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Changes in Running and Multiple Object Tracking Performance During a 90-minute Intermittent Soccer Performance Test (iSPT): A Pilot Study

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CHANGES IN RUNNING AND MULTIPLE OBJECT TRACKING PERFORMANCE DURING A 90-MINUTE INTERMITTENT SOCCER PERFORMANCE TEST (iSPT). A PILOT STUDY.

by

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ABSTRACT

Multiple object tracking (MOT) is a cognitive process that involves the active processing of dynamic visual information. In athletes, MOT speed is critical for maintaining spatial awareness of teammates, opponents, and the ball while moving at high velocities during a match. Understanding how MOT speed changes throughout the course of a competitive game may enhance strategies for maintaining optimal player performance. The objective of this study was to examine changes in MOT speed and running performance during a 90-minute intermittent soccer performance test (iSPT). A secondary purpose was to examine the relationship between aerobic capacity and changes in MOT speed.

Seven competitive female soccer players age: 20.4 ± 1.8 y, height: 166.7 ± 3.2 cm, weight: 62.4 ± 4.0 kg, VO_{2max}: 45.8 ± 4.6 ml/kg/min^{-1}) completed an intermittent soccer performance test (iSPT) on a Curve™ non-motorized treadmill (cNMT). The iSPT was divided into two 45-minute halves with a 15-minute halftime [HT] interval, and consisted of six individualized velocity zones. Velocity zones were consistent with previous time motion analyses of competitive soccer matches and based upon individual peak sprint speeds (PSS) as follows: standing (0% PSS, 17.8% of iSPT), walking (20% PSS, 36.4% of iSPT), jogging (35% PSS, 24.0% of iSPT), running (50% PSS, 11.6% of iSPT), fast running (60% PSS, 3.6% of iSPT), and sprinting (80% PSS, 6.7% of iSPT). Stand, walk, jog and run zones were combined to create a low-speed zone (LS). Fast run and sprint zones were combined to create a high-speed zone (HS). MOT speed was assessed at baseline (0 min.) and three times during each half of the iSPT. Dependent t-tests and Pearson correlation coefficients were utilized to analyze the data.

Across 15-minute time blocks, significant decreases in distance covered and average speed were noted for jogging, sprinting, low-speed running, high-speed running, and total distance (p's < 0.05). Players covered significantly less total distance during the second half compared to the first ($p = 0.025$). Additionally, significant decreases in distance covered and average speed were observed during the second half for the sprint and HS zones (p's ≤ 0.008). No significant main effect was noted for MOT speed across 15-minute time blocks. A trend towards a decrease in MOT speed was observed between halves ($p = 0.056$). A significant correlation was observed between the change in MOT speed and VO_{2max} ($r = 0.888$, $p = 0.007$). The fatigue associated with 90 minutes of soccer specific running negatively influenced running performance during the second half. However, increased aerobic capacity appears to be associated with an attenuation of cognitive decline during 90-minutes of soccer specific running. Results of this study indicate the importance of aerobic capacity on maintaining spatial awareness during a match.

To my dad, Darren,

thank you for constantly reminding

your little man to keep playing hard.

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LIST OF ACRONYMS/ABBREVIATIONS

0-15min	15-minute time block from 0 to 15 minutes of iSPT
16-30min	15-minute time block from 16 to 30 minutes of iSPT
31-45min	15-minute time block from 31 to 45 minutes of iSPT
3D	Three-Dimensional
46-60min	15-minute time block from 46 to 60 minutes of iSPT
61-75min	15-minute time block from 61 to 75 minutes of iSPT
76-90min	15-minute time block from 76 to 90 minutes of iSPT
ANOVA	Analysis of Variance
AU	Arbitrary Units
BIA	Bioelectrical Impedance Analysis
Cm	Centimeters
cNMT	Curve Non-Motorized Treadmill
D1	Day 1
D2	Day 2
D3	Day 3
FINST	Fingers of Instantiation model
GPS	Global Positioning System
HPL	Human Performance Laboratory
HS	High-Speed Running
Hz	Hertz
iSPT	Intermittent Soccer Performance Test
Kg	Kilograms
Khz	Kilohertz
Km	Kilometers

$K \cdot h^{-1}$	Kilometers per hour
LS	Low-Speed Running
M	meters
M/min	Meters per minute
MHQ	Medical and Activity History Questionnaire
Mmol · kg dry weight^{-1}	Millimoles per Kilogram of Dry Weight
$Ml \cdot kg^{-1} \cdot min^{-1}$	Milliliters per Kilogram per Minute
$ml \cdot min^{-1}$	Milliliters per minute
MOT	Multiple Object Tracking
NCAA	National Collegiate Athletic Association
NMT	Non-Motorized Treadmill
PAR-Q^{+}	Physical Activity Readiness Questionnaire
PSS	Peak Sprint Speed
S	Seconds
SD	Standard Deviation
UCF	University of Central Florida
USG	Urine Specific Gravity
η_p^2	Partial Eta Squared

CHAPTER ONE: INTRODUCTION

Soccer is a team sport that utilizes a number of cognitive processes including decision making, reaction time, and multiple object tracking; which together compliment the physical skill of an athlete during gameplay (Huijgen et al., 2015). As a competitive match progresses, decrements in running performance and skill execution become evident, which is often related to fatigue (Goodall et al., 2016; Krustrup, Zebis, Jensen, & Mohr, 2010; Russell, Benton, & Kingsley, 2011). National Collegiate Athletic Association (NCAA) soccer rules are unique in that up to 11 players can be substituted in any given game. Further, substituted players are subsequently allowed to re-enter the game one time during the second half. This provides coaches the opportunity to implement player management strategies that can be tailored to maximize both performance and athlete well-being. Nevertheless, previous research from our lab has shown that coaches tend to rely more heavily on starters versus non-starters during key games and postseason play (Jajtner et al., 2013; Wells et al., 2015). We have also shown that the demand of increased minutes played is associated with reduced recovery and increases in self-reported perception of stress (Coker et al., 2016). As playing time increases, athletes are subjected to a multitude of physical stressors that can result in decreased physical and cognitive performance. During key moments of a competitive match, each player's ability to maintain cognitive function becomes increasingly important. The ability for a player to "read the game" has been shown to be a distinguishing factor between skilled and less skilled players (Williams, 2000). Compromised cognitive performance has previously been associated with tactical errors, missed scoring opportunities, and blown defensive plays (Foskett, Ali, & Gant, 2009). Therefore, the ability to maintain the cognitive skills necessary to track teammates, opponents and the ball is crucial (Faubert & Sidebottom, 2012). Notwithstanding, it remains unclear when decrements in cognitive function are observed during a competitive match.

The capacity to effectively assess and quantify physiological and running performance measures within and after a live soccer match is limited by the dynamic nature of the sport. Drawing comparisons across multiple matches is also difficult due to the large degree of variability in performance characteristics reported from game to game (Gregson, Drust, Atkinson, & Salvo, 2010). A number of contextual factors including strength of opponent, location of the match (i.e. home or away), whether a team is winning or losing, and the employment of conscious or subconscious pacing strategies among players appear to be factors responsible for the variability between matches (Lago, Casais, Dominguez, & Sampaio, 2010). The poor reliability associated with this large variability in match demands makes it difficult to make meaningful conclusions from interventions assessing player performance measures between live games (Gregson et al., 2010). Recently, the development of the intermittent soccer performance test (iSPT) has allowed researchers to somewhat circumvent this issue. The iSPT is a laboratory based non-motorized treadmill (NMT) running protocol that simulates the running patterns and physiological demands of a 90-minute soccer match in an individualized manner. The iSPT can induce an acute state of fatigue indicated by decrements in high-speed distance running similar to those reported in previous match-play data (Mohr, Krustrup, & Bangsbo, 2003). Having been shown to be a valid and reliable soccer simulation, the iSPT may be a preferable mode through which to assess the effectiveness of a soccer specific performance intervention.

To our knowledge, no previous study has examined real-time cognitive ability in a live game or simulated match. A better understanding of changes in cognition across the duration of a match may provide coaches with valuable information that could influence how they manage athletes during a competitive game. This information could prompt more efficient substitution patterns, which in turn may lead to more desirable outcomes. Furthermore, measures of match running performance have been extensively investigated in male soccer athletes, but only a small number of studies have assessed the movement patterns of females. Consequently, characterizing potential changes in cognitive and running performance among Division I female soccer athletes during a competitive 90-minute match appears to be warranted.

CHAPTER TWO: LITERATURE REVIEW

Description of Soccer

Soccer is characterized as a high intensity, intermittent, non-continuous sport (Ekblom, 1986). Matches are played by teams consisting of a goalkeeper and 10 outfield players, including attackers, midfielders, and defenders. Matches at the NCAA collegiate level have a duration of 90 minutes, consisting of two 45-minute halves separated by a 15-minute halftime period. The activity profile of a soccer match features stretches of lower intensity activity (jogging, walking, standing, and complete rest) interspersed with periods of high intensity movement (high-speed running, sprinting etc.) (Brewer, Dawson, Heasman, Stewart, & Cormack, 2010; Tofari, McLean, Kemp, & Cormack, 2015). On average, elite players will cover approximately 9-12 km throughout the duration of a match (Mohr, Krustrup, & Bangsbo, 2005). Approximately 10% of this distance is covered while sprinting or running at high intensities (Mohr et al., 2003), and players will spend a considerable portion of a match at intensities averaging 80–90% of their maximum heart rate (Stølen, Chamari, Castagna, & Wisløff, 2005). The ball is typically in play for 52-76 minutes (Tumilty, 1993), during which time a player will experience between 150 and 250 brief intense actions that vary in both intensity and duration; including sprinting, jumping, tackling, heading, and battling for possession of the ball (Mohr et al., 2003; Wells et al., 2015). Each of these activities contribute to the overall demands placed upon a player during a match (Bangsbo, 1994). The energy demands from these bouts of intermittent anaerobic activity combined with the aerobic load of competing for 90 minutes ultimately contributes to the onset of fatigue, which typically becomes evident during the later stages of a match (Andersson et al., 2008; Krustrup et al., 2010; Rahnama, Reilly, Lees, & Graham-Smith, 2003).

In addition to the physical stressors associated with the game of soccer, there are also cognitive demands throughout the duration of a match. Players rely on a number of cognitive abilities such as decision making, reaction time, and multiple object tracking, which compliment physical skills (Huijgen et al., 2015). Players are required to maintain high levels of concentration across prolonged periods of time in order to make fast and accurate decisions based on the stimuli provided within a dynamic game environment (Smith et al., 2016). The ability to successfully integrate this cognitive aspect into skillful performance has been shown to differentiate elite from lesser caliber players (Foskett et al., 2009). Interestingly, reaction time has been shown to improve during the later stages of a competitive match. However, these improvements are reported to be accompanied by an increased frequency of error (Greig, Marchant, Lovell, Clough, & McNaughton, 2007). Consistent with this, player errors have been shown to increase during the later stages of simulated matches, with these errors being attributed to the mental fatigue associated with prolonged exercise (Greig et al., 2007). On the field, these mistakes are often manifested as missed scoring opportunities, turnovers, or blown defensive coverages (Smith et al., 2016). Consequently, the maintenance of optimal cognitive function may be vital to both player performance and team success as a match progresses.

The NCAA utilizes unique substitution rules allowing for up to 11 players to be substituted in any given game. Substituted players are allowed to re-enter the game one time during the second half (National Collegiate Athletic Association, 2016). The ability of coaches to efficiently substitute players in a strategic manner may play a critical role during the later stages of a match as this is when most goals are scored (Njororai, 2013). This is often due to lapses in concentration, decision making and/or skill performance indicative of player fatigue (Jinshan, Xiaoke, Yamanaka, & Matsumoto, 1993; Reilly, 1996). Perhaps even more importantly, compromised cognitive performance has also been associated with an increased rate of injury (Wilkerson, 2012). Recent evidence has indicated that increased neurocognitive reaction time is a predictor of lower body injuries (Wilkerson, 2012). The ability to minimize the negative physical and neurocognitive effects of fatigue is therefore key for optimizing player performance, player well-being, and team success.

Running Demands of Collegiate Women's Soccer

To our knowledge, an investigation conducted by Vescovi and colleagues is one of the only large-scale studies that has directly examined and reported the locomotor actions of Division I women's soccer matches (Vescovi & Favero, 2014). In this study, 113 Division I female soccer players were tracked via global positioning units for the duration of one NCAA match to determine the amount of distance covered at various velocity ranges. Comparisons were made between forward, midfield and defensive positions, and between players who were substituted out at some point during the match, substituted in to the match, and those that played the entire match. The substitution rules for Division I soccer are unique to the NCAA regarding how many more substitutions are permitted as compared to the three provided to teams at the professional level. The impact of these rules on running performance had yet to be examined prior to this investigation. Of the 113 players examined in this study only 17 of the 35 defenders, 12 of the 45 midfielders and 2 of the 33 forwards played a complete match indicating that it is not necessary for most players to be on the field for the entirety of a match (Vescovi & Favero, 2014).

Distances covered were analyzed each time an athlete played a complete half. Defenders that played a complete half covered an average of 4,878 and 4,618 meters in the first and second halves respectively. Midfielders averaged 5,186 and 4,939 meters in the first and second halves, while forwards covered an average of 5,232 and 5,065 meters during first and second halves. These distances fall in line with previous soccer time motion analyses not specific to NCAA Division I soccer athletes (Bangsbo, Norregaard, & Thorso, 1991a).

Another objective of this study was to examine the distances covered at varying velocity ranges and what proportion of locomotor activity during playing time is spent within these ranges (Vescovi & Favero, 2014). Movement velocities were organized as follows: standing and walking, 0–6.0 $km \cdot h^{-1}$; jogging, 6.1–8.0 $km \cdot h^{-1}$; low-intensity running, 8.1–12.0 $km \cdot h^{-1}$; moderate-intensity running, 12.1–15.5 $km \cdot h^{-1}$; high-intensity running, 15.6–20.0 $km \cdot h^{-1}$; and sprinting, >20.0 $km \cdot h^{-1}$. The greatest total distances were reflected in the work rates of each position. Forwards ranged from 98-114 $m \cdot min^{-1}$, midfielders ranged from 98-103 $m \cdot min^{-1}$, and defenders covered between 92 and 103 $m \cdot min^{-1}$ between both halves. Forwards covered the greatest distances in high-intensity running and sprinting zones. On average forwards covered an average of 1,268 meters per game at speeds greater 15.5 $km \cdot h^{-1}$. Midfielders and defenders covered an average of 959 and 1,014 meters per match at such velocities. When playing the complete first half, movement at these velocities accounted for about 12%, 9% and 9% of total distances covered by forwards, midfielders and defenders respectively. During the second half, these proportions increased to 12%, 10% and 12%. Based on the movement velocity categorization, players covered the greatest distances while running at low velocities. When playing a complete first half, forwards covered 34% of their total distance running at low intensities between 8 and 12 $km \cdot h^{-1}$. For midfielders, 32% of a completed first half was spent within this range. Defenders were the only position that covered greater distances in any other movement category. 31% of their first half and 28% of their second half distances were covered while running at low intensities while 34% of both halves were spent walking at or below 6 $km \cdot h^{-1}$. Forwards covered 23% and 27% of their total distances walking during the first and second halves respectively while midfielders walked 28% and 30% of their total covered distances during completed first and second halves (Vescovi & Favero, 2014). Total distances covered at each velocity range and positional work rates for completed halves are displayed in Table 1.

Table 1: Locomotor activity during Division I Women's soccer competition

Adapted from: (Vescovi & Favero, 2014)

	Total Distance (m)	Walking (m)	Jogging (m)	Low-Intensity Running (m)	Moderate-Intensity Running (m)	High-Intensity Running (m)	Sprinting (m)	Work Rate (m/min)
FORWARDS								
First Half	5232 ± 153 (4924-5540)	1482 ± 69 (1342-1622)	667 ± 41 (584-748)	1655 ± 102 (1449-1861)	800 ± 79 (640-960)	475 ± 51 (372-577)	146 ± 26 (94-198)	107 ± 3 (100-113)
Second Half	5065 ± 185 (4689-5442)	1540 ± 61 (1416-1664)	570 ± 42 (485-656)	1483 ± 117 (1246-1720)	818 ± 78 (660-977)	454 ± 47 (358-550)	193 ± 27 (137-248)	106 ± 4 (98-114)
MIDFIELDERS								
First Half	5186 ± 76 (5032-5340)	1516 ± 35 (1446-1586)	677 ± 20 (637-718)	1675 ± 51 (1572-1778)	843 ± 40 (762-923)	384 ± 25 (333-435)	87 ± 13 (61-113)	106 ± 2 (103-109)
Second Half	4939 ± 121 (4696-5184)	1647 ± 40 (1566-1728)	639 ± 27 (583-695)	1446 ± 76 (1292-1600)	715 ± 51 (612-818)	378 ± 31 (316-441)	110 ± 18 (74-146)	103 ± 3 (98-108)
DEFENDERS								
First Half	4878 ± 74 (4728-5028)	1540 ± 34 (1472-1608)	607 ± 20 (567-647)	1442 ± 50 (1341-1542)	771 ± 39 (693-849)	384 ± 25 (334-434)	131 ± 13 (106-156)	100 ± 2 (97-103)
Second Half	4618 ± 101 (4413-4823	1586 ± 33 (1518-1653)	567 ± 23 (520-613)	1292 ± 64 (1163-1421)	671 ± 43 (585-758)	364 ± 26 (312-417)	135 ± 15 (105-165)	96 ± 2 (92-101)

An investigation by Wells and colleagues compared volume and intensities of locomotor activity between regular season and postseason play across an entire season for nine Division I female athletes (Wells et al., 2015). During the regular season, players averaged only 72.6 minutes of playing time compared to 85.08 minutes during the postseason. During the regular season, an average of 37.36 of those minutes were played in the first half and 35.25 minutes in the second half of each match. This increased to an average of 44.23 first half minutes and 40.85 minutes of play in the second half during postseason play. This increased playing time was reflected in the recorded player load which increased by 12% from regular season to postseason. Along with these increases in total player load and minutes played, there was a decrease in the intensity of locomotor activity during the postseason. When accounting for minutes played, player load decreased by 6.2% per minute from regular season to postseason. Average total distance covered increased by 719 meters from regular season to postseason but the average player work rate declined from 105 meters per minute to 98 meters per minute. Decrements in sprinting (>22$km \cdot h^{-1}$) performed during the second half contributed to the decline in overall work rate. Previous research indicates that females reach sprint speeds greater than 25 $km \cdot h^{-1}$ between nine and forty-three times per match, with an average of twenty-six instances (Krustrup, Mohr, Ellingsgaard, & Bangsbo, 2005). During the regular season, these Division I players covered an average of 86.25 meters per game at speeds greater than 22 $km \cdot h^{-1}$ with 41.70 of these taking place during the second half (Wells et al., 2015). Second half sprint distances were reduced to just 34.1 meters during postseason play. These findings indicate that significantly increasing the number of minutes played results in reductions in running performance measures, particularly in high intensity movement during the second half (Wells et al., 2015).

Fatigue

Fatigue from an athletic standpoint can be defined as the failure to maintain required or expected response to stimuli due to overexertion of energy resources (Gibson & Edwards, 1985). There is currently a paucity of research on the development of fatigue in elite female soccer athletes across a competitive season. However, some comparisons may be drawn based upon from existing literature in elite male soccer athletes. In soccer, fatigue is characterized by impaired player performance, which appears to be induced by the aerobic and anaerobic demands of match play (Mohr et al., 2003). Players have high aerobic requirements throughout a 90-minute game as the average heart rate ranges between 152 and 186 beats per minute in elite females (Bangsbo, Iaia, & Krustrup, 2007). This is compounded with the extensive anaerobic demands at various times throughout a match, which contribute to the development of fatigue in the later stages of a match (Bangsbo et al., 2007; Krustrup et al., 2005). This is strongly evidenced by the declines in high-intensity running during the final 15-minutes of a match by both top-class and lower standard male professionals (Mohr et al., 2003). During the final 15 minutes, only 3% of male players are reported to experience their most intense periods of exertion; whereas more than 40% of players experience their least intense periods of activity during the final 15 minutes of a match (Mohr et al., 2003). The fatigue inducing effects of playing a full match are made more evident by findings that male players substituted into a match during the second half are observed to complete 63% more sprinting activity and 25% more high-intensity running activity compared to players that are on the field for the entire match during the same time frame (Mohr et al., 2005).

In conjunction with the fatigue displayed by players during the later stages of a match, evidence suggests that top-class male players also experience more temporary short-term fatigue at various points immediately after bouts of high intensity running (Mohr et al., 2003). Analysis has shown that after the most intense 5-minute periods of a match, the amount of high intensity running activity declines below the match average during the subsequent 5-minute period (Mohr et al., 2003). Several mechanisms are suspected of playing a role in this temporary fatigue, including decreased concentrations of creatine phosphate within individual muscle fibers, and a potential accumulation of potassium in the extracellular space that may disrupt electrical activity within the cell (Mohr et al., 2003).

The development of fatigue that ultimately affects player performance during the later stages of a match has several proposed mechanisms, one of them being muscle glycogen depletion. Previous research indicates that the development of fatigue during prolonged intermittent activity, such as soccer, is strongly associated with a lack of muscle glycogen (Bangsbo, Mohr, & Krustrup, 2006). Considering a player performs 150-250 burst of intense action per match, it has been postulated that muscle glycogen is the most important substrate for energy production throughout a soccer match (Bangsbo et al., 2006; Mohr et al., 2003). In order to maintain a maximal glycolytic rate during a match, players must maintain muscle glycogen concentrations of about 200 mmol · kg dry weight^{-1} (Bangsbo, Norregaard, & Thorso, 1991b). Previous literature has shown muscle glycogen concentrations to be reduced to 150-350 mmol · kg dry weight^{-1} at the end of a game (Krustrup et al., 2006). This would indicate that muscle glycogen is not completely depleted during a match. However, previous studies utilizing histochemical analyses indicate that about 50% of the individual muscle fibers are almost or completely depleted of glycogen upon completion of a match (Krustrup et al., 2006). Further, this decrease in glycogen is associated with reductions in sprint performance immediately after a match (Krustrup et al., 2006). These findings would indicate that it may be the depletion of glycogen from heavily recruited muscle fibers that does not allow for repeated sprints or maximal effort in a single sprint, thus impeding player performance during the later stages of a match (Bangsbo et al., 2006).

Another critical factor that may contribute to the impairments in player performance as a match progresses is the dehydration that occurs from fluid loss during play. Fluid loss as little as 1-2% of a player's body mass has been shown to contribute towards elevated core temperatures as well as cardiovascular strain which may lead to impairments in player performance (Hoffman et al., 1994). Compounding upon the physical declines in performance, dehydration equating to 2% of body mass has been shown to have adverse effects on cognitive function. Moreover, these effects may be present at 1% dehydration (Lieberman, 2007). This may further contribute to decrements in player performance related to fatigue during the later stages of a match. Previous investigations have shown that ingestion of fluids during 90 minutes of soccer-type activity may mitigate increased core temperature and cardiovascular strain while maintaining cognitive perception in female soccer athletes (Ali, Gardiner, Foskett, & Gant, 2011). In contrast, others have shown that fluid ingestion does not prevent the observed degradation in sprint performance during 90 minutes of soccer-type activity in females (Ali et al., 2011).

Numerous stressors inciting various physiological responses are responsible for athletes' decrements in physical output during a soccer match. This fatigue has been cited to occur both temporarily, after energy demanding bouts of high intensity running, and chronically throughout the duration of a match. Ultimately, the combination of these may lead to impaired player performance in the closing minutes (Mohr et al., 2003). Notwithstanding, physical fatigue does not appear to be the sole cause of player performance decrements. An often overlooked factor that may contribute to performance decline is cognitive fatigue and/or changes in cognitive function (Huijgen et al., 2015). Throughout the duration of a match, players constantly rely on various cognitive skills such as decision making, reaction time, and multiple object tracking, to quickly anticipate and react to fast-paced dynamic game situations (Casanova et al., 2013; Huijgen et al., 2015). For example, an attacking forward with the ball must quickly assess the distance of free space between themselves and defenders, available passing lanes to teammates, potential risks for a pass being intercepted, possible paths to the goal, and shot opportunities before selecting and executing an action effectively (Faubert & Sidebottom, 2012). Along with the constant concentration demands of play, the prolonged intermittent activity associated with playing a full match has been shown to cause significant detrimental changes in cognitive processing performance for both low-level and elite soccer athletes across the duration of a match (Casanova et al., 2013).

Information processing and cognition have been shown to have both positive and negative relationships with physical exertion (Tomporowski & Ellis, 1986). Some investigations have reported that physical exertion facilitates thinking processes, while others have made claims that exercise's effect on cognition is debilitating (Tomporowski & Ellis, 1986). It has been proposed that the inverted-U hypothesis may explain these contrasting findings (Martens, 1974). The inverted-U hypothesis suggests that as physical arousal increases, cognitive performance is predicted to increase until it reaches an optimal point. As physical arousal continues to increase beyond this optimal point, cognitive performance begins to decline (Tomporowski & Ellis, 1986). Easterbrook et al. developed a theory for the impacts of physical activity on changes in attentional processes (Easterbrook, 1959). The theory states that an increase in physical arousal will cause a narrowing shift of attention. As arousal increases individuals will narrow their attention to the elements of a task that are most critical to correct or successful performance. If the level of physical arousal continues to increase, the amount of attention dedicated to task related stimuli may be narrowed to the point of being restricted from being able to perform optimally (Easterbrook, 1959).

To identify how physical demand and arousal across a full soccer match affect cognition, Casanova and colleagues examined changes in perceptual-cognitive performance during prolonged periods soccer specific intermittent activity between players of high (professional and semi-professional experience) and low (amateur experience) skill levels (Casanova et al., 2013). At various time points throughout a 119-minute soccer-specific intermittent exercise protocol, participants were presented filmed sequences of offensive game situations and assessed on their ability to correctly anticipate and respond with the same action (pass, shoot, retain possession) that occurred next in the film sequence (Casanova et al., 2013). Participants' visual search patterns were monitored during the assessment (Casanova et al., 2013). Intermittent exercise led to significant decreases in response accuracy in both groups, but the high-level group performed significantly better than the low-level group throughout the simulated match, particularly in the closing minutes (Casanova et al., 2013). The high-level players in this study were able to mitigate the decrements in anticipation performance with more efficient search behaviors (Casanova et al., 2013). The fact that cognitive fatigue has been a frequently overlooked facet of soccer research makes it difficult to isolate and identify the specific cognitive process that was responsible for the preserved search patterns of high-level players. There appears to be a gap in the literature regarding the behavior and fatigue of individual cognitive functions throughout the duration of a full soccer match.

Multiple Object Tracking

In dynamic sports, such as soccer, the ability to "read the game" is a distinguishing factor between skilled and less skilled players (Williams, 2000). The ability to maintain spatial awareness of teammates, opponents, and the ball is critical. Multiple object tracking includes dynamic visual information that has to be actively processed, which is a crucial part of the perceptual component involved in decision making (Romeas, Guldner, & Faubert, 2016). The selective attention and processing speed of multiple moving targets necessary for multiple object tracking task may be crucial for the efficient execution of decision making during a match (Romeas et al., 2016). This skill is highly solicited in team sports as an athlete's ability to track multiple elements (teammates, opponent, ball, etc.) is important for swift and effective reactions during a game or match (Faubert & Sidebottom, 2012; Williams, Hodges, North, & Barton, 2006). As the athlete fatigues, their ability to maintain tracking ability may be compromised. A decrease in tracking may result in a delayed reaction to game stimuli, which could result in a potential negative outcome (Jajtner et al., 2013).

Multiple object tracking was originally investigated by Pylyshyn and colleagues to examine how individuals are able to keep track of multiple targets in a dynamic environment (Z. W. Pylyshyn & Storm, 1988). Subjects viewed a screen displaying ten targets and were instructed to track up to five targets during each trial session (Z. W. Pylyshyn & Storm, 1988). This initial investigation found that individuals could track four to five independently moving targets among distractors with about 85% accuracy (Z. W. Pylyshyn & Storm, 1988). These initial experiments had targets change speed at random during each trial (Z. W. Pylyshyn & Storm, 1988). More recent investigations have used speed as a dependent variable. Utilizing the speed of the targets in this way provides a methodological advantage by providing a continuous ratio scale for scoring values as opposed to assessing the number of correct responses when tracking a given number of moving targets (Faubert & Sidebottom, 2012). Utilizing speed as a measure of multiple object tracking ability presents the limitation of an increased rate of interaction between targets as speed increases during trials (Faubert & Sidebottom, 2012). This may lead to more interactions between the targets occurring simultaneously in multiple places further increasing the perceptual-cognitive demands of each trial (Faubert & Sidebottom, 2012).

There are several theoretical models regarding the plausible psychological mechanisms responsible for multiple object tracking. Pylyshyn first proposed the *Fingers of Instantiation* (FINST) model following his initial multiple object tracking investigations (Z. Pylyshyn, 1989). This proposed model is its own individual, encapsulated cognitive system that is reliant on early vision and detection of targets. During multiple object tracking tasks, four to five targets are identified and assigned an index or pointer that remains attached to each target as it moves through the individual's line of vision (Z. Pylyshyn, 1989). These indexes do not require attention resources to remain attached to the moving target's location and serve to allow rapid attentional access to the location of each index (Cavanagh & Alvarez, 2005; Z. Pylyshyn, 1989). However, attention can only be directed towards a single index at a time (Cavanagh & Alvarez, 2005; Z. Pylyshyn, 1989). In this model, the FINST mechanism is effortless and automatic so the attentional demands associated with successful multiple object tracking are a product of occasional efforts to reestablish target indexes (Z. W. Pylyshyn & Storm, 1988).

Yantis and colleagues proposed a differing model for tracking multiple objects in which the individual will group individual targets into a single virtual object (Yantis, 1992). This theoretical model suggests that multiple object tracking ability is a reflection of one's ability to maintain a perceptual grouping of moving targets (Yantis, 1992). The model proposes two stages during performance: group formation and group maintenance (Yantis, 1992). The group formation stage is similar to Pylyshyn's indexing process as the selection of targets is pre-attentative and automatic (Cavanagh & Alvarez, 2005; Yantis, 1992). However, the group maintenance phase demands effort and attention resources to continuously update the orientation of the shape of targets as they move (Cavanagh & Alvarez, 2005; Yantis, 1992). Increased ability to make continuous mental spatial transformations allows for more efficient tracking skills (Cavanagh & Alvarez, 2005; Yantis, 1992).

The *Object-File* theory of Kahneman and colleagues presumes that an accurate perception of a dynamic environment requires temporary memory representations of the objects being tracked within the environment (Cavanagh & Alvarez, 2005; Kahneman, Treisman, & Gibbs, 1992). Unlike the indexes that only note location, object files collect various information about selected targets, which are then only addressed by their spatiotemporal properties (Cavanagh & Alvarez, 2005; Kahneman et al., 1992). The number of object files that can be maintained is limited in respect to an individual's visuospatial working memory. For this reason, tracking ability, according to the Object-File theory, is dependent on visuospatial working memory capacity (Cavanagh & Alvarez, 2005; Kahneman et al., 1992).

Pylyshyn and Yantis have also detailed a theoretical model that opposes the previous three proposing serial attention switching as the mechanism responsible for tracking multiple objects (Z. W. Pylyshyn & Storm, 1988; Yantis, 1992). In this serial attention switching model, only a single spatial region can be targeted at a time and successful object tracking is performed by continuously switching the position of focal attention amongst the objects being tracked (Z. W. Pylyshyn & Storm, 1988; Yantis, 1992). By continuously shifting the position of attention, the coordinates of the targets are repeatedly updated within the working memory (Z. W.

Pylyshyn & Storm, 1988; Yantis, 1992). Performance under this theory would be dependent on the efficiency of attentional processing and visuospatial short-term memory (Z. W. Pylyshyn & Storm, 1988; Yantis, 1992). This method is considered to be taxing and requires effort to continually cycle focal attention amongst targets (Z. W. Pylyshyn & Storm, 1988; Yantis, 1992). Additional models have been proposed that combine concepts from those that have been mentioned, but further investigation is needed to provide enough empirical data to identify which theory truly represents the working mechanism responsible for effective multiple object tracking ability (Cavanagh & Alvarez, 2005).

Following Pylyshyn's initial multiple object tracking performance investigations involving college-age students, research expanded to other populations including high-level and professional athletes (Faubert & Sidebottom, 2012). Anecdotal findings reported by Faubert indicate professional soccer, rugby, and ice hockey players possess a wide spread of initial baseline ability when assessed with a multiple object tracking task (Faubert & Sidebottom, 2012). However, this anecdotal report also noted that most athletes consistently improved with repetition of a multiple object tracking assessment regardless of their baseline scores (Faubert & Sidebottom, 2012). Incorporating multiple object tracking training into the training programs of professional sports teams has increased in popularity in recent years (Faubert & Sidebottom, 2012). By including multiple object tracking as part of any athlete's training program, Faubert has hypothesized three main on-field benefits for which to investigate further (Faubert & Sidebottom, 2012). The first is a potential increase in the visual field in which player movement is able to be perceived. This would likely increase the number of objects that could be efficiently tracked thus increasing the basis for tactical decision making (Faubert & Sidebottom, 2012). Secondly, it may be possible to improve the management of concentration resources while tracking objects at submaximal exertion levels (Faubert & Sidebottom, 2012). Lastly, Faubert postulates that it may benefit athletes' ability to perform multiple perception tasks simultaneously such as reading opponent body language while maintaining spatial awareness of surrounding players (Faubert & Sidebottom, 2012).

NeuroTracker

The NeuroTracker (NT; CogniSens Athletic, Inc., Montreal, Quebec, Canada) system software is a multiple object tracking assessment that isolates cognitive skills (i.e. attention, working memory, executive function, visual information processing speed) that are critical for processing dynamic environments. Neurotracker distributes athletes' attention across multiple moving targets interspersed with identical distractor targets moving at varying speed thresholds within a large visual field (Faubert & Sidebottom, 2012; Parsons et al., 2016). The system is a modernization of the multiple object tracking apparatus utilized in Pylyshyn's original experiments (Z. W. Pylyshyn & Storm, 1988). NeuroTracker assessments require an individual to simultaneously track a given number of moving targets at increasing speeds. The goal of the assessment is to determine at what speed an individual can consistently track the moving targets. The ability to track the Neurotracker targets at greater speeds results in a greater threshold score. This greater threshold score would indicate an increased capacity to maintain tracking ability in a dynamic environment such as a soccer match. A detailed description of a single core session on the NeuroTracker can be found in the Methods section. To date, several investigations have utilized the NeuroTracker to assess multiple object tracking speed and its impact on soccer players, other team sport athletes, and various other populations that would benefit from an increased tracking capacity.

Romeas and colleagues conducted a study to determine if three dimensional NeuroTracker training sessions would benefit the on-field skill performance of 25 university level soccer players during small-sided games (Romeas et al., 2016). Over the course of 10 training sessions across five weeks, players in an experimental and active control group performed 30 core sessions on the NeuroTracker and viewed three-dimensional footage of World Cup matches, respectively, whereas a control group received no training during the five weeks (Romeas et al., 2016). Prior to, and after the five-week training period, players competed in 40 minutes worth of small-sided matches in which their decision making ability (i.e. dribble, pass, shoot) was assessed via video recorded coding system (Romeas et al., 2016). Results from the objective decision making assessment indicated that players that trained with the NeuroTracker displayed significant improvements in passing accuracy from pre- to post- (Romeas et al., 2016). These findings represent the first empirical evidence that the NeuroTracker provides a stimulus that is transferable to the field for soccer athletes (Romeas et al., 2016).

NeuroTracker has been shown to be indicative of performance in other professional team sports. Mangine and colleagues examined the relationship between NeuroTracker performance and basketball specific performance measures (i.e. assists, turnovers, steals) throughout an entire National Basketball Association season in professional basketball athletes (Mangine et al., 2014a). Their findings indicated that increased multiple object tracking speed was related to increased ability to see and make plays based on the stimuli on the court (Mangine et al., 2014a). Players that performed better on the NeuroTracker also showed better performance based on the number of assists, steals and ratio of assists to turnovers (Mangine et al., 2014a). This was the first evidence that NeuroTracker scores had pragmatic meaning for game performance in team sport athletes (Mangine et al., 2014a).

During an investigation involving a Division I university women's soccer team, Jatner and colleagues compared multiple object tracking speed between starters and non-starters across a full season (Jajtner et al., 2013). Twenty-eight female soccer athletes completed NeuroTracker assessments to determine multiple object tracking speed at three time points throughout their competitive season: preseason, midseason, and postseason (Jajtner et al., 2013). No significant differences were identified between starters and non-starters but a significant main effect for time was seen from preseason to midseason and to postseason with each session displaying increasing multiple object tracking speeds during each of the NeuroTracker trials (Jajtner et al., 2013). These findings indicate that even without regular training via NeuroTracker, improvements in multiple object tracking can be achieved across the duration of a women's Division I soccer season (Jajtner et al., 2013). Participation in practice and game situations appear to provide a potent training effect for multiple object tracking (Jajtner et al., 2013). There is currently no research indicating the effect of playing time within a single competition on multiple object tracking.

Intermittent Soccer Performance Test (iSPT)

The dynamic nature of soccer presents significant challenges with regards to effectively isolating and evaluating individual components of player performance, such as multiple object tracking. To control for these dynamic elements, high-intensity intermittent performance tests have been developed to assess player performance and replicate the physiological demands of a match within a controlled laboratory setting (Aldous et al., 2014; Bangsbo, Iaia, & Krustrup, 2008). Laboratory treadmill-based protocols have been used predominantly to ensure control of the environmental conditions during assessment (Aldous et al., 2014). A non-motorized treadmill

(NMT) protocol provides an accurate soccer stimulus allowing for decrements in performance as well as for maximal exercise performance to be quantified (Aldous et al., 2014). The use of an NMT also provides the ability to individualize speed thresholds according to each athlete's peak sprint speed (PSS) (Aldous et al., 2014). This allows for a true measure of each individual's performance capacity throughout the duration of the simulated match (Abt, Reaburn, Holmes, & Gear, 2003; Drust, Reilly, & Cable, 2000). The utilization of the iSPT provides a valid and reliable soccer-specific stimulus while allowing for the examination and monitoring of other physiological and neuropsychological processes (Aldous et al., 2014).

A previously published intermittent soccer performance test (iSPT) protocol performed on a NMT validated this type of test to be a reliable means of assessing physiological and performance variables in soccer players (Aldous et al., 2014). The iSPT consists of two 45-minute halves, separated by a 15-minute interval. Both halves are comprised of 3 identical 15-minute segments of intermittent exercise. (Aldous et al., 2014). Throughout the running protocol participants interact with a computer program designed to guide the participants' running intensities in a manner that replicates a live soccer match based on previously published time and motion analyses (Aldous et al., 2014; Bangsbo et al., 1991b; Withers, Maricic, Wasilewski, & Kelly, 1982). The software displays a red line indicating the participant's target speed on a screen, located in front of the treadmill. A green line is then generated representing the participant's current speed. Participants are asked to match their speed (green line) with the target speed (red line) as closely as possible throughout the entire 90 minutes (Aldous et al., 2014). The iSPT consists of 7 movement categories assigned to each participant as a percentage of their peak sprint speed (PSS) (Aldous et al., 2014). Movement categories for this iSPT include: standing (0% PSS), walking (20% PSS), jogging (35% PSS), running (50% PSS), fast running (60% PSS), variable running (unset % PSS), and sprint (100% PSS) (Aldous et al., 2014). The variable running consists of four self-selected high-speed runs in which the participant is instructed to cover as much distance as possible without sprinting.

Recent literature utilizing a sample of semi-professional athletes has indicated that players typically only move at velocities between 0 and 80% PSS during a match (Núñez-Sánchez, Toscano-Bendala, Campos-Vázquez, & Suarez-Arrones, 2017). In fact, only 30% of players in this study reached 80-90% PSS and only 2.5% exceeded 90% of their peak velocity (Núñez-Sánchez et al., 2017). These findings indicate that for future studies attempting to accurately simulate a soccer match, utilizing an iSPT protocol 80% PSS may be a more appropriate velocity threshold for top-end movements compared to 100% PSS. Another recent investigation examined the difference in demands associated with the NMT compared to overground and motorized treadmill running (R. B. Edwards, Tofari, Cormack, & Whyte, 2017). These authors concluded that the continual task of overcoming the resistance of the NMT belt may provide increased relative cardiometabolic stress, particularly in females of lesser body mass (R. B. Edwards et al., 2017).

Conclusion

Multiple object tracking is a cognitive skill utilized by soccer athletes to maintain spatial awareness of teammates, opponents and the ball during match play. This is critical for players' ability to read the game which is a distinguishing feature between skilled and lesser skilled players. Throughout the course of a 90-minute soccer match players endure fatigue which has been shown to impact both physical and cognitive performance. How MOT changes during a full match is unknown. The dynamic nature of soccer makes it difficult to effectively quantify cognitive performance during a live match. To circumvent the challenges associated with analyzing performance during a live game, an iSPT can be used to provide players with a physiological stimulus that is similar to a match but can be performed in a controlled laboratory environment. The purpose of this study was to utilize an iSPT to examine changes in running and MOT speed across a 90-minute simulated match in female soccer athletes. A secondary purpose of this study was to examine the relationship between players' aerobic capacity (VO_{2max}) and their changes in MOT speed. We hypothesized that MOT speed would decline across the iSPT. We expected to see a decline in running performance measures as well. We also hypothesized that there would be a positive relationship between VO_{2max} and the ability to maintain multiple object tracking speed.

CHAPTER THREE: METHODOLOGY

Study Design

Multiple object tracking (MOT) speed was assessed in collegiate female soccer players throughout a 90-minute intermittent soccer performance test (iSPT) designed to simulate the running profile of a collegiate soccer match. The iSPT consisted of two 45-minute halves performed on a Curve 3 non-motorized treadmill (Woodway, Waukesha, WI). MOT was assessed utilizing NeuroTracker (NT; CogniSens Athletic, Inc., Montreal, Quebec, Canada). NeuroTracker assessments were performed PRE and in real-time before and at 3 time points during each half of the iSPT. Testing procedures took place in the time between postseason play and spring matches.

Participants

Participants in this study were NCAA Division 1 and collegiate club soccer athletes. The University of Central Florida Student-Athlete Welfare Committee approved the participation of UCF soccer athletes in this study. Participants were females (n = 17) between the ages of 18 and 22 years old. All participants were free of any physical limitations determined by medical and activity history questionnaire (MHQ). Exclusion criteria included the inability to perform exercise as determined by MHQ, taking any other nutritional supplement or performance enhancing drug, regularly taking any type of prescription or over-the-counter medication, having any chronic illness requiring medical care, and/or answering “Yes” to any question on the physical activity readiness questionnaire (PAR-Q+). This research study was approved by the University’s Institutional Review Board.

Procedures

Participants reported to the human performance laboratory (HPL) on three separate occasions. On Day 1 (D1), potential participants were informed of all procedures and demands of the study. Following this, potential participants provided written consent to participate in this study, followed by completion of a Medical and Activity History Questionnaire (MHQ) and Physical Activity Readiness Questionnaire (PAR-Q+) to establish eligibility. Eligible participants were then familiarized with the NeuroTracker, and Curve 3 treadmill (cNMT). Participants returned to the HPL following a 4-hour fast for Day 2 testing (D2) no more than 36 hours after D1. During D2, body composition was assessed via biological impedance analysis. Participants also underwent additional familiarization with the NeuroTracker and cNMT. Participants were then allowed a small snack prior to peak sprint speed (PSS) and aerobic capacity assessments. PSS was assessed via completion of three 40-meter sprints which were measured using global positioning technology (GPS). After a recovery period of at least 60 minutes, VO_{2max} was assessed via a ramp protocol using a motorized treadmill and metabolic cart. At least 48-hours after D2, participants returned to the HPL for Day 3 (D3) which consisted of a modified iSPT performed on the cNMT. The iSPT consisted of two 45-minute halves separated by a 15-minute intermission. Prior to performing the iSPT, participants provided a urine sample to determine hydration status via urine specific gravity (USG). Participants did not begin the iSPT trial until they were in a state of euhydration. Participants were only permitted to rehydrate at half-time. Multiple object tracking speed was assessed via NeuroTracker immediately prior to the iSPT (PRE), and in real-time at three time points during each 45-minute half (9, 24, 39, 54, 69 and 84 minutes). Each NeuroTracker assessment lasted approximately 6-minutes. The iSPT consisted of intermittent patterns of standing (0% PSS), walking (20% PSS), jogging (35% PSS), running (50% PSS), fast running (60% PSS), and sprinting (80% PSS) in a pattern designed to simulate the characteristics of a typical competitive soccer match. The protocol was controlled and administered via Pacer Performance System software (Innervation, Pacer Performance System Software, Innervation, Pacer Performance System Software, Lismore, Australia). This protocol is consistent with previously published time motion analyses of competitive soccer matches (Aldous et al., 2014). Recent literature supported lowering the sprint zone from 100% to 80% PSS (Núñez-Sánchez et al., 2017).

Familiarization

Participants were familiarized with the NeuroTracker and cNMT at both D1 and D2. The familiarization protocol used for each test was the same for both sessions. Familiarization with the Curve 3 non-motorized treadmill consisted of 3-minutes of walking, jogging, and running at a self-selected speed followed by 2-minutes of standing, walking, jogging, and running at speeds ranging from two to five meters per second guided by the Pacer Performance System Software. Familiarization for the NeuroTracker consisted of a full 20-trial session that began while the participant was standing in a stationary position on the treadmill. During NeuroTracker familiarization, participants were instructed to stand, walk, or jog.

Anthropometrics

At D2, body mass (±0.1 kg) and height (±0.1 cm) were measured using a Health-o-meter Professional scale (Patient Weighing Scale, Model 500 KL, Pelstar, Alsip, IL, USA). Body composition was assessed using a direct segmental multi-frequency bioelectrical impedance analyzer (BIA) via InBody (Model 770, InBody Co., Ltd, Cerritos, CA, USA) according to the manufacture's guidelines. BIA estimates body composition using the conductivity differences of the various tissues due to their tissue characteristics (water and electrolyte content). This analyzer processes 30 impedance measurements by using six different frequencies (1, 5, 50, 250, 500, 1000 kHz) at each of five segments of the body (right arm, left arm, trunk, right leg, left leg) using tetrapolar 8-point tactile electrodes (Kurinami et al., 2016). Participants were asked to remove all jewelry and footwear, including socks; and to void the bladder before performing the test. This assessment required the participants to wipe their hands and feet with an InBody tissue to enhance electrical conductivity and reduce surface bacteria before being assessed. The participants were then instructed to stand on the InBody platform electrodes while holding two hand electrodes out to the side. They held this position for one minute as the device conducted the electrical currents through the body to determine body composition. Values for total body fat percentage were recorded.

Peak Sprint Speed Assessment (PSS)

PSS was assessed via a 40-meter sprint test. Participants performed 3 x 40-meter maximal sprints on a grass surface with 4-minutes of rest between trials (Mangine et al., 2014b). Players wore their normal soccer cleats for this test. Players were equipped with a GPS receiver/transmitter (Polar Team Sport System, Polar Electro Oy, Finland). Active GPS units were secured with a strap placed around the players' midsection. Players were tracked in real time using Polar Team Sport Systems. Peak velocity was acquired from each of the 3 trials. The best score was used for individual iSPT velocity threshold calculations.

Maximal Oxygen Uptake

VO_{2max} was assessed via an incremental test to volitional exhaustion on a motorized treadmill (Woodway 4Front™, Waukesha, WI) similar to other studies from our lab (McCormack et al., 2015). Open-circuit spirometry (TrueOne 2400® Metabolic Measurement System, Parvo Medics, Inc., Sandy, UT), calibrated with gases of known concentration, were used to assess VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) via sampling of breath-by-breath expired gases (McCormack et al., 2015). VO_{2peak} was determined to be the highest 30-s VO_2 value during the test coinciding with at least two of the following three criteria: (a) 90% of age predicted maximum heart rate; (b) respiratory exchange ratio > 1.1; and/or (c) a plateau of oxygen uptake (less than 150 $mL \cdot min^{-1}$ increase in VO_2 during the last 60 s of the test (McCormack et al., 2015). Prior to the assessment of maximal oxygen uptake, participants were outfitted with a Zephyr bioharness (Model BH3, Zephyr Technology Corporation, Annapolis, MD, USA). The bioharness is a wireless, ambulatory physiological monitoring device that includes a chest strap and battery operated monitoring device (biomodule). The biomodule attaches to a receptacle in the chest strap, and provides real time heart rate data through conductive fabric skin electrode sensors housed in the chest strap. Previous research has found this device to be valid for ambulatory laboratory testing (Johnstone, Ford, Hughes, Watson, & Garrett, 2012).

Hydration Assessment

Upon arrival on D3, participants provided a urine sample for analysis of urine-specific gravity (USG) via digital refractometer (Misco PA202, Solon OH, USA) to ensure adequate hydration status (USG $\leq$ 1.020 defined as euhydration). Participants that were not deemed “euhydrated” were instructed to continue drinking water until another USG analysis indicated they had reached a state of euhydration. Participants were allowed to drink water ad libitum during the 15-minute intermission, but not during the iSPT.

Intermittent Soccer Performance Test (iSPT)

Prior to the iSPT, participants performed a sport specific warm-up consisting of lower-body dynamic stretching exercises (i.e., abduction, adduction, quad pulls, knee hugs, squat to lateral step, and trunk flexion and extension) followed by 3 minutes of self-paced running on the cNMT. Participants were then outfitted with a Zephyr bioharness, which was worn for the duration of the iSPT. The iSPT consisted of two 45-minute halves on a treadmill, separated by a 15-minute intermission. Based on individualized velocity thresholds determined from the PSS (Aldous et al., 2014), the iSPT consisted of intermittent patterns of standing (0% PSS), walking (20% PSS), jogging (35% PSS), running (50% PSS), fast running (60% PSS), and sprinting (80% PSS) in a pattern designed to mimic the characteristics of a typical collegiate soccer match (Aldous et al., 2014). The total time breakdown for each movement category for all participant assessments was: standing (17.8%), walking (36.4%), jogging (24.0%), running (11.6%), fast running (3.6%), and sprinting (6.7%) (Aldous et al., 2014). The time allotted for each movement category did not change between each participant, only the absolute speed of each movement category (based on PSS). The following adjustments were made from the Aldous protocol: sprinting accounted for 6.7% of the protocol to accommodate the elimination of a "variable run" and sprint threshold was lowered from 100% to 80% of PSS as previous literature has shown that soccer players normally used 0-80% of their peak velocity during a match with only 30% of players reaching 80-90% of their peak velocity (Núñez-Sánchez et al., 2017). Further, only 2.5% are reported to exceed 90% of their PSS. The top-end speed was also adjusted downward to account for the increased cardiometabolic demands associated with running on the cNMT compared to overground running (R. B. Edwards et al., 2017). The 15-minute protocol block was developed to allow comparison of both the performance and physiological capacity between/within-halves (Aldous et al., 2014).

Multiple Object Tracking (MOT) Ability (NeuroTracker)

Visual tracking speed was evaluated during the ISPT via completion of one core session on the NeuroTracker 3D multiple object tracking device (NT; CogniSens Athletic, Inc., Montreal, Quebec, Canada). A single core session is comprised of 20 individual trials calculating spatial awareness by determining a threshold speed for the effective perception and processing of visual information of the athlete being tested. Each trial was performed from the treadmill at 15-minute intervals during the iSPT. During each assessment, a 3D transparent cube containing eight identical yellow balls was presented on the screen. Four of these balls were randomly illuminated for two seconds before returning to the baseline yellow color. Each participant was instructed to track these four balls for the duration of each of the 20 trials. During each trial, all eight yellow balls moved simultaneously and individually throughout all regions of the cube for eight seconds. The random, continuous movement patterns of each ball were only affected by collisions (impact and bounce) with the wall of the cube and the other balls. At the conclusion of eight seconds, the balls froze in place and each assigned a value (1 to 8). The participant was instructed to identify, by number, the four balls that were originally illuminated at the start of the trial. The speed at which the balls moved on the next trial was dependent on the correct identification of the illuminated balls and was adjusted between trials in a staircase (one up one down) fashion (Mangine et al., 2014a). At the end of the 20 trials, visual tracking speed was determined to be the fastest speed (in centimeters per second) at which the player could correctly identify all balls with 100% accuracy (Mangine et al., 2014b). Participants performed assessments on the NeuroTracker, multiple object tracking device at 0 minutes (BL), and at three time points within each half of the iSPT.

Running Performance

Running performance data was collected during the iSPT via the integrated Pacer Performance System Software which continuously records time (s) and distance (m) data via a tachometer mounted on the treadmill drum. Data was sampled at a rate of 100 Hz. Running performance data was assessed for each 15-minute period within both halves. Data analyzed included distances covered (m) and movement velocity ($km \cdot h^{-1}$) within each movement category.

Statistical Analysis

Prior to statistical procedures, all data were assessed for normality using the Shapiro-Wilk's test and assessed for sphericity. If the assumption of sphericity was violated, a Greenhouse–Geisser correction was applied. Differences in running performance and MOT speed scores across the six 15-minute blocks of the iSPT were analyzed using a one-way repeated measures analysis of variance (ANOVA). In the event of a significant F ratio, Bonferroni post hoc analysis was used for pairwise comparisons. Time effects were further analyzed using partial eta squared (η_p^2). Interpretations of η_p^2 were evaluated in accordance with Cohen (1988) at the following levels: small effect (0.01–0.058), medium effect (0.059–0.137), and large effect (>0.138) (Cohen, 1988). Dependent t-tests were utilized to assess differences in MOT speed scores and running performance between halves. Comparisons between halves were further analyzed using Cohen's *d*. Magnitudes of the standardized effects were interpreted using thresholds of <0.2, 0.2–0.6, 0.6–1.2, 1.2–2.0, and 2.0–4.0. These values correspond to trivial, small, moderate, large, and very large ES, respectively (Hopkins, Marshall, Batterham, & Hanin, 2009). The relationship between aerobic capacity and change in MOT speed score was assessed using Pearson correlations coefficients. Correlation coefficient size was interpreted using thresholds of <0.3, 0.3-0.5, 0.5-0.7, 0.7-0.9, 0.9-1.0. These values correspond to negligible, small, moderate, large, and very large, respectively (Mukaka, 2012). Data were analyzed using IBM SPSS Statistics for Windows (version 23.0; IBM Corp., Armonk, NY, USA). Significance was accepted at an alpha level of $p \leq 0.05$. All data are reported as mean ± SD, unless otherwise stated.

CHAPTER FOUR: RESULTS

Participant Characteristics

Following an explanation of all procedures, risks and benefits, a total of 17 participants were enrolled in this study. Of the 17 participants, seven participants discontinued their participation following familiarization, and three began but were unable to complete the iSPT protocol (Figure 1). Of the three that did not complete the iSPT, two were club level athletes that discontinued the iSPT voluntarily and one was a Division I athlete that discontinued the protocol due to unrelated breathing issues. Therefore, seven participants were included in the analysis (20.4±1.8 y, height: 166.7±3.2 cm, weight: 62.4±4.0 kg, VO2max: 45.8±4.6 ml·kg·min^{-1}). Of these seven participants, four were starters and three were non-starters. Two were defenders, two were midfielders, and three played the forward position. Data analyzed was normally distributed.

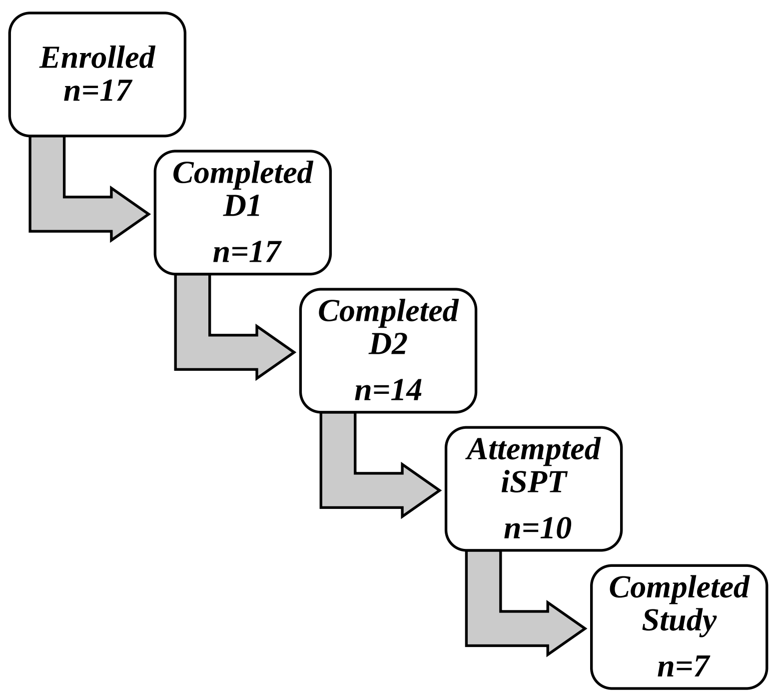

Figure 1: Participant recruitment and enrollment

Running Performance

Distance Covered

Changes in total distance covered within each 15-minute block are reported in Table 2. A significant main effect for time was observed for total distance covered during each 15-minute block of the iSPT (F = 13.162; p = 0.003; η_p^2 = 0.687). Post-hoc analyses revealed a significant decrease in total distance at 16-30min (p = 0.002; d = 0.98; CI_{95} = -131.63 to -41.11m), 31-45min (p = 0.002; d = 1.21; CI_{95} = -166.37 to -50.33m), and 61-75min (p = 0.022; d = 1.5; CI_{95} = -264.04 to -21.26m) compared to 0-15min. A trend towards a decrease in total distance was observed at 46-60min (p = 0.074; d = 1.15; CI_{95} = -221.32 to +9.03m) and 76-90 min (p = 0.085; d = 1.56; CI_{95} = -320.37 to +17.76m) compared to 0-15 minutes.

Changes in distances covered for each movement category within each 15-minute block are reported in Table 2. Significant main effects for time were observed for walking (F = 3.963; p = 0.007; η_p^2 = 0.398), jogging (F = 6.661; p = 0.022; η_p^2 = 0.526), running (F = 5.911; p = 0.001; η_p^2 = 0.496), and sprinting distance (F = 9.982; p = 0.000; η_p^2 = 0.625). Significant decreases in jogging distance were observed at 16-30 min (p = 0.006; d = 0.87; CI_{95} = - 42.49 to -8.64m) and 31-45 min (p = 0.014; d = 1.09; CI_{95} = - 58.52 to -7.23 m) compared to 0-15 min, while significant decreases in sprinting distance were observed at 16-30 min (p = 0.032; d = 0.68; CI_{95} = -35.53 to -1.60 m), 31-45 min (p = 0.050; d = 0.76; CI_{95} = -40.84 to -0.03 m), 46-60 min (p = 0.001; d = 0.94; CI_{95} = -35.52 to -12.79 m), and 61-75 min (p = 0.039; d = 1.08; CI_{95} = -58.57 to -1.44 m) compared to 0-15 min. Post hoc analyses revealed no significant differences between 15-minute blocks for walking and running distance (p's > 0.05). No significant main effects were observed for fast run distance (p > 0.05).

Significant main effects for time was also observed for low-speed distance (F = 8.295; p = 0.017; η_p^2 = 0.580) and high-speed distance (F = 11.589; p = 0.003; η_p^2 = 0.659). Significant decreases in low-speed distance were observed at 16-30 min (p = 0.004; d = 0.83; CI_{95} = -102.75 to -25.41m) and 31-45 min (p = 0.004; d = 1.07; CI_{95} = -133.24 to -32.61m) compared to 0-15 min, as well as at 61-75 min (p = 0.006; d = 0.32; CI_{95} = -41.37 to -8.63m) compared to 46-60 min. Significant decreases in high-speed distance were observed at 16-30 min (p = 0.016; d = 0.66; CI_{95} = -40.09 to -4.50 m), 31-45 min (p = 0.033; d = 0.75; CI_{95} = -48.87 to -1.99 m), 46-60 min (p = 0.003; d = 0.93; CI_{95} = -48.27 to -12.95 m), and 76-90 min (p = 0.029; d = 0.94; CI_{95} = -62.80 to -3.35m) compared to 0-15 min. A trend towards a decrease in high-speed running was also observed at 61-75 min (p = 0.054; d – 1.07; CI_{95} = -84.87 to + 0.64 m) relative to 0-15 min.

Table 2: Distances covered (m) within each movement zone during each 15-minute block of iSPT

	0-15min	16-30min	31-45min	46-60min	61-75min	76-90min
Stand	32.29 ± 7.94	25.39 ± 6.41	28.78 ± 8.82	29.83 ± 7.85	26.48 ± 11.86	29.86 ± 6.86
Walk	426.67 ± 46.47	405.20 ± 39.86	391.37 ± 31.53	399.72 ± 35.15	389.2 ± 42.12	382.83 ± 41.10
Jog	502.43 ± 29.04	476.87 ± 29.45*	470.56 ± 29.71*	471.95 ± 25.53	464.37 ± 27.13	455.94 ± 29.18
Run	350.52 ± 17.56	340.38 ± 23.56	338.28 ± 20.57	334.88 ± 19.31	331.33 ± 23.03	325.05 ± 23.79
Fast Run	129.46 ± 6.69	125.73 ± 8.30	124.46 ± 9.16	123.00 ± 8.19	117.35 ± 15.89	116.54 ± 15.61
Sprint	296.65 ± 23.78	278.08 ± 30.62*	276.22 ± 29.95*	272.50 ± 27.43*	266.64 ± 31.46*	276.50 ± 24.69
Low Speed Run	1311.91 ± 80.87	1247.83 ± 72.92*	1228.99 ± 73.98*	1236.38 ± 76.03	1211.38 ± 80.72¥	1193.68 ± 81.43
High Speed Run	426.11 ± 30.05	403.82 ± 37.46*	400.68 ± 37.08*	395.5 ± 35.52*	383.99 ± 47.09	393.04 ± 39.51*
Total Distance	1738.02 ± 88.78	1651.65 ± 88.02*	1629.67 ± 90.02*	1631.88 ± 95.82	1595.38 ± 100.92*	1586.72 ± 104.54

iSPT = Intermittent soccer performance test; m = meters. * Indicates significant difference from 0-15min. ¥ Indicates significant difference from 46-60min. Data are presented as means ± SD.

Changes in total distance covered between halves are presented in Figure 2. Players covered significantly less total distance during the second half compared to the first half ($p = 0.025$; $d = 0.73$; $CI_{95} = -36.47$ to -374.26 m).

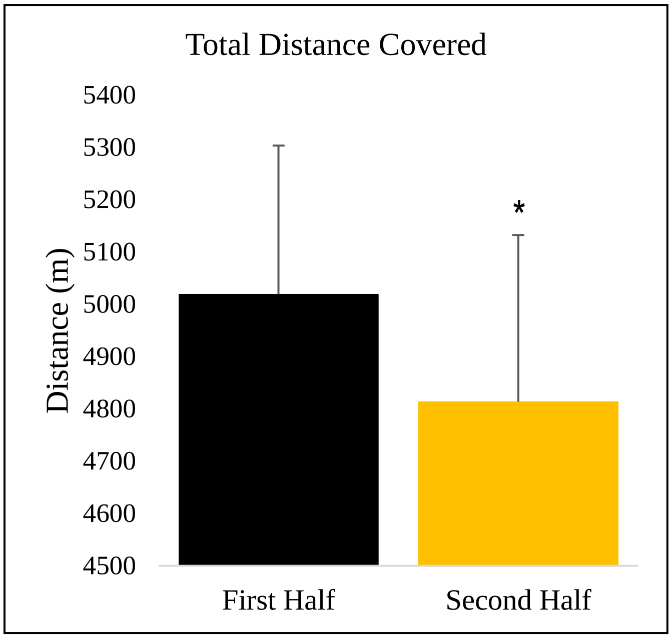

Figure 2: Distance covered during first and second halves of iSPT

Total distance covered during each half of the iSPT reported in meters (m). * Indicates significant difference between halves. Data are presented as means ± SD.

Changes in total distance covered within each movement zone between halves are presented in Table 3. Significant decreases in distance covered were observed between halves for the sprint and HS zones ($p \leq 0.008$; $d = 0.43$; $CI_{95} = -13.28$ to -57.34 m and $p = 0.002$; $d = 0.52$; $CI_{95} = -32.00$ to -84.16 m respectively).

Table 3: Distances covered (m) within each movement zone during each half of the iSPT

	1st Half	**2nd Half**
Stand	86.46 ± 19.91	86.17 ± 25.14
Walk	1223.23 ± 114.38	1171.75 ± 112.86
Jog	1449.86 ± 86.41	1392.26 ± 77.54
Run	1029.18 ± 60.49	991.26 ± 63.61
Fast Run	379.65 ± 23.10	356.88 ± 38.43
Sprint	850.95 ± 83.63	815.64 ± 81.12*
Low Speed Run	3788.74 ± 224.58	3641.44 ± 231.55
High Speed Run	1230.61 ± 103.79	1172.53 ± 118.95*
Total Distance	5019.34 ± 263.17	4813.97 ± 294.90*

iSPT = Intermittent soccer performance test; m = meters. * Indicates significant difference between halves. Data are presented as means ± SD.

Average Speed

Changes in average speed for each movement category within each 15-minute block are reported in Table 4. A significant main effect for time was observed for average walking speed ($F = 4.221$; $p = 0.005$; $\eta_p^2 = 0.413$), average jogging speed ($F = 5.777$; $p = 0.032$; $\eta_p^2 = 0.491$), average running speed ($F = 6.607$; $p = 0.000$; $\eta_p^2 = 0.524$), and average sprinting speed ($F = 9.928$; $p = 0.000$; $\eta_p^2 = 0.623$). Significant decreases in average jogging speed were observed at 16-30min ($p = 0.007$; $d = 0.82$; $CI_{95} = -0.73$ to -0.13 km·h^{-1}) and 31-45min ($p = 0.018$; $d = 0.97$; $CI_{95} = -0.93$ to -0.09 km·h^{-1}) compared to 0-15 min. Significant decreases in average sprinting speed were observed at 16-30 min ($p = 0.033$; $d = 0.67$; $CI_{95} = -2.14$ to -0.09 km·h^{-1}), 31-45 min ($p = 0.050$; $d = 0.75$; $CI_{95} = -2.45$ to $+0.00$ km·h^{-1}), 46-60 min ($p = 0.001$; $d = 0.94$; $CI_{95} = -2.13$ to -0.76 km·h^{-1}), and 61-75 min ($p = 0.040$; $d = 1.07$; $CI_{95} = -3.52$ to -0.08 km·h^{-1}) compared to 0-15 min. Post hoc analyses revealed no significant differences between 15-minute blocks for average walking speed or average running speed (p's > 0.05).

A significant main effect for time was also observed for average low-speed running speed ($F = 7.770$; $p = 0.023$; $\eta_p^2 = 0.564$), and average high-speed running speed ($F = 11.577$; $p = 0.003$; $\eta_p^2 = 0.659$). Significant decreases in average low-speed running speed were observed at 16-30min ($p = 0.005$; $d = 0.77$; $CI_{95} = -0.52$ to -0.12 km·h^{-1}) and 31-45min ($p = 0.004$; $d = 1.10$; $CI_{95} = -0.72$ to -0.17 km·h^{-1}) compared to 0-15 min. A significant decrease in average low-speed running speed was also observed at 61-75 min (0.019; $d = 0.29$; $CI_{95} = -0.22$ to -0.02 km·h^{-1}) compared to 46-60 min. Significant decreases in average high-speed running speed were observed at 16-30 min ($p = 0.016$; $d = 0.66$; $CI_{95} = -1.57$ to -0.18 km·h^{-1}), 31-45 min ($p = 0.034$; $d = 0.75$; $CI_{95} = -1.91$ to -0.08 km·h^{-1}), 46-60 min ($p = 0.003$; $d = 0.93$; $CI_{95} = -1.89$ to -0.51 km·h^{-1}), and 76-90min ($p = 0.029$; $d = 0.94$; $CI_{95} = -2.46$ to -0.13 km·h^{-1}) compared to 0-15 min. A trend towards a decrease in high-speed running speed was observed at 61-75 min ($p = 0.053$; $d = 0.39$; $CI_{95} = -3.32$ to $+0.02$ km·h^{-1}) relative to 0-15min.

Changes in average speed within each movement category between halves are presented in Table 5. Significant differences in average speed were observed between halves for the sprint and HS zones ($p \leq 0.008$; $d = 0.43$; $CI_{95} = -1.14$ to -0.27 km·h^{-1} and $p = 0.002$; $d = 0.52$; $CI_{95} = -1.10$ to -0.42 km·h^{-1} respectively).

Table 4: Average speed ($km \cdot h^{-1}$) within each movement category during each 15-minute block of iSPT

	0-15min	**16-30min**	**31-45min**	**46-60min**	**61-75min**	**76-90min**
Walk	4.68 ± 0.51	4.43 ± 0.44	4.28 ± 0.38	4.38 ± 0.40	4.26 ± 0.48	4.19 ± 0.46
Jog	8.34 ± 0.53	7.91 ± 0.53*	7.84 ± 0.52*	7.87 ± 0.45	7.73 ± 0.48	7.62 ± 0.49
Run	12.03 ± 0.68	11.65 ± 0.86	11.55 ± 0.80	11.48 ± 0.74	11.29 ± 0.87	10.98 ± 0.96
Fast Run	14.56 ± 0.76	14.10 ± 0.96	13.98 ± 1.05	13.85 ± 0.94	13.21 ± 1.79	13.09 ± 1.81
Sprint	17.83 ± 1.43	16.72 ± 1.84*	16.61 ± 1.80*	16.38 ± 1.65*	16.03 ± 1.89*	16.62 ± 1.49
Low Speed Run	7.11 ± 0.43	6.79 ± 0.40*	6.67 ± 0.37*	6.70 ± 0.40	6.58 ± 0.40$^{¥}$	6.47 ± 0.43
High Speed Run	16.69 ± 1.18	15.82 ± 1.47*	15.7 ± 1.45*	15.49 ± 1.39*	15.04 ± 1.85	15.4 ± 1.55*

iSPT = Intermittent soccer performance test; $km \cdot h^{-1}$ = kilometers per hour. * Indicates significant difference from 0-15min. $^{¥}$ Indicates significant difference from 46-60min. Data are presented as means ± SD.

Table 5: Average speed (km·h^{-1}) within each movement category during each half of the iSPT

	1st Half	2nd Half
Walk	4.46 ± 0.42	4.28 ± 0.42
Jog	8.03 ± 0.52	7.74 ± 0.45
Run	11.74 ± 0.76	11.25 ± 0.82
Fast Run	14.22 ± 0.89	13.38 ± 1.47*
Sprint	17.05 ± 1.68	16.35 ± 1.63*
Low Speed Run	6.85 ± 0.40	6.58 ± 0.40
High Speed Run	16.07 ± 1.35	15.31 ± 1.55*

iSPT = Intermittent soccer performance test; km·h^{-1} = kilometers per hour. * Indicates significant difference between halves; Data are presented as means ± SD.

Multiple Object Tracking (MOT)

MOT speed scores during each 15-minute block of the iSPT are presented in Figure 3 and Table 6. No significant main effect for time was observed across the six 15-minute blocks for MOT speed (F = 2.12; p = 0.093; η_p^2 = 0.259).

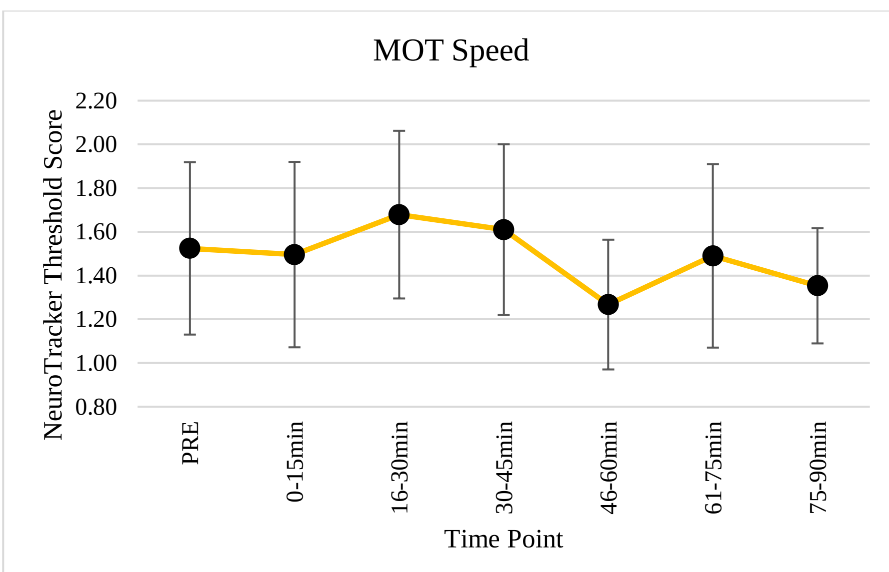

Figure 3: MOT Speed during iSPT

Values indicate the average NeuroTracker threshold speed at each time point

Table 6: MOT Speed during the iSPT

	MOT Scores
Pre	1.52
15min	1.50
30min	1.68
45min	1.61
1st Half	1.59
60min	1.27
75min	1.49
90min	1.35
2nd Half	1.37

Values indicate the average NeuroTracker threshold speed at each time point

A trend towards a decrease in average MOT speed was observed between halves (d = 0.74; $p = 0.056$; CI_{95} = -0.456 to +0.008) (Figure 4).

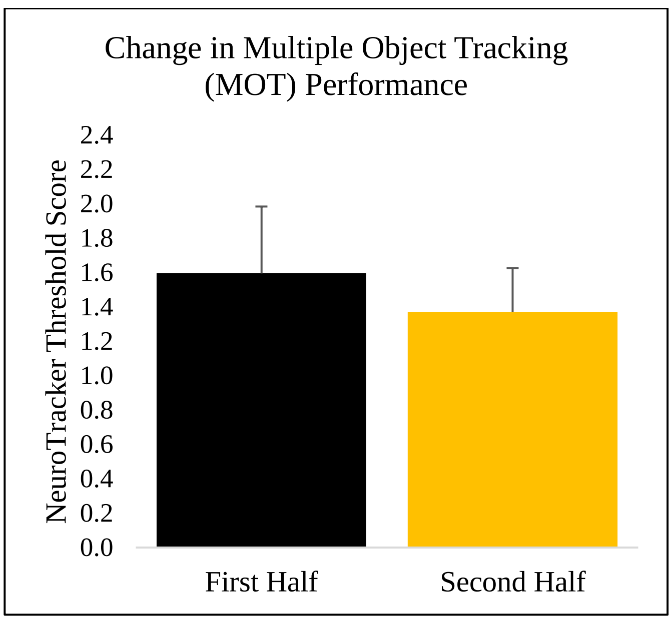

Figure 4: Average NeuroTracker MOT speed during first and second halves of the iSPT

The relationship between VO_{2max} and changes in MOT speed is presented in Figure 5. A large significant correlation was observed between the change in MOT speed and VO_{2max} ($r = 0.888$; $p = 0.007$). Figure 6 displays individual changes in MOT speed between halves with reference to VO_{2max}.

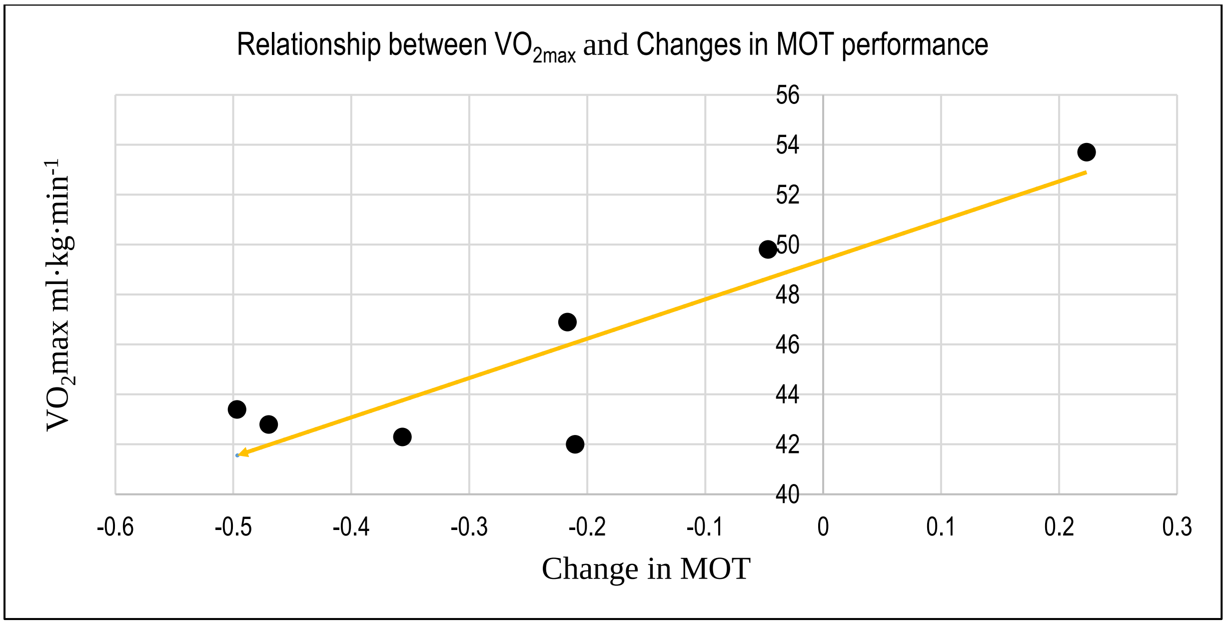

Figure 5: Correlation between VO2max and changes in MOT speed

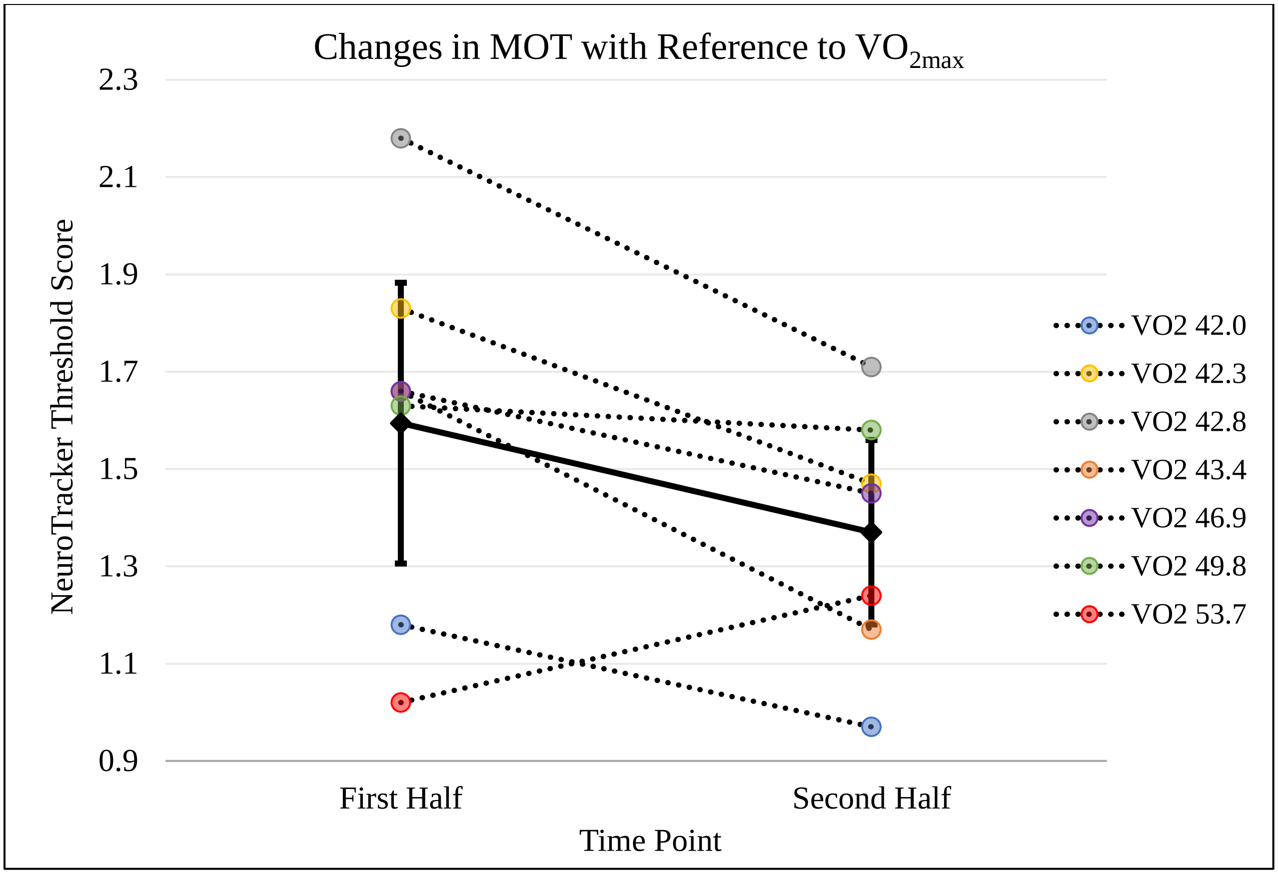

Figure 6: Changes in MOT with Reference to VO_{2max}

CHAPTER FIVE: DISCUSSION

This study examined changes in running performance and MOT speed during a simulated soccer match. The findings of this study suggest that players experience significant decrements in running performance during 90 minutes of soccer-specific running. Significant decrements in distance covered were observed for jogging, sprinting, low-speed running, high-speed running and total distance following the first 15-minute block of the iSPT. Significant decreases in average speed were also observed within each of these movement categories. No significant main effect was observed for MOT speed during the iSPT; however, a large effect was noted ($\eta_p^2 = 0.259$) indicating a potential decline in multiple object tracking speed over time. Additionally, a moderate effect (d = 0.74) was noted between halves, potentially indicating a decline in MOT speed during the second half of the iSPT. A large significant correlation was observed between VO_{2max} and changes in multiple object tracking speed across the 90-minute iSPT. Together these results indicate that female soccer athletes may experience decrements in multiple object tracking speed across a 90-minute match, and that aerobic capacity may be a mitigating factor in this decline. From a practical perspective, superior aerobic capacity may positively impact spatial awareness and processing speed during a match, which speculatively could translate to the prevention of missed scoring opportunities and/or defensive errors. Further research is necessary however, to determine the point at which MOT speed is significantly impaired during a simulated match.

To our knowledge, this is the first study examining the changes in multiple object tracking speed across the duration of a live or simulated soccer match. As such, no comparisons can be drawn from other studies within the literature. Nevertheless, this is not the first examination of changes in cognitive performance during soccer specific activity. An investigation by Casanova and colleagues found that soccer athletes, regardless of playing level, experience decrements in their ability to anticipate offensive situations during the second half of a match compared to the first half. High level athletes were more resistant to these decrements; however, whether this was related to aerobic conditioning status is unclear (Casanova et al., 2013). Similarly, when examining the technical skill performance of soccer athletes, Smith and colleagues report that cognitive fatigue is associated with reduced running performance, increased ball control errors, passing errors, as well as slower and less accurate shooting (Smith et al., 2016). These findings are consistent with the present study where a large effect was observed for a decrease in MOT speed across the iSPT, and highlight the necessity of addressing and accounting for cognitive performance changes across the duration of competitive matches.

The work of Vescovi and colleagues indicates that division I female soccer athletes cover between 4,728 and 5,540 meters and 4,413 and 5,442 meters during the first and second half of a competitive matche respectively (Vescovi & Favero, 2014). They also observed a significant main effect for total distance covered between halves during their investigation of Division I women's locomotor match performance. The average total distances covered during the iSPT in the present study decreased significantly from 5,019.34 to 4,813.97 meters between the first and second halves, respectively. These findings indicate that the iSPT closely reproduced the demands of a competitive match from a total distance standpoint. Additionally, the iSPT successfully induced a degree of fatigue similarly to that experienced by female collegiate soccer athlete during a competitive match.

We observed significant decreases in distance covered and average speed within the sprint and high-speed running zones, as well as total distance covered during the second half of the iSPT. This is consistent with the findings of Wells et al. that indicate Division I female soccer athletes cover significantly less total distance during the second half of competitive postseason matches compared to the first half (Wells et al., 2015). Wells and colleagues observed that postseason distance covered dropped, on average, from 4,336.75 to 3,864 meters from first to second half of postseason matches. It was also observed that players covered significantly less distance within a high-speed running zone (15.96-21.9 $k \cdot h^{-1}$) and during high-intensity running ($\geq$13 $k \cdot h^{-1}$). These findings are consistent with the significant decreases in distances covered within the sprint and high-speed running categories during the second half of the present study. During postseason play, Wells and colleagues also observed significant decreases in distances covered at lower intensity categories (i.e walking, jogging, low-speed running) between halves. Similar decrements in low-intensity movement categories were noted between 15-minute blocks of the iSPT in the present study, but not between halves.

Limitations

One limitation that must be addressed in the present study is the sample size. Having more participants complete the iSPT protocol may have helped to delineate the true effects of the iSPT, particularly on MOT speed. Despite the total distance covered within the iSPT protocol being consistent with that previously reported in female NCAA athletes, two out of the 10 athletes who attempted the iSPT were unable to complete the protocol. These two athletes were club level players. As such, it is possible that the club athletes may not have been as conditioned as the Division I athletes, and this may have contributed to their inability to finish the iSPT protocol. Another potential contributing factor to their inability to complete the protocol could be the lack of stoppages and/or timeouts during the 90-minute iSPT protocol. Unlike the dynamic environment of a traditional soccer match, the running profile of the iSPT is fixed and pre-determined, and therefore does not account for potential impromptu cessations of in-game activity. Previous research has shown that the ball is typically only in play for between 52 and 76 minutes of a 90-

minute match (Tumilty, 1993). Therefore; in an actual match, it is likely players may undergo extensive periods of low-intensity activity during the course of a match. This could positively impact player recovery, which may permit the athlete to complete a match in its entirety. The nature of the iSPT may also have mitigated the adoption of pacing strategies among the athletes tested. Previous research has suggested that soccer athletes adopt conscious or subconscious pacing strategies during a match in order to maintain high-intensity output (Drust, Atkinson, & Reilly, 2007; A. M. Edwards & Noakes, 2009). Since players were not able to independently modulate their running activity profiles, this may have led to accelerated fatigue. Further, it appears that due to the rules regulating substitutions in NCAA collegiate and club soccer, players are often not required to compete for 90-minutes. Wells and colleagues have previously reported an average playing time of 72 minutes during the regular season and 85 minutes during the post-season among female collegiate athletes across the entirety of a single competitive season (Wells et al., 2015). Therefore, it is feasible that the athletes who did not complete the iSPT protocol may not have been accustomed to the demands of a 90-minute match.

The cNMT was utilized in the present study to circumvent the issues associated with collecting MOT data during a dynamic game environment. Nevertheless, previous research has shown that the cNMT is associated with an increased cardiometabolic demand at the target velocity of each movement category when compared to the demands of overground running at the same velocity (R. B. Edwards et al., 2017). This has been shown to be particularly noticeable in females of smaller stature (R. B. Edwards et al., 2017). We attempted to correct for this by reducing the target speed of the sprint movement category to 80% of PSS from 100% of PSS. However, the impact of this adjustment on the metabolic demand of running on the cNMT is not clear. Because target velocities for each iSPT movement category in the present study were based on PSS obtained via over ground running, the adjustment to the sprint threshold may not have fully accounted for differences in the cardiometabolic load associated with PSS values on the cNMT. Our data indicates that there appears to be a discrepancy between PSS obtained while running on the cNMT compared to overground. It is therefore recommended that future studies utilizing a similar iSPT protocol perform the PSS assessment on the cNMT or make further adjustments to the intensity of movement categories.

It should be noted that the utilization of an iSPT negates the prevalence of other soccer specific movements common in soccer such as jumping, tackling, heading, and contesting possession of the ball. The lack of a ball and a dynamic game environment may have elicited an inward direction of attention, which may have increased perceived exertion during the iSPT (Greig et al., 2007). The iSPT is not intended to directly simulate a soccer match, but rather impose similar demands upon the athlete. The results observed herein are limited to forward running in a laboratory environment, and should be interpreted as such.

Finally, in addition to the inherent limitations of the iSPT protocol, it is also possible that the time of year could have played a role in the two athletes not being able to complete the iSPT protocol. This study was completed prior to preseason training games. Previous research by Caldwell and colleagues suggests that the aerobic performance of semiprofessional soccer athletes' is at its lowest during this point of the year (Caldwell & Peters, 2009). It is therefore possible that the two players who were unable to complete the iSPT protocol may have been experiencing a marked state of deconditioning.

Conclusions

Although further research is needed with a greater number of athletes, it appears that along with decrements in high-intensity running performance, soccer athletes may also experience a decline in multiple object tracking speed during 90-minutes of soccer specific running activity. The degree of decline, appears to be related to the athlete's $VO_{2max.}$ Based on these findings it appears that improving soccer athletes' aerobic conditioning may help mitigate a potential decline in tracking speed and spatial awareness during a match. Speculatively, this could translate to the prevention of missed scoring opportunities and/or defensive errors, particularly during the later stages of a match. Further research is necessary however, to determine the exact point at which MOT speed is significantly impaired during a simulated match. Although the iSPT utilized in this investigation effectively simulated the running demands of playing a complete 90-minute soccer match, future investigations should look into further tailoring an iSPT protocol to more closely replicate demands typically required of Division I female soccer athletes.

The research reported here was supported by the American Athletic Conference Academic Consortium, through a grant to the Institution(s). The opinions expressed are those of the authors and do not represent views of the American Athletic Conference Academic Consortium.

APPENDIX A: UCF IRB APPROVAL LETTER

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Adam J. Wells** and Co-PI: **Ryan Michael Girts**

Date: **September 01, 2017**

Dear Researcher:

On 09/01/2017 the IRB approved the following modifications to human participant research until 08/20/2018 inclusive:

Type of Review: IRB Addendum and Modification Request Form
Expedited Review
Modification Type: Neotracker assessment will be given three times, added familiarization to treadmill, minor revisions reflected in updated protocol and consent.
Project Title: Effects of a Simulated Soccer Match on Neuropsychological and Cognitive Function: A Pilot Study
Investigator: Adam J. Wells
IRB Number: SBE-17-13222
Funding Agency: AAC, American Athletic Conference Academic Consortium(AAC)

Grant Title:
Research ID: 1062677

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 08/20/2018, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a signed and dated copy of the consent form(s).

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual. On

behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Gillian Morien on 09/01/2017 11:10:14 AM EDT IRB

Coordinator

APPENDIX B: INFORMED CONSENT

Effects of a Simulated Soccer Match on Neuropsychological and Cognitive Function: A Pilot Study

Informed Consent

Principal Investigator:	Dr. Adam J. Wells, Ph.D.
Co-Investigator(s):	Ryan Girts, B.S.
Sponsor:	UCF Institute of Exercise Physiology and Wellness
Investigational Site(s):	University of Central Florida College of Education and Human Performance Institute of Exercise Physiology and Wellness, Wellness Research Center

Introduction:

Researchers at the University of Central Florida (UCF) study many topics. To do this we need the help of people who agree to take part in a research study. You are being invited to take part in a research study which will include about 32 people from UCF and the surrounding area. You have been asked to take part in this research study because you are a current or formerly competitive soccer athlete that is recreationally active and between the ages of 18 and 30 years old.

The investigators conducting this research are Dr. Adam J. Wells (Assistant Professor of Sport and Exercise Science in the College of Education and Human Performance) and Mr. Ryan Girts (Graduate student of Sport and Exercise Science in the College of Education and Human Performance). This project is a Master's Thesis. Mr. Girts (Student Co-Investigator) is working under the direction of Dr. Adam Wells (Principle Investigator) to complete this study as part of the requirement to graduate from the Sport and Exercise Science Master's Program.

What you should know about a research study:

- Someone will explain this research study to you.
- A research study is something you volunteer for.

- Whether or not you take part is up to you.
- You should take part in this study only because you want to.
- You can choose not to take part in the research study.
- You can agree to take part now and later change your mind.
- Whatever you decide it will not be held against you.
- A decision to participate or not participate in the study will have no effect on grades or continued enrollment.
- Feel free to ask all the questions you want before you decide.

Purpose of the research study:

The ability to keep track of teammates, opponents and the ball during a soccer match is important. This is known as multiple object tracking. The ability of an athlete react during a game is also important. Decreases in cognitive performance may reduce tracking ability and reaction time. This can lead to defensive errors and missed scoring opportunities. More importantly, decreased cognitive and reaction time performance may increase the chance of injury. We currently do not know at which point cognition begins to decline during a game. This may reduce errors and the number of injuries. We need to learn at what point during a soccer game cognition and tracking ability begin to decline. To do this, we will ask you to participate in 90 minutes of soccer specific running on a treadmill. During this time, you will complete cognitive assessments to help us learn when cognitive performance changes. Your participation in this study may help us understand how a soccer match affects cognition may help coaches manage the athletes playing time better.

Inclusion and Exclusion Criteria

- *Inclusion Criteria*
    - Males and Females between the ages of 18 and 30 years' old
    - Currently participating in soccer at a competitive level or having previous competitive soccer experience and currently recreationally active
    - Free of any physical limitations (determined by health and activity questionnaire).
    - Willing to undergo a 4-hour fast

- *Exclusion Criteria*
    - Participant does not provide consent to participate in this study
    - Inability to perform physical exercise [(determined by health and activity history questionnaire(MHQ)]
    - Taking any nutritional supplement or performance enhancing drug (determined from MHQ) that enhances cognitive or running performance
    - Regularly taking any type of prescription or over-the-counter medication, or having any chronic illnesses which require medical care

- Answering "Yes" to any question on the PAR-Q+
- Not willing to undergo a 4-hour fast

What you will be asked to do in this study:

Screening Visit:

During the screening visit, we will review the inclusion/exclusion criteria with you. We will also inform you of the requirements of the study and determine whether you are eligible to participate.

During the screening visit, the following will be done:

- Physical activity readiness questionnaire (PAR-Q+)
- Your age and gender will be collected
- Self-reported confidential medical and activity history questionnaire (MHQ)

You will be asked to read and sign this consent form before any study-related procedures are performed.

Study Protocol:

Investigator expectations are the same for all participants. All procedures are being done solely for research purposes. Following enrollment into the study, you will report to the Human Performance Lab for assessment on three separate occasions:

- Day 1: On the first visit, you will report to the Human Performance Laboratory (HPL). At the HPL you will complete a medical and activity history questionnaire (MHQ) and a physical activity readiness questionnaire (PAR-Q+) to establish your eligibility for the study. Upon completing the MHQ, PAR-Q+ and this informed consent document you will be familiarized with the assessments for this study. You will be familiarized with the Dynavision, which measures reaction time, the Automated Neuropsychological Assessment Metrics (ANAM) Neuropsychological Screening Test, which measures cognition, the Neuortracker, which measures your ability to track multiple objects simultaneously, and the treadmill.
- Day 2: 24 hours after Day 1 you will return to the HPL having been fasted for at least 4 hours. Day 2 will begin with anthropometric testing consisting of height, weight, and bioelectrical impedance analysis of body composition. Following this, you will be allowed to have a small snack before continuing with performance assessments. Immediately after, you will begin additional familiarization on the Dynavision, ANAM, Neurotracker and treadmill. Following familiarization, you will perform a Peak Sprint Assessment consisting of three (3) 40-meter sprints. After a recovery period, you will have your VO_{2max} assessed via a ramp protocol on a motorized treadmill with a metabolic

cart. You will perform an activity specific warmup prior to both assessments. At least 48 hours later, you will return for Day 3 testing.

- Day 3: On the third visit, you will again report to the HPL. Day 3 will consist of a modified intermittent soccer performance test (iSPT) performed on a treadmill. The iSPT will consist of two 45-minute halves with a 15-minute break in between. Prior to performing the iSPT, you will provide a urine sample to determine hydration status. You will be required to be in a state of euhydration prior to participation in the iSPT (determined via urine specific gravity). In the case that you are not euhydrated, you will consume water until euhydration is achieved. You will perform an activity specific warmup prior to beginning the iSPT. During the iSPT, you will only be permitted to rehydrate at half-time. Reaction time assessments (Dynavision) and cognitive assessments (ANAM) will be performed pre-, mid- (during the 15-minute interval) and post-iSPT. Neurotracker assessments will be administered pre-, at 3 points during each half of the iSPT, and post-iSPT. Neurotracker assessments will be administered in real-time during treadmill running. The iSPT will consist of intermittent patterns of standing, walking, running, jogging, running, fast running, and sprinting in a pattern designed to mimic the characteristics of a typical competitive soccer match consistent with previously published time motion analyses.

Assessments

Anthropometrics
Body composition will be assessed via Biological Impedance Analysis (BIA; InBody 770, Cerritos, CA, USA). You will be asked to remove your footwear, including socks, and stand on a platform while holding two handles out to the side. You will hold this position for one minute. A minute electrical current will be conducted through your body to determine body composition. Values for total and segmental body fat percentage will be recorded. There are no risks or discomforts associated with the use of bioelectrical impedance analysis.

Peak Sprint Assessment

You will perform 3 x 40-meter maximal sprints on a grass surface with 4 minutes of rest between trials. Players will wear their normal soccer cleats for this test. You will be equipped with a 10 Hz GPS receiver/transmitter, which will be placed into a harness that positions the GPS device between the shoulder blades and over the upper-thoracic spine. Peak velocity will be acquired from each of the 3 trials. Your best score will be used to determine individual iSPT velocities.

Maxima oxygen uptake

Your VO2max will be assessed via an incremental test to volitional exhaustion on a motorized treadmill. During the assessment of maximal oxygen uptake, you will be outfitted with a wireless, ambulatory physiological monitoring device that includes a chest strap and battery operated monitoring device (biomodule). The biomodule attaches to a receptacle in the chest strap, and provides real time heart rate data.

Multiple Object Tracking Ability (Neurotracker)
Visual tracking speed will be evaluated during the ISPT via completion of 1 core session on the Neurotracker 3D multiple object tracking device (NT; CogniSens Athletic, Inc., Montreal, Quebec, Canada). A single core session is comprised of 20 individual trials calculating spatial awareness by determining a threshold speed for the effective perception and processing of visual information of the athlete being tested. Each trial will be performed from the treadmill at 15 minute intervals during the iSPT. During each assessment, a 3D transparent cube containing 8 identical yellow balls, measuring 5.5 inches in diameter, will be presented on the screen. Four of these balls are randomly illuminated for 2 seconds before returning to the baseline yellow color. You will be instructed to track these 4 balls for the duration of each of the 20 trials. During each trial, all 8 yellow balls move simultaneously and individually throughout all regions of the cube for 8 seconds. The random, continuous movement patterns of each ball are only affected by collisions (impact and bounce) with the wall of the cube and the other balls. At the conclusion of 8 seconds, the balls are frozen in place and are each assigned a value (1 to 8). You will be instructed to identify, by number, the 4 balls that were originally illuminated at the start of the trial. The speed at which the balls moved on the next trial is dependent on the correct identification of the illuminated balls and is adjusted between trials in a staircase (1 up 1 down) fashion. At the end of the 20 trials, visual tracking speed will be determined to be the fastest speed (in centimeters per second) at which you could correctly identify all balls with 100% accuracy. You will perform assessments on the Neurotracker, multiple object tracking device at 0 minutes (BL), at 3 points during each half of the iSPT, and post-iSPT.

Reaction Time (Dynavision)
Visual-Motor RT to a visual stimulus will be assessed using the light training reaction device, Dynavision D2 (Dynavision International LLC, West Chester, OH, USA). The D2 is a vertically adjustable board (4 ft. × 4 ft.) that consists of 64 target buttons, arranged into 5 concentric circles, which can be illuminated to serve as a stimulus for the participant. The assessment will assess the participant's ability to react to a stimulus as it changes positions on the board, as previously performed in our lab. You will be required to complete three reaction time assessments.
1. The first assessment will measure your visual motor, and physical RT to a 4-choice stimulus with the dominant hand. Your dominant hand will begin by holding down a home button. When another light is illuminated you will use your dominant hand to press that button and return to the home position. This will be repeated 10 times per assessment.
2. The second assessment will assess your ability to react to a stimulus as it changes positions on the board. You will be required to successfully identify and strike as many stimuli as possible within 60 seconds. The number of hits and the average time per hits will be recorded.

3. Similar to the second assessment, you are required to react to a visual stimulus as it changes positions on the board. However, the stimulus will remain illuminated for 1 second before changing to another random location on the board. You will be required again to successfully identify and strike as many stimuli as possible within 60 seconds. The number of hits, average time per hit, and the number of missed stimuli will be recorded. In addition, you will be required to verbally recite a 5-digit number that presents on the center screen of the D2 during each assessment.

Reaction time assessments will be administered pre-iSPT, during the 15-minute interval, and post-iSPT.

Automated Neuropsychological Assessment Metrics (ANAM) General Neuropsychological Screening Test:
The ANAM test system consists of a library of computer-based tests that provide precise measurement of cognitive processing efficiency including attention, concentration, reaction time, memory, processing speed, decision-making, and executive function. Testing and scoring of the ANAM will be administered in accordance with the ANAM manual. You will be required to complete the ANAM during the familiarization day, pre-, mid- and post- iSPT testing.

Location:

All testing will be performed in the Institute of Exercise Physiology and Wellness at the Human Performance and Strength and Conditioning Laboratories at the University of Central Florida.

Time required:

Participation in this study will require three visits (a total of approximately 10 hours) to the Institute of Exercise Physiology and Wellness Human Performance Laboratory. The three visits consist of one initial visit (consent and familiarization) and two additional testing visits. The three visits will occur over the course of approximately one week.

Funding for this study:

This research is being paid for in part by the American Athletic Conference Academic Consortium. No individual or group data will be shared with the study sponsor. The results of this study will be presented as a group at the American Academic Consortium research symposium.

Risks:

The risks involved with this study are minimal but include potential musculo-skeletal injuries during the PSS, VO2max assessment and/or iSPT. These injuries may include muscle strains and pulls. The iSPT stimulus is similar to that of regulation soccer match and carries the same inherent non-contact risks for musculoskeletal injury as a competitive match. If such an injury occurs, you must stop immediately and inform the investigator. If immediate assistance is needed it will be provided via the emergency medical system. For non-emergency injuries, you must seek treatment from your own physician. If you suffer a physical injury as a result of participation in this study, you should receive medical care in the same way as you would normally.

The risks associated with a 4-hour fast aside from feelings of hunger and tiredness, should be minimal, but may include nausea and light-headedness. Other possible side effects may include headache, irritability, and heartburn.

Benefits:

There are no expected benefits to you for taking part in this study

Compensation or payment:

There is no compensation or other payment to you for taking part in this study. The information gathered will not benefit you medically and is being gathered for study purposes only.

Medical care and compensation for injury:

This is a minimal-risk study and it is unlikely that you will experience adverse effects. However, in the event that an adverse effect occurs, you will be instructed to immediately report any discomforts or adverse effects to the principal investigator. An adverse effect is defined as an intolerable response, perceived to be a direct consequence of participation in this study. No funds have been set aside for medical care payments or other forms of compensation (such as for lost wages, lost time, or discomfort) associated with your participation in this study. You do not give up any of your legal rights by signing this consent form. Adverse events/side effects will be reported to the University of Central Florida Institutional Review Board immediately upon notification.

Cost:

N/A

Confidentiality:

This study is being completed as part of a thesis research project. The results of this study will be published as a group as part of a scientific publication. Additionally, the results of this study will be presented as a group at the American Academic Consortium research symposium. No individual results will be published or shared with the funder or any third person or party. If you are a student athlete participating in this study, your results will be shared with your coach. Otherwise, individual results will remain confidential and will only be relayed to you upon request. All information attained from the medical and activity history questionnaire (MHQ) will be held in strict confidence. All medical and activity history questionnaires, signed and dated informed consent forms, and data collection sheets will be kept in a locked cabinet during and following the study.

Study contact for questions about the study or to report a problem:

If you have questions, concerns, or complaints, or think the research has hurt you, talk to Dr. Adam Wells, Assistant Professor, Sport and Exercise Science, College of Education and Human Performance, (407) 823-3906 or contact Ryan Girts, Human Performance Laboratory, Sport and Exercise Science (407) 823-2367 or by email at ryangirts@knights.ucf.edu.

IRB contact about your rights in the study or to report a complaint:

Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). This research has been reviewed and approved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901. You may also talk to them for any of the following:

- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You want to get information or provide input about this research.

If you are harmed because you take part in this study:

Participants are instructed to immediately report any discomforts or adverse effects to the principal investigator. An adverse effect is defined as an intolerable response, perceived to be a direct consequence of participation in this study. If immediate assistance is necessary, it will be provided via the emergency medical system. For non-emergency injuries, participants must seek treatment from their own physician. Adverse events/side effects will be reported to the UCF IRB immediately upon notification.

Withdrawing from the study:

You have the right to discontinue participation without penalty, regardless of the status of the study. Your participation in the study may also be terminated at any time by the researchers in charge of the project for the following reasons.

- Inability to adhere to the study protocol. This includes:

  o Failure to adhere to requirements

  o Failure to complete all visits to the human performance lab

  o Failure to complete the iSPT protocol

- Cancellation of the study.

The investigator or the UCF IRB can also stop your participation in this study at any time.

For students of the University of Central Florida: Your participation in this study is voluntary. You are free to withdraw your consent and discontinue participation in this study at any time without prejudice or penalty. Your decision to participate or not participate in this study will in no way affect your continued enrollment, grades, or relationship with individuals who may have an interest in this study. You will be participating in this study on your own time, not during regular class time.

_______ **Initials**

For employees of the University of Central Florida: Your participation in this study is voluntary. You are free to withdraw your consent and discontinue participation in this study at any time without prejudice or penalty. Your decision to participate or not participate in this study will in no way affect your continued employment or your relationship with individuals who may have an interest in this study.

_______ **Initials**

(Please note you will be participating in this study on your own time, not during regular working hours.)

Results of the research:

As previously stated, individual results will remain confidential, and you will be informed of only your results upon request.

Your signature below indicates your permission to take part in this research

DO NOT SIGN THIS FORM AFTER THE IRB EXPIRATION DATE BELOW

____

Name of participant

______________________________ ______________

Signature of participant Date

______________________________ ______________

Signature of person obtaining consent Date

____

Printed name of person obtaining consent

UCF University of Central Florida IRB
IRB NUMBER: SBE-17-13222
IRB APPROVAL DATE: 09/01/2017
IRB EXPIRATION DATE: 08/20/2018

APPENDIX C: PAR-Q+ AND MEDICAL HEALTH QUESTIONNAIRE

2017 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	**YES**	**NO**
1) Has your doctor ever said that you have a heart condition ☐ OR high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ________	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ________	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it *does not limit your current ability* to be physically active. **PLEASE LIST CONDITION(S) HERE:** ________	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Go to Page 4 to sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow International Physical Activity Guidelines for your age (www.who.int/dietphysicalactivity/en/).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at **www.eparmedx.com** before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

2017 PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1.	**Do you have Arthritis, Osteoporosis, or Back Problems?** If the above condition(s) is/are present, answer questions 1a-1c If **NO** ☐ go to question 2	
1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	**YES** ☐ **NO** ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	**YES** ☐ **NO** ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	**YES** ☐ **NO** ☐
2.	**Do you currently have Cancer of any kind?** If the above condition(s) is/are present, answer questions 2a-2b If **NO** ☐ go to question 3	
2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?	**YES** ☐ **NO** ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	**YES** ☐ **NO** ☐
3.	**Do you have a Heart or Cardiovascular Condition?** *This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm* If the above condition(s) is/are present, answer questions 3a-3d If **NO** ☐ go to question 4	
3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	**YES** ☐ **NO** ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	**YES** ☐ **NO** ☐
3c.	Do you have chronic heart failure?	**YES** ☐ **NO** ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	**YES** ☐ **NO** ☐
4.	**Do you have High Blood Pressure?** If the above condition(s) is/are present, answer questions 4a-4b If **NO** ☐ go to question 5	
4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	**YES** ☐ **NO** ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	**YES** ☐ **NO** ☐
5.	**Do you have any Metabolic Conditions?** *This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes* If the above condition(s) is/are present, answer questions 5a-5e If **NO** ☐ go to question 6	
5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	**YES** ☐ **NO** ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	**YES** ☐ **NO** ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	**YES** ☐ **NO** ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	**YES** ☐ **NO** ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	**YES** ☐ **NO** ☐

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6.	**Do you have any Mental Health Problems or Learning Difficulties?** *This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome*	
	If the above condition(s) is/are present, answer questions 6a-6b	If **NO** ☐ go to question 7
6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you have Down Syndrome **AND** back problems affecting nerves or muscles?	YES ☐ NO ☐
7.	**Do you have a Respiratory Disease?** *This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure*	
	If the above condition(s) is/are present, answer questions 7a-7d	If **NO** ☐ go to question 8
7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐
8.	**Do you have a Spinal Cord Injury?** *This includes Tetraplegia and Paraplegia*	
	If the above condition(s) is/are present, answer questions 8a-8c	If **NO** ☐ go to question 9
8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐
9.	**Have you had a Stroke?** *This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event*	
	If the above condition(s) is/are present, answer questions 9a-9c	If **NO** ☐ go to question 10
9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐
10.	**Do you have any other medical condition not listed above or do you have two or more medical conditions?**	
	If you have other medical conditions, answer questions 10a-10c	If **NO** ☐ read the Page 4 recommendations
10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: ______________________

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

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2017 PAR-Q+

If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that the Trustee maintains the privacy of the information and does not misuse or wrongfully disclose such information.

PARTICIPANT ID ______________________ DATE ______________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________

For more information, please contact

www.eparmedx.com

Email: eparmedx@gmail.com

Citation for PAR-Q+

Warburton DER, Jamnik VK, Bredin SSD, and Gledhill N on behalf of the PAR-Q+ Collaboration. The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+). Health & Fitness Journal of Canada 4(2):3-23, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

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01-01-2017

Human Performance Laboratory
University of Central Florida

Confidential Medical and Activity History Questionnaire

Participant# _______________

When was your last physical examination? ________________________________

1. List any medications, herbals or supplements you currently take or have taken the last month:

Medication	Reason for medication
____________________	______________________________
____________________	______________________________
____________________	______________________________
____________________	______________________________
____________________	______________________________
____________________	______________________________
____________________	______________________________

2. Are you allergic to any medications? If yes,please list medications and reaction.

3. Please list any allergies, including food allergies that you may have?

4. Have you ever been hospitalized? If yes, please explain.

Year of hospitalization	Reason
____________________	______________________________
____________________	______________________________
____________________	______________________________
____________________	______________________________
____________________	______________________________
____________________	______________________________

5. Illnesses and other Health Issues

List any chronic (long-term) illnesses that have caused you to seek medical care.

6. Have you undergone major surgery within the previous 16 weeks? If yes, please explain.

7. Have you ever had (or do you have now) active malignant disease or cancer. If yes, please explain.

8. Have you ever had (or do you have scheduled) any procedure with Iodine, Barium, or Nuclear Medicine Isotopes? (CT and PET scans are examples) If yes, please specify the date of the procedure.

Human Performance Laboratory
University of Central Florida

Have you ever had (or do you have now) any of the following. Please circle questions that you do not know the answer to.

Cystic fibrosis	Yes	No
Water retention problems	Yes	No
Epilepsy	Yes	No
Convulsions	Yes	No
Dizziness/fainting/unconsciousness	Yes	No
Chronic headaches	Yes	No
Chronic cough	Yes	No
Chronic sinus problem	Yes	No
High cholesterol	Yes	No
Rheumatic fever	Yes	No
Bronchitis	Yes	No
Hepatitis	Yes	No
Bladder problems	Yes	No
Tuberculosis (positive skin test)	Yes	No
Yellow jaundice	Yes	No
Anemia	Yes	No
Endotoxemia	Yes	No
Hyperprolactinemia	Yes	No
Anorexia nervosa	Yes	No
Bulimia	Yes	No
Stomach/intestinal problems	Yes	No
Arthritis	Yes	No
Back pain	Yes	No
Gout	Yes	No
Dementia	Yes	No
Artificial limb	Yes	No
Alzheimer's	Yes	No

Human Performance Laboratory
University of Central Florida

Have you ever had (or do you have now) any of the following. Please circle questions that you do not know the answer to.

Cardiovascular Disease

Peripheral vascular disease	Yes	No
Cerebrovascular disease	Yes	No
Coronary artery disease	Yes	No
Aortic stenosis	Yes	No
Congestive heart failure	Yes	No
Atrial fibrillation	Yes	No
"Heart block"	Yes	No
Myocardial infarction (Heart Attack)	Yes	No
Poorly controlled hypertension	Yes	No
Heart pacemaker	Yes	No
High blood pressure	Yes	No
Heart murmur	Yes	No

Pulmonary Disease

Chronic obstructive pulmonary disease	Yes	No
Asthma	Yes	No
Interstitial lung disease	Yes	No
Emphysema	Yes	No
Chronic respiratory disorder	Yes	No

Metabolic Disease

Diabetes mellitus (type 1, type 2)	Yes	No
Diabetes insipidus	Yes	No
Thyroid disorders	Yes	No
Renal disease	Yes	No
Liver disease	Yes	No
Immunodeficiency disorder	Yes	No

Any others (specify): ____

____

____

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Do you smoke cigarettes or use any other tobacco products?	Yes	No
Do you have a history of drug or alcohol dependency?	Yes	No
Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?	Yes	No
Do you feel pain in your chest when you do physical activity?	Yes	No
In the past month have you had chest pain when you were not doing physical activity?	Yes	No
Are you ever bothered by racing of your heart?	Yes	No
Do you ever notice abnormal or skipped heartbeats?	Yes	No
Do you ever have any arm or jaw discomfort, nausea, or vomiting associated with cardiac symptoms?	Yes	No
Do you ever have difficulty breathing?	Yes	No
Do you ever experience shortness of breath?	Yes	No
Do you lose your balance because of dizziness or do you ever lose consciousness?	Yes	No
Have you ever had any tingling or numbness in your arms or legs?	Yes	No
Has a member of your family or close relative died of heart problems or sudden death before the age of SO?	Yes	No
Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?	Yes	No
Do you have a bone or joint problem that could be made worse by a change in your physical activity?	Yes	No

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Has a health care practitioner ever denied or restricted your participation in sports for any problem. If yes, please explain:

Do you know of any other reason why you should not do physical activity? yes no

Are you presently taking any nutritional supplements or ergogenic aids? (if yes, please detail.)

I have answered these questions honestly and have provided all past and present health and exercise information to the best of my knowledge.

Signature Date

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