The relationship between heart rate recovery following the submaximal Yo-Yo Intermittent Recovery Test (Level 1) and temporary fatigue in soccer players

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Abstract

This study examined soccer match running performance using rolling 5-min periods to determine if transient declines in physical performance were associated with submaximal heart rate recovery (HRR). Physical performance (high-speed running and high metabolic load distances, average metabolic power) data was collected from 13 elite soccer players (Age 19 ± 1 years; Stature 182.1 ± 6.1 cm; Body mass 80.0 ± 7.4 kg) across six competitive fixtures, prior to each fixture HRR was assessed after a submaximal Yo-Yo Intermittent Recovery Test (Level 1) (YYIR1). The peak 5-min period of match play was higher than both the subsequent 5-min period and the match average for all physical variables ($P < 0.001$). Following the peak 5-min period, high-speed running and high metabolic load distances were reduced by 71% and 55%, respectively, (131 ± 37 vs. 37 ± 28 m; 181 ± 34 vs. 82 ± 33 m, respectively) which were 31% and 21%, respectively, lower than the match average (54 ± 18 m; 104 ± 22 m, respectively, both $P < 0.001$). No significant correlation was observed between the subsequent decrement in physical performance following the peak period and HRR following submaximal YYIR1 testing. These findings demonstrate that physical performance is reduced following intense periods. This reduction does not appear to be related to cardiorespiratory fitness inferred by HRR and the ability to recover and return to homeostasis. Further research is warranted to establish if the temporary reduction following peak periods is a consequence of pacing or contextual match factors reducing opportunity for physical work.

Key Words: *Metabolic Power, GPS, Match Analysis, Pacing*

CHAPTER 1: INTRODUCTION

Brief bouts of high-intensity (HI) activity interspersed with longer, variable recovery periods are characteristic of soccer match play, with the ability to perform and recover rapidly from such intense periods a key attribute (Bangsbo, Mohr, & Krustrup, 2006). Whilst the total distance covered during match play has largely remained constant, evolution within the game has seen large increases in HI running distance and sprinting performed during match play (Barnes, Archer, Hogg, Bush, & Bradley, 2014). Match HI running activity provides a valid measure of physical performance capacity among soccer players, reflecting the training status and discriminating between performance levels (Bradley, Di Mascio, Peart, Olsen, & Sheldon, 2010; Mohr, Krustrup, & Bangsbo, 2003).

Despite the importance of HI running bouts in soccer match play, it appears players are unable to sustain such activity throughout matches (Bradley et al., 2009; Bradley, Di Mascio, et al., 2010; Mohr et al., 2003). It is well established that player's physical performance in the form of sprinting, and HI running declines from the first to the second half of match play (Mohr et al., 2003), with the amount of HI running shown to be lower in the last 15-min period of a game compared to the first (Mohr et al., 2003). In addition, recent research has revealed elite soccer players exhibit signs of acute fatigue after intense periods of play evident through reductions in HI running, a phenomenon observed in team sports known as temporary fatigue (Bradley et al., 2009; Bradley, Di Mascio, et al., 2010; Mohr et al., 2003). The phenomenon of temporary fatigue has typically been identified by a 5-min period of reduced running intensity, below the match average, occurring immediately subsequent to the peak 5-min period of HI exertion, followed by a full recovery of HI work rate (Bradley et al., 2009; Bradley, Di Mascio, et al., 2010; Mohr et al., 2003). The volume of HI running immediately after the peak period has been shown to be reduced by 12% compared to the match average in soccer players (Bradley, Di Mascio, et al., 2010; Mohr et al., 2003), reflecting a marked reduction in a player's capacity to perfrom HI work during that period of the match.

Whilst increases in markers of fatigue have been shown to occur immediately following the most intense period of play (Krustrup et al., 2006), the precise cause of fatigue during various periods of elite soccer match play has proved difficult to identify (Mohr, Krustrup, & Bangsbo, 2005). An increase in muscle lactate concentrations, a decrease in muscle creatine phosphate, and an accumulation of extracellular potassium in the muscle have all been identified as proposed mechanisms (Bangsbo, Madsen, Kiens, & Richter, 1996; Mohr et al., 2005; Bangsbo, Iaia, & Krustrup, 2007). Despite this, no single physiological factor suggested to to be related to temporary fatigue during match play has been shown to be directly responsible for the temporary development of fatigue during match play (Mohr et al., 2005; Bangsbo et al., 2007). Muscle lactate and pH recorded during the final phase of the Yo-Yo intermittent recovery (YYIR) test have been shown to be similar to those recorded at exhaustion (Krustrup et al., 2003). Similarly, players have been shown to be able to continue to perform during the YYIR test with low muscle creatine phosphate concentrations (Krustrup et al., 2003). Furthermore, no relationship was found between lowered sprint performance after an intense period of match play and moderate reductions in muscle pH and elevations in muscle lactate (Krustrup et al. 2006). These findings appear to indicate that temporary periods of fatigue are not caused by an accumulation of lactate, lowered muscle pH, and muscle creatine phosphate concentrations. More recently, the concept of pacing has been explored with reference to the development of acute fatigue during team sports, providing an alternative mechanism for the observed temporary reductions in running intensity. It has been proposed that the fluctuations in running intensity during match play indicative of fatigue represent a more complex phenomenon mediated by a central control system (Bradley & Noakes, 2013; Edwards & Noakes, 2009; Waldron & Highton, 2014). The presence of temporary fatigue during matches is considered to merely reflect the continual modification of running intensity in response to symptoms of fatigue induced by a centrally controlled behaviour change to ensure homeostasis, thus avoiding the premature failure of any physiological system (Edwards & Noakes, 2009).

The non-random occurrence of temporary fatigue during match play lends support to the concept of pacing. The non-random pattern whereby intense periods are followed by temporary periods of reduced activity, are suggestive of a conscious behavioural decision to dynamically regulate HI activity to limit physiological disturbances and preserve energy for latter periods of match play, ensuring the successful completion of the match is not compromised (Waldron & Highton, 2014). Situational match influences have also been suggested to explain the variations in physical effort observed in match play with the score line shown to influence HI running in the second half of matches (Bradley & Noakes, 2013). Furthermore, opportunities to engage in HI activity have been suggested to influence physical output with greater playing time as a consequence of the time the ball spent in play observed during the peak 5-min period (Kempton, Sirotic, & Coutts, 2015). Player's conscious behavioural decisions to regulate effort are therefore, suggested to be based on pre-match experience, current fitness levels, and situational match variables (Edwards & Noakes, 2009). Homeostatic control is considered to be better maintained among experienced and well trained players during match play (Edwards & Noakes, 2009). Furthermore, the superior conditioning of elite players has been shown to contribute to an enhanced ability to sustain a higher work output during match play (Mohr et al., 2003). Therefore, within the context of the game, players operate in an individualised pacing schema, whereby behavioural changes based off each player's own perceptions of homeostatic disturbance are implemented. Players are considered to consciously employ temporary tactical alternatives to maximal work when homeostasis is threatened such as passing rather than dribbling, and covering an opponent rather than tackling and intercepting (Edwards & Noakes, 2009). Furthermore, deliberate tactical strategies such as kicking the ball in to touch to provide breaks in play have been suggested to account for reduced playing time observed following the peak 5-min period in rugby league (Kempton et al., 2015). The consistent intensity reduction following the most intense period of play provides evidence for the need to recover to avoid unsustainable elevations in physical discomfort. As a consequence, homeostasis is required to be continually maintained or restored in several physiological systems during match play in response to the perception of effort from multiple afferent signals (Lambert, St Clair Gibson, & Noakes, 2005). Homeostatic disturbances and subsequent changes in work rate intensity are interpreted from afferent and efferent feedback signals from numerous peripheral physiological variables (Lambert et al., 2005). In addition, to the peripheral and metabolic factors, cardiopulmonary factors such as heart rate (HR), oxygen uptake (VO_2), and respiratory and ventilatory rate are considered to induce similar perceptions of effort that are used to regulate exercise intensity and maintain homeostasis (Hampson, St Clair, Lambert, & Noakes, 2001). Considering the role of cardiopulmonary afferent signals on the perception of effort and the suggested effects of pre-match fitness status on match pacing, it is possible that measurements of pre-match cardiorespiratory fitness relate to temporary fatigue during match play. Such findings would provide further justification for the inclusion of this test into a soccer specific testing battery.

It is recognised the high aerobic requirements and anaerobic demands of more intense periods of match play impose a substantial metabolic load on players (Bangsbo et al., 2007; Bangsbo et al., 2006). As a consequence, energy substrate availability has been suggested to be associated with pacing mechanisms, with behavioural changes to reduce work intensity suggested to be initiated in response to diminishing energy substrate stores (Edwards & Noakes, 2009). Whilst substrate availability underpins and supports HI running performance, the typical use of distances covered in various speed zones have been suggested to only partially represent the the physical cost of match play (Osgnach, Poser, Bernardini, Rinaldo, & di Prampero, 2010). Traditional running speed variables have been shown to underestimate the HI demands of soccer activity (Gaudino et al., 2013). Despite this, temporary fatigue during match play has generally been identified and described by the distance covered in various speed zones and specifically HI running distance (Bradley et al., 2009; Bradley, Di Mascio, et al., 2010; Bradley & Noakes, 2013; Mohr et al., 2003). Distances covered in HI running zones fail to take into consideration the high energetic cost imposed by highly demanding acceleration and deceleration movements, and soccer-specific movements that may contribute to the accumulation of fatigue. Discrete movements over short distances have been shown to be reduced temporarily during match play, with the distance covered at high acceleration thresholds reduced by approximately 10% following the peak period of high acceleration output compared to the match average (Akenhead, Hayes, Thompson, & French, 2013). Velocity changes in the form of acceleration and deceleration movements are considered high energy activities heavily taxing energy recourses (Osgnach et al., 2010).

A new energetic-based approach utilising metabolic power values, combining estimates of energetically demanding accelerated and decelerated movements with traditional running speed estimates appear to provide a more comprehensive assessment of the physical cost of match play (Osgnach et al., 2010). The distance covered at a high metabolic power (>20 $W \cdot Kg^{-1}$) has been shown to be almost twice that of the distance covered at the equivalent HI running threshold (>14.4 $Km \cdot h^{-1}$) when directly compared during training exercises (Gaudino et al., 2013) and match play (Osgnach et al., 2010). Metabolic power estimates may, therefore, better represent the energetic demands of match play, which may provide a greater insight into the phenomenon of temporary fatigue and how players distribute and manage their energy resources. Recently, metabolic power has been used to identify transient fatigue in Rugby Sevens (Furlan et al., 2015), supporting is use as a measure to help better understand match-related fatigue in soccer and thus inform the physiological preparation of players.

The ability to perform and recover from repeated HI intermittent exercise is reliably assessed using the the Yo-Yo intermittent endurance (YYIE) (Bradley, Mohr, et al.,

2010) and recovery (YYIR) (Bangsbo, Iaia, & Krustrup, 2008) tests respectively, shown to represent valid measures of physical performance in soccer match play (Bradley, Mohr, et al., 2010; Castagna, Impellizzeri, Cecchini, Rampinini, & Alvarez, 2009; Krustrup et al., 2003). Consistent correlations between elite soccer match play HI running distance and YYIR level 1 (YYIR1) performance have been observed (Castagna et al., 2009; Fanchini et al., 2015; Mohr et al., 2003) with test performance changes linked to changes in the ability to perform more HI running during match play (Castagna et al., 2009; Fanchini et al., 2015). Furthermore, the YYIR tests are suggested to asses the ability to recover from intense exercise at a similar intensity to that of match play, with the heart rate (HR) response during phases of tests similar to those observed during the most intense period of match play (Krustrup et al., 2003).

Submaximal versions of the Yo-Yo test using HR to predict maximum performance have been developed in an attempt to limit the need to maximally test players. Thus, increasing the effectiveness during the competitive season where players are already exposed to high match and training loads (Svensson & Drust, 2005). The assessment of submaximal exercise HR (HRex) and HR recorded at predetermined recovery time points termed HR recovery (HRR) can provide useful information relating to improvements in fitness and match running performance (Buchheit et al., 2013; Daanen, Lamberts, Kallen, Jin, & Van Meeteren, 2012). A greater parasympathetic function inferred by a faster post exercise HRR is associated with superior cardiorespiratory fitness (Buchheit, 2014), a physical quality considered to support improved tolerance to HI intermittent exercise (Buchheit, Hader, & Mendez-Villanueva, 2012). Furthermore, faster post exercise HRR is considered a positive training adaptation facilitating a faster return to homeostasis following exercise stress (Bellenger et al., 2016). Subsequently, the assessment of HRR may provide valuable insight in to the phenomenon of temporary fatigue and pacing during match play since, running intensity during match play is seemingly temporarily reduced when homeostasis is threatened (Edwards & Noakes, 2009; Waldron & Highton, 2014).

Despite this, HRR has not previously been considered with respect to the phenomenon of temporary fatigue during match play. Furthermore, the HRR response to the submaximal YYIR1 test has received little attention within the literature, even though the test is considered valid in assessing the capacity of elite soccer players to recover from repeated HI intermittent exercise. HR expressed as a percentage of individual maximal values attained after 6-min of the YYIR1 test, have been shown to correlate to match HI running (r = 0.48) (Bangsbo et al., 2008) and inversely relate to performance in the YYIR2 test (r = -0.61) (Mohr & Krustrup, 2014), which has been shown to significantly correlate to peak 5-min values of HI running during match play (r = 0.72) (Bangsbo et al., 2008). It is conceivable, that players with a heightened ability to recover their HR, may exhibit less pronounced fluctuations in running intensity, maintaining a higher exercise intensity throughout a match and therefore have more direct involvements with the ball and within key decisive movements of the game. It would be of interest to establish if the HRR response following submaximal YYIR1 testing relates to peak periods of match running intensity and whether the test could be used to predict the decline in physical performance in the period immediately subsequent to the most intense period of play.

To date, no study has investigated the transient fluctuations in physical performance during elite level soccer match play using energetic based metabolic power indices. Consequently, the aims of the study were to: 1) investigate transient fluctuations in locomotor based metabolic power estimates during elite level soccer match play and 2) explore the relationship between peak periods of match play and submaximal YYIR1 testing.

CHAPTER 2: METHODS

2.1 Participants and Study Design

Consent from the club to conduct research and ethical approval was attained prior to the collection of data from six English U21 Premier League games during the 2015-16 competitive season. Data from players completing the full duration of matches were included in the study (n=13; Age 19 ± 1 years; Stature 180.3 ± 4.8 cm; Body mass 75.2 ± 6.0 kg). Forty-six full match files from the six competitive matches were recorded for analysis with all incomplete match data excluded from the study. Players continued to participate in normal team training and fixtures in-line with the periodised team training plan and fixture schedule. The non-exhaustive assessment of HRR was assessed using a standardised submaximal version of the YYIR1 test to control the exercise duration and intensity to ensure consistent reliable measures of HRR (Daanen et al., 2012). The submaximal YYIR1 test was completed prior to the commencement of a pre-training warm up, two days prior to a competitive fixture in which physical match performance data was collected for analysis using global positioning systems (GPS) (STATSports, Viper, Co. Down, N.Ireland). All submaximal YYIR1 assessments were conducted following a training free day to minimise any impact of acute fatigue on HRR (Borresen & Lambert, 2007). A standardised warm up routine was performed prior to each competitive match and submaximal YYIR1 test, which all players were familiarised with prior to the commencement of the study. Data was only collected during single game weeks, once every 6-week training cycle on six separate occasions with multiple game weeks excluded from the study. All players were examined by the club's medical staff and were deemed to be free from injury and illness.

2.2 Physical Match Performance Analysis

Player physical match activity was recorded in competitive English U21 Premier League games using 10Hz GPS integrated with a 100Hz accelerometer. This type of system has previously been shown to accurately quantify the distance covered at high speed (Rampinini et al., 2015) and acceleration, deceleration and constant velocity running phases during team sports to a sufficient level (Varley, Fairweather, & Aughey, 2012). The GPS devices were always activated outdoors 20-min prior to the commencement of all activity to ensure the acquisition of a satellite signal (Jennings, Cormack, Coutts, Boyd, & Aughey, 2010a). Players were assigned the same GPS device on all occasions in order to avoid inter-unit error (Jennings, Cormack, Coutts, Boyd, & Aughey, 2010b).

Average Metabolic Power (AMP), energy consumption per kilogram per second ($W \cdot kg^{-1}$) and High Metabolic Load (HML) distance, calculated as the distance covered with a metabolic power above the value of 25.5 $W \cdot kg^{-1}$ were used as measures of movement intensity (Gaudino et al., 2015) and thus used to identify the peak 5-min period of match play. Based on energy expenditure, the HML measure combines the energetic cost of highly demanding running movements including all constant velocity running above 5.5 $m \cdot s^{-1}$ and acceleration and deceleration activity over 2 $m \cdot s^{-1}$ during intermittent running, providing a better representation of total high intensity activity and thus the physiological load imposed (Coutts et al., 2015; Osgnach et al., 2010). The energetic cost of accelerations and decelerations during intermittent accelerated running was estimated based on a theoretical model that considers accelerated running on a flat surface to be metabolically equivalent to incline running at a constant velocity (di Prampero et al., 2005). The "equivalent slope," where the degree of forward acceleration is equal to the angle of incline running was used to obtain the instantaneous measure of the energy cost of accelerated running and estimate metabolic power output (Buchheit, Manouvrier, Cassirame, & Morin, 2015; Osgnach et al., 2010). High-speed running (HSR) reported as the distance covered at a velocity ≥14.4 $Km \cdot h^{-1}$ (Abt & Lovell, 2009; Coutts et al., 2015; Gaudino et al., 2015) was used as a traditional running speed based measure of intensity and was also used to identify the peak 5-min period during match play.

A 5-min rolling time interval was applied across each half of games, with the peak period of HSR and HML identified as the 5-min period that contained the most distance. A 5-min rolling average was used to identify the peak period of AMP with the peak period represented as the 5-min period with the highest mean intensity. A rolling time interval has been shown to provide a more accurate representation and better indication of temporary fatigue in team sports (Varley, Elias, & Aughey, 2012). The 5-min period immediately subsequent to the peak was identified as the post-peak period and was used to identify changes in movement intensity. Incidences whereby the peak 5-min period was observed in the final 5-min period of either half were excluded from the study due to an inability to analyse the subsequent 5-min period. Any data recorded from injury time during either half of matches and any incidences where the players failed to complete the full match were all excluded form the study and not included within any part of the analysis. Pre-game preparations including nutrition, hydration, and warm up strategies were kept consistent across all games.

2.3 Submaximal YYIR1 Test

The submaximal YYIR1 test was performed as has previously been described for the maximal version (Bangsbo et al., 2008; Krustrup et al., 2003; Mohr & Krustrup, 2014) differing only in terms of duration. All testing sessions were conducted on an outdoor UEFA standard 3G surface. The players completed 20 m shuttle runs at a progressively increasing running velocity with 10-s of active recovery interspersed between runs until the test was terminated after 6-min and a total distance of 720 m (Fanchini et al., 2015). Upon termination of the test, the players were instructed to stop immediately and stand still for a 2-min period, avoiding any excessive movement so no further increases in HR were induced allowing for the calculation of HRR. A 6-min time frame was selected in line with previous protocols that have shown HR expressed as the percentage of maximal values (% of HR_{max}) following 6-min of the YYIR1 to be inversely related to maximum YYIR1 performance a relationship that has not been establish for shorter times frames (Bangsbo et al., 2008).

All players were fitted with a HR monitor (Polar T31-Coded, Polar Electro, Kempele, Finland) that was compatible and recorded via the GPS device. HRR was measured during the recovery period following cessation of the submaximal YYIR1 test and was calculated as the absolute (beats · min^{-1}) difference between the mean HR during the last 30-s of the 6-min test period (HRex) and the HR recorded at 60-s during recovery (HR_{60s}) (Buchheit, Papelier, Laursen, & Ahmaidi, 2007). Post exercise HRR calculated after 60-s (HRR_{60s}) is considered to represent the most reliable measure of post exercise parasympathetic reactivation (Dupuy et al., 2012) and compared to a 2-min period has been shown to have a superior ability to detect changes over time (Daanen et al., 2012). HRR_{60s} expressed as a percentage of Hrex (%HRR_{60s}) was used to account for likely changes in Hrex expected to occur over the study period impacting HRR expressed in absolute terms (Daanen et al., 2012).

2.4 Statistical Analysis

The peak 5-min periods of match play were compared to the 5-min period immediately subsequent (post-peak) and the match average. Differences between peak, post-peak, and match average periods were determined using analysis of variance (ANOVA) with repeated measures. Assumptions of sphericity were assessed using Mauchly test of sphericity, with any violations adjusted by the Greenhouse-Geisser correction. When significant main effects were observed, Bonferroni adjusted pairwise comparisons were used to identify specific differences between the means. Significance was set at $P < 0.05$. Cohen's *d* effect sizes were used to determine the meaningfulness of the difference. Effect sizes (ES) were interpreted as trivial (<0.2), small (0.21-0.6), moderate (0.61-1.20), large (1.21-2.00) and very large (<2.01) (Hopkins, Marshall, Batterham, & Hanin, 2009). The Pearson product-moment *r* correlation was used to investigate the relationship between HR_{60s}, HRR_{60s}, and %HRR_{60s} following submaximal YYIR1 testing and the peak, post-peak, match average 5-min values, and the decrement (absolute and %) in physical performance immediately subsequent to the peak 5-min period. The correlation coefficient (*r*) was considered trivial (<0.1), small (0.1-0.3), moderate (0.3-0.5), large (0.5-0.7), very large (0.7-0.9) and an almost perfect association (0.9-1.0) (Hopkins et al., 2009). All statistical analysis was conducted using Statistical Package for the Social Sciences (SPSS 20 for Mac, SPSS Inc., Chicago, IL).

CHAPTER 3: RESULTS

There was a significant main effect across match 5-min periods for HSR ($F_{1.33, 60.04}$ = 223.759, P < 0.001), AMP ($F_{1.23, 55.50}$ = 185.442, P < 0.001), and HML distance ($F_{1.28, 57.37}$ = 332.206, P < 0.001). Post hoc analysis showed peak 5-min periods were significantly higher than the match average and post-peak periods for HSR (both P < 0.001, ES = 2.64 and 2.86 respectively), AMP (both P < 0.001, ES = 2.76 and 2.22 respectively) and HML distance (both P < 0.001, ES = 2.67 and 2.97 respectively) (Figure 1). Post-peak 5-min periods were significantly lower than the match average for both HSR (37 ± 28 vs. 54 ± 18 m, P < 0.001, ES = 0.70) and HML distance (82 ± 33 vs. 104 ± 22 m, P < 0.001, ES = 0.80), no significant difference was found for AMP (9.8 ± 1.7 vs. 10.1 ± 1.0 $W \cdot kg^{-1}$, P = 0.594, ES = 0.19) (Figure 1). Peak, post-peak, and the match average HML distance were significantly higher than the corresponding HSR distance (all P < 0.001, ES = 1.40, 1.48 and 2.45 respectively) (Figure 3).

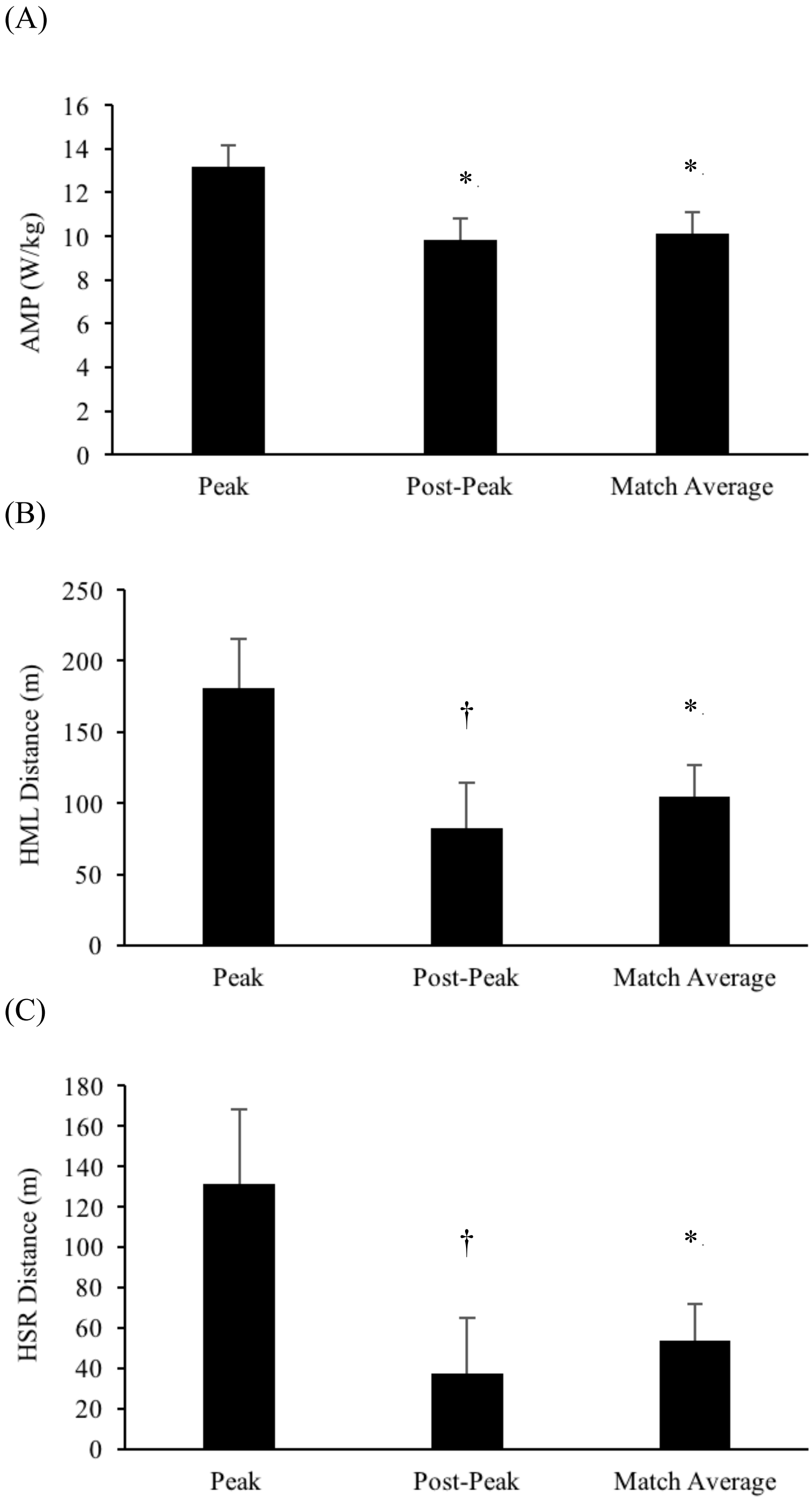

Figure 1. Peak, post-peak and match average 5-min match play data, identified using average metabolic power (AMP) (A), high metabolic load (HML) distance (B) and high-speed running (HSR) distance (C).

* Significantly different to the peak period ($P < 0.05$)
† Significantly different to the peak period and match average ($P < 0.05$)
Data are presented as mean ± SD ($n = 46$)

There was a moderate relationship between HR_{60s} following the submaximal YYIR1 test and peak 5-min periods of AMP (r = -0.321; moderate; P = 0.036) and HML distance (r = -0.371; moderate; P = 0.014) and the match average HML (r = -0.347; moderate; P = 0.022) and HSR distance (r = -0.313; moderate; P = 0.041) covered during 5-min periods (Table I). There was a moderate relationship between $\%HRR_{60s}$ following the submaximal YYIR1 test the peak 5-min period of HML distance (r = -0.331; moderate; P = 0.030) and the match average HML distance covered during 5-min match periods (r = -0.308; moderate; P = 0.044) (Table I). No relationship was found between the absolute and percentage HRR_{60s} following submaximal YYIR1 testing and the absolute and relative (%) decrement in AMP, HSR, and HML distance following the peak 5-min period (Figure 2).

Table I. Pearson's product-moment correlation coefficients (*r*) between heart rate and heart rate recovery measures after 60-s recovery following the 6-min submaximal Yo-Yo intermittent recovery test (level 1) and peak, post-peak, and match average 5-min values of running intensity.

	HR_{60s} (b・min^{-1})	HRR_{60s} (b・min^{-1})	$\%HRR_{60s}$
AMP (W・kg-^{1})			
Peak	-0.321*	0.249	-0.273
Post-peak	-0.114	0.068	-0.095
Match Average	-0.269	0.182	-0.222
HML distance (m)			
Peak	-0.371*	0.297	-0.331*
Post-peak	-0.159	0.15	-0.156
Match Average	-0.347*	0.277	-0.308*
HSR distance (m)			
Peak	-0.267	0.217	-0.224
Post-peak	-0.029	0.074	-0.063
Match Average	-0.313*	0.266	-0.283

Note: HR_{60s} = absolute heart rate measured after 60-s recovery; HRR_{60s} = absolute heart rate recovery after 60-s recovery; $\%HRR_{60s}$ = percentage heart rate recovery after 60-s recovery; AMP = average metabolic power; HML = high metabolic load; HSR = high-speed running.
*$P < 0.05$; **$P < 0.01$.

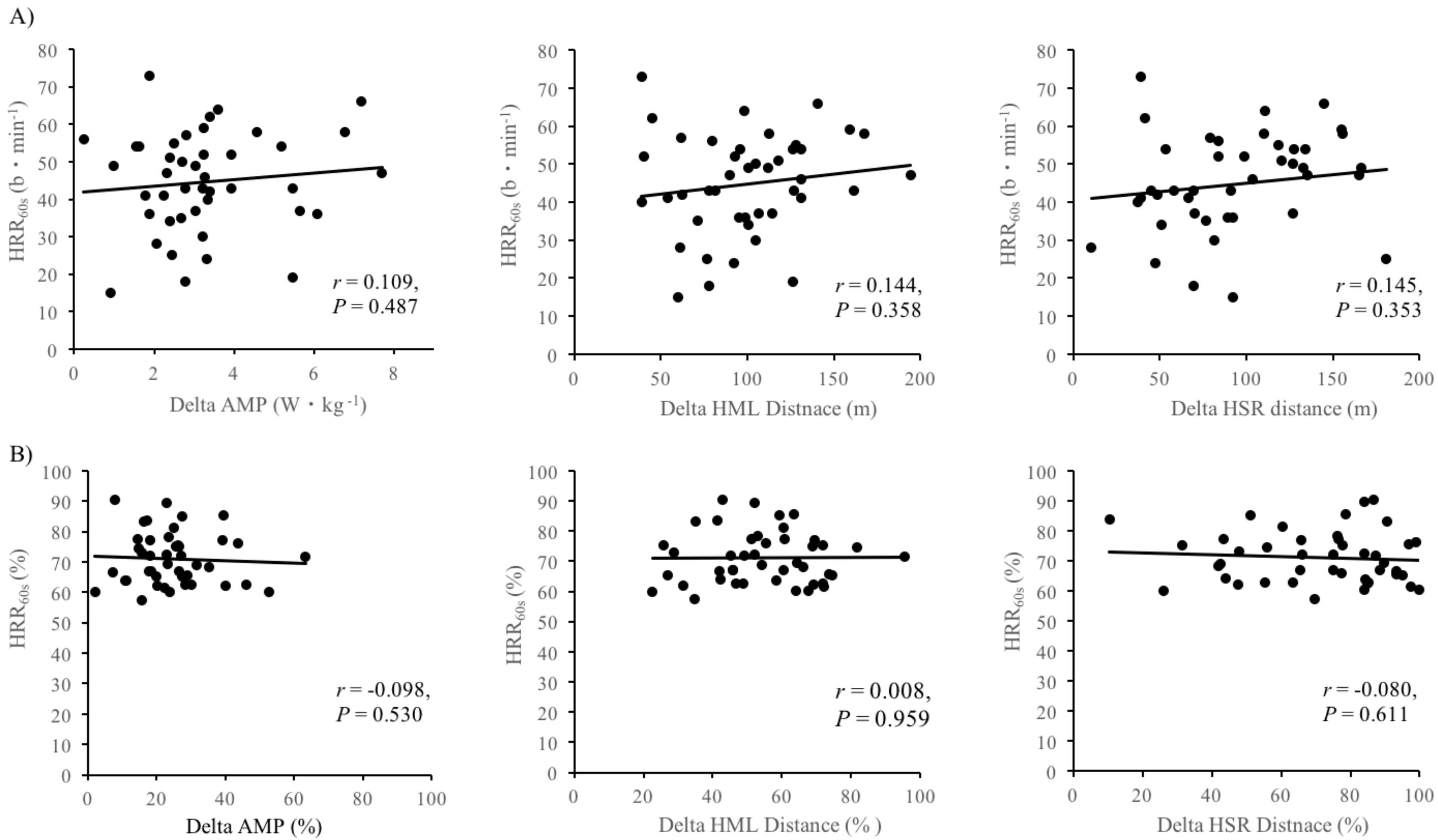

Figure 2. The relationship between the absolute (A) and relative (B) decrement (delta) in average metabolic power (AMP), high metabolic load (HML), and high-speed running (HSR) distance from peak to post-peak 5-min periods during match play and heart rate recovery after 60-s recovery following the 6-min submaximal Yo-Yo Intermittent Recovery test (level 1).

CHAPTER 4: DISCUSSION

The main aim of the study was to determine if temporary reductions in physical performance and metabolic power are related to HRR following submaximal testing. The main findings were that both running speed and metabolic power derived indices were higher in the most intense 5-min period of play (peak) compared with both the 5-min period immediately subsequent (post-peak) and the match average. Following the peak 5-miunte period a reduction in HSR and HML distance below the match average was observed. Furthermore, HRR following the submaximal YYIR1 test was found to be moderately associated with peak periods of locomotor related metabolic power during match play. The submaximal HRR response, however, was not found to be related to the subsequent decrement in locomotor related metabolic power and HSR following the peak period of match play.

In the current study, identified periods (5-min) of peak intensity determined by locomotor related metabolic power using a rolling time interval, were subsequently followed by an immediate reduction in intensity. This finding is consistent with previous research investigating the phenomenon of temporary fatigue in soccer using running speed based measures (Bradley et al., 2009; Bradley, Di Mascio, et al., 2010; Mohr et al., 2003). A reduction in HML distance covered below the match average was evident in the 5-min period immediately subsequent to the peak a trend also observed with HSR. The HSR distance covered (≥14.4 km·h^{-1}) during peak, subsequent and average 5-min periods reported in the current study were lower than has previously been reported for elite senior players (Bradley, Di Mascio, et al., 2010; Carling & Dupont, 2011; Mohr et al., 2003). Furthermore, the magnitude of change reported in the current study is greater than the 12% reduction below the match average previously reported for HI running distance (≥14.4 $Km \cdot h^{-1}$) (Bradley, Di Mascio, et al., 2010; Mohr et al., 2003). Reductions below the match average of 31% and 21% were reported for HSR and HML distance, respectively, immediately subsequent to the peak period. Differences in prior experience and match exposure between the U21 players used in the present study and senior players studied previously may explain these observations. The subconscious modulation of exercise intensity in response to afferent feedback is suggested, to be influenced by prior experience and knowledge of the requirements of an exercise task (Hampson et al., 2001; Lambert et al., 2005). Elite senior players are considered to have greater a priori experience of distributing energy resources during match play and knowledge from which to base their pacing schema as a consequence of increased match and training exposure (Edwards & Noakes, 2009). Player's less experienced in building match play pacing schemas as a consequence of less exposure may misinterpret afferent feedback and, therefore, the perception of effort which may result in an unnecessary or drastic resetting of exercise intensity (Hampson et al., 2001).

The reduction in HSR and HML distance in the subsequent 5-min period below the match average, observed in the current study is in stark contrast to Lovell, Barrett, and Abt (2013), who did not find temporary fatigue to be apparent in similar aged elite players (17 ± 1 years). As part of the long term development of elite youth players, the volume of weekly training and match loads increase with age (Wrigley, Drust, Stratton, Scott, & Gregson, 2012). The 2-year difference from late adolescence to adulthood, therefore, represents a noteworthy difference in training age and exposure. This apparent difference in experience, however, is unlikely to fully explain the contrasting absence of temporary fatigue indicative of pacing. Successful pacing behaviour has been observed in young children in different stages of cognitive development (Lambrick, Rowlands, Rowland, & Eston, 2013) which is likely to continue to latter years of development. This difference may, therefore, be better explained, in part, by the approach used in the current study to identify the peak 5-min period. The findings of Lovell et al. (2013), are considered limited by the use of predefined 5-min periods, considered to underestimate the most intense period of play and overestimate the subsequent period, therefore underestimating the decrement in intensity following the peak period (Varley et al, 2012). The rolling time interval approach employed in the current study is considered to provide a more accurate representation of the peak period and, therefore, the subsequent decrement in intensity (Varley et al., 2012). It is possible that the decrement observed subsequent to the peak period in the current study is more representative of the phenomenon of temporary fatigue in elite soccer match play than has previously been proposed. The greater magnitude of change observed in the current study may, therefore, represent differences in the pacing strategy adopted/employed by relatively young professionals (19 ± 1 years) during match play.

The AMP response was lowered by 25% following the peak period, however, in contrast to HML distance, the post-peak period was not significantly different to the match average (9.8 ± 1.7 vs. 10.1 ± 1.0 $W \cdot kg^{-1}$, $P = 0.198$). Since the measure of instantaneous metabolic power is based on the energy cost per unit of body mass per second necessary to support the velocity and distance of locomotion (Osgnach et al., 2010), the AMP response is likely to continue to accumulate during periods of low activity such as walking and jogging. This variable therefore would appear less sensitive to transient fluctuations in intensity indicative of temporary fatigue during soccer match play.

Not surprisingly, the distance covered in peak, subsequent, and average 5-min periods were all higher for HML compared to HSR (all $P < 0.001$). This discrepancy is likely attributed to the capacity of running speed based measures to accurately quantify the intensity of match play. Running speed based metrics such as HSR and HI distance are suggested to underestimate the HI demands of soccer activity (Gaudino et al., 2013). Furthermore, the use of running speed based metrics to identify peak periods of match play is considered to underestimate the metabolic strain experienced by players, with running speed based approaches shown to underestimate the intensity of the peak period of Rugby Sevens compared to metabolic power derived metrics (Furlan et al., 2015).

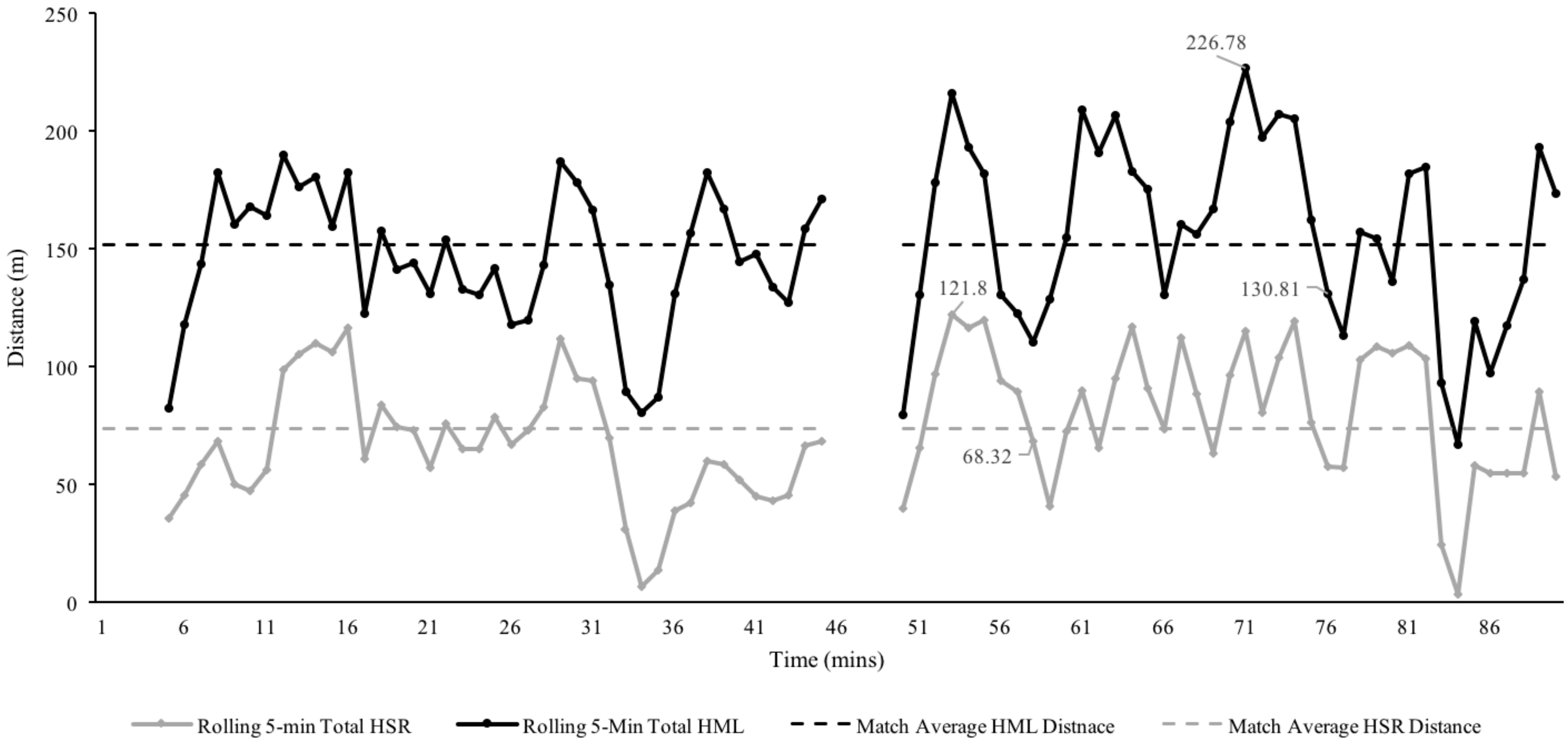

Figure 3. A single data profile for a representative player across a single match for rolling 5-min high-speed running (HSR) and high metabolic load (HML) distance. Peak and post-peak distances (m) are highlighted for both variables.

Peak 5-min periods of match play measured by locomotor related metabolic power were found to correlate with the HR response following submaximal YYIR1 testing. In fact, players with a lower HR_{60s} and $\%HRR_{60s}$ following submaximal YYIR1 testing showed higher match average and peak 5-min running intensities. Despite the low magnitude of the correlations reported in the present study, they appear to be in accordance with those previously described. Peak HI running in a 5-min period during match play has previously been shown to be related to maximal YYIR2 test performance (r = 0.72) (Bangsbo et al., 2008) and inversely related to the 6-min submaximal YYIE2 test HR expressed as the % of HR_{max} (r = -0.71) (Bradley, Mohr, et al., 2010). Although, no relationship was observed in the present study between 6-min submaximal YYIR1 test HRR and the peak 5-min period of HSR (table I). The most interesting finding, however, was HRR following the submaximal YYIR1 test was not found to be related to the observed decrement in AMP, HML, and HSR distance from the peak 5-min period to the subsequent 5-min period. This finding was unexpected and suggests pre-match cardiorespiratory fitness inferred by HRR does not explain the the subsequent decrement in running intensity following the most intense period of play.

Differences in study design likely explain the lower strength correlations, and the contrasting lack of relationship for peak 5-min HSR distance. The submaximal YYIR1 test is predominately an aerobic based test compared to the more anaerobic YYIR2 test (Mohr & Krustrup, 2014) which may explain the differences in the strength of the relationships observed, since a greater anaerobic contribution will be present during peak periods of match play (Bangsbo et al., 2006; Stølen, Chamari, Castagna, & Wisløff, 2005). The submaximal YYIR1 test also does not elicit the same intensities as those seen in the peak 5-min period despite being related to YYIR2 performance (Mohr & Krustrup, 2014). Therefore, in contrast, to the YYIR2 test, the submaximal YYIR1 test does not asses the ability to recover from intense exercise at a similar intensity to that of the most intense period of play. This, therefore, may explain the lack of any relationship in the current study between the decrement in physical performance following the peak period and HRR following the submaximal YYIR1 test. However, the extent to which environmental factors may have contributed to this is unclear. Therefore, ambient temperature effects on changes in HRR, need to be considered when interpreting the data (Daanen et al., 2012).

The use of HRR in the current study is also likely to have contributed to the low strength correlations and lack of relationships observed. It has recently been argued that HRR is more determinative of endurance capacity than intermittent running performance (Buchheit, Simpson, Al Haddad, Bourdon, & Mendez-Villanueva, 2012). Concomitant changes in HRR and endurance performance have often been reported (Daanen et al., 2012; Lamberts, Swart, Capostagno, Noakes, & Lambert, 2010). However, although the same relationship is suggested to be present for HI intermittent exercise performance (Daanen et al., 2012), no correlation or low magnitude correlations have recently been reported for measures of HRR and physical performance changes in intermittent team sport players (Buchheit et al., 2013; Buchheit et al., 2012). What's more, the use of post exercise HRR as an isolated marker of physiological training status has recently been questioned (Bellenger et al., 2016). Increases in post exercise HRR have not only been seen in response to positive training adaptations and subsequent increases in exercise performance but also in response to overreaching and its associated negative impact on exercise performance (Bellenger et al., 2016).

Whilst the interpretation of correlations of such a magnitude should be done so with caution, the findings could be considered to suggest, that players with a heightened ability to recover their HR and therefore attain a lower HR_{60s} following submaximal YYIR1 testing not only achieve a higher running intensity during the peak period of match play, but are also better equipped to maintain a higher running intensity throughout the match. Greater parasympathetic function inferred by a faster post-exercise HRR facilitates a faster return to homeostasis following exercise stress (Bellenger et al., 2016). Despite this, no relationship was observed within the current study between parasympathetic function inferred by HRR and the decrement in physical performance following the peak period of match play. It could therefore, conceivably be hypothesised that the decrement following the peak period is not directly related to the individual's ability to recover following the high intensity bout, but represents a conscious behavioural decision to preserve energy resources, lending support to concept of pacing (Waldron & Highton, 2014).

Caution, however, must be applied, and it should be considered that whilst high levels of acceleration and deceleration impose high metabolic loads and are physiologically taxing (Osgnach et al., 2010), they also place a high muscular load on the quadriceps and gluteal muscles due to the eccentric strength and power requirements (Buchheit et al., 2015). Recovery following peak periods of match play identified by locomotor related metabolic power is therefore likely not only related to cardiorespiratory fitness but also to neuromuscular related factors. Players with a better capacity to perform powerful soccer specific activities such as sprint and change of direction abilities have been shown to have an increased ability to maintain performance following intense periods of match play demonstrating a lower decrement in HI running following the peak period of match play (Silva, Magalhães, Ascensão, Seabra, & Rebelo, 2013). This, therefore, may require further attention. Superior single effort sprint performance is unlikely to directly impact the ability to recover following peak periods of match play, it will, however, determine the proportion of the anaerobic speed reserve (ASR) used (Buchheit et al., 2012). A lower use of the ASR as a consequence of a higher maximal sprint speed will lessen the anaerobic reliance of peak periods, likely reducing physiological discomfort and preventing the disturbance of homeostasis (Buchheit et al., 2012). Further research is required to explore this concept in the context of pacing and transient fluctuations in running intensity during match play.

The lack of any relationship within the current study between parasympathetic function inferred by HRR and the decrement in physical performance following the peak period of match play would suggest there is more to the phenomenon of temporary fatigue than just the need to recover following the most intense period. However, before attributing these findings to the presence of pacing it is important to take into account that the time the ball was in play during peak and subsequent 5-min periods was not considered within the current study. Concomitant changes in the time the ball spent out of play and match running performance across selected time periods during match play have been reported in soccer (Carling & Dupont, 2011) and ruby league (Kempton et al., 2015). The time the ball was in play was significantly higher in the peak 5-min period, presenting a greater opportunity to work physically (Carling & Dupont, 2011; Kempton et al., 2015). In addition, differences across selected time periods during match play have also been reported for the time spent in attacking and defensive phases, revealing a greater time spent defending in the the peak 5-min period during rugby league match play (Kempton et al., 2015). However, defensive and attacking play in rugby league and soccer are very different and no study to date has examined this in elite soccer match play. Furthermore, the studies are limited in their use of predefined 5-min periods as apposed to a rolling time interval. Therefore, further research using a rolling time period in elite soccer is required to establish if the transient fluctuations in running intensity observed in match play are a behavioural pacing phenomenon or an inherent outcome of reduced opportunities for physical work as a consequence of reduced playing time and changes in possession following peak periods of play. Sports science practitioners should, therefore, be encouraged to consider the influences of contextual and situational match factors in addition to pacing, before drawing any inferences on player's physical attributes from match data.

CHAPTER 5: CONCLUSION

The current study is the first to demonstrate transient fluctuations in locomotor related metabolic power estimates during elite soccer match play. In addition, this study further extended our knowledge of temporary fatigue by investigating the relationship between pre-game cardiorespiratory fitness and parasympathetic function inferred by post exercise HRR and the decrement in physical performance immediately subsequent to the most intense period of play in elite soccer. Although the current study is based on a small sample of participants, the findings suggest that the magnitude of decrement in physical performance immediately subsequent to the most intense period of match play is not directly related to an individual's ability to recover and return to homeostasis following exercise stress. Thus, the temporary reduction appears more consistent with a behavioural pacing schema to modify running intensity in response to symptoms of fatigue to preserve energy recourses. The subconscious or conscious acts to reduce running intensity appear to be based on the player's pre-existing experience and knowledge of what is required to complete matches and associated intense periods, within their biomechanical and metabolic limits. The applied practitioner should, therefore, use this information to inform the structuring of specific training to ensure that it facilitates schema building. Contextual match factors have, however, not been accounted for within the current study, therefore further investigation of these influences is warranted.

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Appendices

Appendix A - Ethical Approval Application

St Mary's University

Ethics Sub-Committee
Application for Ethical Approval (Research)

This form must be completed by any undergraduate or postgraduate student, or member of staff at St Mary's University, who is undertaking research involving contact with, or observation of, human participants.

Undergraduate and postgraduate students should have the form signed by their supervisor, and forwarded to the School Ethics Sub-Committee representative. Staff applications should be forwarded directly to the School Ethics Sub-Committee representative. All supporting documents should be merged into one PDF (in order of the checklist) and clearly entitled with your **Full Name, School, Supervisor.**

Please note that for all undergraduate research projects the supervisor is considered to be the Principal Investigator for the study.

If the proposal has been submitted for approval to an external, properly constituted ethics committee (e.g. NHS Ethics), then please submit a copy of the application and approval letter to the Secretary of the Ethics Sub-Committee. Please note that you will also be required to complete the St Mary's Application for Ethical Approval.

Before completing this form:

- Please refer to the **University's Ethical Guidelines**. As the researcher/ supervisor, you are responsible for exercising appropriate professional judgment in this review.
- Please refer to the Ethical Application System (Three Tiers) information sheet.
- Please refer to the Frequently Asked Questions and Commonly Made Mistakes sheet.
- If you are conducting research with children or young people, please ensure that you read the **Guidelines for Conducting Research with Children or Young People**, and answer the below questions with reference to the guidelines.

Please note:

In line with University Academic Regulations the signed completed Ethics Form must be included as an appendix to the final research project.

If you have any queries when completing this document, please consult your supervisor (for students) or School Ethics Sub-Committee representative (for staff) .

Approved by the Ethics Sub-Committee on the 30th April 2014.

St Mary's Ethics Application Checklist

The checklist below will help you to ensure that all the supporting documents are submitted with your ethics application form. The supporting documents are necessary for the Ethics Sub-Committee to be able to review and approve your application.

Please note, if the appropriate documents are not submitted with the application form then the application will be returned directly to the applicant and may need to be re-submitted at a later date.

	Enclosed? (delete as appropriate)		Version No
Document	Yes	Not applicable	
1.Application Form	Mandatory		
2.Risk Assessment Form	Y		
3.Participant Invitation Letter	Y		
4.Participant Information Sheet	Mandatory		
5.Participant Consent Form	Mandatory		
6.Parental Consent Form		n/a	
7.Participant Recruitment Material - e.g. copies of Posters, newspaper adverts, website, emails		n/a	
8. Letter from host organisation (granting permission to conduct the study on the premises)	Y		
9. Research instrument, e.g. validated questionnaire, survey, interview schedule		n/a	
10.DBS included		n/a	
11.Other Research Ethics Committee application (e.g. NHS REC form)		n/a	

I can confirm that all relevant documents are included in order of the list and in one PDF document entitled with you: ***Full Name, School, Supervisor.***

Signature of Applicant: Robert Fox

Signature of Supervisor:

Ethics Application Form

1) Name of proposer(s)	Mr Robert Fox
2) St Mary's email address	115582@live.stmarys.ac.uk
3) Name of supervisor	Dr Mark Waldron

4) Title of project: The relationship between heart rate recovery following the submaximal Yo-Yo Intermittent Recovery Test (Level 1) and temporary fatigue in soccer players

5) School or service	School of Sport, Heath & Applied Science
6) Programme (if undergraduate, postgraduate taught or postgraduate research)	Postgraduate (MSc) Strength & Conditioning
7) Type of activity/research (staff / undergraduate student research / postgraduate student)	Postgraduate Student

8) Confidentiality	
Will all information remain confidential in line with the Data Protection Act 1998	YES

9) Consent	
Will written informed consent be obtained from all participants / participants' representatives?	YES

10) Pre-approved protocol	
Has the protocol been approved by the Ethics Sub-Committee under a generic application?	YES/NO/ Not applicable Date of approval:

11) Approval from another Ethics Committee	
a) Will the research require approval by an ethics committee external to St Mary's University?	NO
b) Are you working with persons under 18 years of age or vulnerable adults?	NO

12) Identifiable risks	
a) Is there significant potential for physical or psychological discomfort, harm, stress or burden to participants?	NO
b) Are participants over 65 years of age?	NO
c) Do participants have limited ability to give voluntary consent? This could include cognitively impaired persons, prisoners, persons with a chronic physical or mental condition, or those who live in or are connected to an institutional environment.	NO
d) Are any invasive techniques involved? And/or the collection of body fluids or tissue?	NO
e) Is an extensive degree of exercise or physical exertion involved?	YES, but no more than the players are expected to perform as part of their normal daily practice
f) Is there manipulation of cognitive or affective human responses which could cause stress or anxiety?	NO
g) Are drugs or other substances (including liquid and food additives) to be administered?	NO

h) Will deception of participants be used in a way which might cause distress, or might reasonably affect their willingness to participate in the research? For example, misleading participants on the purpose of the research, by giving them false information.	NO
i) Will highly personal, intimate or other private and confidential information be sought? For example sexual preferences.	NO
j) Will payment be made to participants? This can include costs for expenses or time.	NO
k) Could the relationship between the researcher/ supervisor and the participant be such that a participant might feel pressurised to take part?	YES, but every effort will be made to minimise this

13) Proposed start and completion date
Please indicate: • When the study is due to commence. • Timetable for data collection. • The expected date of completion. Please ensure that your start date is at least 3 weeks after the submission deadline for the Ethics Sub-Committee meeting.
The proposed study is to be conducted during the 2015-2016 season with all data to be collected during the competitive in-season phase. The submaximal Yo-Yo Intermittent Recovery Level 1 will be conducted two days prior to a competitive fixture once every 6-week training cycle with corresponding match physical performance analysis conducted within two days of each test on 4 separate occasions.

14) Sponsors/Collaborators
Please give names and details of sponsors or collaborators on the project. This does not include you supervisor(s) or St Mary's University. • Sponsor: An individual or organisation who provides financial resources or some other support for a project.

- Collaborator: An individual or organisation who works on the project as a recognised contributor by providing advice, data or another form of support.

Stoke City Football Club will support the study, providing use of facilities for the testing to be conducted and the equipment to undertake the collection of data.

15. Other Research Ethics Committee Approval

- Please indicate whether additional approval is required or has already been obtained (e.g. the NHS Research Ethics Committee).
- Please also note which code of practice / professional body you have consulted for your project
- Whether approval has previously been given for any element of this research by the University Ethics Sub-Committee.

n/a

16. Purpose of the study

In lay language, please provide a brief introduction to the background and rationale for your study.

- Be clear about the concepts / factors / performances you will measure / assess/ observe and (if applicable), the context within which this will be done.
- Please state if there are likely to be any direct benefits, e.g. to participants, other groups or organisations.

Recent research has revealed a brief reduction in elite soccer players high intensity work rate after intense periods of play during matches (Bradley & Noakes, 2013; Bradley, Di Mascio, et al., 2010; Bradley et al., 2009; Mohr et al., 2003). Players are suggested to exhibit signs of temporary fatigue evident through reductions in high intensity running activity after intense periods of play (Bradley, Di Mascio, et al., 2010; Bradley et al., 2009; Mohr et al., 2003). Temporary fatigue during match play has generally been identified and described using measures of running speed and specifically the distances covered in high speed running zones (Bradley et al., 2009; Bradley, Di Mascio, et al., 2010; Bradley & Noakes, 2013; Mohr et al., 2003). Recent evidence has however, questioned the use of traditional running speed measurements such as high intensity running distance to assess the high intensity demands of match play (Osgnach, Poser, Bernardini, Rinaldo, & Di Prampero, 2010; Gaudino, Iaia, Alberti, Strudwick, Atkinson, & Gregson, 2013). Distances covered in high running speed thresholds fail to take into consideration the high energetic cost imposed by highly demanding acceleration and deceleration movements (Gaudino et al., 2013; Osgnach et al., 2010). It has been shown that different energetic demands are generated from a running speed dependent on the acceleration used, to the extent that high intensity activity can wrongly be classified as low intensity activity when running speed alone is assessed (Osgnach et al., 2010). A new approach based on metabolic power values, combining estimates of energetically demanding accelerated and decelerated movements with traditional running speed estimates appears to provide a more comprehensive assessment of physical match running performance (Osgnach et al., 2010). Energetic based metabolic power values may better represent the high intensity demands of match play, which may provide a greater insight into the phenomenon of temporary fatigue and how players distribute and manage their energy resources to help better inform the physiological preparation of players.

Whilst temporary fatigue has been demonstrated across a number of studies using traditional kinematic measures of intensity in elite level soccer match play (Bradley & Noakes, 2013; Bradley, Di Mascio, et al., 2010; Bradley et al., 2009; Mohr et al., 2003), no study to date, has attempted to use metabolic approaches to identify peak intensity periods to evaluate the transient fluctuations in intensity during elite level soccer match play. The study therefore aims to investigate the transient fluctuations in high intensity activity suggestive of temporary fatigue in elite level soccer match play utilising metabolic measures of match intensity in an attempt to contribute to an enhanced understanding of how players optimise match-running performance through the distribution of their energy sources and management of fatigue during matches.

The consistent intensity reduction immediately following the most intense period of match play provides evidence of the need for recovery following the most intense periods of match play. Whether the recovery following these periods can be optimised through training to allow players to reduce the diminution in high intensity activity and still allow for the maintenance of homeostasis has yet to be investigated. Monitoring players' physical capabilities via the use of the Yo-Yo intermittent endurance (YYIE) and recovery (YYIR) tests developed to assess players' ability to perform repeated intense intermittent exercise (Bradley, Mohr et al., 2010) and the ability to recover from intermittent high intensity exercise (Bangsbo, Iaia, & Krustrup, 2008) respectively, have been shown to represent a valid measure of match related physical performance (Bradley, Mohr, et al., 2010; Castagna, Impellizzeri, Cecchini, Rampinini, & Alvarez, 2009; Krustrup et al., 2003). The heart rate response during phases of the YYIR test has been reported to be similar to those observed during the most intense periods of a game, suggesting the test measures the ability to recover from intense exercise at a similar intensity to that of soccer match play (Krustrup et al., 2003). The YYIR Level 2 (YYIR2) test has been shown to significantly correlate to the peak 5-minute period of high intensity running during match play ($r = 0.72$; $P < 0.05$) (Bangsbo et al., 2008) with performance in the YYIR2 test related to maximal YYIR1 performance and inversely related to submaximal YYIR1 performance expressed as the percentage of maximum heart rate at 6 minutes ($r = -0.61$; $P < 0.05$) (Mohr & Krustrup, 2014).

Submaximal versions of the Yo-Yo tests have been developed in an attempt to limit the need to maximally test players, increasing their effectiveness during the competitive season, where players are already exposed to high match and training loads (Svensson & Drust, 2005). No research, to date, has attempted to evaluate the relationship between the heart rate response to the submaximal YYIR1 test and the phenomenon of temporary fatigue during competitive elite soccer match play, despite reflecting a valid measure of assessing the ability to recover from intense exercise in soccer. There is an apparent lack of research investigating the heart rate recovery response to submaximal YYIR1 testing. A grater parasympathetic function inferred by faster post exercise heart rate recovery is associated with superior cardiorespiratory fitness (Buchheit, 2014), an important physical quality for improved tolerance to HI intermittent exercise (Buchheit, Hader, & Mendez-Villanueva, 2012). Furthermore, changes in submaximal heart rate recovery have been shown to relate to changes in maximal single effort and repeated sprint performance (Buchheit, Simpson, Haddad, Bourdon, & Mendez-Villaneva, 2012). It may be possible that players, who are better able to recover their heart rate at a faster rate, may be permitted to repeat more higher intensity efforts and therefore, have more direct involvements with the ball and within key decisive moments of the game. It would be of interest to establish if the heart rate recovery response following submaximal YYIR1 testing could be used to predict the decline in physical performance in the period immediately subsequent the most intense period of play. The study will also therefore, aim to investigate if peak periods of match intensity are related to submaximal YYIR1 testing performance. The study will aim to investigate if the heart rate recovery response following submaximal YYIR1 testing can predict the decline in physical performance following the peak period of match intensity.

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17. Study Design/Methodology

In lay language, please provide details of:

a) The design of the study (qualitative/quantitative questionnaires etc.)
b) The proposed methods of data collection (what you will do, how you will do this and the nature of tests).
c) You should also include details regarding the requirement of the participant i.e. the extent of their commitment and the length of time they will be required to attend testing.
d) Please include details of where the testing will take place.
e) Please state whether the materials/procedures you are using are original, or the intellectual property of a third party. If the materials/procedures are original, please describe any pre-testing you have done or will do to ensure that they are effective.

A descriptive research design will be used to evaluate the relationship between YYIR1-Submax HRR and temporary fatigue during elite competitive soccer match play throughout the 2015-2016 competitive season.

The non-exhaustive assessment of heart rate recovery (HRR) will be assessed using a submaximal version of the YYIR1 test. The use of a standardised exercise protocol, whereby the exercise duration, intensity, and mode are controlled is essential to ensuring consistent reliable measures of HRR (Daanen, Lamberts, Kallen, Jin, & Van Meeteren, 2012). Post exercise heart rate (HR) during submaximal versions of the Yo-Yo test have been shown to exhibit good reproducibility with a coefficient of variation 1.4% (Bradley, Mohr, et al., 2010). The YYIR1-Submax will be conducted prior to the commencement of a pre-training warm up two days prior to a competitive fixture in which physical match performance data will be collected for analysis using global positioning systems (GPS). A training free day will precede the assessment of HRR through the YYIR1-Submax, to ensure the subjects are fully recovered prior to testing, since acute fatigue has been reported to possibly affect HRR (Borresen & Lambert, 2007). YYIR1-Submax testing will be conducted once every 6-week training cycle with corresponding match physical performance analysis conducted within 2 days of each test. A standardised warm up routine will be performed prior to each competitive match and YYIR1-Submax test that all players will be familiar with prior to the commencement of the study. Multiple game weeks will be excluded from the study, with YYIR1-Submax testing and subsequent match physical performance analysis only taking place during single game weeks.

The YYIR1-Submax will be performed as has previously been described for the maximal version (Krustrup et al., 2003; Mohr & Krustrup, 2014) with the only difference being the duration. The players will be required to complete 20-metre shuttle runs at a progressively increasing running velocity with 10 seconds of active recovery interspersed between runs until the test is terminated after 6 minutes equating to a total distance of 720 metres being completed (Fanchini et al., 2015). The HR response expressed as the percentage of maximum heart rate (% of HR_{max}) following the YYIR1 terminated after 6 minutes has been shown to be inversely correlated to maximum YYIR1 performance, this time frame is significant as such a relationship has not been established for other shorter time frames of the test (Bangsbo et al., 2008). Upon termination of the test, the players will be instructed to stop immediately and stand still for 2 minutes, avoiding any excessive movement so no further increases in HR are induced and the recovery process is not impaired.

Exercise HR (HRex) and HRR will be used as a marker of performance during the YYIR1-Submax test. All players will wear a HR monitor (Polar T31-Coded, Polar Electro, Kempele, Finland) that is compatible and recorded on the GPS device. The mean HR during the last 30 seconds of the 6-minute YYIR1-Submax will be recorded and used as a measure of HRex, with post exercise HRR calculated as the absolute difference between HRex and HR after 60 seconds of passive recovery. A superior ability to detect meaningful changes over time associated with HRR calculated after 60 seconds compared to 2 minutes has been highlighted (Daanen et al., 2012). Changes in HRex, are likely to occur across the study period, to account for this and the potential impact on HRR expressed in absolute terms (beats per minute), HRR will be expressed as a percentage of HRex (% of HRex) (Daanen et al., 2012). All testing sessions will be conducted at Stoke City Football Club's Clayton Wood Training Ground on an outdoor UEFA standard artificial 3G surface to help further standardise the protocol.

Individual players' physical match activity will be recorded in competitive English Barclays U21Premier League games using a 10Hz GPS system (Viper, STATSports Technologies LTD, Co.Down, N.Ireland). GPS devices with a 10 Hz Sampling frequency have been shown to demonstrate a sufficient level of accuracy to quantify the distance covered at high speed (Rampinini et al., 2015) and acceleration, deceleration and constant velocity phases during team sports (Varley, Fairweather, & Aughey, 2012). Players will be assigned the same GPS unit for all competitive fixtures to avoid inter unit error (Jennings, Cormack, Coutts, Boyd, & Aughey, 2010b), with the units activated outdoors, approximately 20 minutes prior to the start of all activity to ensure a satellite signal is established (Jennings, Cormack, Coutts, Boyd, & Aughey, 2010a). Only data from players completing the full duration of the match will be included within the study to ensure validity. All matches will be played on outdoor natural turf pitches in accordance with English Football Association (FA) rules with the dimensions of the pitches in line with Premier League standards.

A 5-minute rolling average will be applied across the entire game, with the peak period being identified as the period with the highest mean intensity. A rolling time interval has been shown to provide a more accurate representation and better indication of temporary fatigue (Varley, Elias, & Aughey, 2012). Average Metabolic Power (energy consumption per kilogram per second) (W/Kg) and High Metabolic Load (HML) distance, calculated as the distance covered (metres) with a metabolic power above the value of 25.5 W/Kg will be used to identify the peak 5-minute periods of movement intensity during soccer match play. Based on energy expenditure, the measures combine the energetic cost of highly demanding running movements including all constant velocity running above 5.5 metres per second (m/s) and acceleration and deceleration activity during intermittent running, providing a better representation of total high intensity activity and thus the physiological load imposed on players (Coutts, Kempton, Sullivan, Bilsborough, Cordy, & Rampinini, 2015; Osgnach et al., 2010). The energy cost of accelerated running is estimated based on a theoretical model (Di Prampero, Fusi, Sepulcri, Morin, Belli, & Antonutto, 2005) assuming that accelerated running on a flat surface is metabolically equivalent to incline running at a constant velocity (Coutts et al., 2010). A change in forward velocity can impose a high energetic cost even when the speed is low, therefore velocity changes in the form of acceleration and deceleration movements are considered high energy activities, heavily taxing energy resources, even at low speeds (Osgnach et al., 2010), thus, contributing to the high physiological strain and energy cost of brief intense running activity.

Pre and post-peak periods will be identified as the periods adjacent the peak and will be used to identify changes in movement intensity. Incidences whereby the peak 5-minute period is observed in the final 5-minute period of either half will be omitted form the study due to an inability to analyse the subsequent 5-minute period. In addition any data recorded from injury time during matches and any incidences where the players fail to complete the full match will not be included as part of any analysis within the study. Pre-game preparations including nutrition, hydration and warm up strategies will be kept consistent across all games used within the study.

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measuring instantaneous velocity during acceleration, deceleration, and constant motion. *Journal of Sports Sciences*, *30*, 121–127.

18. Participants

Please mention:

a) The number of participants you are recruiting and why. For example, because of their specific age or sex.
b) How they will be recruited and chosen.
c) The inclusion / exclusion criteria's.
d) For internet studies please clarify how you will verify the age of the participants.
e) If the research is taking place in a school or organisation then please include their written agreement for the research to be undertaken.

Twenty-two male outfield players from the same club of a professional Premier League elite development squad will be approached to volunteer to participate in the study. Since, only data from players completing the full duration of the match will be included within the study, data collection during match play will be limited to a maximum of ten players on each occasion. Due to the possible problem of player withdrawal due to injury, transfer/loan activity, and player rotation, the recruitment of all twenty-two members of the squad is considered to ensure sufficient data samples will be collected. All participants will be required to be free from injury and illness and deemed eligible to participate by the clubs medical staff to be included within the study.

19. Consent

If you have any exclusion criteria, please ensure that your Consent Form and Participant Information Sheet clearly makes participants aware that their data may or may not be used.

a) Are there any incentives/pressures, which may make it difficult for participants to refuse to take part? If so, explain and clarify why this needs to be done

b) Will any of the participants be from any of the following groups?

- Children under 18
- Participants with learning disabilities
- Participants suffering from dementia
- Other vulnerable groups.

c) If any of the above apply, does the researcher/investigator hold a current DBS certificate? A copy of the DBS must be included with the application.

d) How will consent be obtained? This includes consent from all necessary persons i.e. participants and parents.

The potential for the participants to feel pressurised to participate through a pre-existing position of authority held by the researcher will be considered and addressed through a clear statement that participation is entirely optional and participants are free to not participate or withdraw from the study at any point.

All participants will be over the age of 18, and therefore able to give complete consent of their own accord.

Blanket consent for the use of all data collected at Stoke City Football Club for the purposes of research is obtained from players at the time the player signs his scholarship and professional contract. In addition to this all players that participate in the study will be required to complete further informed consent, detailing what, how, and why the data will be collected and the intended use of the data once collected.

20. Risks and benefits of research/ activity

a) Are there any potential risks or adverse effects (e.g. injury, pain, discomfort, distress, changes to lifestyle) associated with this study? If so please provide details, including information on how these will be minimised.

b) Please explain where the risks / effects may arise from (and why), so that it is clear why the risks / effects will be difficult to completely eliminate or minimise.

c) Does the study involve any invasive procedures? If so, please confirm that the researchers or collaborators have appropriate training and are competent to deliver these procedures. Please note that invasive procedures also include the use of deceptive procedures in order to obtain information.

d) Will individual/group interviews/questionnaires include anything that may be sensitive or upsetting? If so, please clarify why this information is necessary (and if applicable, any prior use of the questionnaire/interview).

e) Please describe how you would deal with any adverse reactions participants might experience. Discuss any adverse reaction that might occur and the actions that will be taken in response by you, your supervisor or some third party (explain why a third party is being used for this purpose).

f) Are there any benefits to the participant or for the organisation taking part in the research (e.g. gain knowledge of their fitness)?

Risks and adverse effects are minimal owing to the use of a submaximal testing procedure. With the data being collected as part of normal practice to monitor the players the risks and adverse effects are no greater than the normal risks associated with soccer match play and training. Suitably qualified medical personnel (physiotherapists, paramedics and a medical doctor) will be in attendance at every competitive match in line with Premier League rules. In addition, an appropriately qualified medical professional will be in attendance during all testing sessions. All participants will have the opportunity to be checked by a medical professional prior to all testing sessions should they require.

Findings from the study hopefully may be used to help better inform the physiological preparation players, using the information gathered to develop training drills that aim to stimulate the peak high intensity movement demands of match play. The findings may also contribute to an enhanced understanding of how players optimise match-running performance through distributing their energy sources and management of fatigue during match play. The use of the findings from the submaximal YYIR1 test could be used to provide valuable information on players' physical capabilities, and monitoring of fitness and readiness to train throughout the season.

21. Confidentiality, privacy and data protection

a) What steps will be taken to ensure participant's confidentiality?

- Describe how data, particularly personal information, will be stored.
- Consider how you will identify participants who request their data be withdrawn, such that you can still maintain the confidentiality of theirs and others data.

b) Describe how you manage data using a data a management plan.

- You should show how you plan to store the data securely and select the data that will be made publically available once the project has ended.
- You should also show how you will take account of the relevant legislation including that relating data protection, freedom of information and intellectual property.

c) Who will have access to the data? Please identify all persons who will have access to the data (normally yourself and your supervisor).

d) Will the data results include information which may identify people or places?

- Explain what information will be identifiable.
- Whether the persons or places (e.g. organisations) are aware of this.
- Consent forms should state what information will be identifiable and any likely outputs which will use the information e.g. dissertations, theses and any future publications/presentations.

Every effort will be made to ensure participant confidentiality and anonymity is maintained. All data collected for the study will remain on a password-protected computer only accessed by the named proposer. A unique coding system will be used, with only the named proposer having access to the raw data, to ensure participants who request their data be withdrawn can be identified and withdrawn whilst maintaining the confidentiality of the remaining participants.

No one participant shall be identifiable form the results of the study, and therefore none of the collected information or analysis will be used against any of the participants, with information and data only reported back as averages.

22. Feedback to participants

Please give details of how feedback will be given to participants:

- As a minimum, it would normally be expected for feedback to be offered to participants in an acceptable to format, e.g. a summary of findings appropriate written.
- Please state whether you intend to provide feedback to any other individual(s) or

organisation(s) and what form this would take.
Feedback will be provided to the participants, summarising the key findings. Further individual feedback will be provided should participants request it. Participant confidentiality and anonymity will be maintained throughout, none of the collected information or analysis will be used against any of the participants. In addition feedback will be provided to coaching and support staff at Stoke City Football Club who were directly affected/involved within the study. Information and data will only be reported back to coaching and support staff at Stoke City Football Club as averages, with only the researcher having access to the raw data.

The proposer recognises their responsibility in carrying out the project in accordance with the University's Ethical Guidelines and will ensure that any person(s) assisting in the research/ teaching are also bound by these. The Ethics Sub-Committee must be notified of, and approve, any deviation from the information provided on this form.

Signature of Proposer(s) Robert Fox	Date: 18/01/16
Signature of Supervisor (for student research projects) 	Date:18/01/16

St Mary's University Twickenham London

Approval Sheet

Name of applicant: Mr Robert Fox Name of supervisor: Dr Mark Waldron Programme of study: Postgraduate (MSc) Strength and Conditioning Title of project: The relationship between heart rate recovery following the submaximal Yo-Yo Intermittent Recovery Test (Level 1) and temporary fatigue in soccer players

Supervisors, please complete section 1 or 2. If approved at level 1, please forward a copy of this Approval Sheet to the School Ethics Representative for their records.

SECTION 1 Approved at Level 1 Signature of supervisor (for student applications).. x M... Date..........18/01/16..
SECTION 2 Refer to School Ethics Representative for consideration at Level 2 or Level 3 Signature of supervisor.. Date..
SECTION 3 To be completed by School Ethics Representative Approved at Level 2 Signature of School Ethics Representative... Date..

SECTION 4

To be completed by School Ethics Representative. Level 3 consideration required by the Ethics Sub- Committee (including all staff research involving human participants)

Signature of School Ethics Representative ……………………………………………

Date...

Level 3 approval – confirmation will be via correspondence from the Ethics Sub-

Committee

A.1 Participant Information Sheet

St Mary's University Twickenham London

PARTICPANT INFORMATION SHEET

Study Title: The relationship between heart rate recovery following the submaximal Yo-Yo Intermittent Recovery Test (Level 1) and temporary fatigue in soccer players

I would like to take the time to invite you to take part in a research study looking into the phenomenon of temporary fatigue during soccer matches. Temporary fatigue is commonly seen in matches evident through a brief reduction in the physical work rate of players following intense periods of play.

It is important that you fully understand what you would be helping us to do. Please take as much time as you want to read this information sheet carefully, asking as many questions as you feel necessary before you decide whether or not you would like to take part. If you choose to take part we thank you. If you don not decide take part, there will be no disadvantage to you of any kind and we thank you for considering our request.

What is the purpose of the study?

As mentioned above, we are interested in investigating the phenomenon of temporary fatigue in soccer matches, and in particular whether a simple submaximal YO-YO Intermittent Recovery test can be used to predict the brief decline in physical performance following intense periods of matches.

Who is organising the research?

Robert Fox will conduct the research in collaboration with St Mary's University.

Why have I been approached to take part?

We want to explore the use of a submaximal YO-YO Intermittent Recovery test to predict temporary fatigue in matches with an elite group of soccer players.

Do I have to take part?

It is entirely your own decision to take part or not. If you choose to take part we thank you. If you decide not to take part that is okay, there will be no disadvantage to you of any kind and we thank you for considering our request.

What happens if I take part?

You will be asked sign a consent form to show you agree to take part in the project, you will be given a copy of this form together with a copy of this information sheet to keep for your records. All testing and data collection sessions/matches will be organised around your training and match schedule with very little inconvenience to your training schedule. You will be asked to complete a submaximal YO-YO intermittent recovery test lasting for 6 minutes on four separate occasions over the course of the season prior to a training session whilst wearing a heart rate monitor to allow the assessment of your recovery following the test. Your match physical performance will then be reordered and analysed using a global positioning system (GPS) worn during matches to assess your high intensity running activity.

In summary the study only requires you complete a submaximal YO-YO intermittent recovery test lasting 6 minutes followed by a 2-minute recovery period. The time commitment of taking part in the study is therefore 8-minutes (6minutes of activity and 2 minutes of rest) on 4 separate occasions during the season. All match physical performance will be collected during scheduled competitive league fixtures, and therefore requires no additional time commitments beyond your usual.

What will I have to do?

As mentioned above you will be required to provide written consent prior to taking part in the study. On testing days you will only be able to take part if you are deemed fit, and are taking part in full training following. If you have any concerns regarding your fitness during or before testing sessions and matches, please make sure we are made aware of them. Before all testing sessions and matches you should be well rested, hydrated and have eaten appropriately. You will need to ensure you wear your heart rate monitor and GPS device as instructed prior to testing sessions and matches. If you have any problems or have had any problems in the past with wearing heart rate monitors and GPS devices, please make sure you raise them with us so we can discuss the best solution.

What are the possible risks of taking part?

You will not be exposed to any greater risks during any period of the study beyond that of the normal day-to-day risks you are exposed to as a professional footballer participating in training and competitive matches. Trained medical staff will be present during both testing sessions and matches, and will be available prior to both should you need attention or should you have any concerns over your ability or fitness to take part.

What are the possible benefits of taking part?

No promises can be made that the study will directly help you, but the information we get from the study will hopefully contribute to a greater understanding of elite soccer player's physical qualities, that may contribute to new improve training and testing techniques that can aid player preparation. If you wish feedback based on the findings can be discussed with you and your coaches.

Will my participation in the study be kept confidential?

All testing results will be made anonymous, with individual names and identifying features removed so that you cannot be recognised. All electronic data will be stored on a password-protected computer known only by the researcher. Any paper copies of information will be stored in a locked cabinet, within a locked office, and where possible will be transferred to electronic copies and then destroyed.

What will happen if I don't want to continue with the study?

You are free to withdraw from the study at any point. If you no longer wish to take part in the study you just need to inform us of your intentions, you do not have to explain why you have decided to withdraw and it will be done without prejudice. All information and data collected will be immediately removed from study files and destroyed.

What will happen with the results of the study?

The results of the study will be presented in the form of a written research report and poster and submitted for assessment. Following this it is planned the findings will be disseminated by presenting them in the form of a poster at international conferences and if necessary publishing them in academic journals. Please note that you nor your team or club will be identified in any report, presentation or publication.

What if there is a problem?

If you have a concern or issue with any aspect of this study, or need to report anything you should contact Robert Fox on **07835211162** or by Email **115582@live.stmarys.ac.uk**. If you are not happy with the response you receive or wish to complain formally you can do so by contacting the School of Sport, Health and Applied Sciences at St Mary's University directly on **020 8240 4261**.

YOU WILL BE GIVEN A COPY OF THIS FORM TO KEEP TOGEATHER WITH A COPY OF YOUR CONSENT FORM

A.2 Participant Consent Form

St Mary's University Twickenham London

Name of Participant:
____

Title of the Project: The relationship between heart rate recovery following the submaximal Yo-Yo Intermittent Recovery Test (Level 1) and temporary fatigue in soccer players

Main investigator: ROBERT FOX
Contact details: PHONE: 07835211162 EMAIL: 115582@live.stmarys.ac.uk

Members of the research team:

1. I agree to take part in the above research. I have read the Participant Information Sheet, which is attached to this form. I understand what my role will be in this research, and all my questions have been answered to my satisfaction.
2. I understand that I am free to withdraw form the research at any time, for any reason and without prejudice.
3. I have been informed that the confidentiality of the information that I provide will be safeguarded.
4. I am free to ask any questions at any time before and during the study.
5. I have been provided with a copy of this form and the Participant Information Sheet.

Data Protection: I agree to the University processing personal data, which I have supplied. I agree to the processing of such data for any purposes connected with the Research Project as outlined to me.

Name of participant (print) ……………………. Signed ………………………. Date ……………..

Name of witness (print) ……………………. Signed ………………………. Date ……………………

If you wish to withdraw form the research, please complete the form below and return to the main investigator named above.

Title of Project:

____

I WISH TO WITHDARW FROM THIS STUDY

Name: ____

Signed: ____ Date: ___________

A.3 Ethical Approval Supporting Documents

15th December 2015

Dear Robert,

Thank you for taking the time to discuss your current Masters dissertation in which you are looking to use data collected from the U21 squad here at the Academy.

Just to confirm that as per the Children Act 1989 & 2004, we hold Parental Responsibility for players residing here whose own main carers do not reside in the United Kingdom, in addition to Players over the age of 18 that give their verbal and written consent for data at the start of each season for the purposes of research.

I can confirm we gain blanket consent for the use of data for the purposes of research at the start of a player's scholarship & professional contracts, and feel that it is a real positive that you are able to use this as your own research.

All players over the age of 18 are able to give you complete consent of their own accord, and we discussed that you will inform these players of what you intend to use the data for prior to gaining informed consent.

If you or St Mary's University wish to discuss any further information in relation to players, please do not hesitate to contact me.

I wish you all the best with the proposals we discussed, and look forward to reading your findings.

Kind Regards,

Kirsty Cavanagh
Head of Academy Welfare & Safeguarding

M: +44(0) 7788 368875
E: kirsty.cavanagh@stokecityfc.com

Stoke City Football Club Limited
Britannia Stadium, Stanley Matthews Way, Stoke-on-Trent, Staffordshire ST4 4EG
Tel: 01782 367 598 Fax: 01782 592 221 Email: info@stokecityfc.com
www.stokecityfc.com www.scfcdirect.com

25th November 2015

Dear Robert,

Thank you for providing me with the details of your proposed Masters dissertation in which you are looking to utilise data collected from the U21 squad here at the Academy.

I can confirm the data that you wish to utilise for the purpose of your study is collected as part of normal practice at the club, for the purpose of monitoring players in line with the club's sports science philosophy.

Permission has been granted for you to use the data collected at Stoke City Football Club for your Masters Research project, based on the condition that all data will be anonymised in any written reports.

I am informed that all players provide consent for any data collected by club to be used for the purposes of research upon signing their scholarship and professional contracts.

If you or St Mary's University wish to discuss any further information in relation to this, please do not hesitate to contact me.

I wish you all the best with your research, and look forward to reading your findings.

Sincerely,

Dr Andrew Dent
Head of Medicine

P. White

Paul White
Head of Academy Sports Science & Athletic Development

Stoke City Football Club Limited
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FIFA®

For the Game. For the World.

TO THE MEMBERS OF FIFA

Circular no. 1494

Zurich, 8 July 2015
SG/sco/ovo

Approval of Electronic Performance and Tracking System (EPTS) devices

Dear Sir or Madam,

Technology is advancing at a great pace in all aspects of our daily life, and of course, our beautiful game is not an exception. One example of this is the use of electronic devices aimed at monitoring, tracking and storing data about the performance of players on the field of play.

Requests have been made to The IFAB to permit players to wear such devices during matches. Although the permission to wear EPTS devices was given in principle by The IFAB, the final decision as to whether or not EPTS devices may be used lies with the respective association, league or competition (according to The IFAB Circular No. 1, sent to the member associations in May this year).

FIFA has put in place a process to control the use of these tools for its own final competitions. For instance, for the FIFA U-20 World Cup New Zealand 2015 and the FIFA Women's World Cup Canada 2015™, the teams were requested to send these electronic performance and tracking system devices to be inspected by FIFA.

In general terms, the approval of such tools are subject to the following principles:

- All devices will be inspected (including those devices already inspected) at the Team Arrival Meeting by the FIFA referee instructor or another occasion as considered appropriate by FIFA. If there are any concerns, the devices will be presented to the FIFA Medical Officer for further inspection and a joint final decision with either the match commissioner or general coordinator.
- The data to be collected by an approved electronic performance or tracking system device, or any interpretation of it, may only be used by the respective participating team and/or the individual player for performance monitoring purposes (including physical, technical and tactical data) and by no means for any commercial purpose and/or in association with any third party.
- In order to protect the integrity of, and FIFA's rights in, the competition, FIFA may impose further restrictions on the use of the data collected by an approved electronic performance or tracking system device.

Fédération Internationale de Football Association
FIFA-Strasse 20 P.O. Box 8044 Zurich Switzerland T: +41 (0)43 222 7777 F: +41 (0)43 222 7878 www.FIFA.com

FIFA

For the Game. For the World.

- According to art. 25 of the FIFA Equipment Regulations, the device shall not display the branding of its manufacturer or any third party with the exception of one tonal identification of its manufacturer which is not visible whilst such device is used.
- No technical devices will be allowed in the technical area, nor may any data/information collected through such devices be transmitted to the technical area during the match.

Furthermore, according to Law 4 of the Laws of the Game, such devices shall not cause any danger to the player himself/herself or any opposing player.

Participating member associations shall ensure that all team delegation members fully comply with the above requirements. The responsibility for failing to do so will be borne by the member association.

FIFA would like to emphasise that any device worn is at the risk and responsibility of the player and/or member association concerned.

Thank you for your cooperation with the above.

Yours faithfully,

FÉDÉRATION INTERNATIONALE
DE FOOTBALL ASSOCIATION

Jérôme Valcke
Secretary General

cc: - FIFA Executive Committee
- Confederations

CMP

CS

2/

31 July 2015

TO: PREMIER LEAGUE CLUB SECRETARIES

CC: FIRST TEAM MANAGERS
CLUB DOCTORS
SENIOR ANALYSTS
PGMO, THE FA, THE FOOTBALL LEAGUE, PFA, LMA

PREMIER LEAGUE

Dear Secretary

ELECTRONIC PERFORMANCE AND TRACKING SYSTEM ("EPTS") DEVICES

Your attention is drawn to FIFA Circular no. 1494 attached.

This concerns the use of Electronic Performance and Tracking System devices within competitive games.

Following this FIFA directive the Premier League Board has agreed to sanction the use of such devices during Season 2015/16 subject to any Club wishing to utilise an EPTS in Premier League matches (First Team, Under 21 etc) first obtaining the written permission of the Premier League.

The Premier League will grant such request subject to it being satisfied that the device does not constitute a danger to the player wearing it (or any other player) and the Club agreeing to abide by the following conditions:

1. That the data collected from an EPTS device may only be used retrospectively and not live.

2. That the data collected from an EPTS device may not be viewed in the Technical Area during the course of a game.

3. That the data collected from an EPTS device may not be used for any commercial activity.

4. That any branding on the EPTS device must not be visible.

For the avoidance of doubt the data collected during the first half of a match may be used at half time.

The Premier League retain the right to take action against any Club found not to be observing the conditions of use.

In order for the Premier League to sanction the use of an EPTS, Clubs are required to submit a sample of the device and how it will be worn, an explanation of the data to be captured and confirmation that the Club accepts the conditions of use.

Please submit requests to:

Steve Palmer, Head of Performance Systems
spalmer@premierleague.com / 020 7864 9277

Yours sincerely

MIKE FOSTER
Director of Football

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