdM): 63.02 ± 7.84 kg; height: 165.66 ± 5.53 cm; sprint and resistance training experience: 1-4 years) and sixty NCAA Division I male soccer players (freshmen, *n* = 21; sophomores, *n* = 9; juniors, *n* = 14; seniors, *n* = 15, graduates, *n* = 1; age: 20.0 ± 1.45 [age range, 18-24]; body mass (BdM): 75.01 ± 8.93 kg; height: 177.75 ± 6.32 cm; sprint and resistance training experience: 1-4 years) participated in the study. Player data were only included in analysis if the player had (a) played in an outfield position (defender, midfielder, or forward), (b) completed the 20-meter sprint and Yo-Yo IR1 test prior to participation in the Fall competitive season. Only the most recent pre-season testing data was used in this study for each player. The data analyzed in this study was obtained retrospectively from on-going athlete monitoring programs. The players signed written consent forms for their data to be stored in the repository. This study was approved by the East Tennessee State University institutional review board.

Procedures

20-meter Sprint Assessment

Players completed two, 20-meter warm up trials at 75% of perceived maximal efforts with ~30 seconds rest between each trial. Timing gates (Brower; Draper, Utah, USA & Microgate; Mahopac, NY, USA) were placed at 0, 10 and 20-meters. The players positioned

themselves in a staggered stance, 30-centimeters behind the first timing gate. This aimed to prevent an early trigger at the first timing gate. The players then performed two trials at maximal perceived effort with ~2-minutes rest between each trial. The best time of the two trials was used for analysis.

Yo-Yo Intermittent Recovery Test Level 1

The Yo-Yo IR1 test is controlled via audio bleeps from a CD (compact disk) and consists of 2 x 20-meter shuttle runs, with a 10-second period of active recovery between each running bout (Bangsbo et al., 2008; Sánchez-García et al., 2018). The test begins with four running bouts between 10-13 $km \cdot h^{-1}$ (0–160 m), followed by seven running bouts between 13.5–14 $km \cdot h^{-1}$ (160– 440 m). The speed then continues to increase in 0.5 $km \cdot h^{-1}$ increments after every eight running bouts (Krustrup et al., 2003). The test concluded when players failed twice to reach the line, or abandoned the test due to perceived exhaustion. The speed level in which the players discontinued the test was recorded. Speed levels correspond to distance covered during the test. The distance (meters) covered by each player during the test was used for analysis.

Statistical Analysis

Descriptive data have been represented as mean ± SD. Performance data from each athlete's pre-season testing sessions were used to examine the relationship between distance covered during the Yo-Yo IR and 20-meter sprint times. Intra-class correlations (ICC) were calculated between the two 20-meter sprint trials to determine intra-session reliability. ICC was only calculated for female subjects, as trial data in male subjects was limited. Two separate Pearson product-moment correlations were calculated to determine the relationship between the Yo-Yo IR1 and 20-meter sprint for male and female players. The critical alpha level was set at $p \leq 0.05$. The strength of the relationship as measured by Pearson product-moment correlation

coefficient was evaluated with the following scale: r = 0.0-0.1 (trivial); r = 0.1-0.3 (small); r = 0.3-0.5 (moderate); r = 0.5-0.7 (large); r = 0.7-0.9 (very large); r = 0.9-0.1 (nearly perfect) (Hopkins, 2009). All statistical analysis calculations were performed with IBM SPSS statistics (SPSS, Chicago, IL, version 27).

Results

Means and standard deviations for performance tests are presented in Table 1. A high degree of reliability was found between 20-meter sprint trials in female subjects. The ICC average measure was 0.92 with a 95% confidence interval from 0.88 to 0.95 for female players. The total distance covered during the Yo-Yo IR1 test averaged 2131.33 ± 399.19 meters (CV = 18.7%) for male players and 1057.68 ± 288.47 meters (CV = 27.8%) for female players. The average sprint speed for the male players was 3.016 ± .103 seconds (CV = 3.4%) and 3.426 ± .175 seconds (CV = 4.1%) for the female players (Table 1). The distance covered in the Yo-Yo IR1 test was significantly correlated with 20-meter sprint times in the male players (r = -0.33, p = 0.009). There was a non-significant trivial (r = -0.04, p = 0.74) relationship between the distance covered in the Yo-Yo IR1 test and 20-meter sprint times in the female players.

Table 1. Descriptive data (mean ± SD, 95% CI for sprint and Yo-Yo IR1 in Division I male and female soccer players

Test	Mean ± SD		95% CI for mean Lower-Upper	
	Male	Female	Male	Female
Yo-Yo IR1	2131.33 ± 399.19	1057.68 ± 288.47	2028.21-2234.45	988.38-1126.98
Sprint	3.016 ± .103	3.39 ± .140	2.99-3.04	3.36-3.43

Discussion

The purpose of this study was to investigate the relationship between Yo-Yo IR1 testing performance and 20-meter sprint times in NCAA Division I collegiate men's and women's soccer players. The main findings of this study were a significant correlation between the distance covered in the Yo-Yo IR1 test and 20-meter sprint times in male players, while a non-significant trivial relationship was established between the two field-based tests in female players (r = -0.33, p = 0.009 and r = -0.04, p = 0.74, respectively).

In the present study, a moderate correlation was found between Yo-Yo IR1 testing performance and 20-meter sprint times in male players. These results are consistent with the data that was previously reported by Ingebrigtsen et al. (2014), where a moderate correlation between 20 and 35-meter sprint and Yo-Yo IR1 test performance in fifty-seven high-level male soccer players was established (r = -0.28 and r = -0.321, respectively [$p \leq 0.05$]). Similarly, Gumusdag et al. (2013) demonstrated a moderate correlation between 30-meter sprint times and Yo-Yo IR1 test performance in twenty-five male professional soccer players (p = 0.002). However, a weak correlation was found in relation to 10-meter sprint time and Yo-Yo IR1 test performance (p = 0.12). In addition, Sánchez-García et al. (2018) observed a moderate correlation between the velocity reached during the 40-meter sprint and the distance covered in the Yo-Yo IR1 test, while investigating the relationship between sprint ability and endurance capacity in twenty-three experienced and trained soccer referees (r = 0.40, p <0.05).

In contrast, a non-significant trivial relationship between Yo-Yo IR1 testing performance and 20-meter sprint times in the female players was determined in the current study. Recently, Lockie et al. (2019) conducted a similar study examining the relationship between soccer related field tests using twenty-one Division I female collegiate soccer players. Sprint times were

assessed at 0-5, 0-10 and 0-30-meters and were correlated with distances covered during the Yo-Yo IR1 test. Results showed that Yo-Yo IR1 performances did not significantly correlate with sprint times at 0-5, 0-10 or 0-30-meters ($r = 0.05$, $r = 0.17$, $r = 0.27$, respectively [$p \leq 0.05$], which is comparable to the findings observed in the present study.

It is evident that based on the findings from this study and from previous literature, the Yo-Yo IR1 test and maximal linear sprint output tests, particularly over distances of 20 to 40-meters, demonstrate greater significant relationships among high-level, professional and Division I collegiate male soccer players, and experienced male officials than Division I female soccer players.

In the present study, the male players covered larger average total distances during the Yo-Yo IR1 test and displayed less variation in Yo-Yo IR1 test scores in comparison to the female players (2131.33 ± 399.19, CV = 18.7%, 1057.68 ± 288.47, CV = 27.8%, respectively). Furthermore, male players produced faster average 20-meter sprint outputs and demonstrated less variation in 20-meter sprint times in comparison to female players (3.016 ± .103, CV = 3.4%, 3.426 ± .175, CV = 4.1%, respectively). There may not have been a significant relationship between female Yo-Yo IR1 and female sprint time due to more variation in total distance covered during the Yo-Yo IR and greater variation in 20-meter sprint times. In addition, a relationship between the tests may not have been granted for the female players, as they may not have been able to produce the speed requirements of the Yo-Yo IR1 in order to advance through the increasing speed levels of the test. Whereas men, on average, produced greater speed outputs and were able to advance through the levels of the Yo-Yo IR1 test.

Previous research has demonstrated moderate correlations between maximal velocity reached in linear sprint tests and the distance covered during the Yo-Yo IR1 test, suggesting that the ability to produce high speed outputs is a contributing factor in Yo-Yo IR1 testing performance (Sánchez-García et al., 2018). The structure of Yo-Yo IR1 test consists of 40-meter bouts that are performed in 20-meter shuttle runs. It has been proposed that the running pattern of the Yo-Yo IR1 test may induce neuromuscular fatigue due to the constant accelerations and decelerations required by the test, which isn't observed in linear sprint efforts (Sánchez-García et al., 2018). Considering the Yo-Yo IR1 test procedure, Sánchez-García et al. (2018) recommends assessing acceleration ability over a 5-10 meter distance to evaluate interim actions at high intensity. Lockie et al. (2019) has previously studied the relationship between 0-5 and 0-10 meter sprints and the distance covered in the Yo-Yo IR1 and found no significant correlation between the tests in Division I female soccer players. Nonetheless, this does not rule out potential relationships amongst other populations. Conversely, Ingebrigtsen et al. (2014) concluded that sprint performance and Yo-Yo IR1 test performance largely depends on different physiological capacities, whereby sprinting capability depends on anaerobic energy delivery, and Yo-Yo IR1 test performance relies upon substantial input from the aerobic system.

Practical Application

The Yo-Yo IR1 test and linear sprint tests should be utilized by male collegiate soccer coaches during periodical physical testing sessions as means of assessing the ability to repeatedly perform high intensity running and measure maximal linear sprint outputs. Based on the findings from this study and previous research, it may be appropriate for coaches to presume that improving the sprinting capabilities of male collegiate soccer players will improve Yo-Yo IR1 testing performance and match performance variables.

Collegiate soccer coaches should also utilize the Yo-Yo IR1 and linear sprint tests when assessing the physical readiness of female soccer players. Since a non-significant correlation was found between the Yo-Yo IR1 test and maximal linear speed outputs in this study and previous research, both tests can be used to measure different physical capabilities in collegiate female soccer players. It may be beneficial for collegiate soccer coaches to pay special attention to developing the anaerobic speed reserve of collegiate female soccer players through the inclusion of more speed training. If strength underpins speed, the presence of resistance training may also assist in creating a more robust female soccer player (Beattie et al., 2014; Comfort et al., 2014; Delecluse et al., 1995; Kotzamanidis et al., 2005; Peñailillo et al., 2016; Young et al., 1995; Young et al., 2001).

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Chapter 4. Summary And Future Research Considerations

The purpose of this study was to provide collegiate soccer coaches with a better understanding of match readiness and preparation, by investigating the relationship between Yo-Yo intermittent recovery testing ability and 20-meter sprint times in NCAA Division I men's and women's collegiate soccer players. The main findings from this study were a significant relationship between Yo-Yo IR1 test performance and 20-meter sprint times in the male soccer players, and a non-significant trivial relationship between Yo-Yo IR1 test performance and 20-meter sprint times in female players. The findings from the present study suggests that improving the sprinting capabilities of male collegiate soccer players will lead to improvements in Yo-Yo IR1 testing performance and match performance variables. Furthermore, it may be beneficial for coaches to pay special attention to developing the anaerobic speed reserve in collegiate female soccer players to improve Yo-Yo IR1 test performance and match performance variables.

The findings from the current study are limited to the Division I collegiate soccer level, therefore, further investigation is warranted between the two field-based tests at other playing levels. To adequately assess how performances in the Yo-Yo IR1 test and maximal linear sprint test relate to match performance, comparing match performance data to testing performance should be considered. The findings from the present study demonstrate that male collegiate soccer players produce faster average speed outputs and achieve greater distance in Yo-Yo IR1 test, however, female and male collegiate soccer players cover similar total distances, distances at high intensity and sprinting distances during a match. Thus, additional investigation should be conducted to determine whether male collegiate soccer players are covering distances at a faster velocity compared to female players. Lastly, since improving the anaerobic speed reserve may lead to improvements in Yo-Yo IR1 test performance and match performance variables, further

research should be directed towards the relationship between Yo-Yo IR1 test and linear sprint performance after a speed emphasis training block.

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