

Examination of Aerobic and Anaerobic Contributions to Yo-Yo Intermittent Recovery  
Level 1 Test Performance in Female Adolescent Soccer Players

by

Leanne Dickau  
B.Sc., University of Alberta, 2006

A Thesis Submitted in Partial Fulfillment  
of the Requirements for the Degree of

MASTER OF SCIENCE

in the School of Exercise Science, Physical and Health Education

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## **Supervisory Committee**

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Dr. Catherine Gaul, (School of Exercise Science, Physical and Health Education)  
**Supervisor**

Dr. Lynneeth Stuart-Hill, (School of Exercise Science, and Physical and Health Education)  
**Departmental Member**

Dr. John Anderson, (Educational Psychology and Leadership)  
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## Abstract

### Supervisory Committee

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The purpose of the study was to examine the physiological components related to the Yo-Yo intermittent recovery level 1 (YYIRL1) test in female adolescent soccer players. Eighteen female soccer players (age  $16.3 \pm .77$  years) were tested for maximal oxygen uptake ( $VO_2$  max) and ventilatory threshold (VT) on a motorized treadmill. Anaerobic power and capacity were assessed by peak power (W) measured during a counter movement jump (CMJ) and performance on an anaerobic speed test (AST), respectively. As well, participants completed the Multistage 20m Shuttle run (Leger). YYIRL1 performance (meters) was significantly correlated to  $VO_2$  max ( $r = .59$ ), VT ( $r = .42$ ), Peak Power ( $r = .41$ ), CMJ height ( $r = .41$ ), AST ( $r = .52$ ) and the Leger ( $r = .72$ ,  $p < .05$ ). Leger performance (m) was significantly correlated to  $VO_2$  max ( $r = .60$ ) and AST ( $r = .47$ ,  $p < .05$ ). Multiple stepwise linear regression equations were run with YYIRL1 and Leger as the dependent variables.  $VO_2$  max was the only variable that contributed to prediction of YYIRL1 or Leger performance with  $R^2$  values of .35 and .36. The results of the study showed that YYIRL1 performance is related to both aerobic and anaerobic variables, although predominantly maximal aerobic power ( $VO_2$  max). It is recommended that the YYIRL1 be used when assessing female adolescent soccer players as the results provide evidence that the YYIRL1 is related to anaerobic variables

associated with soccer match performance. As well, coaches can efficiently test their athletes in a shorter amount of time compared to the Leger.

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## **Dedication**

I dedicate this thesis to my family and friends, whose unwavering support and encouragement gave me the strength to accomplish this goal. You are all God's blessings in my life.

## **Chapter 1**

### **Introduction**

In team sports such as soccer, field hockey, rugby and basketball, the movement patterns during game play consist of intermittent periods of high-intensity exercise interspersed with periods of recovery or low-intensity activity (Meckel, Machnai, & Ellakim, 2009). In the sport of soccer it has been found, through motion analysis, that during a 90 min match the movement patterns of players is characterized by actions such as sprinting, jogging, walking, tackling and changes of direction (Mohr, Krustup, & Bangsbo, 2003; Stølen, Chamari, Castagna, & Wisløff, 2005; Wisløff, Helgerud, & Hoff, 1998). In order to meet these energy demands, the use of both the aerobic and anaerobic energy systems is required (Meckel et al., 2009) and includes both the power and capacity of each system. The power of a system refers to the maximal amount of energy that can be generated during exercise, per unit time, and the capacity of a system refers to the total amount of energy available to perform work (Gastin, 1994).

To assess the aerobic and anaerobic energy systems in team sport athletes, field tests are commonly used to estimate or predict these variables. Most field tests are designed with the assumption of logical or face validity (Rampinini et al., 2007) in that they visually or intuitively have a relationship with a particular skill or physiological component (Thomas, Nelson, & Silverman, 2005). Validity is often determined by comparing test outcomes to a gold standard, criterion validity, in order to be able to predict or estimate a particular performance measure such as  $VO_2$  max (Docherty, 1996).

VO<sub>2</sub> max, or maximal aerobic power, is defined as the maximum rate at which oxygen can be consumed (Bassett & Howley, 2000). It is commonly used to represent the cardiorespiratory or aerobic fitness of an athlete and is often measured in research studies to demonstrate if a training effect has occurred (Bassett & Howley, 2000). Laboratory testing of VO<sub>2</sub> max is often not available or a practical means of testing team sport athletes. However, as energy provision is predominately from the aerobic system during a 90 min soccer match (Bangsbo, 1994), field tests are often used that provide an estimation of this value.

A well known reliable and valid field test to estimate VO<sub>2</sub> max is the Multistage 20m Shuttle Run (Leger) (Léger & Lambert, 1982). The Leger is a continuous test whereby participants run a distance of 20m back and forth at progressively increasing speeds. Due to its ease of use and ability to estimate VO<sub>2</sub> max it is often used by coaches to determine the aerobic fitness of their players in place of laboratory testing. However, most team sports, such as soccer, are not continuous in nature and consist of intermittent periods of high-intensity activity. Therefore, although it is important for team sport athletes to possess an optimal level of aerobic power, the ability of an athlete to maintain high-intensity short duration spurts of effort over the length of a match is equally, or perhaps even more important. In other words, the ability of an athlete's anaerobic system to produce energy over repeated bouts may better represent performance on the soccer field. When players are directly involved in "the play" it has been reported that this game event is dependent largely on anaerobic fitness components and may constitute the crucial moments of the game such as winning possession of the ball or scoring a goal (Reilly, Bangsbo, & Franks, 2000).

The Yo-Yo Intermittent Recovery Level 1 (YYIRL1) test was designed in order to be a more appropriate and valid testing tool to assess the fitness level of soccer players (Bangsbo, Iaia, & Krstrup, 2008). Specifically, the purpose of the YYIRL1 is to assess the ability of a player to recover from repeated, short duration, incrementally increasing, intense exercise (Reilly et al., 2000). The underlying structure of the test is similar to the Leger, however, the YYIRL1 incorporates periods of 10s active recovery after every 2 x 20 m shuttles (40 m) and starts at a faster speed than the Leger (Krstrup et al., 2003). The YYIRL1 has been found to be a reliable and valid test for assessing the fitness level of soccer players and is able to discriminate between various levels of players from the recreational to the elite competitive player (Bangsbo et al., 2008) (See Appendix A).

YYIRL1 performance has been significantly correlated with the amount of high-intensity running performed in a match (Castagna, Impellizzeri, Cecchini, Rampinini, & Alvarez, 2009; Krstrup et al., 2003; Krstrup, Mohr, Ellingsgaard, & Bangsbo, 2005). Analysis of muscle biopsies found that both aerobic and anaerobic energy systems were highly stressed during YYIRL1 test performance (Krstrup et al., 2003). Conversely, it has also been reported that the YYIRL1 is not effective at estimating VO<sub>2</sub> max compared to the Leger (Bangsbo et al., 2008). This suggests that performance on the YYIRL1 is attributable to other physiological or metabolic factors than those strictly associated with maximal aerobic power (Thomas, Dawson, & Goodman, 2006).

The majority of YYIRL1 studies have been conducted using university aged or adolescent male soccer players (Bangsbo et al., 2008; Castagna et al., 2009; Castagna, Manzi, Impellizzeri, Weston, & Barbero Alvarez, 2010; Rampinini et al., 2010). Only two studies have reported YYIRL1 test performance in female adolescents (Kirkendall &

O'Malley, 2002; Mujika, Santisteban, Impellizzeri, & Castagna, 2009) and only one of the two studies compared the YYIRL1 with other fitness parameters (Mujika et al., 2009). Differences in physical performance variables have been shown between males and females, both junior and senior players (Mujika et al., 2009). As well, differences have also been observed between adolescent and adult female soccer players (Mujika et al., 2009; Vescovi, Rupf, Brown, & Marques, 2010). Over 400,000 female youth (<18 years old) were recorded as registered players in Canada in 2006 (FIFA Big Count, 2006). Therefore, it is of value to assess field tests such as the YYIRL1 with this population to compare with previous research.

Physiological measures associated with YYIRL1 performance have been examined (Krustrup et al., 2003; Rampinini et al., 2010), however, further studies are required due to the varying discrepancies and inconsistencies in research designs with variables such as: gender, age, level of soccer ability and other tests that have been compared with the YYIRL1. Studying the physiological components that impact YYIRL1 performance in female adolescent soccer players is important for understanding what the test is measuring.

Coaches often use tests such as the YYIRL1 for evaluation and/or development of their players. By understanding the relative contributions of the aerobic and anaerobic systems to performance on the YYIRL1 valuable information may be provided to coaches for appropriate interpretation of test performance. As well, this information aids in understanding if the YYIRL1 is more or less representative of these components and whether or not it is a more appropriate tool of measurement for this population compared to other field tests such as the Leger.

## **Purpose and Rationale of Study**

The purpose of the study was to examine the physiological components that contribute to YYIRL1 test performance in female adolescent soccer players. In particular, the study aimed to enhance understanding of the relative contributions of the aerobic and anaerobic metabolic systems to YYIRL1 performance. A secondary purpose was to examine the contributions of these metabolic systems to Leger test performance and to compare them to the YYIRL1.

## **Research Questions**

The following research questions were addressed in this study:

1. What are the aerobic and anaerobic components that contribute to YYIRL1 test performance in female adolescent soccer players?
2. What are the aerobic and anaerobic components that contribute to Leger test performance in female adolescent soccer players?
3. Are the aerobic and anaerobic contributions to performance on the YYIRL1 and Leger test similar?

## **Delimitations**

Participants were post-menarcheal female soccer players aged 15 - 17 years from Victoria, BC.

## **Limitations**

1. A small sample size due to challenges with recruitment related to the invasiveness of testing required. For example, blood lactate was collected multiple times for all

cardiorespiratory tests. As well, participation required completing a maximal test at all 4 sessions.

2. Impact of training on test performance. Although most testing occurred during the same phase of each participants' training season.
3. The phase of the participants' menstrual cycle was not controlled for during the study, however, research indicates that phase of menstrual cycle does not effect blood lactate concentration, HR or VO<sub>2</sub> max (Janse de Jonge, 2003).

### **Assumptions**

1. Participants exerted maximal effort for each test and were equally motivated. This was assessed by measuring heart rate, blood lactate and ratings of perceived exertion (RPE).
2. Researchers and research assistants provided the same amount of encouragement on all tests for all participants.
3. There was no difference in pre-test rest, nutritional or hydration status.

Participants were asked of any prior physical activity the day before at each testing session and to ensure accurate results, a few participants were asked to repeat one of the field tests based on sickness, injury, or a perceived lack of motivation by the researcher.

### **Operational Definition**

**Adolescent:** An individual who is 13 to 17 years of age.

## **Chapter 2**

### **Methods**

#### **Participants**

A total of eighteen female adolescent soccer players, between the ages of 15 - 17 years old, were recruited for this study. All participants were post-menarcheal, regularly menstruating, free from injury, and were training on junior select or premier women's teams. In addition, majority of participants had previous experience and familiarity with the field tests used in this study. Each participant provided written informed consent (Appendix B) and was verbally reminded each testing day of their right to withdraw from the study without future consequence. Ethical approval was obtained from the University of Victoria Human Research Ethics Board (HREB) and Biohazard Safety Committee prior to participant recruitment.

#### **Experimental Design**

The study employed a descriptive, cross-sectional, correlational design. Data collection occurred between June 2010 – November 2010. Each participant completed 4 visits over 3 – 5 weeks during this period (Table 1). Participants were asked to arrive at all testing sessions in a hydrated state, to avoid eating within 2 hours of testing, and to restrict vigorous physical activities 24 hours before testing. At the beginning of each testing session, participants were asked when they had last eaten and if they had refrained from physical activity. Testing sessions for each participant were scheduled depending on participant availability and were kept as consistent as possible across all testing sessions. The order of testing was also kept as consistent as possible. A summary of testing order is

shown in Table 1. The Yo-Yo Intermittent Recovery Level 1 (YYIRL1) or Multistage 20m Shuttle run (Leger) test was conducted during visit #2 and #3, with the specific test selected in random order.

Table 1

*Summary of Data Collection Timeline*

Time	Date Collected
Visit 1	Anthropometric Assessment: <ul style="list-style-type: none"> <li>• Skinfolds</li> <li>• Waist and hip girths</li> <li>• Height and body weight</li> </ul> Vertical Jump Cunningham-Faulkner Treadmill Test
Visit 2	1 of Yo-Yo Intermittent Recovery Level 1 <b>or</b> Multistage 20m Shuttle Run Test
Visit 3	Dependent on field test completed in Visit 2 1 of Yo-Yo Intermittent Recovery Level 1 <b>or</b> Multistage 20m Shuttle Run Test
Visit 4	Vertical Jump Maximal Graded Exercise Test on a Treadmill

### **Anthropometric Measurements**

Anthropometric measures were collected using the standardized protocols of the International Society for the Advancement of Kinanthropometry (Marfell-Jones, Olds, Stewart, & Carter, 2006). Weight was measured to the nearest 0.1kg using a Health-O-Meter kilo-pound beam (Congenital Scale Corporation, Bridgeview, Illinois). Height was measured to the nearest 0.1 cm using a stadiometer (Congenital Scale Corporation, Bridgeview, Illinois). Sum of 7 skinfolds was conducted at the following 7 sites (using Harpenden Calipers to the nearest 0.1mm): biceps, subscapular, triceps, supraspinale, abdominal, quadriceps and medial calf. Waist and gluteal girth measurements were also

taken using a Lufkin tape to the nearest 0.1 cm. The ratio of waist to hip was determined by waist circumference (cm)/hip circumference (cm). Body mass index (BMI) was determined using the formula:  $BMI = \text{body weight}/\text{height}^2$  (kg/m<sup>2</sup>).

Body fat percentage was calculated using the following equation by Siri (1961):

$$\% \text{ Body Fat} = (495 / \text{Body Density}) - 450$$

Body density was calculated using the following equation by Withers et al. (1987) for female athletes:

$$\text{Body Density} = 1.17484 - 0.07229(\log_{10} X_1)$$

where:  $X_1 = \sum 4$  skinfolds (triceps, subscapular, supraspinale, medial calf in mm)

### **Warm-up Protocols**

A consistent warm-up protocol was employed on all laboratory-based tests (Vertical Jump, Cunningham, and Maximal Graded Exercise Test (MGXT)). This included a 5-minute warm-up on a motorized Woodway treadmill (Model: DESMO-EVO, Waukesha, WI) at a speed of 4.0 - 5.0 mph. A consistent warm-up was also employed for the YYIRL1 and Leger tests. Prior to commencement of each test, all participants were instructed to engage in a self directed warm-up of approximately 5 minutes similar to their practice or game routine. As well, after initial instructions on test protocol, all participants completed 2 - 4 shuttles of the test to become familiar with timing.

### **Pre and Post-test Measures to Assess Intensity**

For each of the Cunningham, YYIRL1, Leger and MGXT, blood lactate was measured pre-test and at 1, 3, and 5 minutes post-test using a lancet (Accu-Chek Softclix

Pro) and lactate analyzer (Arkray Lactate Pro). Protocol for taking blood lactate is described in Appendix E. The reliability of measurements of blood lactate using the Lactate Pro has been previously established by Tanner, Fuller, & Ross (2010). Blood lactate was collected in order to assess intensity and effort of participants in each test. The serial post-test blood lactate collection protocol was used to ensure accurate peak values were collected. Rating of Perceived Exertion (RPE) was also assessed immediately post-test using Borg's CR10 scale (Borg, Hassmén, & Lagerström, 1987).

### **Vertical Jump (Counter Movement Jump)**

Vertical jump was completed on a Kistler force plate (Kistler, type 9286AA, Winterthur, Switzerland) set at a sampling frequency of 1200 Hz and data processed via BioWare software (version 4.1, 2010, Kistler, Winterthur, Switzerland). Participants were given a demonstration of the counter movement jump (CMJ) and completed a sub-maximal practice jump to ensure correct form. Standard test protocol was followed and included participants being asked to remain motionless on the force plate before jumping in order to zero the voltage outputs. Each participant began the CMJ in a standing position and from there dropped into a squat position, swinging the arms back. From that position they immediately jumped vertically. The amount of arm movement and depth of knee flexion was determined by each participant. Attempts were excluded if the participant tucked her knees on the landing to increase time in the air. A total of 6 jumps (3 per two testing sessions) were completed by each participant with a minute of rest between each jump.

Peak values for each participant were compared between the two testing sessions using a paired t-test. As there was no significant difference between the two testing sessions the maximum peak power value was recorded and used to represent Force (N), Peak Power (W), Relative Peak Power (W/kg), and Jump Height (cm). Force (N) represents the maximum force recorded over the force-time curve during the jump. Power (W) can be defined as the rate of doing work or the average force times the average velocity along the line of action of that force (McGinnis, 2005). Relative Power (W/kg) is in relation to the respective body weight of each participant. Jump height represents the displacement of the individual's center of mass from its initial vertical position to maximal height (McGinnis, 2005). The impulse method was used to calculate jump height and has been shown to be valid and reliable (Street, McMillan, Board, Rasmussen, & Heneghan, 2001). This method uses an estimation of takeoff velocity to determine jump height (Street et al., 2001).

### **Cunningham-Faulkner Treadmill Test**

The Cunningham-Faulkner Test or Anaerobic Speed Test (AST) was administered following the protocol described by Cunningham & Faulkner (1969). Good reliability of the test has been shown in soccer players with an intraclass reliability coefficient of .97 (Thomas, Plowman, & Looney, 2002). After the warm-up, the treadmill was set at 8 mph ( $12.9 \text{ km}\cdot\text{h}^{-1}$ ) at a 20% incline grade. The participant held onto the handrails while stepping/running onto the treadmill in preparation of the test. The timing of the test started when the participant let go of the handrails and stopped when the participant could not keep up and grabbed the handrails again. For greater accuracy of

timing, two research assistants timed the test with stop watches and the highest of the two times was recorded. To ensure safety of the participant, a spotter was positioned at the side of the treadmill. Verbal encouragement was provided throughout each trial. Heart rate (HR) was continuously sampled by telemetry using a Polar heart rate monitor (Polar, Finland) and the peak value was recorded.

### **Yo-Yo Intermittent Recovery Level 1 Test**

The Yo-Yo Intermittent Recovery Level 1 (YYIRL1) test was conducted in a gymnasium following standard protocol (Krustrup et al., 2003). A straight line of 20m was marked by red cones at each end using a measuring tape to set the running distance and another set of cones was positioned 5m past the start/finish line. Participants were instructed to run the distance between the cones in the time allotted as determined by the audio cues on the CD. The test started off with 4 running shuttles at 10 – 13 km·h<sup>-1</sup> (0 - 160 m), proceeded by 7 shuttles at 13.5 – 14 km·h<sup>-1</sup> (160 - 440 m) after which the test continued with stepwise 0.5 km·h<sup>-1</sup> speed increments after every 8 shuttle runs. After each 2 x 20 m shuttle (40 m), participants had a 10 s period of active recovery during which they walked/jogged to a cone and back, which was set 5 m from the finish line. The test ended when the participant stopped due to exhaustion or failed to reach the finishing line in time to the audio signals (i.e., did not complete the 20 m distance) two times. The test performance score was determined by the total distance covered within the shuttles completed (Appendix C). HR was continuously sampled by telemetry using a Polar heart rate monitor (Polar, Finland) and the peak value was recorded.

### **Multistage 20m Shuttle Run (Leger)**

The Multistage 20m Shuttle Run (Leger) test was conducted in a gymnasium setting and adhered to the protocol described by Léger & Lambert (1982) & Léger, Mercier, Gadoury, & Lambert (1988). A straight line of 20 m distance was marked by red cones using a measuring tape. Participants were instructed to run the distance between the cones in the time allotted as determined by the audio cues on the CD. The test started at a speed of  $8.5 \text{ km}\cdot\text{h}^{-1}$  and increased to  $0.5 \text{ km}\cdot\text{h}^{-1}$  every minute (Léger et al., 1988). The test ended when the participant stopped due to exhaustion or was not able to keep up with the audio signals (i.e., did not complete the 20 m distance) two times. The test performance score was determined by the total distance covered within the shuttles completed (Appendix C). HR was continuously sampled by telemetry using a Polar heart rate monitor (Polar, Finland) and the peak value was recorded.

### **Maximal Graded Exercise Test on the Treadmill (MGXT)**

The protocol for the MGXT was as follows:

- 1) 1 minute warm-up at 4 mph
- 2) 2 minutes at 6 mph
- 3) Increased speed by 0.5 mph every 2 min until RER was 0.98 – 1.02 or participant reached a comfortable running speed
- 4) At this time the grade increased by 2.0% each minute until the criteria for  $\text{VO}_2$  max was met.

At least 2 of the following criteria were met for determination of  $\text{VO}_2$  max:

- 1) Attainment of predicted maximum heart rate ( $220 - \text{age}$ )
- 2) A rise in  $\text{VO}_2$  of less than  $2 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  with a consistent increase in workload
- 3) A respiratory exchange ratio (RER) greater than 1.15
- 4) Volitional exhaustion

During the test, expired air was collected and analysed using a Rudolph valve collection system with a TrueOne 2400 Parvo Medics Metabolic Measurement System (Model: MMS-2400, Sandy, UT) and OUSW computer software program (Parvomedics, USA). The metabolic cart was calibrated using gases of known concentrations (oxygen 16% and carbon dioxide 4%) and a volume sensor with a 3 L calibration syringe.  $\text{VO}_2$  max values were recorded relative to body weight (kg). HR was continuously sampled by telemetry using a Polar heart rate monitor (Polar, Finland) and the peak value was recorded.

Ventilatory threshold (VT) was established from the MGXT results. The criteria for determining VT included the nonlinear increase in  $\text{VCO}_2$  compared to  $\text{VO}_2$  (Beaver, Wasserman, & Whipp, 1986). Separately, VT was visually verified by two independent researchers. Consensus was then reached collaboratively for all values.

### **Statistical Analysis**

The data were analyzed using SPSS (version 19.0, 2010, SPSS Inc., Chicago IL) software. All demographic and anthropometric data along with CMJ, AST, YYIRL1, Leger,  $\text{VO}_2$  max and VT values were expressed as means and standard deviations. Prior to data analysis, normality of distribution of data was tested by the Kolmogorov-Smirnov

test (significance was set at  $p \leq .05$ ).

Pearson correlations were used to describe the relationships between the following variables: CMJ (Force, Peak Power, Relative Peak Power, and Jump Height), AST, YYIRL1, Leger, VO<sub>2</sub> max and VT. A paired t-test was run to compare direct VO<sub>2</sub> max values with the estimated VO<sub>2</sub> max values from the Leger test scores (Léger et al., 1988). A paired t-test was also run between distances achieved on the Leger and YYIRL1.

Repeated measures ANOVA was conducted to compare peak HR, peak blood lactate, and RPE recorded on the AST, YYIRL1, Leger, and MGXT. Lastly, a multiple stepwise linear regression analysis was conducted to assess the contribution of the performance indicators, which represented the aerobic and anaerobic energy systems, with the variance of YYIRL1 and Leger test performance. Statistical significance was set at  $p \leq .05$ . Results are presented as means ( $\pm$ SD).

## Chapter 3 Results

### Participant Characteristics

Eighteen adolescent female soccer players (aged 15 – 17yrs) participated in the study. The majority of the players were from junior select or women’s premier teams and on average practiced  $7 \pm 2$  hours/week. Descriptive statistics of participant characteristics are summarized in Table 2.

Table 2

*Descriptive Statistics of Participant Characteristics (n=18)*

<b>Variable</b>	<b>Mean (SD)</b>	<b>Range</b>
Age (years)	16.3 (.7)	15 - 17
Weight (kg)	61.4 (4.2)	55.8 - 69.7
Height (cm)	165.9 (5.0)	158.9 - 175.0
BMI (kg/m <sup>2</sup> )	22.4 (1.5)	19.7 - 24.7
Sum of 7 Skinfolds (mm)*	103.7 (20.4)	61.0 - 150.6
% Body Fat	19.8 (3.1)	12.7 - 25.3
Waist to Hip Ratio	0.76 (.03)	.72 - .81
Training (hrs/week)	7 (2)	3 - 10

\*Skinfold sites: biceps, triceps, subscapular, front thigh, calf, supraspinale, abdominal

Means and standard deviations for scores achieved on the field and laboratory tests are shown in Table 3. Of the 18 participants, 2 athletes did not complete the Multistage 20m Shuttle run (Leger) due to scheduling conflicts, only 17 participants had their blood lactate measured and ventilatory threshold (VT) could only be verified for 17 of the participants. Where appropriate, both relative and absolute values are provided. As

VO<sub>2</sub> max was determined by a maximal graded exercise test on a treadmill (MGXT), only relative values are reported. Yo-Yo Intermittent Recovery Level 1 (YYIRL1) and Leger performance are provided by distance covered and test score. There was a significant difference between distances covered on the YYIRL1 and Leger ( $p < .01$ ), with longer distances covered during the Leger.

Table 3

*Means (SD) and Ranges of Test Scores in Adolescent Female Soccer Players (n=18, unless noted)*

<b>Variable</b>	<b>Mean (SD)</b>	<b>Range</b>
AST (s)	34.21 (8.96)	25.69 - 60.94
CMJ		
Force (N)	872.26 (177.25)	655.74 - 1388.03
Peak Power (W)	1843.08 (317.11)	1278.55 - 2295.23
Relative Peak Power (W/kg)	29.92 (5.18)	21.71 - 39.11
Jump Height (cm)	35.56 (4.96)	26.73 - 43.76
YYIRL1 (m)	933 (235) <sup>*</sup>	520 - 1360
YYIRL1 Score	15.5 (0.7)	14.2 - 16.7
Leger (m) <sup>a</sup>	1556 (255)	1000 - 1900
Leger Score <sup>a</sup>	9 (1)	6 - 10
MGXT		
VO <sub>2</sub> max (ml·kg <sup>-1</sup> ·min <sup>-1</sup> )	51.0 (3.4)	43.1 - 56.1
VT <sup>b</sup>	40.6 (3.8)	32.4 - 48.3
%VT <sup>b</sup>	79.0 (4.7)	71.8 - 88.2

<sup>a</sup>n=16; <sup>b</sup>n=17

<sup>\*</sup>distance (m) sig. different than Leger (m),  $p < .01$

The measures of peak heart rate ( $HR_{\text{peak}}$ ), peak blood lactate, and ratings of perceived exertion (RPE) were collected to compare intensity across the fitness tests (Table 4). Due to missing data in one or more of the variables, only 15 participants could be compared across tests for all variables.

$HR_{\text{peak}}$  was significantly lower during the anaerobic speed test (AST) compared to YYIRL1, Leger and MGXT ( $p < .05$ ). It was also found that  $HR_{\text{peak}}$  was significantly lower during the YYIRL1 compared to MGXT ( $p < .05$ ), however, the difference between the means was only 3 bpm.

Peak blood lactate concentration was significantly higher at the end of the YYIRL1 compared to the MGXT ( $p < .05$ ); however, there was no significant difference across all tests when looking at the ratio of absolute peak to pre-lactate ( $p > .05$ ). The ratio of absolute peak to pre-lactate was calculated from the difference between peak and pre-test lactate divided by the pre-test lactate.

Correlations were also used to assess the relationships between peak blood lactate concentration and AST (s), YYIRL1 (m), Leger (m) and  $VO_2$  max ( $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ). No significant relationships were found between peak blood lactate with either YYIRL1 ( $r = -.26, p > .05; n = 17$ ), Leger ( $r = .16, p > .05; n = 15$ ) or  $VO_2$  max values ( $-.31, p > .05; n = 17$ ). However, there was a significant correlation between peak blood lactate post-exercise and performance on the AST ( $r = .61, p < .01; n = 17$ ).

Collection of blood lactate occurred at 1, 3, and 5 minutes post exercise. It was consistently found that peak blood lactate concentration occurred at 1 minute post-exercise. In regard to the YYIRL1, only 1 out of 18 participants did not reach peak lactate at 1 minute. For the Leger, only 3 out of 15 participants did not have a peak lactate at

1 minute (with 2 at 3 minutes and 1 at 5 minutes) and all 18 participants reached peak lactate at 1 minute post-exercise for the MGXT test.

There was a significant difference in RPE between the AST and MGXT ( $p < .05$ ), however, there was no significant difference between the AST and either the YYIRL1 or Leger ( $p > .05$ ). As well, between the YYIRL1, Leger and MGXT there were no significant differences ( $p > .05$ ).

Table 4

*Mean (SD) Peak Heart Rate, Peak Blood Lactate, and RPE Values in Adolescent Female Soccer Players Across Maximal Tests (n=15)*

<b>Test</b>	<b>Peak Heart Rate (bpm)</b>	<b>Peak Lactate (mmol/L)</b>	<b>Ranges for Peak Lactate (mmol/L)</b>	<b>Ratio of Absolute Peak to Pre-Test Lactate (mmol/L)</b>	<b>RPE</b>
AST	183 (7)*	11.9 (2.2)	8.6 - 16.9	5.73 (3.04)	7 (1)**
YYIRL1	197 (7)**	11.3 (2.1)**	7.2 - 14.8	5.19 (2.06)	8 (1)
Leger	199 (7)	11.0 (2.2)	8.3 - 14.6	5.38 (2.10)	8 (1)
MGXT	200 (7)	9.6 (2.3)	5.9 - 15.7	5.69 (2.63)	9 (1)

\* sig. different from YYIRL1, Leger & MGXT,  $p < .05$

\*\* sig. different from MGXT,  $p < .05$

As mentioned previously, only 16 participants completed the Leger and VT could only be verified for 17 participants. Correlations of physiological variables and test scores are listed in Table 5. Unless noted, all correlations used a sample size of 18.

The YYIRL1 was significantly correlated to Peak Power ( $r = .41, p < .05$ ), CMJ Ht ( $r = .41, p < .05$ ), AST ( $r = .52, p < .05$ ), Leger ( $r = .72, p < .01; n = 16$ ), and  $\text{VO}_2$  max ( $r = .59, p < .01$ ). As well, the YYIRL1 was significantly correlated to VT ( $r = .42, p < .05; n = 17$ ).

Similarly, the Leger was significantly correlated to AST ( $r = .47, p < .05; n = 16$ ) and  $VO_2$  max ( $r = .60, p < .01; n = 16$ ). Unlike the YYIRL1, it was not significantly correlated to Peak Power ( $r = .23, p > .05; n = 16$ ), CMJ Ht ( $r = .09, p > .05; n = 16$ ) or VT ( $r = .44, p > .05; n = 16$ ).

An assessment of the inter-relationships between metabolic and performance measures found that CMJ Ht was significantly correlated with AST ( $r = .64, p < .01$ ) and  $VO_2$  max ( $r = .56, p < .01$ ); however, it was not significantly correlated to VT ( $r = .33, p > .05; n = 17$ ). Other variables of vertical jump including Force and Relative Peak Power were not significantly correlated to YYIRL1, Leger,  $VO_2$  max, or VT,  $p > .05$ . AST was not significantly correlated to Force or Peak Power; however, it was significantly correlated to Relative Peak Power ( $r = .45, p < .05$ ).

Lastly, both YYIRL1 and Leger test performances were significantly correlated to speed ( $km \cdot h^{-1}$ ) reached at VT ( $r = .56, p < .01; n = 17$  &  $r = .52, p < .05; n = 16$ ).

Table 5

*Correlation Matrix for Physiological Variables and Test Scores in Adolescent Female Soccer Players (n=18, unless noted)*

Test/Variable	Peak Power (W)	CMJ Ht (cm)	AST (s)	YYIRL1 (m)	Leger (m)
$VO_2$ max ( $ml \cdot kg^{-1} \cdot min^{-1}$ )	.21	.56**	.41*	.59**	.60** <sup>b</sup>
VT ( $ml \cdot kg^{-1} \cdot min^{-1}$ )	.07 <sup>c</sup>	.33 <sup>c</sup>	.24 <sup>c</sup>	.42* <sup>c</sup>	.44 <sup>a</sup>
Leger (m)	.23 <sup>b</sup>	.09 <sup>b</sup>	.47* <sup>b</sup>	.72** <sup>b</sup>	
YYIRL1 (m)	.41*	.41*	.52*		
AST (s)	.34	.64**			

\* sig.,  $p < .05$ ; \*\* sig.,  $p < .01$

<sup>a</sup>n=15; <sup>b</sup>n=16; <sup>c</sup>n=17

A multiple stepwise linear regression was performed with the YYIRL1 as the dependent variable and Peak Power, AST, VO<sub>2</sub> max and VT as the independent variables. These variables were significantly correlated with the YYIRL1. All variables were excluded except VO<sub>2</sub> max which, with a  $R^2 = .35$ , contributed 35% of the variance in YYIRL1.

Table 6

*Multiple Stepwise Linear Regression Analysis for the YYIRL1 in Adolescent Female Soccer Players (n=17)*

Variable	B	SE <sub>B</sub>	$\beta$	p
Constant	-1235.12	763.88		.127
VO <sub>2</sub> max	42.39	14.87	.593	.012

$R^2 = 0.35$

A multiple stepwise linear regression was performed between the Leger as the dependent variable and AST and VO<sub>2</sub> max as the independent variables. These variables were significantly correlated with the Leger. All variables were excluded except VO<sub>2</sub> max which, with a  $R^2 = .36$ , contributed 36% of the variance in Leger.

Table 7

*Multiple Stepwise Linear Regression Analysis for the Leger in Adolescent Female Soccer Players (n=16)*

Variable	B	SE <sub>B</sub>	B	p
Constant	-1114.65	963.79		.267
VO <sub>2</sub> max	51.74	18.64	.596	.015

$R^2 = .36$

Estimated VO<sub>2</sub> max was determined by age and Leger test score using the table provided by Léger et al. (1988). The correlation between estimated and direct VO<sub>2</sub> max

was significant ( $r = .63, p < .01; n = 16$ ). A paired t-test was run between estimated (Mean =  $48.81 \pm 3.16 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ) and direct  $\text{VO}_2$  max values (Mean =  $51.62 \pm 2.94 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ) ( $n = 16$ ). A significant difference was found between estimated and direct  $\text{VO}_2$  max values ( $p < .01$ ). On average, the estimated value was approximately 5% or  $2.81 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  lower than the direct values.

## **Chapter 4**

### **Discussion**

The purpose of the study was to describe the physiological contributions of the two energy systems (aerobic and anaerobic) to the Yo-Yo Intermittent Recovery Level 1 (YYIRL1) test in female adolescent soccer players. A secondary purpose was to examine these physiological contributions with performance on the YYIRL1 in comparison to performance on a Multistage 20m Shuttle Run (Leger) test. The nature of soccer match play is intermittent and a player must rely on her anaerobic energy system to perform repeated bouts of high-intensity exercise at maximum intensity. As well, in order to recover from these bouts of exercise, a player requires a certain level of aerobic fitness. Therefore, due to the intermittent nature of the sport of soccer and the design of the YYIRL1, it was hypothesized that both the aerobic and anaerobic contributions to performance on the YYIRL1 would be significant. The main finding of the study is that an athlete's  $VO_2$  max (maximal aerobic power) is the main predictor of performance on the YYIRL1 in female adolescent soccer players. The results also provide evidence that performance on the YYIRL1 is related to anaerobic variables.

In regards to the Leger test, the main predictor of performance was also  $VO_2$  max, however, in comparison to the YYIRL1, its relationship with the anaerobic variables measured appeared to be somewhat weaker. Therefore it is suggested that the YYIRL1 may be a more applicable test for the assessment of female adolescent soccer players.

A limitation of the study is the small sample size, however, it is comparable to other studies analyzing the YYIRL1 in adolescent soccer players with sample sizes

between 16 - 26 (Ferrari Bravo et al., 2008; Castagna et al., 2009; Castagna, Manzi et al., 2010; Castagna, Impellizzeri, Rampinini, D'Ottavio, & Manzi, 2008; Hill-Haas, Coutts, Rowsell, & Dawson, 2009; Mujika et al., 2009; Rampinini et al., 2008).

### **Physiological Characteristics**

Compared to university (Krustrup, Zebis, Jensen, & Mohr, 2010; Todd, Scott, & Chisnall, 2002) and adolescent female soccer players (Mujika et al., 2009), the participants in the present study were similar in regards to height, weight, and body fat %/sum of skinfolds. As well,  $\text{VO}_2$  max values fell within the range commonly observed in female soccer players of 39 – 58  $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  (Krustrup et al., 2005; Stølen et al., 2005). The majority of the participants in the study competed on junior select or premier women's teams in the area indicating level of play was high for this age group.

All participants were post-menarcheal and assumed to be at a stage 4 or 5 for sexual maturation. Although the maturation of these players may be similar to that of adult female soccer players, it is still important to conduct research with this population as significant differences in physical performance variables have been shown between adolescent and adult female players (Mujika et al., 2009; Vescovi et al., 2010). Further, information in regards to this population allows coaches to make informed decisions in regards to evaluation and development.

### **Assessment of Intensity**

Peak heart rate ( $\text{HR}_{\text{peak}}$ ), peak blood lactate and ratings of perceived exertion (RPE) were measured to assess intensity across the tests performed. This was to ensure

that all participants were motivated to complete the tests at a similar maximal intensity. It has been observed that prior to completing a field test, participants may set a target score to achieve and finish once they have reached their goal even if premature (Wilkinson, Fallowfield, & Myers, 1999). Wilkinson et al. (1999) reported a high drop-out rate on the first shuttle of each new level during a multistage 20m shuttle run (20MSR). However, across the testing sessions the measures of  $HR_{\text{peak}}$ , peak blood lactate and RPE showed similar intensity indicating participants worked at a high level and were motivated on all tests.

#### **i. Peak Heart Rate**

A significant difference in  $HR_{\text{peak}}$  was found when comparing the YYIRL1 to the maximal graded exercise test (MGXT). Rampinini et al. (2010) observed no significant difference in peak HR between YYIRL1 and a MGXT with male professional and amateur soccer players. In terms of a percentage, the current study found HR on the YYIRL1 to be 99% of peak HR obtained during the MGXT, which is identical to the result found in a group of adult males (Krustrup et al., 2003). It has been suggested that the YYIRL1 can be used to determine an individual's maximal heart rate (Bangsbo et al., 2008). Due to the intermittent nature of the YYIRL1, a true  $HR_{\text{max}}$  may not be achieved during the test compared to the Leger, which is continuous. The present study found no significant difference between  $HR_{\text{peak}}$  during the Leger and MGXT which is in agreement with the results of Stickland, Petersen, & Bouffard (2003) in a group of adult male and female recreational athletes.

## **ii. Blood Lactate**

### **a) Measurement Across Tests**

There were no significant differences in peak blood lactate concentrations observed between the anaerobic speed test (AST), Leger and MGXT. Similar to Krstrup et al. (2003), there was a significant difference in peak blood lactate concentration between the YYIRL1 and the MGXT, however, there was no difference across any of the tests when looking at the ratio of absolute peak lactate to pre-lactate. This ratio took into consideration the magnitude of the increase in blood lactate concentration in relation to pre-test values. Large variability in blood lactate values is often seen between individuals as lactate kinetics may be affected by nutritional status and training/recovery state (Gollnick, Bayly, & Hodgson, 1986). For example, muscle glycogen depletion from dietary manipulations can result in decreased lactate production (Bourdon, 2000). Therefore, calculating this ratio allows a more accurate comparison between individuals and across test scores. From these results, it can be concluded that the magnitude of the blood lactate increase across the fitness tests was not significantly different and that participants completed the tests at a similar maximal intensity.

### **b) Relationship of YYIRL1 and Peak Blood Lactate**

Post-exercise YYIRL1 peak blood lactate values ( $11.3 \pm 2.1 \text{ mmol}\cdot\text{L}^{-1}$ ) were similar to values reported for adult males ( $10.10 \pm 0.6 \text{ mmol}\cdot\text{L}^{-1}$  to  $10.75 \pm 1.1 \text{ mmol}\cdot\text{L}^{-1}$ ) (Atkins, 2006; Krstrup et al., 2003; Thomas et al., 2006). No significant relationship between YYIRL1 performance (m) and peak lactate was observed, which is consistent with that reported in male rugby players (Atkins, 2006) and in a group of male

recreational athletes (Thomas et al., 2006). Krstrup et al. (2003) observed significant, inverse correlations ( $r = -.41$  to  $-.81$ ) between YYIRL1 and blood lactate measured during the test; however, post-exercise values and performance were not discussed. Castagna, Abt, & D'Ottavio (2005) reported that top-level/semi-professional Italian referees had significantly lower blood lactate values post YYIRL1 compared to medium and low level referees (i.e., refereed for 3<sup>rd</sup> and 4<sup>th</sup> division teams), but performed significantly better on the YYIRL1. Similarly, Rampinini et al. (2010) reported a greater rate of blood lactate accumulation ( $\text{mmol}\cdot\text{L}^{-1}\cdot\text{min}^{-1}$ ) in amateur male soccer players compared to professional male soccer players with relation to the YYIRL1. The professional players who had a lower rate of blood lactate accumulation, performed significantly better on the YYIRL1 compared to the amateur players.

This suggests that players with a greater ability to perform high-intensity intermittent exercise will have lower lactates levels post-exercise and highlights that lactate removal is dependent on the level of training in an individual (Gastin, 1994). Blood lactate concentration is hypothesized to increase during intense exercise when energy demand is not being met through aerobic metabolism and therefore anaerobic glycolysis increases (Wasserman, Whipp, Koyl, & Beaver, 1973). Adaptations of training include an increase in the size and number of mitochondria per unit area along with increases in enzymes of the Krebs cycle and electron transport chain (Jones & Carter, 2000). These adaptations enable a trained individual to meet the energy demand, at a similar work rate before training, via oxidative phosphorylation, with a decreased demand on glycolytic pathways (Bassett & Howley, 2000). A reduction in rate of lactate production as a result of endurance training (i.e., greater aerobic fitness) may also be due

to a lower rate of muscle glycogen utilization, speeded oxygen uptake kinetics that may increase initial O<sub>2</sub> availability/utilization, or an increased ability to exchange and remove lactate from the blood (Jones & Carter, 2000). These adaptations allow an athlete to sustain a higher relative (% VO<sub>2</sub> max) or absolute exercise intensity without accumulation of blood lactate (Jones & Carter, 2000).

The results of the current study found no relationship between YYIRL1 performance and blood lactate. However, it is suggested that analysis or interpretation of blood lactate response to exercise is best conducted at the individual level (Bourdon, 2000). The variability within and between individuals for blood lactate is often great due to the fact that blood lactate concentration represents the balance between production, removal and oxidation of lactate prior to entering the blood (Gastin, 1994). Therefore, the use of blood lactate may be better served by tracking changes in individuals over time in relation to YYIRL1 performance to further understand the relationship.

### **c) Timing of Blood Lactate Collection**

It has been observed that blood lactate reaches a peak approximately 5 min post-exercise (Gollnick et al., 1986) and often serial measurements are taken at 1, 3, and 5 minutes post-exercise to ensure accurate peak values are collected. This is due to variability seen between individuals and suggested differences in blood lactate removal/clearance in trained athletes (Tomlin & Wenger, 2001). However, the current data indicates that this may not be necessary. Majority of the participants reached peak lactate at 1 min post-exercise for the Leger (80%), YYIRL1 (94%), and MGXT (100%). This provides valuable evidence that collecting blood lactate at 1 min post-exercise for

these tests in female adolescent soccer players is quite adequate in ensuring correct values are collected. The results are also inline with past research that has found aerobically fit individuals to attain peak lactate levels sooner post-exercise with passive or active recovery (Tomlin & Wenger, 2001). The advantages of measuring blood lactate only once post-exercise is that it is less invasive for the participants and more cost effective for both researchers and coaches.

### **YYIRL1 Performance**

The average YYIRL1 distance achieved was  $933 \pm 235$  m, which corresponds to an average test score of  $15.5 \pm 0.7$ . The participants in the current study performed better than female adolescent players (Kirkendall & O'Malley, 2002; Mujika et al., 2009), but lower than university aged female players (Kirkendall & O'Malley, 2002; Krustup, Mohr, Ellingsgaard, & Bangsbo, 2005; Mujika et al., 2009) (Table 8). As there are a limited number of studies with this population, it is difficult to set a standard for what scores are considered norms or acceptable values for this age group or level of play. Most of the participants in the study competed on junior select or premier women's teams in the area indicating level of play was high. As well, as previously mentioned,  $VO_2$  max values were similar to university aged female soccer players suggesting the participants in the current study had a good level of aerobic fitness and that average YYIRL1 performance achieved reflects a certain standard required for this age group playing at an elite level.

Performance on the YYIRL1 is often used as a means of comparing level/standard of play between athlete groups (Mohr et al., 2003; Mujika et al., 2009; Rampinini et al.,

2010; Veale, Pearce, & Carlson, 2010) and positions on a team (Krustrup et al., 2003; Mohr et al., 2003). As well, the test has been used to track changes during all or part of the competitive season (Krustrup et al., 2003; Weston, Helsen, MacMahon, & Kirkendall, 2004) and evaluate the effects of a training program (Ferrari Bravo et al., 2008; Hill-Haas et al., 2009; Krustrup & Bangsbo, 2001).

Table 8

*YYIRL1 Performance in Female Adolescent and Adult Soccer Players*

<b>Study</b>	<b>Standard</b>	<b>Country</b>	<b>Age Mean (SD)</b>	<b>YYIRL1 (m) Mean (SD)</b>
<i>Present Study</i>	<i>Select/Elite</i>	<i>Canada</i>	<i>16.3 (.7)</i>	<i>933 (235)</i>
<b>Adolescent</b>				
Kirkendall et al. (2002)	Club team	USA	U16	625
Kirkendall et al. (2002)	Club team	USA	U18	585
Mujika et al. (2009)	Elite	Spain	17.3 (1.6)	826 (160)
<b>Adult</b>				
Kirkendall et al. (2002)	National team	USA	university aged	1216 - 1374
Krustrup et al. (2005)	Elite	Denmark	24	1379
Mujika et al. (2009)	Elite	Spain	23.1 (2.9)	1224 (255)

**Relationship of Anaerobic Variables to Fitness Tests****i. Anaerobic Capacity**

The AST was used to assess the anaerobic capacity of the participants. In terms of assessing anaerobic capacity, there is no gold standard (Davison, Van Someren, & Jones, 2009; Stølen et al., 2005). The AST has been shown to be reliable in a group of male and female college aged soccer players and was appropriate for this study due to its specificity to soccer (Thomas et al., 2002). Mean performance on the AST in the current study ( $34.21 \pm 8.96$  s) is comparable to performance seen in female college players of  $34.1 \pm 7.9$  s (Rhodes & Mosher, 1992) and  $28.8 \pm 6.6$  s (Thomas et al., 2002). Similarly,

in a group of recreational adult females the mean was  $28.5 \pm 2.2$  s (Lebrun, McKenzie, Prior, & Taunton, 1995).

AST was significantly correlated to Relative Peak Power (W/kg). As well, AST was significantly correlated to peak blood lactate post-exercise, which indicates that participants with greater performance had higher lactate values post-exercise. This supports the use of the AST to represent anaerobic metabolism, particularly anaerobic capacity, of the participants. AST was also significantly correlated to the YYIRL1, which highlights the importance of anaerobic capacity as a variable contributing to YYIRL1 performance and further supports the inclusion of AST as a measure of anaerobic capacity.

## **ii. Anaerobic Power**

Counter Movement Jump (CMJ) was tested to assess the anaerobic power of the participants and whether this variable would contribute to YYIRL1 performance. Due to the nature of the test, it was thought anaerobic power would be a factor as at the end of the first 20m shuttle, participants must use eccentric force to slow down quickly and concentric force to overcome body inertia during the push off to accelerate and reach the desired speed (Aziz, Tan, & Teh, 2005). As well after each 2 x 20 m shuttles, the participants must accelerate from a stand still. No significant correlations were shown between YYIRL1 and Force (N) or Relative Peak Power (W/kg). However, the YYIRL1 was significantly correlated to Peak Power (W) and Jump Height (CMJ Ht) (cm).

Mean CMJ Ht in the study was  $35.56 \pm 4.96$  cm. Comparable results have been found in adolescent female soccer players of  $33.10 \pm 2.7$  cm (Mujika et al., 2009) and

37.65 ± 4.77 cm (Siegler, Gaskill, & Ruby, 2003). A study comparing vertical jump in different female age groups found averages of 37.4 ± 4.8 cm in 12 - 13 year olds, 38.7 ± 5.0 cm in 14 - 17 year olds, and 42.0 ± 5.0 cm in 18 - 21 year olds (Vescovi et al., 2010). For adult female soccer players, results have ranged from 26.2 ± 0.9 cm to 39 ± 3.32 cm (Andersson et al., 2008; Can, Yilmaz, & Erden, 2004; Krstrup et al., 2010; Mujika et al., 2009; Polman, Walsh, Bloomfield, & Nesti, 2004; Sedano Campo et al., 2009). The results of the current study are comparable to previous research, however, it is difficult to make direct comparisons as studies have used a variety of instruments, methods and equations to calculate jump height. For example, in the current study, CMJ was measured with arm swing compared to some other studies where participants maintained their hands on their hips. Slinde, Suber, Suber, Edwén, & Svantesson (2008) observed that CMJ without arm swing resulted in significantly lower jump height in university-aged men and women than with arm swing.

Similar to the present findings, Mujika et al. (2009) reported a significant correlation between YYIRL1 and Jump Height (cm) ( $r = .63$ ) in a group of junior and senior female soccer players. However, this relationship was not seen in male junior and senior players within the same study even though there was a significant difference in YYIRL1 performance between the two groups of males. Castagna et al. (2006) observed in a group of amateur adult male soccer players that YYIRL1 and Relative CMJ Peak Power scaled ( $W \cdot kg^{-0.67}$ ) were significantly correlated, however, the relationship between YYIRL1 and CMJ Height (cm) was not significant. The study did show a moderate correlation of  $r = .50$ ,  $p < .05$  between the variables, but it was deemed not significant as in contrast to most studies a Bonferroni correction was used reducing significance to

$p < 0.003$ .

The relationship between vertical jump and match related soccer activity is inconclusive. Krustup et al. (2010) observed peak sprint time during a 3 x 30 m sprint to be significantly correlated with vertical jump (cm) ( $r = .60$ ) in a group of adult female soccer players. Wisløff, Castagna, Helgerud, Jones, & Hoff (2004) also found a significant correlation between CMJ Ht and 10 m and 30 m sprint time ( $r = .72$  &  $.60$ ). In contrast, Rampinini et al. (2007) found no correlation between vertical jump height and match related physical performance variables (e.g., total distance, high-intensity running, and sprinting) and vertical jump did not discriminate players with different physical match performance abilities.

In regards to positions on a team, Sporis, Jukic, Ostojic, & Milanovic (2009) observed that CMJ Ht was not able to discriminate between professional male soccer players. Gil, Gil, Ruiz, Irazusta, & Irazusta (2007) reported in a group of non elite male soccer players aged 14 - 21 that CMJ Ht was significantly higher in forwards compared to midfielders, however, there was no difference between forwards and defenders and defenders and midfielders.

The current study found Peak Power and CMJ Ht to be significantly related to YYIRL1 performance, however, no significant correlations were observed between Leger performance and Peak Power or CMJ Ht (cm). This could be related to the design of the YYIRL1, as after each 2 x 20 m (40 m) participants must accelerate to the desired speed from a standstill, compared to the Leger, which is continuous.

## **Relationship of Aerobic Variables to Fitness Tests**

### **i. Aerobic Capacity**

In this study, ventilatory threshold (VT) was determined from the MGXT and used to represent aerobic capacity. Aerobic capacity is defined as the ability to sustain an exercise intensity for a prolonged period of time (Reilly et al., 2000). Often in order to assess players on a team, coaches will use  $\text{VO}_2$  max to monitor changes in maximal aerobic power; however, this may not be a sensitive measure. Research has found aerobic training to show an increase in exercise intensity that is related to changes in VT without an increase in  $\text{VO}_2$  max (Edwards, Clark, & Macfadyen, 2003).

The present findings showed a significant, but low correlation between YYIRL1 and VT. Conversely, no significant relationship was observed between Leger and VT. Only two other studies have examined the relationship between YYIRL1 and VT. Castagna, Impellizzeri, Chamari, Carlomagno, & Rampinini (2006) observed no significant relationship between VT and YYIRL1; however, they did observe a significant correlation between YYIRL1 and speed at VT in a group of adult male soccer players. The results of the current study also found for both YYIRL1 and Leger a significant correlation between speed ( $\text{km}\cdot\text{h}^{-1}$ ) at VT and test performance. However, in a group of adolescent male basketball players, no significant correlation was found between YYIRL1 and speed at VT (Castagna et al., 2008). They did show a significant inverse relationship between %VT and YYIRL1 (Castagna et al., 2008), however, the present study did not confirm this finding.

No comparable studies could be found that examined the relationship of performance on the Leger or any other valid 20MSR with VT. However, if our definition

of aerobic capacity is the ability to sustain exercise intensity for a prolonged period, the design of the Leger may not be structured to measure this variable as the speed increases every minute. Conversely, the design of the YYIRL1 could be a reason to explain the significant correlation between YYIRL1 and VT. Once a participant reaches level 14, the speed is only increased every 8 shuttles (2 x 20 m) requiring the participants to maintain the exercise intensity for longer than on the Leger. To fully understand if there is a relationship between YYIRL1 and VT, further studies are required.

## **ii. Maximal Aerobic Power**

### **a) YYIRL1 and VO<sub>2</sub> max**

A significant and moderate correlation between YYIRL1 and VO<sub>2</sub> max was found in the current study. Similarly, a correlation of  $r = .55$  was found in Danish female soccer players (Krustrup et al., 2005). As well, in a group of female soccer players a correlation of  $r = .58$  was found between VO<sub>2</sub> max and the Yo-Yo Intermittent Endurance level 2 test (YYIEL2) (Krustrup et al., 2010). The YYIEL2 is similar to YYIRL1, but has 5 s of rest instead of 10 s and starts at a speed of  $11.5 \text{ km}\cdot\text{h}^{-1}$ . A significant and strong correlation ( $r = .70 - .77$ ) has been demonstrated between YYIRL1 and VO<sub>2</sub> max (Bangsbo et al., 2008; Castagna et al., 2008; Krustrup et al., 2003; Rampinini et al., 2010). In a group of adult male recreational athletes the relationship was shown to be even greater at  $r = .87$  (Thomas et al., 2006). This suggests that maximal aerobic power is an important component influencing performance on the YYIRL1.

The lower correlation seen in the present study could be due to the small sample size and the homogeneity of the participants. For example, studies that found larger

correlations in recreationally active males also showed larger variation in YYIRL1 and VO<sub>2</sub> max values (Krustrup et al., 2003; Thomas et al., 2006). As only one other study by Krustrup et al. (2005) has compared YYIRL1 and VO<sub>2</sub> max in female soccer players, the relationship can not be fully explained. In a group of recreationally active females with lower VO<sub>2</sub> max values ( $40 \pm 4.3 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ), YYIRL1 results were similar to the present findings ( $958 \pm 368 \text{ m}$ ) (Sirotic & Coutts, 2007). This supports the suggestion that other components contribute to YYIRL1 test performance as individuals with large variability in VO<sub>2</sub> max can have similar performance on the YYIRL1.

#### **b) Leger and VO<sub>2</sub> max**

To test the aerobic fitness of their players, coaches often use the Leger test. A significant correlation was observed in the current study between Leger and VO<sub>2</sub> max. Estimated VO<sub>2</sub> max values can be calculated from test scores using predication equations developed by Léger and colleagues (Léger et al., 1988; Léger & Gadoury, 1989) and for the current study, VO<sub>2</sub> max was calculated using the equation developed by Léger et al. (1988). The relationship between estimated and direct VO<sub>2</sub> max values was  $r = .63$ , which is lower but similar to the original correlation of .71 between estimated and direct VO<sub>2</sub> max values for males and females aged 8 - 19 (Léger et al., 1988).

Numerous studies have examined the relationship between estimated VO<sub>2</sub> max, from the Leger equation, and direct VO<sub>2</sub> max. In youth male and females (aged 12 - 19), correlations of .59 to .90 have been found (Ruiz et al., 2008; Ruiz et al., 2009; Williford, Scharff-Olson, Duey, Pugh, & Barksdale, 1999). Adult populations have shown correlations of .61 to .88 (Kilding, Aziz, & Teh, 2006; Penry, Wilcox, & Yun, 2011; St

Clair Gibson, Broomhead, Lambert, & Hawley, 1998; Stickland et al., 2003). As well, two studies of adolescent male soccer players observed correlations of .67 (Fairbrother, Jones, & Hitchen, 2005) and .78 (Williford et al., 1999). A paired t-test was run to compare the differences in  $\text{VO}_2$  max between estimated and direct values. A significant difference between the two sets of values was found with the prediction equation under estimating  $\text{VO}_2$  max on average by 5% or  $2.81 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ . This is in line with other studies which have also shown the Leger equation to underestimate  $\text{VO}_2$  max values in both adolescent and adult populations (Fairbrother et al., 2005; Kilding et al., 2006; Penry et al., 2011; Ruiz et al., 2008; Ruiz et al., 2009; St Clair Gibson et al., 1998; Stickland et al., 2003).

A reason for this underestimation may be due to the techniques that were used to measure  $\text{VO}_2$  max directly (Ruiz et al., 2009; Stickland et al., 2003).  $\text{VO}_2$  max was measured with backward extrapolation (Léger et al., 1988), which is only able to estimate actual  $\text{VO}_2$  max and a plateau in  $\text{VO}_2$  cannot be obtained (Ruiz et al., 2009). As well, the Douglas bag method was used at the end of the shuttle run test to estimate  $\text{VO}_2$  max (Léger et al., 1988). This allows only one  $\text{VO}_2$  value to be collected and therefore is not as sensitive a method as using a metabolic cart (Stickland et al., 2003). Lastly, it is also suggested that the sample size used by Léger et al. (1988) was not large enough to conclude that one formula has the ability to predict  $\text{VO}_2$  max for both men and women (Stickland et al., 2003). Stickland et al. (2003) observed, in university aged male and female recreational athletes, an interaction effect for gender and test using the two predication equations reported by Léger (Léger et al., 1988; Léger & Gadoury, 1989). Estimated  $\text{VO}_2$  max was significantly lower than direct  $\text{VO}_2$  max for both males and

females. In addition, the difference between estimated and direct VO<sub>2</sub> max was greater in the men than women.

### **Contribution of Metabolic Components to YYIRL1 and Leger**

In line with the current findings, research has shown similar correlations with Leger and VO<sub>2</sub> max compared to YYIRL1 and VO<sub>2</sub> max. This suggests that both the YYIRL1 and Leger represent VO<sub>2</sub> max to the same extent and is supported by the results of the regression equation that was run with the measured metabolic components in relation to YYIRL1 or Leger performance.

VO<sub>2</sub> max was the only significant predictor of YYIRL1 performance with a  $R^2 = .35$ . This represents that VO<sub>2</sub> max explains only 35% of the variance in test performance and indicates that other factors not explained or tested also play a role. AST was significantly correlated with YYIRL1, however, compared to VO<sub>2</sub> max the relationship was not strong enough to contribute to the prediction of YYIRL1. The  $\beta$  of AST was .329, suggesting that if the sample size was larger AST may have contributed to the prediction equation along with VO<sub>2</sub> max. AST was entered, as the lone variable, into a regression equation to predict YYIRL1 and it was significant with a  $R^2 = .27$ .

Similar to the YYIRL1, VO<sub>2</sub> max was the only significant predictor of Leger performance with a  $R^2 = .36$ . When AST was entered, as the lone variable, into a regression equation to predict Leger no equation was developed. As mentioned previously, these results suggest that VO<sub>2</sub> max contributes almost equally to performance in both tests and that anaerobic capacity may play a larger role in YYIRL1 test performance than Leger.

### **Relationship of the YYIRL1 and Leger**

The Leger is often used by coaches to assess a team's aerobic fitness although it was not initially designed for use with soccer players. The YYIRL1 was designed to be more specific to the intermittent nature of soccer play compared to the Leger due to the inclusion of 10 s of rest between each 2 x 20 m shuttles and a higher starting speed (Krustrup et al., 2003). The results of the current study suggest that the YYIRL1 and Leger are both able to represent aerobic and anaerobic variables as measured in relation to performance. This is highlighted by the significant and high correlation shown between the YYIRL1 and Leger. Castagna, Manzi et al. (2010) observed the relationship between a 20MSR and YYIRL1 to be .89 in male adolescent soccer players. Similar correlations were seen in adolescent male cricket players ( $r = .86$ ) and adult female field hockey players ( $r = .84$ ) (Thomas et al., 2006).

Compared to the Leger, the YYIRL1 has not been found to estimate  $VO_2$  max values (Bangsbo et al., 2008), which has been seen as an important value in assessing aerobic fitness. Although, as previously mentioned, numerous studies have demonstrated in adolescent and adult populations that  $VO_2$  max is often underestimated (Fairbrother et al., 2005; Kilding et al., 2006; Penry et al., 2011; Ruiz et al., 2008; Ruiz et al., 2009; St Clair Gibson et al., 1998; Stickland et al., 2003). Therefore, the novelty/benefit of coaches determining this value may not be useful and due to the error surrounding these predications, it is often suggested that results should be expressed as a score instead of estimated  $VO_2$  max values (Stølen et al., 2005).

The suggested validity of using the YYIRL1 has been its relationship with high-intensity running during a match. If parameters measured during an actual competitive

setting can be directly compared to performance on a fitness test, direct validity can be determined (Boddington, Lambert, & Waldeck, 2004). Observations of female soccer players during game play show approximately 7.2% of a match is spent in high-intensity running and sprinting (Mohr, Krstrup, Andersson, Kirkendall, & Bangsbo, 2008). Although this is a small percentage of the total match, when players are directly involved in “the play” this may constitute the crucial moments of the game such as winning possession of the ball or scoring a goal (Reilly et al., 2000). Mohr et al. (2008) also demonstrated that professional female soccer players (i.e., playing in the U.S. top league) compared to elite players from Denmark and Swedish ran significantly longer at high-intensities and sprinted more often. This suggested that the higher the standard of women’s soccer the more high-intensity running was required to perform successfully.

Castagna, Manzi et al. (2010) found in a group of adolescent male soccer players that correlations between match activities (e.g., high-intensity running and sprinting) and YYIRL1 ( $r = .65$  &  $.76$ ) or a 20MSR ( $r = .70$  &  $.72$ ) were similar. Through motion analysis, it has also been shown that  $VO_2$  max is significantly correlated to high-intensity running during a match in male ( $r = .45$ ) (Impellizzeri et al., 2006) and female soccer players ( $r = .81$ ) (Krustrup et al., 2005). Although, this was not supported by Krustrup et al. (2003) or Bangsbo & Lindquist (1992) who reported no significant correlation between these two variables in professional male soccer players.

Significant correlations of  $.77$  and  $.71$  between YYIRL1 and high-intensity running during a match, in both adolescent (Castagna et al., 2009) and adult male soccer players (Krustrup et al., 2003), have been reported. Similarly, in female soccer players the relationship was found to be  $.76$  (Krustrup et al., 2005). Mohr et al. (2003)

demonstrated that top-class/professional male soccer players (i.e., playing on an elite European team), who performed significantly better on the YYIRL1, also completed more high-intensity running and sprinting during a match than professional male soccer players of moderate ability (i.e., playing for top Danish league).

These studies suggest that both the YYIRL1 and Leger are related to high-intensity running during match play. Due to these findings, along with the results of the current study, it is suggested that the YYIRL1 and Leger may be interchangeable in regards to assessing female adolescent soccer players (Castagna, Manzi et al., 2010).

### **Advantages of the YYIRL1**

Although it is suggested that the YYIRL1 and Leger may be interchangeable, an argument can be made for the preferential use of the YYIRL1 with high performance soccer populations, including adolescent females. The first advantage of using the YYIRL1 with adolescent soccer players is the time required to complete the test. In a group of adolescent male soccer players, with similar YYIRL1 scores to the current study, the average length of test time was 6 minutes (Castagna, Manzi et al., 2010). As well, the present study found a significant difference between distances covered on the YYIRL1 and Leger, indicating that the YYIRL1 took less time for participants to reach exhaustion than the Leger. For coaches this is particularly appealing as practice time is often limited.

Another advantage of using the YYIRL1 is that speeds reached during the test are higher and more related to intensities required during game play. Castagna, Manzi et al. (2010) examined the movement patterns of adolescent male soccer players during match

play using GPS technology. It was observed that 15% of the total distance run during a game was spent at speeds of  $13 \text{ km}\cdot\text{h}^{-1}$  or greater (Castagna, Manzi et al., 2010). Mohr et al. (2008) found in elite female soccer players that 27.7% of the total distance run was spent at speeds  $12 \text{ km}\cdot\text{h}^{-1}$  to  $14 \text{ km}\cdot\text{h}^{-1}$  and 7.2% at speeds  $15 \text{ km}\cdot\text{h}^{-1}$  or greater.

Therefore, it is important that soccer players are able to compete at this level of intensity. During the YYIRL1, participants must perform shuttles at higher speeds for a longer period than the Leger and speeds reached during the YYIRL1 often correspond to maximal speeds reached at exhaustion in the Leger and/or higher (Castagna, Manzi et al., 2010). For example, in the present study, the average level reached on the Leger was 9, which corresponds to an end test speed of  $12.5 \text{ km}\cdot\text{h}^{-1}$ . In comparison, the average YYIRL1 score was 15.5 corresponding to an end test speed of  $15 \text{ km}\cdot\text{h}^{-1}$ .

High-intensity running and sprinting are important factors in match play.

Therefore, it would seem logical for coaches to use a test that stresses their athletes at intensities required during competitive performance. It has been suggested for younger players and those less aerobically fit that it may be more applicable to use the Leger test (Castagna, Impellizzeri, Manzi, & Ditroilo, 2010; Castagna, Manzi et al., 2010). As well, the test may be more appropriate for those athletes participating in endurance sport events that do not rely as heavily on performing intermittent high-intensity bouts of exercise. However, for most adolescent soccer players, and particularly those playing at an elite level, it would be recommended for coaches to administer the YYIRL1 for assessment.

The YYIRL1 has also been shown to discriminate changes in performance through training and, therefore, may demonstrate a high level of construct validity.

Construct validity can be established by the *known group difference method* in which test

scores are compared between groups that should perform differently (Thomas et al., 2005). For example, if a particular test is able to discriminate fitness status in different levels of athletes (i.e., recreational and elite), construct validity can be tested (Boddington et al., 2004).

Hill-Haas et al. (2009) studied the effect of generic versus small-sided game training in elite male adolescent soccer players. After 7 weeks, there was no difference in total distance covered during a 20MSR, however, there was a significant improvement in total distance covered during the YYIRL1 for both groups. As the players initially had high  $\text{VO}_2$  max in both groups ( $60.2$  and  $59.3 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ), the authors suggest that improvements in physical capacity may not be found using a 20MSR (Hill-Haas et al., 2009). Ferrari Bravo et al. (2008) compared the effects of high-intensity aerobic interval (ITG) and repeated sprint ability (RSA) training in two groups of male adolescent soccer players with similar YYIRL1 baseline performance. After 7 weeks, no significant differences were found in  $\text{VO}_2$  max values between groups, although there was a significant increase of 5.8% from baseline. However, greater increases were seen in YYIRL1 performance with the ITG group having an increase of 12.5% and the RSA group having an increase of 28.1% (Ferrari Bravo et al., 2008).

Rampinini et al. (2010) observed in two groups of male professional and amateur soccer players no significant differences in  $\text{VO}_2$  max values, however, the professional players had significantly greater YYIRL1 performance. Lastly, Krstrup & Bangsbo, (2001) reported that after a 12-week intermittent training program with male soccer referees, YYIRL1 performance significantly increased by 31% with no significant change seen in  $\text{VO}_2$  max. These studies provide evidence that the YYIRL1 is a sensitive measure

for discriminating changes in a player's ability to perform high-intensity intermittent exercise (Hill-Haas et al., 2009).

Lastly, results of the current study provide evidence that the YYIRL1 is related to both aerobic and anaerobic variables. The aerobic fitness of a player allows her to maintain performance throughout the test and may aid in recovery during the 10 s rest periods. In addition, the anaerobic fitness of a player allows her to quickly generate the power needed to perform the high-intensity shuttles at maximum performance. Therefore, a weak performance on the YYIRL1 may indicate that a player needs to strengthen both her aerobic and/or anaerobic fitness.

## **Conclusion**

Results of the current study add to and support the few published studies examining the YYIRL1 in female soccer players (Kirkendall & O'Malley, 2002; Krstrup et al., 2005; Mujika et al., 2009). The results provide further descriptive data of adolescent female soccer players including expected values on the YYIRL1 and Leger tests. The current study is the first to analyze physiological variables related to YYIRL1 performance in adolescent female soccer players. Maximal aerobic power was found to be the main predictor of performance, however, the results also provide evidence that anaerobic power and capacity are related to YYIRL1 test performance.

Although significant results were found, they may be somewhat conservative due to the small sample size and homogeneous nature of the participants used in this study. Therefore further research is needed, with a larger and more heterogeneous group of participants, to validate the results found in this study. Also, it would be beneficial to

examine YYIRL1 and/or Leger performance in relation to motion analysis during a match for adolescent females as previously studied in adolescent males (Castagna, Manzi et al., 2010). This would allow researchers to compare test performance with characteristics of match play. Over 400,000 female youth (<18 years old) were recorded as registered players in Canada in 2006 (FIFA Big Count, 2006). Therefore, it is important to continue to assess the validity of using field tests such as the YYIRL1 with this population.

Information from this type of research leads to a better understanding of test performance and provides guidance to coaches who administer and assess field test results in their player development. However, it is important to remember that even though a particular field test may be valid and reliable, none can fully determine or predict performance during game play as each sport is complex and it is difficult to isolate all possible physical parameters necessary to succeed (Svensson & Drust, 2005). Therefore, the most appropriate use of field-testing is for determining possible physiological strengths and weaknesses related to game performance in order to design training programs to improve an athlete's ability.

### **Practical Implications**

The results of the current study suggest the YYIRL1 and Leger to be interchangeable and therefore it may be redundant for coaches to administer both tests with their athletes. Advantages of using the YYIRL1 in adolescent female soccer players are suggested. These are: 1) Less testing time is required; 2) Speeds reached during the test are more representative of match play; and 3) It is a sensitive measure for

discriminating changes in fitness through training.

The results of the study also provide evidence that the YYIRL1 may be representative of a player's anaerobic ability. A significant correlation was found between YYIRL1 and the variables of Peak Power, CMJ Ht and AST. In addition, AST as a lone variable significantly contributed to the prediction of YYIRL1. By administering the YYIRL1, coaches are able to assess their athletes' maximal aerobic power, without an estimation of  $VO_2$  max, and in addition, are able to track improvements or decrements throughout a competitive season. As well, the test provides coaches with further information in regards to the ability of their players to perform high-intensity intermittent exercise at speeds similar to match play which may constitute the crucial moments of the game such as winning possession of the ball or scoring a goal (Reilly et al., 2000). Therefore, it is recommended that soccer coaches administer the Yo-Yo Intermittent Recovery Level 1 test (YYIRL1) for assessment of physical characteristics in adolescent female soccer players.

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## **Appendix A**

### **Review of Literature**

#### **Soccer**

Soccer is the most popular sport in the world and is played in 208 associations affiliated with the International Federation of Association Football (FIFA) ([www.fifa.com](http://www.fifa.com)). Through motion analysis it has been determined that elite adult male players cover 10-12 km over a 90 min match (Stølen et al., 2005). Similarly, a study of 14 Danish elite female soccer players found an average distance of 10.3 km covered during a match (Krustrup et al., 2005). Distance covered during a match represents a measure of the work rate averaged over the 90 min which includes various categories of movement such as: walking, jogging, high-intensity running, sprinting, jumping, tackling, moving backwards or sideways (Reilly, 2007). In professional European male soccer players, it was found that players walked for 41.8%, of the game, jogged 29.9%, while high-intensity running and sprinting accounted for 10.1% of the distance covered (Mohr et al., 2003). Similar percentages of 42.8%, 27.7%, and 7.2% were seen in professional female players (Mohr et al., 2008). During a typical match, it is not unusual for players to have over 1,000 breaks in activity, with changes in activity occurring about every 4 - 6s (Krustrup et al., 2005; Mohr et al., 2003; Mohr et al., 2008; Reilly, 2007). It has also been observed during a match that elite male soccer players perform 150 - 250 brief, intense actions (Mohr et al., 2003). This has also been seen in female players with a reported average of 150 (Krustrup et al., 2005).

Due to the intermittent nature of activity in a soccer match, there is a reliance on both the aerobic and anaerobic energy systems (Meckel et al., 2009). The aerobic activity during a match is related to movements 'off-the-ball' as players look to create space,

deceive opponents or follow runs by opposition players (Reilly et al., 2000). The mean relative work rate during a match is reported to be approximately 70% of  $\text{VO}_2$  max (Bangsbo, 1994).  $\text{VO}_2$  max for elite male soccer players has been reported as being 56 – 69  $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  (Bangsbo & Lindquist, 1992; Reilly et al., 2000; Stroyer, Hansen, & Klausen, 2004). For females it has been shown to be between 39 – 58  $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  (Krustrup et al., 2005; Stølen et al., 2005). These maximal aerobic power values are relatively low compared to other endurance type athletes such as male elite runners who have been reported to have  $\text{VO}_2$  max scores in the range of 70 – 80  $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  (Saltin & Astrand, 1967).

A significant but moderate correlation between  $\text{VO}_2$  max and total distance covered in a match has been found in professional male soccer players ( $r = .52$  &  $.64$ ) (Bangsbo & Lindquist, 1992; Krustrup et al., 2003) and adolescent male soccer players ( $r = .55$ ) (Impellizzeri et al., 2006). However, Krustrup et al. (2005) found there was no significant relationship between  $\text{VO}_2$  max and distance covered in a group of female soccer players. Although Bangsbo & Lindquist (1992) & Krustrup et al. (2003) found significant correlations between  $\text{VO}_2$  max and distance covered during a match, there was no significant correlation between  $\text{VO}_2$  max and high-intensity distance covered during a match ( $r = .40$  &  $r = .38$ ). There was a significant relationship between  $\text{VO}_2$  max and high-intensity distance found in junior male players, however, the correlation was only moderate ( $r = .45$ ) (Impellizzeri et al., 2006). Despite a positive relationship with distance covered in a match,  $\text{VO}_2$  max (aerobic power) may not be a truly sensitive measure of soccer performance (Svensson & Drust, 2005). This may be due to differences in factors such as: the variable activity patterns required during a soccer match (Svensson & Drust,

2005); the impact of player position on distance covered (Mohr et al., 2003); and the possibility that exercise intensity may be higher during a match than that achieved during a VO<sub>2</sub> max test (Bangsbo, 1994).

On average during a match, sprinting takes place approximately every 90s and lasts 2 – 4s (Hoff & Helgerud, 2004). A player's ability to perform high-intensity running and sprinting is reliant on anaerobic or alactic energy sources to produce maximum power (Hoff & Helgerud, 2004). This is especially important when players are directly involved in the play during a match as this activity is dependent largely on anaerobic components and may also constitute the crucial moments of the game such as winning possession of the ball or scoring a goal (Reilly et al., 2000).

Overall, in order to compete at a high level, it is important for soccer players to develop both their aerobic and anaerobic systems to be able to handle the duration of a match along with the intermittent nature of game play.

## **Energy Systems**

### **i. Aerobic Capacity**

Determination of a person's ventilatory threshold (VT) allows one to understand the aerobic capacity of the individual. Aerobic capacity represents the ability to sustain an exercise intensity for a prolonged period of time (Reilly et al., 2000). This has also been defined as anaerobic threshold or the level of work, or oxygen consumption, just below which metabolic acidosis and changes in gas exchange occur (Wasserman et al., 1973). When exercising, oxygen is transported to the tissues in order to facilitate ATP production by aerobic metabolism. If the demand for oxygen from the muscles exceeds ATP production, there will be an increased rate in anaerobic glycolysis with a resulting

consequence of increased lactate production (Wasserman et al., 1973). The lactate will then be buffered by the bicarbonate system causing an increase in the amount of  $\text{CO}_2$  exhaled resulting in an increased  $\text{VCO}_2$  and consequently respiratory exchange ratio (Wasserman, Van Kessel, & Burton, 1967). It has been suggested that the more physically fit an individual is, the lower the lactate level is at a given work rate, indicating a greater aerobic capacity (Wasserman et al., 1973).

A few techniques are used to determine  $\text{VT}$ . The common technique is to examine the  $\text{V}_E$  work rate curve during an incremental exercise test (Wasserman et al., 1973).  $\text{VT}$  can also be determined from the increase in the ventilatory equivalent for  $\text{VO}_2$  ( $\text{V}_E/\text{VO}_2$ ) without  $\text{V}_E/\text{CO}_2$  increasing (Whipp, Davis, Torres, & Wasserman, 1981). Lastly,  $\text{VT}$  can be indicated by looking at the relationship between  $\text{VCO}_2$  and  $\text{VO}_2$  and may be more applicable than other methods (Beaver et al., 1986). This is because it is thought to better detect the increased  $\text{CO}_2$  production from buffering metabolic acid which addresses the central mechanism of anaerobic threshold (Beaver et al., 1986).

## **ii. Anaerobic Capacity**

Anaerobic capacity can be defined as the maximal amount of ATP formed by anaerobic metabolism during a short duration of maximal exercise (Gastin, 1994; Green, 1994). Due to the nature of intermittent high-intensity activity seen in soccer, a player's anaerobic capacity has been identified as influencing performance during a match (Stølen et al., 2005). However, it is difficult to directly determine anaerobic capacity in an accurate and reproducible way as there is no universally accepted method or "gold standard" (Davison et al., 2009; Stølen et al., 2005). This is because anaerobic ATP

production is an intracellular process with little reliance on central processes and there is no available direct mechanism for its validation (Gastin, 2001). The theory behind evaluating anaerobic capacity is dependent on research surrounding the length or capacity of the particular system to provide energy. It is generally accepted that during a maximal bout the first 10 – 15 s can be used to assess the alactic anaerobic power of an individual and during a maximal effort of 60 to 90 s the lactic anaerobic capacity can be assessed (Gastin, 2001). Although there is a distinction between the alactic and lactic systems it is thought that both systems contribute simultaneously a few seconds after the start of exercise and do not operate in isolation (Davison et al., 2009; Gastin, 1994).

One approach to evaluate anaerobic energy contribution is by analyzing exhaustive high-intensity exercise through measurement of excess post-exercise oxygen consumption, intramuscular substrate and enzyme content before and after exercise, maximal accumulated oxygen deficit and post-exercise blood lactate concentration (Davison et al., 2009). Blood lactate may give evidence of the rate of glycolysis (anaerobic metabolism), however, it cannot be used quantitatively as a measure of anaerobic capacity as it represents the balance between production, removal and oxidation of lactate prior to entering the blood (Gastin, 1994).

Ergometric assessments of mechanical work are often used to give an indirect assessment of anaerobic performance (Gastin, 1994). For example Sargent (1921) first suggested that a vertical jump test could be used as an assessment of muscular power by calculating power from estimating the time in which the work was done. Commonly used tests to measure anaerobic energy contribution include the Cunningham and Faulkner treadmill test, the Wingate anaerobic test and/or variations of these tests (Davison et al.,

2009). These tests use a constant intensity to exhaustion to test anaerobic performance, however, this type of test termination may not relate fully to the exhaustion of the anaerobic capacity, but to an inability to maintain a supramaximal power output (Gastin, 1994). For example, during a treadmill test, the inability of an individual to continue may be due to running economy at the selected speed and not exhaustion (Gastin, 1994). It may be more appropriate to continue a test until power drop off is approximately the same as aerobic levels (Gastin, 1994). It has also been suggested by Vandewalle, Peres, & Monod (1987) that high performance on an all out or constant intensity ergometric test for anaerobic capacity may be related to factors other than anaerobic metabolism such as: increased capacity for production of lactic acid, increased CP stores, increased buffer capacity of muscles and blood, increased efflux of lactate and hydrogen ions during exercise, improvement of the oxygen uptake transient &/or maximal oxygen uptake, increased myoglobin concentration, improvement of mechanical efficiency, along with motivational factors. These tests can provide a simple quantification of mechanical work, however, they are not able to isolate anaerobic energy contribution (Davison et al., 2009).

Due to the complex nature of energy metabolism there is no “gold standard” in regards to measurement and/or the ability to quantify anaerobic contribution during exercise. As well, attempts at direct measurement can be invasive and/or not readily available or feasible for most athletes. Although there are limitations to ergometric testing, if the tests are used to assess comparable performance between individuals or assess the effectiveness of manipulations within studies, then a test to exhaustion may be satisfactory, but not as a quantitative measure of anaerobic capacity (Gastin, 1994).

## **Intermittent Exercise**

Intermittent exercise is characterized by regularly repeated short duration, high-intensity bouts of activity, interspersed with longer intervals of sub-maximal activity or rest over a prolonged period of time (Sirotic & Coutts, 2007). In field team sports it has been shown that the average length of sprinting is 10 – 20 m, lasting on average 2 – 3 s and occurring approximately 20 – 60 times in a match (Spencer, Bishop, Dawson, & Goodman, 2005). An analysis of elite male soccer players showed an average mean recovery time of 72 s between very high-intensity running bouts (Bradley et al., 2009). During a single bout of brief dynamic maximal exercise it is thought that the majority of energy provided is by anaerobic pathways, leading to phosphocreatine degradation and lactate formation in order to restore ATP in the muscle (Gaitanos, Williams, Boobis, & Brooks, 1993; Hargreaves et al., 1998). The ability of an athlete to continually perform at the necessary speed or power output is dependent on an individual's ability to recover (Meckel et al., 2009). If a player is able to recover for a minute or two between sprints it is unlikely that performance will suffer, however, other movements during the game may lead to fatigue along with the unpredictable nature of the match leading to repeated sprints without recovery time (Spencer et al., 2005). If this occurs, the magnitude of energy demand must be reduced, thereby reducing the intensity of the activity. Using motion analysis, it has been demonstrated that during a soccer match there is a significant decrease in high-intensity running (Krustrup et al., 2005), distance covered, and sprinting between the first and second halves along with the last 15 minutes of each half (Mohr et al., 2003; Mohr et al., 2008).

It is suggested that, due to a decrease in the rate of ATP production by anaerobic processes over a series of sprints, there is a significant shift to aerobic metabolism in the latter stages (Gaitanos et al., 1993; Gatin, 2001). Balsom, Ekblom, & Sjodin (1994) found in a group of healthy male physical education students with increased haemoglobin concentration, due to administration of rhEPO, that following an intermittent exercise protocol the accumulation of plasma hypoxanthine was significantly lower after rhEPO administration. This suggested that differences in plasma hypoxanthine were related to a reduction in ATP resynthesis via the adenylate kinase reaction and anaerobic glycolysis and greater contribution to energy production from aerobic metabolism. This is because plasma hypoxanthine is thought to be a marker of adenine nucleotide degradation which allows the continuation of muscle activity during intense exercise (Balsom, Seger, Sjödin, & Ekblom, 1992). As well, a higher rate of PCr resynthesis was seen in the study which may have occurred during the recovery period due to the increase in oxygen availability to the muscle from the administration of rhEPO (Balsom et al., 1994).

Creatine phosphate (CP) availability is an important factor in high-intensity exercise performance. During repeated sprints, contribution of CP for ATP production is dependent on the amount that is replenished during recovery periods (Glaister, 2005). It has been shown by examining CP recovery kinetics in ischaemic conditions that resynthesis of CP is through aerobic ATP resynthesis (Glaister, 2005), however, during high-intensity exercise the amount of aerobic ATP production is not able to meet the overall energy demand which causes a decline in power output. Hargreaves et al. (1998) found that after two 30s all out sprints with 4 min passive recovery between each, CP

level before the 3<sup>rd</sup> sprint was significantly lower than before the 1<sup>st</sup> sprint and resulted in a significantly lower peak power output in the third sprint. It was also found that high-intensity intermittent exercise resulted in a decrease of muscle ATP, CP and glycogen with accompanying increases in lactate, H<sup>+</sup>, and ATP degradation products (Hargreaves et al., 1998).

Although a decline in power output is inevitable after repeated sprints or high-intensity intermittent exercise, research suggests that soccer athletes with a greater ability to restore energy through aerobic metabolism will perform better on the field over the duration of a match. In a group of adolescent male soccer players, Meckel et al. (2009) found a significant negative correlation between peak VO<sub>2</sub> max and performance decrement on a short repeated sprint protocol (12 x 20 m every 20 s), which incorporated similar soccer-related movement patterns. A study by Impellizzeri et al. (2008) looked at the effect of aerobic interval training on the decline in short-passing ability induced by a 5 min high-intensity simulation in adolescent male soccer players. The results showed that the aerobic interval training group, over 4 weeks, showed a significant increase in VO<sub>2</sub> max compared to the control group and an attenuated increase in penalty time on the Loughborough Soccer Passing Test (LSPT) after a 5 minute high intensity simulation. Using the same passing test, Rampinini et al. (2008) found that performance on the test after a 5 min high-intensity simulation had a significant correlation with performance on the Yo-Yo Intermittent Recovery Level 1 (YYIRL1) in a group of male junior soccer players. Players who performed better on the YYIRL1 also performed better on the LSPT. Results from Helgerud, Engen, Wisløff, & Hoff (2001) showed, in a group of junior male soccer players, that with a significant increase in VO<sub>2</sub> max there was also a

significant increase in number of sprints, involvement with the ball, and distance covered during a match. As well through motion analysis it has been shown that  $\text{VO}_2$  max is significantly correlated to high-intensity running during a match in male ( $r = .45$ ) (Impellizzeri et al., 2006) and female soccer players ( $r = .81$ ) (Krustrup et al., 2005).

In conclusion, research supports the theory that during intermittent activity, ATP generation is dependent on PCr stores and during recovery it is predominantly through aerobic processes (Glaister, 2005). A high level of aerobic fitness aids in both PCr resynthesis and intracellular  $\text{P}_i$  removal (via ADP phosphorylation) and increases an athlete's ability to maintain power output during intermittent activity (Glaister, 2005).

### **Field Tests & Validity**

Field tests are often used as an alternative method, in place of laboratory tests, for measuring physiological and performance components of team sport athletes (Castagna et al., 2006). Often, field tests are more feasible and practical to assess team sport athletes due to cost, required equipment, expertise needed for a laboratory test (Impellizzeri, Rampinini, & Marcora, 2005) and the convenience to be used in a typical training environment. The use of field tests enhance the specificity of evaluation and can increase the validity of a particular test (Svensson & Drust, 2005). The general assumption when using a field test is that a relationship exists between changes in performance on a particular test and performance in a competitive setting, whether positive or negative (Reilly, 2007).

In the initial development of field tests, validity is often based on intrinsic characteristics (logical validity). This is predicated on the assumption that the primary

fitness components linked to performance are known and that a particular field test measures these components (Boddington et al., 2004). However, before a test can be considered valid it must be able to demonstrate reliability. This means that repeated measures of a test are reproducible under the same conditions (Morrow, Jackson, Disch, & Mood, 2005). This is often assessed by comparing the results of two separate trials within a short period of time. Reliability of a test can be influenced by a number of factors including: fatigue, practice, subject variability, time between testing, precision of measurement, and environmental conditions (Morrow et al., 2005).

A test is considered valid if, after numerous studies, evidence is found in regards to logical, construct and criterion related validity. Logical validity, also called content-related or face validity, is based on evidence that supports truthfulness of the test from logical decision-making and interpretation (Morrow et al., 2005). If a test does not have logical validity, it fails to measure the components or parameters of the attribute being measured (Currell & Jeukendrup, 2008; Docherty, 1996). If parameters measured during an actual competitive setting can be directly compared to performance on a fitness test, direct validity can be determined (Boddington et al., 2004).

Another way to determine the validity of a test is to determine if there is a relationship between an already determined criterion measure and test scores. For example, criterion-related validity is used when a researcher wants to determine if, for example, a sub-maximal test can estimate  $\text{VO}_2$  max by comparing predicted values to laboratory values (Morrow et al., 2005). Criterion validity can be further broken down into concurrent and predictive validity. Concurrent validity indicates that the criterion is measured at the same approximate time as the alternative measure and indicates that the

performance protocol is correlated with a criterion measure (Currell & Jeukendrup, 2008; Morrow et al., 2005). For example when used in measuring skin folds or  $\text{VO}_2$  max. Predictive validity in regards to fitness testing is an extension of concurrent validity with criterion performance predicted from performance on a substitute test (Docherty, 1996; Thomas et al., 2005). In order to determine concurrent or predictive validity it is necessary to use a correlation coefficient to assess the relationship between the criterion and test (Docherty, 1996; Thomas et al., 2005).

Lastly, construct validity is often used to validate measures that are unobservable yet exist in theory such as a person's IQ or measure of attitude (Morrow et al., 2005). It is often determined by relating test scores to a certain behaviour and indicates to what degree the score can measure a hypothetical construct (Thomas et al., 2005). Another way to establish construct validity is referred to as the *known group difference method* in which test scores are compared between groups that should perform differently (Thomas et al., 2005). For example, if a particular test is able to discriminate fitness status in different levels of athletes (i.e., recreational and elite), construct validity can be tested (Boddington et al., 2004).

Although a particular field test may be found to be valid and reliable, none can fully determine or predict performance during game play as each sport is complex and it is difficult to isolate all possible physical parameters necessary to succeed (Svensson & Drust, 2005). The most appropriate use of field-testing is for determining possible physiological strengths and weaknesses related to game performance in order to design training programs to improve an athlete's ability.

## **Yo-Yo Intermittent Recovery Field Tests**

Although Dr. Jens Bangsbo designed the Yo-Yo field tests approximately 15 years ago, it is only in the last 10 years that peer reviewed research articles have been published to provide evidence of the reliability and validity of these tests (Bangsbo et al., 2008). In total, there are three different protocols, each comprised of two levels, that fall under the umbrella of “Yo-Yo” tests: (1) Yo-Yo Endurance test (YYE), (2) Yo-Yo Intermittent Endurance test (YYIE), & (3) Yo-Yo Intermittent Recovery test (YYIR). The running part of these tests is similar to the Multistage 20m Shuttle run (Leger), where participants run back and forth completing 20 m shuttles to the sound of audio cues on a cd player (Léger & Lambert, 1982). However, the YYIE and YYIR tests incorporate a rest period of 5 or 10 s after 2 x 20 m shuttles and the YYIR starts at a higher speed to mimic the intermittent nature of activity during a soccer match. Both the Yo-Yo intermittent endurance and intermittent recovery tests have been used by professional soccer teams in European countries (Reilly, 2007). The Yo-Yo intermittent recovery test (Level 1 and 2) has also been used by the US Soccer Association and is currently promoted by SPARQ (affiliated with Nike) for the training and testing of soccer players (Kirkendall & O'Malley, 2002); [www.nike.com](http://www.nike.com)).

The most often researched and tested protocol of the Yo-Yo tests is the Yo-Yo Intermittent Recovery (YYIR) test which incorporates periods of 10 s active recovery after 2 x 20 m shuttles (40 m) (Krustrup et al., 2003). The intent of the YYIR test is to determine the ability of a player to recover from intense, short bursts of exercise, which is consistent with the type of activity typical of soccer match play (Reilly et al., 2000). Level 1 of the YYIR test starts at  $10 \text{ km}\cdot\text{h}^{-1}$  and Level 2 starts at  $13 \text{ km}\cdot\text{h}^{-1}$ . It is suggested

that YYIR Level 1 demonstrates the ability of a player to carry out intermittent exercise leading to maximal activation of the aerobic system and that performance on Level 2 of the test determines the capacity to recover from repeated exercise with a high contribution from the anaerobic system (Bangsbo et al., 2008).

The YYIR test is the most commonly cited and used Yo-Yo test for research and analysis of soccer players (Bangsbo et al., 2008; Castagna et al., 2006; Krustup et al., 2003; Krustup et al., 2005; Rampinini et al., 2010; Sirotic & Coutts, 2007). In terms of assessing validity and reliability, most studies have examined the YYIR Level 1 test (YYIRL1) (Bangsbo et al., 2008; Krustup et al., 2003), although studies of Level 2 have been reported (Krustup et al., 2006; Rampinini et al., 2010). In a study of 13 adult males, the test-retest reproducibility for the YYIRL1 test after one week was found to be 0.98 with a coefficient of variance (CV) value of 4.9% (Krustup et al., 2003). Thomas et al. (2006) also showed that in a group of recreational adult males the test-retest reliability for YYIRL1 was ICC = .95. In a group of junior male soccer players (n=18) results showed a significant ICC of 0.98 with a CV of 3.5% (Castagna et al., 2009).

Most research has studied the YYIR in soccer players, however, both levels (1 or 2) of the YYIR have also been used in basketball, Australia rules football, rugby, and handball players (Atkins, 2006; Castagna et al., 2008; Souhail, Castagna, Mohamed, Younes, & Chamari, 2010; Veale et al., 2010; Young et al., 2005).

#### **i. Validity of YYIRL1**

Research has shown the construct validity of the YYIRL1 in various populations. Top-class male soccer players (i.e., playing on an elite European team) were found to

perform better on the YYIRL1 than professional male soccer players of moderate ability (i.e., playing for top Danish league) (Mohr et al., 2003). Similar results were also found in a study by Rampinini et al. (2010) comparing groups of male professional and amateur players. It has been demonstrated in adolescent male rugby players that elite players performed significantly better on the YYIRL1 compared to sub-elite and non-athletic groups (Veale et al., 2010). Comparing males and females, a study by Mujika et al. (2009) found that Senior Men and Women professional soccer players performed significantly better on the YYIR Level 1 test compared to their junior counterparts. As well, both Senior Men and Junior Men performed significantly better than the Senior Women and Junior Women.

In addition, research has shown the YYIRL1 is able to distinguish between positions on a team. This is important as research has shown differences in total distance and high-intensity running covered between player positions during a match. Bradley et al. (2009) reported, within male soccer players in the English Premier League, total distance during a match was greatest for wide and central midfielders than full-backs, attackers and central defenders. Di Salvo, Gregson, Atkinson, Tordoff, & Drust (2009) observed, with male soccer players in the English Premier League, that total high-intensity running and total sprint distance were influenced by playing position. Wide midfielders completed the highest amount of high-intensity running and sprinting and central defenders completed the least (Di Salvo et al., 2009). Mohr et al. (2008) reported no difference in total distance covered between playing positions in female soccer players, however, this could be due to the smaller sample size compared to the other studies. Although, the researchers did observe defenders to have less high-intensity

running during a match than midfield and attackers, with no difference found between midfielders and attackers. Similarly, Andersson, Randers, Heiner-Moller, Krstrup, & Mohr (2010) found, in female soccer players during international matches, that defenders completed less high-intensity running and less total distance than midfielders.

In relation to YYIRL1, it was observed that midfield players and full backs had significantly better performance on the YYIRL1 compared to attackers and defenders (Mohr et al., 2003). Similarly, Krstrup et al. (2003) found that when examining YYIRL1 performance in 37 male elite soccer players, fullbacks had significantly higher scores than central defenders and attackers. In regards to female soccer players, no published study to date has examined differences in player position with YYIRL1 performance.

## **ii. YYIRL1 and High-Intensity Running**

In order to demonstrate direct validity of the test in relation to game performance, test performance on the YYIRL1 has been compared to high-intensity running during a match. The amount of high-intensity running during a match has been measured through motion analysis of video tapes (Krstrup et al., 2003) and GPS technology (Castagna et al., 2009). Significant correlations of .77 and .71 between YYIRL1 and high-intensity running during a match, in both adolescent (Castagna et al., 2009) and adult male soccer players (Krstrup et al., 2003), have been reported. Similarly, in female soccer players the relationship was found to .76 (Krstrup et al., 2005). It has also been shown that the amount of high-intensity running in the last 15 minutes of each half, during a match, is significantly correlated to YYIRL1 performance (Krstrup et al., 2005; Mohr et al., 2010). In addition, Mohr et al. (2003) demonstrated that top-class/professional male

soccer players (i.e., playing on an elite European team), who performed significantly better on the YYIRL1, also completed more high-intensity running and sprinting during a match than professional male soccer players of moderate ability (i.e., playing for top Danish league).

Performance on the YYIRL1 has also been shown to relate to other high-intensity simulations/drills. The YYIRL1 was performed in 16 junior male soccer players along with a 5 minute high-intensity simulation (Rampinini et al., 2008). It was found that the decrement in short-passing ability using the LSPT after the high intensity simulation was significantly correlated to YYIRL1 performance. Those players who performed better on the YYIRL1 performed better on the LSPT. As well, considering peak velocity attained on the YYIRL1 ( $V_{Y_0-Y_0}$ ) in 14 adult male amateur soccer players, time to exhaustion, on a series of repeated 90m distance runs in 15 s with 15 s of passive recovery, was significantly related with  $V_{Y_0-Y_0}$  (Dupont et al., 2010). As well, Sirotic & Coutts (2007) found a moderate significant correlation between YYIRL1 test performance and distance covered in a 30 minute prolonged high-intensity intermittent running simulation. Ferrari Bravo et al. (2008) compared two groups of junior male soccer players who completed high-intensity aerobic intervals (ITG) or repeated sprint shuttles (RSG) over a 7 week period in addition to normal training. Both groups had an increase in aerobic fitness and YYIRL1 but the RSG showed a significantly higher increase in score on the YYIRL1 after the 7 weeks than the ITG group. Overall, these studies demonstrate that performance on the YYIRL1 is related to the ability of soccer players to perform high-intensity running which is an important on field activity during a match.

### iii. YYIRL1 and VO<sub>2</sub>max

A significant and strong correlation ( $r = .70 - .77$ ) between YYIRL1 test performance and VO<sub>2</sub> max has been previously demonstrated (Bangsbo et al., 2008; Castagna et al., 2008; Krstrup et al., 2003; Rampinini et al., 2010). In a group of adult male recreational athletes, this relationship was even shown to be greater at  $r = .87$  (Thomas et al., 2006). In contrast, Castagna et al. (2006), found, in 24 adult male amateur soccer players, no significant correlation between YYIRL1 and VO<sub>2</sub> max. The study did show a moderate correlation of  $r = .46$ ,  $P < .05$  between the variables, but it was deemed not significant as in contrast to most studies a Bonferroni correction was used reducing significance to  $P < 0.003$ .

Even with a strong correlation between the two variables, large inter-individual differences have been shown between players (Bangsbo et al., 2008; Krstrup et al., 2003). For example, 4 participants with a VO<sub>2</sub> max of approximately 48 – 49 ml·kg<sup>-1</sup>·min<sup>-1</sup> had a range of YYIRL1 performance from 1560 – 2200m (Krstrup et al., 2003). Similarly, a study of 14 male adult amateur soccer players found large inter-individual differences when considering peak velocity on the YYIRL1 compared to VO<sub>2</sub> max even though a significant moderate correlation was found ( $r = 0.59$ ) (Dupont et al., 2010). It is suggested that this may be connected to the coordination and agility required by the YYIRL1 and increases in distance may be due to factors such as the ability to recover between the shuttles, anaerobic capacity, and technical aspects of the test: reaction time to the audio cue, acceleration, and changes of direction (Dupont et al., 2010). This highlights that although YYIRL1 is correlated to VO<sub>2</sub> max, there are other variables that influence YYIRL1 performance. Krstrup et al. (2003) found a significant

correlation between YYIRL1 and high-intensity running but in contrast, no correlation was found between VO<sub>2</sub> max and high-intensity running during a game (Krustrup et al., 2003). The literature suggests that although a certain level of aerobic fitness is required to complete the YYIRL1 there are other components that factor into test performance. These may include a player's aerobic capacity along with anaerobic variables of power and capacity.

#### **iv. YYIRL1 and Adolescents**

Limited research has been conducted with adolescent soccer players in regards to the YYIRL1 test. To the best of the author's knowledge only six studies have examined the YYIRL1 with male adolescents (Ferrari Bravo et al., 2008; Castagna et al., 2009; Castagna, Manzi et al., 2010; Hill-Haas et al., 2009; Mujika et al., 2009; Rampinini et al., 2008) and only one article has examined the YYIRL1 with female adolescents (Mujika et al., 2009). Differences in physical performance variables have been shown between males and females, both junior and senior players (Mujika et al., 2009). As well, differences have been observed between adolescent and adult female players (Mujika et al., 2009; Vescovi et al., 2010). Over 400,000 female youth (<18 years old) were recorded as registered players in Canada in 2006 (FIFA Big Count, 2006). Therefore, it is prudent to assess the validity of using field tests such the YYIRL1 with this population. Information provided from this type of research leads to a better understanding of test performance and also provides further guidance to coaches who administer and assess test results in their players for evaluation and development.

## Conclusion

Evidence suggests that the YYIRL1 is a valid and reliable field based testing tool to understand a soccer player's ability to perform intermittent high-intensity exercise. It has been demonstrated to be significantly related to aerobic fitness and high-intensity running performed during a match. As well, it has been observed to be a sensitive tool to discriminate between players at different levels of soccer play (i.e., amateur and professional) and positions between players (Bangsbo et al., 2008). However, most of the research has been conducted using university aged or adolescent male soccer players (Bangsbo et al., 2008; Castagna et al., 2009; Castagna, Manzi et al., 2010; Rampinini et al., 2010). Limited research has been conducted with female university aged soccer players (Krustrup et al., 2005; Mujika et al., 2009). Only two studies have reported YYIRL1 test performance in female adolescent players (Kirkendall & O'Malley, 2002; Mujika et al., 2009) and only one of the two studies compared the YYIRL1 with other fitness parameters (Mujika et al., 2009).

Physiological measures related to YYIRL1 performance have been examined (Krustrup et al., 2003; Rampinini et al., 2010), however, further studies are needed. This is due to the varying research designs and variables such as: gender, age, level of soccer ability and other tests that are used to compare with the YYIRL1. The study of physiological components that impact performance on the YYIRL1 in female adolescent soccer players is important for understanding what the test is measuring and if it is related to physical characteristics required for match play.

Specifically, understanding the relative contributions of the aerobic (i.e., power and capacity) and anaerobic (i.e., power and capacity) systems in relation to performance

on the YYIRL1 will provide information in regards to what components contribute the most to test performance. As well, it will provide information in regards to whether the YYIRL1 is more or less representative of these components and/or a more appropriate tool of measurement compared to other field tests. Lastly, this information is also invaluable to coaches who administer and assess test results in their players for evaluation and development.

## **Appendix B Consent Form**

### **Information/Consent Form- Participants and Parents**

#### **Validation and comparison of soccer related field tests in adolescent athletes**

You are invited to participate in a study entitled “Validation and comparison of soccer related field tests in adolescent athletes” (Ethics Approved Protocol #10-122) that is being conducted by Leanne Dickau, a graduate student in the department of Exercise Science, Physical and Health Education at the University of Victoria. You may contact her if you have further questions by email [ldickau@uvic.ca](mailto:ldickau@uvic.ca) or phone (250) #### – #####.

As a graduate student, she is required to conduct research as part of the requirements for a Masters degree in Kinesiology. It is being conducted under the supervision of Dr. Catherine Gaul. You may contact my supervisor at [kgaul@uvic.ca](mailto:kgaul@uvic.ca), (250) 721 – 8380 or (250) 472-5537.

#### **Purpose and Objectives**

The purpose of this research project is to evaluate the aerobic and anaerobic physiological factors that contribute to Yo-Yo Intermittent Recovery Level 1 test in adolescent athletes. The study will also examine if there are any significant differences between the Yo-Yo Intermittent Recovery Level 1 test and the more commonly used 20m Leger Shuttle Run (sometimes referred to as the “Beep Test”).

This research is important as few studies have looked at the use of the Yo-Yo Intermittent Recovery Level 1 test in adolescent soccer players even though it is one of the most regularly used soccer-related fitness tests in European and American Football (Soccer) clubs. A better understanding of the Yo-Yo test will help coaches choose their athlete assessment methods appropriately, help them interpret the test scores achieved by their players and assist in identifying player strengths and weaknesses.

#### **Participant Selection**

You are being asked to participate in this study because you are a soccer player between the ages of 14 – 17 registered on a soccer team with at least 4 years experience.

#### **What is involved**

If you agree to voluntarily participate in this research, your participation will include 4 visits to the University of Victoria for data collection within a 3-week timeline (approximately). The anticipated total time commitment is 4 to 8 hours. During the first

visit you will be given an overview of the study and a familiarization with the protocols and instruments used during the study.

Ideally, you will participate in the following tests in this order:

**Visit #1:** Sign consent forms and PAR-Q along with familiarization of study and instrumentation. A study researcher will collect your anthropometric data and you will complete the Vertical Jump Test and Cunningham Treadmill Test. Blood droplet collection will occur immediately before the Cunningham test, and then at 1, 3 and 5 minutes post test.

**Visit #2:** You will complete the Vertical Jump Test and either the YYIRL1 test or 20m Leger Shuttle Run. Blood droplet collection will occur immediately before the YYIRL1 or 20m Leger test, and then at 1, 3 and 5 minutes post test.

**Visit #3:** You will complete either the YYIRL1 or 20m Leger Shuttle Run (which ever was not completed in Visit #2). Blood droplet collection will occur immediately before the YYIRL1 or 20m Leger test, and then at 1, 3 and 5 minutes post test.

**Visit #4:** You will complete the Maximal Graded Exercise Test on the treadmill. Blood droplet collection will occur immediately before test, and then at 1, 3 and 5 minutes post test.

The 4 visits will occur over a 3-week period. The YYIRL1 test and 20m Leger Shuttle Run will be conducted in small groups of maximum 5 or 6 participants. All other fitness tests will be performed individually. At all times standard, recognized, best practice, exercise testing laboratory procedures will be followed. For each of the testing sessions conducted in this study, there will be at minimum an equal ratio of participants to research assistants.

#### Sum of 8 Skinfolds

Skinfold measurements will be taken at 8 sites on the body using Harpenden calipers. These include: triceps, biceps, shoulder blade, top of hipbone, supraspinale, abdominal, front thigh, and calf.

#### Vertical Jump

Participants will stand on a force plate and be instructed to squat and jump as high as possible with counter arm movement. Each participant will be given 3 attempts to obtain the highest jump possible with 60 – 90s rest between each trial.

### Cunningham Treadmill Test

Each participant will be given a 10 minute warm up at a moderately increasing speed followed by a 5 minute rest. After which time the treadmill will be set at 8 mph (12.9 km/h) with a 20% grade. The participant will then hold onto the handrails while stepping/running onto the treadmill. The timing of the test starts when the participant lets go of the treadmill hand rails and stops when the participant cannot keep up, or grabs the hand rails again. For greater accuracy of timing, two research assistants will time the test with stop watches and the mean of the two times will be recorded for the participant. To ensure safety of the participant a spotter will be positioned at the side of the treadmill.

### Yo-Yo Intermittent Recovery Level 1

The test will take place in the McKinnon gymnasium at the University of Victoria. A straight course of 20 meters distance will be marked on the gym floor to set the running distance. Another set of cones will be positioned 5 m past the finish line. You will be instructed to run the distance between the cones (“shuttles”) in the time allotted as determined by the audio cues on the sound system. The test starts off with 4 running shuttles at 10 – 13 km/h (0-160m), proceeded by 7 shuttles at 13.5 – 14 km/h (160-440m) after which the test continues with stepwise 0.5 km/h speed increments after every 8 shuttle runs. After each 2 x 20m shuttle (40 m), you will have a 10s period of active recovery during which you will walk/jog to the cone and back set 5 m from the finish line. The test ends when you stop due to an inability to continue or you fail twice to reach the finishing line in time to the audio cue. The test performance score is determined by the total distance covered within the shuttles completed.

### Leger 20m Shuttle Run

The test will take place in the McKinnon gymnasium at the University of Victoria. A straight course of 20 meters distance will be marked on the gym floor using a measuring tape. You will be instructed to run the distance between the cones in the time allotted as determined by the audio cues on the sound system. The test starts at a speed of 8.5 km•h<sup>-1</sup> and increases 0.5 km•h<sup>-1</sup> every minute. The test ends when you stop due to an inability to continue or you are not able to keep up with the audio signals (i.e. do not complete the 20 m distance) two consecutive times. The test performance score will be determined by the total distance covered within the shuttles completed.

### Maximal Graded Exercise Test on the treadmill

This test will be performed in the Athlete Performance Laboratory in the McKinnon Building at UVIC.

The protocol for the graded exercise test on the treadmill is as follows:

- 1) 1 minute warm-up at 3 - 4 mph
- 2) 1 – 3 minute light jog at 6 mph
- 3) Increase speed by 0.5 mph every 2 min until participant has reached a high but manageable speed
- 4) At this time the grade will be increase by 2.0% each minute until the participant can no longer continue.

During the test, you will be wearing a heart rate monitor and a Rudolph valve will be used to collect and analyze expired oxygen and carbon dioxide levels. This is the gold standard test for measuring aerobic fitness and is what we use to test our international athletes.

### Blood Lactate

Blood lactate will be analyzed before and after each of the following tests: Cunningham Treadmill Test, Leger 20m Shuttle run, Yo-Yo Intermittent Recovery Level 1 test and the Maximal Graded Exercise Test on the treadmill.

This will involve a small fingertip prick following appropriate standard care. This very small blood droplet collection is similar to that used for those who regularly test their blood sugar (glucose) for diabetes. These small blood droplets will be collected before each test (listed above) and then at 1, 3 and 5 minutes post test for a total of 4 finger prick blood droplet collections per test.

### Rating of Perceived Exertion (RPE)

Rating of Perceived Exertion (RPE) will be assessed at the end of the following tests: Cunningham Treadmill Test, YoYo Intermittent Recovery Level 1 test, Leger 20m Shuttle run, and Maximal Graded Exercise Test on the treadmill.

This will involve choosing a number on a scale from 0 to 10 (0 meaning nothing at all and 10 meaning very, very strong) to indicate the level of effort you feel you made during the test.

## **Risks**

There are some potential risks to you by participating in this research and they include feeling fatigued or physically stressed. This is due to the maximal effort required for each test, which may result in temporary physical discomfort, fatigue, dehydration, exhaustion, vertigo, or muscle cramps. In the rare occasion some participants may experience nausea

and/or vomiting. Due to the nature of stop and go actions during the YYIRL1 and Leger field tests, when running between the cones, there is a risk of physical injury such as turning an ankle. However, these actions are no different, and could be less stressful, than those you regularly experience during your training and competitions. The movements are consistent with what you are already well familiar with and trained to do.

To prevent or to deal with these risks the following steps will be taken. You will be required to complete a PAR-Q form that ensures you are physically able to participate in physical activity. During all tests, the investigator and research assistants will follow standard, best practices laboratory procedures, which include close and consistent monitoring of participants during all parts of each testing session, in addition to a recovery period. Proper warm up and cool down activities will be instructed to minimize the risk of muscle soreness. As well, you will be advised to avoid eating 2 hours prior to testing and vigorous activities 24 hrs prior along with arriving in a hydrated state. All researchers will be trained in First Aid and CPR.

## **Benefits**

The potential benefits of your participation in this research include information on your personal level of cardiovascular fitness, experiencing the same athlete assessment methods as those used for our National and Olympic athletes, as well as suggestions on how to improve your fitness level. Following completion of the study, a report will be sent to you providing your individual fitness results, the group means and a brief interpretation of your performance scores.

Further understanding of the Yo-Yo Intermittent Recovery Level 1 test will also allow coaches a better tool to gauge the fitness levels of their athletes to aid in training strategies for developing stronger players.

## **Inconvenience**

Participation in this study may cause some inconvenience to you, including travel time to the university along with the length of time for each visit. The main inconvenience for you is physical exertion, caused by taking the fitness tests. Additional inconveniences include: refraining from eating 2 hours prior to testing, refraining from vigorous activity 24 hours prior to testing, and the finger pricks for blood droplet collection. The finger prick will be no greater an inconvenience than that experienced by an individual who monitors their blood glucose for diabetes management.

### **Compensation**

As a way to compensate you for the inconvenience of time related to your participation, parking costs for each visit made to the University of Victoria for participation in the study will be paid.

### **Voluntary Participation**

Your participation in this research must be completely voluntary. If you decide to participate, you may withdraw at any time without any consequences or any explanation. If you do withdraw from the study, your data will still be used provided you have completed the Leger 20m Shuttle Run and Yo-Yo Intermittent Recovery Level 1 test. The researcher will ask for your verbal consent that the data can still be used. If not, the data will not be used. Data from the study will be withheld for a maximum of 5 years.

### **On-going Consent**

To make sure that you continue to consent to participate in this research, I will explain at the start of each visit and each test that you are free to withdraw from the study at any point in time, even in the middle of a fitness test, with no consequence or explanation.

Participation in this study will not have impact on your involvement or recognition on your team. All coaches have been notified of the requirement that participation in this study is voluntary and confidential.

### **Anonymity**

In terms of protecting your anonymity, when the results of the study have been analyzed and disseminated, no one will be aware that you have taken part in this study.

### **Confidentiality**

Your confidentiality and the confidentiality of the data will be protected. All names and personal information will only be released to the investigators. Once data has been collected and analyzed, your data will be assigned a number and will be referred to on a numerical basis. From this point on, no data will contain names and all results will be interpreted and displayed as group data and individual data by their assigned number.

With your consent, pictures will be taken during the testing. At the bottom of the consent form, you have the option to have your images used in the presentation of the findings of this research (such as at conferences or in publications, and to interested professionals). If you would only like your image to be viewed by the research team and never used in presentation, just tick the “No” box and your image will never be used. All data will be kept in a password-protected computer and locked in a cabinet in the office of Dr. Gaul at the University of Victoria.

**Dissemination of Results**

It is anticipated that the results of this study will be shared with others in the following ways: 1) Used in a thesis; 2) Published in a peer reviewed journal; and 3) Presented at a national/international academic conference.

**Disposal of Data**

Data from this study will be disposed of 5 years after completion of the study by deleting computer files and shredding paper data.

**Contacts**

Individuals that may be contacted regarding this study include Leanne Dickau and Dr. Catherine Gaul. Their contact information can be found on the first page of this form.

In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria (250-472-4545 or [ethics@uvic.ca](mailto:ethics@uvic.ca)).

### **Athlete Consent to Participate in Study**

Your signature below indicates that you understand the above conditions of participation in this study and that you have had the opportunity to have your questions answered by the researchers.

<i>Name of Participant</i>	<i>Signature of Participant</i>	<i>Date</i>
<i>Participant Phone number</i>	<i>Participant Email Address</i>	

I agree to have my images used in the presentation of the results of this study.

Yes     No

\_\_\_\_\_

*Signature*

### **Parent/Guardian Confirmation of Awareness**

It is important that your parent(s)/guardian are aware and informed of your participation in this study. Your confidentiality will be maintained and your individual results will only be provided back to you.

The signature of your parent/guardian below indicates that they are informed and aware of your participation in this study.

<i>Name of Participant Parent/Guardian</i>	<i>Signature of Participant Parent/Guardian</i>	<i>Date</i>
<i>Participant Parent/Guardian Phone number (Emergency purposes only)</i>	<i>Participant Parent Guardian Email Address (Emergency Purposes only)</i>	

***A copy of this consent will be left with you, and a copy will be taken by the researcher.***

## Appendix C Data Collection Sheets

### PARTICIPANT INFORMATION SHEET

<b>First and Last Name:</b>	
<b>Gender (Circle):</b> Male or Female	<b>Birth date (mm-dd-yyyy)</b>
<b>Participant Contact Information:</b> <b>Phone number:</b> <b>Email:</b>	
<b>Emergency Contact :</b>	
<b>Name of Club &amp; Team (previous or current):</b>	
<b>Years of Soccer Experience:</b>	<b>Commonly Played Position:</b>
<b>Level of Team (Circle):</b> Bronze Silver Gold Metro Super Y Other <b>If other please specify:</b>	
<b>Are you currently training/playing soccer? (Circle) Yes or No</b> <b>How many hours a week do you train/play games?</b>	
<b>Have you started having your period? (Circle) Yes or No</b> <b>If so, when was your first period?</b>	

<i>Filled in by Researcher Only</i>	
<i>Participant #:</i>	
<i>Consent Form Signed by Participant</i> <input type="checkbox"/>	<i>PARQ Form</i> <input type="checkbox"/>
<i>Consent Form Signed by Parent/Guardian</i> <input type="checkbox"/>	<i>Waiver Form</i> <input type="checkbox"/>

<b>Cunningham Treamill Test</b>		Date: _____		
Participant # _____				
HR Watch: _____		1 min	3min	5min
Pre Lactate _____	Post Lactate _____			
Baseline HR _____	Max HR _____	RPE: _____		
Timer 1 (s): _____	Timer 2 (s): _____			
<p>Have you participated in physical activity in the last 24 hours? If yes, what?</p> <p>When was the last time you had something to eat?</p>				

<b>YoYo Intermittent Recovery Level 1 Test</b>		Date: _____		
Participant # _____				
HR Monitor: _____		1 min	3min	5min
Pre Lactate _____	Post Lactate _____			
Baseline HR _____	Max HR _____			
Final Stage: _____	Total Distance (m): _____	RPE: _____		
<p>Have you participated in physical activity in the last 24 hours? If yes, what?</p> <p>When was the last time you had something to eat?</p>				

**YoYo Intermittent Recovery Level 1  
(Tracking Sheet)**

Date: \_\_\_\_\_

Stage	Shuttles Completed	Participant #	Stage Completed	Warning
5	1			
9	1			
11	1 2			
12	1 2 3			
13	1 2 3 4			
14	1 2 3 4 5 6 7 8			
15	1 2 3 4 5 6 7 8			
16	1 2 3 4 5 6 7 8			
17	1 2 3 4 5 6 7 8			
18	1 2 3 4 5 6 7 8			
19	1 2 3 4 5 6 7 8			
20	1 2 3 4 5 6 7 8			
21	1 2 3 4 5 6 7 8			
22	1 2 3 4 5 6 7 8			
23	1 2 3 4 5 6 7 8			

**YoYo Intermittent Recovery Level 1**

Date: \_\_\_\_\_

Stage	Shuttles Completed	Total Distance
5	1	40
9	1	80
11	1 2	160
12	1 2 3	280
13	1 2 3 4	440
14	1 2 3 4 5 6 7 8	760
15	1 2 3 4 5 6 7 8	1080
16	1 2 3 4 5 6 7 8	1400
17	1 2 3 4 5 6 7 8	1720
18	1 2 3 4 5 6 7 8	2040
19	1 2 3 4 5 6 7 8	2360
20	1 2 3 4 5 6 7 8	2680
21	1 2 3 4 5 6 7 8	3000
22	1 2 3 4 5 6 7 8	3320
23	1 2 3 4 5 6 7 8	3640

<b>Leger 20m Shuttle Run</b>		Date: _____						
Participant # _____								
HR Monitor: _____		<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 33%; text-align: center;">1 min</td> <td style="width: 33%; text-align: center;">3min</td> <td style="width: 33%; text-align: center;">5min</td> </tr> <tr> <td style="height: 20px;"></td> <td style="height: 20px;"></td> <td style="height: 20px;"></td> </tr> </table>	1 min	3min	5min			
1 min	3min	5min						
Pre Lactate _____	Post Lactate _____							
Baseline HR _____	Max HR _____							
Final Stage: _____	Total Distance (m): _____	RPE: _____						
<p>Have you participated in physical activity in the last 24 hours? If yes, what?</p> <p>When was the last time you had something to eat?</p>								

**Leger 20m Shuttle Run Tracking Sheet**

Stage	Shuttles Completed	Stage	Shuttles Completed		
0	1 2 3 4	9	1 2 3 4 5		
0.5	1 2 3	9.5	1 2 3 4 5 6		
1	1 2 3 4	10	1 2 3 4 5 6		
1.5	1 2 3 4	10.5	1 2 3 4 5		
2	1 2 3 4	11	1 2 3 4 5 6		
2.5	1 2 3 4	11.5	1 2 3 4 5 6		
3	1 2 3 4	12	1 2 3 4 5 6		
3.5	1 2 3 4	12.5	1 2 3 4 5 6		
4	1 2 3 4 5	13	1 2 3 4 5 6		
4.5	1 2 3 4	13.5	1 2 3 4 5 6 7		
5	1 2 3 4 5	14	1 2 3 4 5 6 7		
5.5	1 2 3 4	<b>Participant #</b>	<b>Stage Completed</b>	<b>Shuttles within Stage</b>	
6	1 2 3 4 5				
6.5	1 2 3 4 5				
7	1 2 3 4 5				
7.5	1 2 3 4 5				
8	1 2 3 4 5				
8.5	1 2 3 4 5				

### Leger 20m Shuttle Run Tracking Sheet

Stage	Shuttles Completed	Total Distance	Stage	Shuttles Completed	Total Distance
0	1 2 3 4	80	9	1 2 3 4 5	1680
0.5	1 2 3	140	9.5	1 2 3 4 5 6	1800
1	1 2 3 4	220	10	1 2 3 4 5 6	1920
1.5	1 2 3 4	300	10.5	1 2 3 4 5	2020
2	1 2 3 4	380	11	1 2 3 4 5 6	2140
2.5	1 2 3 4	460	11.5	1 2 3 4 5 6	2260
3	1 2 3 4	540	12	1 2 3 4 5 6	2380
3.5	1 2 3 4	620	12.5	1 2 3 4 5 6	2500
4	1 2 3 4 5	720	13	1 2 3 4 5 6	2620
4.5	1 2 3 4	800	13.5	1 2 3 4 5 6 7	2760
5	1 2 3 4 5	900	14	1 2 3 4 5 6 7	2900
5.5	1 2 3 4	980			
6	1 2 3 4 5	1080			
6.5	1 2 3 4 5	1180			
7	1 2 3 4 5	1280			
7.5	1 2 3 4 5	1380			
8	1 2 3 4 5	1480			
8.5	1 2 3 4 5	1580			





Date: \_\_\_\_\_

**Sum of 8 Skinfolts**

Participant: \_\_\_\_\_

Age: \_\_\_\_\_

Height (cm): \_\_\_\_\_

Weight (kg): \_\_\_\_\_

Site	Trial #1	Trial #2	Trial #3	Mean
Triceps				
Subscapular				
Biceps				
Iliac Crest				
Supraspinale				
Abdominal				
Thigh				
Calf				

Girths	Trial #1	Trial #2	Trial #3	Mean
Waist				
Hip				

## Appendix D Data Collection Protocols

### Sum of 8 Skinfolds

**Volunteers:** (1-2) ISAK certified, (1-2) scribes

**Equipment:**

Harpenden callipers  
Pen/marker

Measuring tape  
Data collection sheet

**Protocol:**

*Familiarization:*

1. Explain the protocol (described below) to the participant
2. Explain the purpose of the taking skinfolds for measurement.

*Data Collection:*

1. Participant will stand with feet shoulder length apart in a relaxed position
2. Researcher will landmark the 8 sites on the right hand side of the participant using anatomical landmarks.
3. Using a pen, the researcher will make a light mark at the following 8 sites: triceps, biceps, subscapular (shoulder blade), iliac crest (top of hipbone), supraspinale, abdominal, quadriceps (front thigh), and calf.
4. The researcher will perform the skinfold measurements in the order that the sites are landmarked.
5. At each site, the researcher will take a fold of skin plus the underlying fat between their thumb and forefinger.
6. The contact faces of the callipers are then placed one centimetre below the point where the skinfold is raised.
7. The trigger of the callipers is then fully released while maintaining the pressure of the fingers on the skinfold.
8. Measurement is noted when the indicator stabilizes which is approximately two seconds after the full pressure of the calliper jaws is applied to the skinfold.
9. Researcher will then repeat the same procedure at each site.
10. After one complete round of measurements a second will be taken.
11. The mean of the two measures at each site will be taken unless the distance between the first and second measure is greater than 0.4 mm.
12. If the distance is greater than 0.4 mm a third measure will be taken at that site.

Notes:

- Measurement of skinfolds will be conducted in a private room with the researcher and a research assistant
- If a third measure is taken for a site the mean will taken by: 1) Choosing the two measures which most closely match each other in value; 2) Should the three measures be equidistant, determine the mean of all three values.

### **Vertical Jump Test**

***Volunteers needed:*** 1

***Equipment:***

Portable Force Plate  
Pencil/Pen

Clipboard with data collection sheet

***Data Collection:***

1. Researcher will explain protocol to the participant
2. Researcher will calibrate plate to participants wt.
3. When signalled, participant will stand on the force plate with no movement for 1 – 2 seconds
4. Participant will squat, swinging arms down and back
5. Participant will then jump as high as possible with counter arm movement
6. Researcher will save data in computer file.
7. Participant will rest for 60 – 90 s
8. Participant will attempt 2 more jumps following the above mentioned protocol

Note: Force plate will be set at a sampling frequency of 1200 Hz.

### **Cunningham Treadmill Test**

***Volunteers needed:*** 2

***Equipment:***

Treadmill  
Heart Rate monitors – straps & watches  
Clipboard with data collection Sheet  
Blood Lactate Supplies: Test Strips,  
Analyzers, Lancets, Gauze, Sharps  
Container, Alcohol Swabs, Band Aids,  
Bleach solution (10%)

Stop Watches (x2)  
Towels  
Pencil/Pen  
Mats positioned behind treadmill

***Protocol:***

***Familiarization and Practice***

(minimum 1x)

1. Explain the protocol (described below) to the participant
2. Explain the purpose of the heart rate monitors and blood lactate analyzers
3. Have participant practice light jog/run on treadmill

*Data Collection:*

1. Put heart rate monitor on participants
2. Researcher or assistant takes baseline blood lactate
3. Have participant warm-up on treadmill for 5 minutes at moderately increasing speed
4. Participant has 5-minute rest period.
5. Treadmill will be set to a speed of 8mph (12.9 km/h) with a 20% grade.
6. The participant will hold onto handrails with feet on the sides of the treadmill
7. When ready, the participant will step/run onto the treadmill, letting go of the handrails and run for 10 – 15 s, to practice the test speed
8. After 1 – 3 practice attempts, the participant will have a 1- 2 min rest before commencing with the test.
9. When ready, the participant will step/run onto the treadmill, letting go of the handrails and run for as long as possible until grabbing the handrails again to end the test. Stop HR watch.
10. Ask for RPE value
11. Researcher or assistant will take blood lactate at 1, 3 and 5 min.
12. Speed and grade of the treadmill will be dropped and participant will be given a cool down at a light speed followed by stretching.

Notes:

- Two research assistants will be timers and one will spot the participant by standing to the side of the treadmill.
- The mean of the two times will be recorded for the participant

**Yo-Yo Intermittent Recovery Level 1 Test*****Equipment:***

Measuring tape/wheel	Duct Tape
Pylons	Clipboard with recording sheet
Extension Cord	Whistle
Heart Rate Monitors	CD Player
YoYo Intermittent Recovery Level 1 CD	Pencil/Pen
Pinnies for participants to wear	Blood Lactate Supplies: Test Strips, Analyzers, Lancets, Gauze, Sharps Container, Alcohol Swabs, Band Aids, Bleach solution (10%)

***Set-up:***

1. Measure a straight distance of 20m and place pylons at start and end.
2. Approximately 10-15 m away, horizontally, measure another straight distance of 20m from this point to form a square and place pylons at the start and end.
3. To clearly indicate start and finish lines, place duct tape horizontally across floor
4. From the start/finish line measure 5m back at both corners and mark with pylons at corners and along the horizontal line

5. Ensure that the participants can hear the beeps on the CD from the 20-m distance; if not a whistle should be blown alongside the beeps or hand signals should be made.

***Protocol:***

*Familiarization and Practice*

(minimum 1x)

1. Explain the protocol (described below) to the participant
2. Explain the purpose of the heart rate monitors and blood lactate analyzers
3. Demonstrate the test
4. Have participants practice running to audio cues for 2 shuttles (40m).

*Data Collection*

1. Put heart rate monitors on participants and make sure they are recording.
2. Researcher or assistant takes baseline blood lactate of participant.
3. Recap of testing procedure.
4. Participants start at the start/finish line, and start the test after the 5-second count-down on the CD. Indicate start time for heart rate monitors.
5. A beep indicates the start and end of each shuttle.
6. After 40 m (2 Shuttles) the participant will have 10s to walk/jog to the pylon marked 5m away from the start/finish and back to begin the next 2 shuttles (40m)
7. The test ends when the participant cannot keep up with the beeps for two consecutive laps. Ask participant for RPE reading.
8. Indicate stop time on computer when last participant has finished test.
9. Record the number of laps completed
10. Take participant's blood lactate 1, 3 and 5 minutes post test
11. Offer the participant water
12. Cool-down activities and stretching

**The Multistage 20m Shuttle Run (Leger) test**

***Equipment:***

Measuring tape/wheel	Duct Tape
Pylons	Clipboard with recording sheet
Extension Cord	Whistle
Heart Rate Monitors	CD Player
Leger 20m Shuttle Run CD	Pencil/Pen
Pinnies for participants to wear	Blood Lactate Supplies: Test Strips, Analyzers, Lancets, Gauze, Sharps Container, Alcohol Swabs, Band Aids, Bleach solution (10%)

***Set-up:***

1. Measure a straight distance of 20m and place pylons at start and end.
2. Approximately 10-15 m away, horizontally, measure another straight distance of 20m from this point to form a square and place pylons at the start and end.
3. To clearly indicate start and finish lines, place duct tape horizontally across floor
4. Ensure that the participants can hear the beeps on the CD from the 20-m distance; if not a whistle should be blown alongside the beeps or hand signals should be made.

***Protocol:******Familiarization and Practice***

(minimum 1x)

1. Explain the protocol (described below) to the participant
2. Explain the purpose of the heart rate monitors and blood lactate analyzers
3. Demonstrate the test
4. Have participants practice running to audio cues for 2 shuttles (40m).

***Data Collection***

1. Put heart rate monitors on participants and make sure they are working.
2. Researcher or assistant takes baseline blood lactate of participant.
3. Recap of testing procedure.
4. Participants start at the start line, and start the test after the 5-second count-down on the CD. Indicate start time on computer.
5. A beep indicates the end of a lap. The CD allows 9 seconds to run the 20-m distance (1 lap) during the first minute. The pace increases by approximately 0.5 seconds each following minute.
6. The test ends when the participant cannot keep up with the beeps for two consecutive laps. Ask participant for RPE reading.
7. Indicate stop time when last participant has finished the test.
8. Record the number of laps completed
9. Take participant's blood lactate 1, 3 and 5 minutes post test
10. Offer the participant water
11. Cool-down activities and stretching for participant
12. Researcher will ensure proper clean up and of all instruments used for collecting blood lactate and HR

## The Maximal Graded Exercise Test on the Treadmill

### ***Equipment:***

Treadmill	Metabolic Measurement Cart
Heart Rate monitors	Towels
Breathing Apparatus – Head piece, Rudolph valve and hose	Blood Lactate Supplies: Test Strips, Analyzers, Lancets, Gauze, Sharps Container, Alcohol Swabs, Band Aids, Bleach solution (10%)
Pencil/Pen	Clipboard with data collection sheet

### ***Protocol:***

#### *Familiarization and Practice (minimum 1x)*

1. Explain the protocol (described below) to the participant
2. Explain the purpose of the heart rate monitors and blood lactate analyzers
3. Have participants practice light jog/run on treadmill

#### *Data Collection:*

1. Put heart rate monitor on participant
2. Have participant warm-up on treadmill for 5 min at a light speed (4 - 5 mph)
3. Researcher or assistant takes baseline blood lactate.
4. Place head piece on participant along with Rudolph valve in the mouth. Adjust accordingly.
5. Recap of testing procedure
6. Have participant run on treadmill for 1 minute at 3 – 4mph
7. Next 2 minutes jog at 6mph
8. Increase speed by 0.5 mph every 2 minutes until:
  - a. RER is 0.98 – 1.02
  - b. Participant has reached a high but manageable speed
9. Participant stays at test speed for 2 minute
10. Increase grade by 2.0% each minute until the criteria for  $\text{VO}_2\text{max}$  is met which include:
  - (1) Attainment of predicted maximum heart rate ( $220 - \text{age}$ ); (2) a rise in  $\text{VO}_2$  of less than  $2 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  with an increase in workload; (3) a respiratory exchange ratio (RER) greater than 1.15; (4) volitional exhaustion.
11. Head set and Rudolph valve are removed from participant. Ask for RPE rating.
12. Participant has cool down on treadmill at light walking speed and is given water
13. Researcher or assistant take post test blood lactate at 1, 3 and 5 minutes.
14. Participant steps down from treadmill and continues to cool down and stretch

Notes:

- At least one other research assistant will be present at test as a spotter.
- Data will be recorded manually during the test in case of computer malfunction.
- Researcher will download and print data from the metabolic cart.
- Rudolph valve and hose will be sanitized for each participant

**Blood Lactate Testing Instructions*****Equipment:***

Gloves	Lactate analyzer (Arkray Lactate Pro)
Lactate strips and calibration strip (Arkray Lactate Pro Test Strips)	Gauze pads (Source 2" x 2" non-sterile) (pkg)
Alcohol swabs (Loris Medium) (box)	Lancet (Accu-Chek Softclix Pro)
Disposable lancet tips (Accu-Chek Softclix Pro lancets) (box)	Sharps container (BD Sharps collector)
Biohazard Bag	Band-aids
Regular garbage can	Beaker with dilute bleach (soaking lancets)
Hand sanitizer and antibacterial wipes	

**EQUIPMENT CALIBRATION**

- Lactate analyzer - Calibrate lactate analyzer using check strip & calibration strip and insert new test strip (see Lactate Pro instructions for more details)

**GENERAL PROCEDURE****Testing prep**

- wash hands, put clean, new gloves on
- prep bleach solution - **MUST PREP NEW BLEACH SOLUTION EACH DAY** (bleach solution only effective for 1 day) - dilution 1/10 (bleach/water)
- disinfect the counter and equipment where you will be taking blood
- set out equipment and supplies you will be using for data collection

*Data collection:*

1. Load lancet with tip
2. Wipe subjects finger with alcohol swab – discard swab
3. Wipe excess alcohol from finger with gauze
4. Puncture finger tip with lancet
5. Gently squeeze finger to start flow of blood
6. Wipe first drop of blood with gauze
7. Gently squeeze finger to encourage flow of blood
8. Collect blood sample
9. Apply gauze and pressure to finger tip to stop blood flow, athlete holds onto gauze until next blood sample - gauze is then disposed of in biohazard
10. Dispose of used lancet tip in sharps container
11. After recording lactate value dispose of used lactate test strip in biohazard bag

12. Dispose of gauze wrappers and alcohol wrappers in the regular garbage can
13. For multiple samples
  - use fresh alcohol swab & gauze for each sample
  - Note: do not usually need to lancet each time - check to see if blood is still flowing (may have to perform gentle squeeze)
  - Excessive squeezing will cause erroneous results
  - NOTE: watch for blood spray or splatter when squeezing (point finger away from face)
14. Apply Band-aid at end of test
15. Discard gloves in appropriate garbage receptacle at the end of each test – use a fresh pair of gloves for each new subject
16. All equipment (lactate analyzer, lancet, bench top, etc) needs to be cleaned with alcohol or bleach between subjects

**Post test**

- Ensure all garbage has been disposed of appropriately (see above)
- Bleach all surfaces that may have been in contact with blood or body fluids
  - surfaces - spray with bleach , leave for 5 min, then wipe with cloth or paper towel
  - **SPILLS** – cover with paper towel, spray with bleach, leave for 5 min, then wipe with paper towel, re-spray with bleach & re-wipe
- Wipe lancet with alcohol & soak tip in dilute bleach solution between tests & at end
- Wipe analyzers, pens, keyboard, mouse, (anything you touch with gloves) with alcohol &/or bleach
- Put all equipment and unused supplies away in appropriate storage places

If your subject becomes light headed, queasy or faints - get them to lie down immediately, raise feet slightly. Stay with the person even if they say they feel okay. Accompany them to the washroom, or out of the room. Watch for skin color, dilated pupils. If they did faint and have fallen, check for injuries. Get an accident report form and fill it out.