# Contemporary Factors Impacting Match Performances Of Elite Soccer Players: The Development And Evolution Of Performance In The English Premier League.

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**Abstract**

This thesis analysed the modern trends in soccer performance, with specific reference to the physical and technical performance of matches played in the English Premier League (EPL) between 2006-07 and 2012-13. Following previous literature, the thesis analysed whether performance could be predicted through performance stability calculations. This section of the research highlighted the highly variable nature of the sport and suggested the minimum number of matches required for an accurate assessment of performance, particularly for low frequency variables (number of tackles performed, number of times tackled, shots) was less than effective. An alternative method to calculate performance benchmarks, the thesis looked into the coefficients of variation associated between matches, expanding previous assessments on physical performance and expanding this knowledge into technical variables. To follow on from this initial study, the thesis introduced findings on the interaction of physical and technical parameters to ascertain whether correlations existed between physical and technical match performance and whether formulae could be generated to aid predicting future performance. The conclusion from these studies suggests predicting performance through previously suggested means and using physical data to estimate technical performance are unsupported. Instead a possible solution would be to use coefficients of variation to calculate benchmarks around a typical performance. As a result this would provide coaches and support staff set boundaries that players should achieve during games. In addition these boundaries should inform and aid the development of training regimes providing players with the baseline required. The final studies in this thesis charted the evolution of physical and technical

performance parameters and the potential causes for any changes found, using the evidence from the earlier studies to ascertain whether evolution had occurred beyond the level of variability or whether changes in performance could be attributed entirely to variability. These studies found large increases in both physical and technical performance parameters across all outfield positions; nevertheless the causes of these changes in performance are unclear. One hypothesis was that the number of non-UK players now performing in the EPL have driven changes in match performance and resulted in greater technical quality. These results indicated trivial to small differences between UK and non-UK players in 2006-07, although by 2012-13 these small differences had all but disappeared. Thus suggesting the different numbers between UK and non-UK players could have influenced the changes in performance although there appears to be other factors driving the evolution.

The results from this thesis can be used in the physical and technical preparation of players, providing them with the baselines required to compete at the level required. In addition this information is valuable for both medical staff at clubs as well as for the recruitment of future players, providing both with concurrent information on modern match performances. The results also provide suggestions for future research proving researchers need to be cautious when analysing data across a number of seasons. Following on from this series of studies, future research could analyse the most effective means for providing this information to coaches and other staff at professional clubs in order to maximise the application.

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**List Of Publications**

Publications From Thesis

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Bush, M., Barnes, C., Archer, D.T., Hogg, B. and Bradley, P.S. (2016). Longitudinal Match Performance Characteristics of UK and Non-UK Players in the English Premier League. *Science and Medicine in Football, In press*

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Additional Publications

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# *Chapter 1* : Introduction

## 1.1 Introduction

Soccer is one of the most popular sports worldwide, with an ever increasing number of both players and spectators, due largely to the relative simplicity of the rules and the lack of equipment required (D'Orazio & Leo, 2010). Nonetheless, the sport itself is complex, multi-dimensional and unpredictable in nature; incorporating physical, technical and tactical elements leading to the success or failure of the game (Bradley et al., 2009; Drust, Atkinson, & Reilly, 2007; Mackenzie & Cushion, 2013; Rampinini et al., 2008). Soccer matches involve a complex series of interactions with players randomly transitioning between brief maximal, or near-maximal, multidirectional efforts and longer periods of low-intensity activity or inactivity; all whilst performing a variety of technical and tactical skills (Bangsbo, Mohr, & Krustrup, 2006; Carling, Bloomfield, Nelsen, & Reilly, 2008; Drust et al., 2007; Rampinini, Impellizzeri, Castagna, Coutts, & Wisløff, 2009). It is widely accepted that the overall technical performance and quality of technical actions is affected by the physical requirements of the game as well as the occurrence of temporary or permanent fatigue (Drust et al., 2007; Rampinini et al., 2008; Russell & Kingsley, 2011).

In order to understand the various aspects of soccer performance, and therefore to maximise the chances of success, the area of sport science has become a vast area both in research and applied areas (Bishop, 2008). Initially sport science included sub-disciplines of physiology, psychology and biomechanics (Nevill, Atkinson, & Hughes, 2008), but was expanded in the 1990's to include the rapidly expanding discipline of performance analysis (Hughes, 2004b; Sarmento, Marcelino, et al., 2014). Research into the performance analysis of soccer began in the 1970's although it was not until the 1990's when the research area saw a rapid increase in the number and quality of published articles (Coutts, 2014). This significant interest in the field of performance analysis in sport, and particularly soccer, led to the development of numerous purpose built computer systems (Barris & Button, 2008; Hughes, Hughes, & Behan, 2007; O'Donoghue, 2006b). These analysis systems can be as simple as recording the frequency of a set measure, tracking physical data through GPS, or far more comprehensive systems combining the analysis of technical and physical performance through automated player tracking (Hughes & Franks, 2004a; Hughes & Hughes, 2005; Liebermann et al., 2002; Randers et al., 2010). The development of automated systems has led to a significant increase in the amount of performance data available and can therefore provide large sample sizes for analytical purposes; a clear advantage over other sport science disciplines (Coutts, 2014). Although these advanced and comprehensive analysis systems have numerous advantages, they may not be feasible or cost effective for soccer clubs looking to evaluate performances. Therefore, clubs need to balance the costs of the detailed systems against the visible returns, which may lead them to select simpler and cheaper methods of analysis such as hand-based notation systems (Barris & Button, 2008; Carling, Williams, & Reilly, 2005; Hughes & Franks, 2004b).

The vast majority of research analysing the physical demands of match-play in European soccer leagues has focused predominately in; the English Premier League (Bradley et al., 2009; Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009), Italian Serie A (Mohr, Krustrup, & Bangsbo, 2003; Vigne, Gaudino, Rogowski, Alloatti, & Hautier, 2010), Spanish La Liga (Castellano, Blanco-Villaseñor, & Alvarez, 2011), as well as other leagues worldwide and international competitions (Barros et al., 2007; Bradley, Dellal, Mohr, Castellano, & Wilkie, 2014; Di Salvo et al., 2010). Based on the findings of these studies it has been proposed that soccer players cover ~10-13km per match, with approximately 10-15% of this distance covered at speeds >19km·h$^{-1}$ (Bradley, Dellal, et al., 2014; Bradley & Noakes, 2013; Carling, 2013; Carling, Le Gall, & Dupont, 2012; Di Salvo, Pigozzi, González-Haro, Laughlin, & Witt, 2013). The majority of the high-intensity actions occur when teams are without possession of the ball (Bradley et al., 2009; Carling, 2010; Di Salvo et al., 2009). Differences between first half and second half performance have been reported consistently through research yet the causes of this variation have been widely debated (Andersson, Raastad, et al., 2008; Bradley & Noakes, 2013; Carling, 2013; Edwards & Noakes, 2009; Mohr et al., 2003; Mohr, Krustrup, & Bangsbo, 2005; Reilly, 1997). It has been suggested that players suffer from physical fatigue during the second half, though alternatively the observed reductions in performance are proposed to be due to pacing strategies, aiming to maintain player performances for the entire 90 minutes of a match (Bradley & Noakes, 2013; Carling, 2013; Edwards & Noakes, 2009). It is evident however that players suffer from temporal fatigue following the most intense periods of a match. There are observed reductions in overall distance covered and distances covered at high-intensities for the 5 minutes following these intense efforts (Bradley et al., 2009; Bradley & Noakes, 2013; Mohr et al., 2005).

There is considerably less information and research on the technical aspects of soccer performance compared to physical measures. The limited research that has been conducted has however highlighted differences in the positional requirements with respect to technical match play (Bradley, Carling, et al., 2013; Bradley, Dellal, et al., 2014; Di Salvo et al., 2007). Although rather arbitrary, it has been identified that a pass success rate of >70% is deemed necessary for both individual and team success, irrespective of playing position (Dellal et al., 2011). More specifically team performance is stated to be more successful when performing a greater number of passes, successful passes, tackles, interceptions, shots and goals (Castellano, Casamichana, & Lago, 2012). Tactical analysis has often been overlooked in the academic literature and rarely been conducted in soccer. This is due to the highly changeable formations and tactics adopted during matches. Tactical variables are largely dependent upon the changing match status and varying opposition tactics and therefore the ability to monitor or measure tactical aspects of play consistently and accurately, is too difficult and challenging with current circumstances and software (Bradley, Carling, et al., 2011). Despite the current research analysing both physical and technical performance measures during soccer matches, there remains a number of methodological limitations. For example, current research is often based on a small number of soccer seasons (generally one or two seasons); therefore the data may only be applicable to the years in question. One of the aims of this thesis is to address these issues and analyse soccer performances over multiple seasons, thus identifying any long-term trends within performance, both physical and technical, and the potential causes of any changes identified.

Contextual match factors such as match location, opposition standard and score line have been identified as having an effect on match performance (Bradley, Lago-Peñas, Rey, & Sampaio, 2014; Lago, Casais, Dominguez, & Sampaio, 2010; Lago-Peñas & Dellal, 2010; Lago-Peñas & Lago-Ballesteros, 2011; Taylor et al., 2008; Tucker, Mellalieu, James, & Taylor, 2005). Nevertheless, despite this evidence these factors are still not commonly factored into the data collection process or reported effectively in the results section of reports (Mackenzie & Cushion, 2013). Research has identified that matches played at a team's home ground results in greater performance of both physical and technical performance (Castellano et al., 2011; Jacklin, 2005; Lago et al., 2010; Lago, 2009; Pollard & Pollard, 2005; Pollard, 2008; Sánchez, García-Calvo, Leo, Pollard, & Gómez, 2009; Taylor et al., 2008). Playing against weaker opposition has been shown to increase technical performance, generally due to increases in the amount of possession (Bradley, Lago-Peñas, et al., 2014; Lago-Peñas & Lago-Ballesteros, 2011; Lago, 2009). However, physical performance was observed to decrease for stronger teams playing weaker opposition and increased for weaker opposition when playing stronger opposition (Castellano et al., 2011; Lago et al., 2010). One key consideration is the dynamic nature of the sport and the associated level of inherent variability present between matches (Gregson, Drust, Atkinson, & Di Salvo, 2010; Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007; Weston, Drust, Atkinson, & Gregson, 2011). Multiple methods have been proposed to assess the match-to-match changes between performances (Gregson et al., 2010; Hughes, Evans, & Wells, 2001). One such proposed method is to measure the minimum number of matches to display a stable profile of performance (Hughes et al., 2001). Alternatively, another proposed measure is to analyse the variability within performance (Gregson et al., 2010; Rampinini et al., 2007). Previously there has been little or no assessment of the variability between performances on physical and technical parameters or the most effective methods of measuring performance inconsistency Therefore another aim of this thesis is to develop and expand previous research in match-to-match variability of physical performance whilst developing an initial understanding of the variability of technical performance, with the aim of developing an understanding of the benchmarks required for a typical performance.

Sport science in general, and performance analysis in particular, has been shown to be highly beneficial to applied practitioners and coaches; nevertheless there is a lack of interaction between research findings and the applied sciences (Bishop, 2008). Despite the wealth of knowledge that can be gained on sporting performance through performance analysis, little research has investigated the understanding of the information by coaches and athletes and thus the application of performance analysis data within a sporting context (Fleming, Young, Dixon, & Carré, 2010; Groom & Cushion, 2004; Mackenzie & Cushion, 2014; Nelson, Potrac, & Groom, 2011). It has been suggested that this lack of communication is due to the complex and dynamic nature of the coaching process and sporting performance overall (Cushion et al., 2010). Additionally the majority of research conducted within the area is centred in academic environments and has neglected both practitioners perspectives and application within professional sports and applied situations (Cushion et al., 2010; Mackenzie & Cushion, 2014). Although data analysis has existed in sporting contexts for a number of years, it is perhaps unsurprising that little research has examined its effectiveness in the coaching process, as it is only more recently that the importance of, and methods of, coach learning and coach education has begun to be examined in detail (Abreham, Collins, & Martindale, 2006; Cushion, 2001; Cushion et al., 2010; Dawson, Dobson, & Gerrard, 2000; Williams & Kendall, 2007). Although current research has highlighted both the perceived and actual importance of performance analysis in the coaching process (Fleming et al., 2010; Groom & Cushion, 2004; Groom, Cushion, & Nelson, 2011; Hughes & Franks, 2004b; Nevill et al., 2008; O'Donoghue, 2006b), without identifying or investigating the coaches' perceptions or understanding of performance analysis (visual and statistical feedback), and how these develop over time, it will remain difficult for practitioners to maximise the feedback potential.

In summary, the area of performance analysis has become an essential sub-section of sport science, particularly in soccer. Much research has been conducted to understand both the physical and technical characteristics of match performance. This research has recently begun to investigate the variability of performances between matches, but has so far solely analysed the variability of physical performances and has not attempted to investigate technical performance. In addition previous research has included many methodological issues; using limited number of seasons, restricting the application of findings; as well as not accounting for contextual influences on performance.

### 1.2 Aims Of the Current Research

This thesis will examine the current trends in both physical and technical match performance parameters in the English Premier League (EPL), with specific focus on how playing position and player nationality influence these trends over a number of seasons. Additionally, the current research will investigate the variability associated with player performance on a match-to-match basis and how the physical and technical performance variables interact with performance. The research within this thesis will provide an alternative method for setting both physical and technical performance benchmarks. This data will initiate and develop greater understanding of the current playing performance in the EPL. The results of the thesis will allow for the assessment of players through talent identification and for enhancing the physical preparation of players.

# ***Chapter 2*** **: Literature Review**

## 2.1 Performance Analysis

### 2.1.1 Background to Performance Analysis

Professional sports have been an accepted aspect of society for many decades (Reilly, 1996). The science of sports has often been associated with the physiological and psychological ability, and preparation of the individuals involved within sport (Reilly & Gilbourne, 2003; Stølen, Chamari, Castagna, & Wisløff, 2005). Performance analysis in sport can be dated back to the early 1900s, the first publication was based on the probabilities of success in baseball according to combinations of batting, pitching and fielding (Fullerton, 1912). It was not until the 1960s when analysis systems became commercially available that increased both the research base and the application of performance analysis in professional sports clubs (Hughes & Franks, 2004b). Nonetheless, it was not until the start of the 21st century that witnessed the introduction of specific performance analysis journals (International Journal of Performance Analysis in Sport) and specific areas within journals that published performance analysis articles (Journal of Sports Sciences, Human Movement Sciences, International Journal of Sports Physiology and Performance), which enabled widespread understanding of mainstream sports both in research and applied settings (Coutts, 2014; Mackenzie & Cushion, 2013). Thereby, highlighting the importance of performance analysis within both applied sport and research contexts.

The aim of performance analysis is to enhance the coaching process and therefore provide more effective and accurate feedback both to coaches and players. In contrast to the views of some coaches, performance analysis is not there to replace traditional coaching practices but to supplement them with objectivity and visual evidence, ultimately to enhance performance (Carling et al., 2005; Franks, 2004; Hughes & Bartlett, 2002). Although performance analysis is aimed at improving performance and could therefore be classed as incorporating all areas of sport science (Bartlett, 2001; Hughes & Bartlett, 2002), it is primarily viewed as encompassing three main areas of sport science:

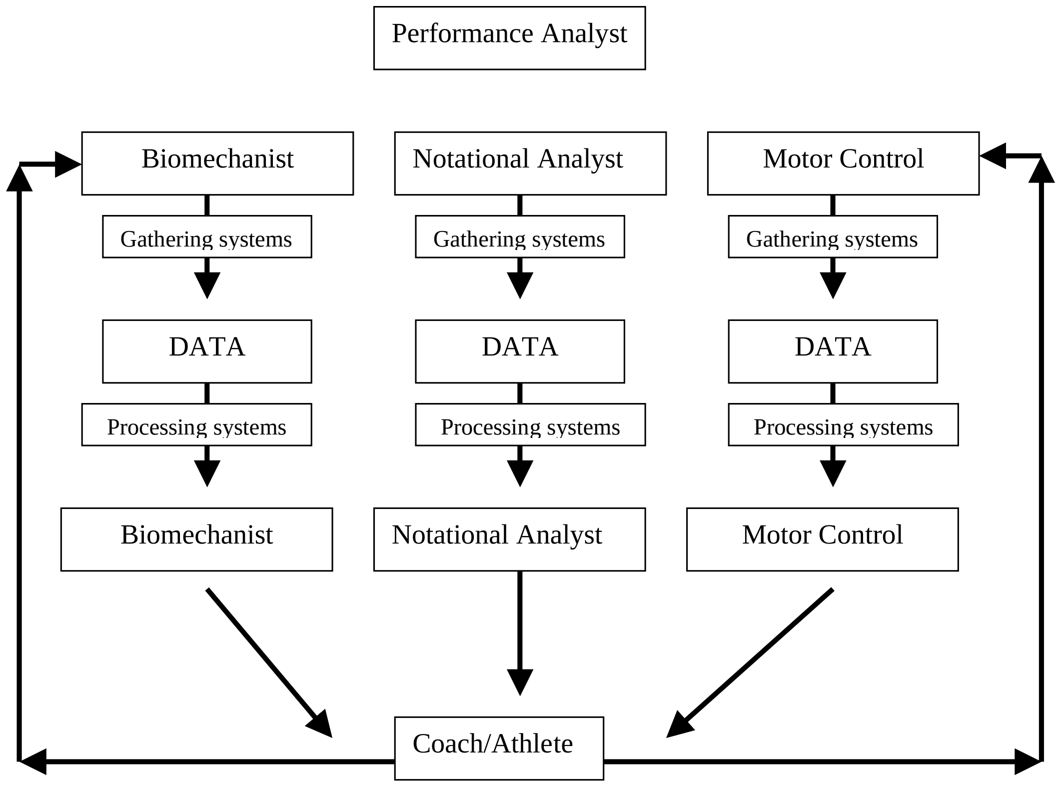


Figure 2.1: Initial sport science set up and feedback procedures in sport (Hughes, 2004b).

1) Notational analysis – this is the term used for the identification of physical and/or technical performance indicators and analysing the frequency of occurrences during a sporting event. The aim of notational analysis is to find and understand the differences between successful and

unsuccessful teams as well as maximising performance (Castellano et al., 2012; Hughes & Franks, 2005; Reep & Benjamin, 1968). Additionally, notational analysis can be used as a scouting tool, providing information on forthcoming opponents (to identify strengths and weaknesses), and in regards to player recruitment and the players which adapt to the playing requirements of the head coach (Hughes et al., 2012),

2) Biomechanics – this is based on the traditional understanding of fundamental movement patterns and the biological mechanisms behind functional movements in sport. Biomechanists use performance indicators based on kinematics and kinetics of movement to identify efficient and inefficient techniques and the methods of improving athlete's movements (Bartlett, 2001; Hughes & Bartlett, 2002), and;

3) Motor control and kinesiology – this includes the analysis of muscle functions in sporting movements and the role they play in maximising techniques. Kinesiology also provides information on the methods in which athletes learn from both intrinsic and extrinsic feedback (Schmidt & Lee, 2011; Winter, 2009).

When performance analysis was first brought into professional sport each sub discipline worked individually, collecting and analysing performance data according to the requirements of their scientific discipline, as a result there were multiple feedback loops providing information to both coaches and athletes (Figure 2.1). These feedback loops begin with the performance being recorded and analysed, this can either be live, allowing feedback to be provided during performance, or post-performance. The areas of performance highlighted by analysis are dependent on the individual players, coach and the sport involved but generally highlights both positive and negative aspects. This information is fed back to the coach in an objective manner, the coach then uses the information to influence their decisions and develop future training strategies with the intention of influencing future performances (Figure 2.2; O'Donoghue, 2006b). Due to the individual feedback loops, the coach would receive information from each sub-discipline and would have to gather the information to make an effective and appropriate decision (Hughes, 2004b).

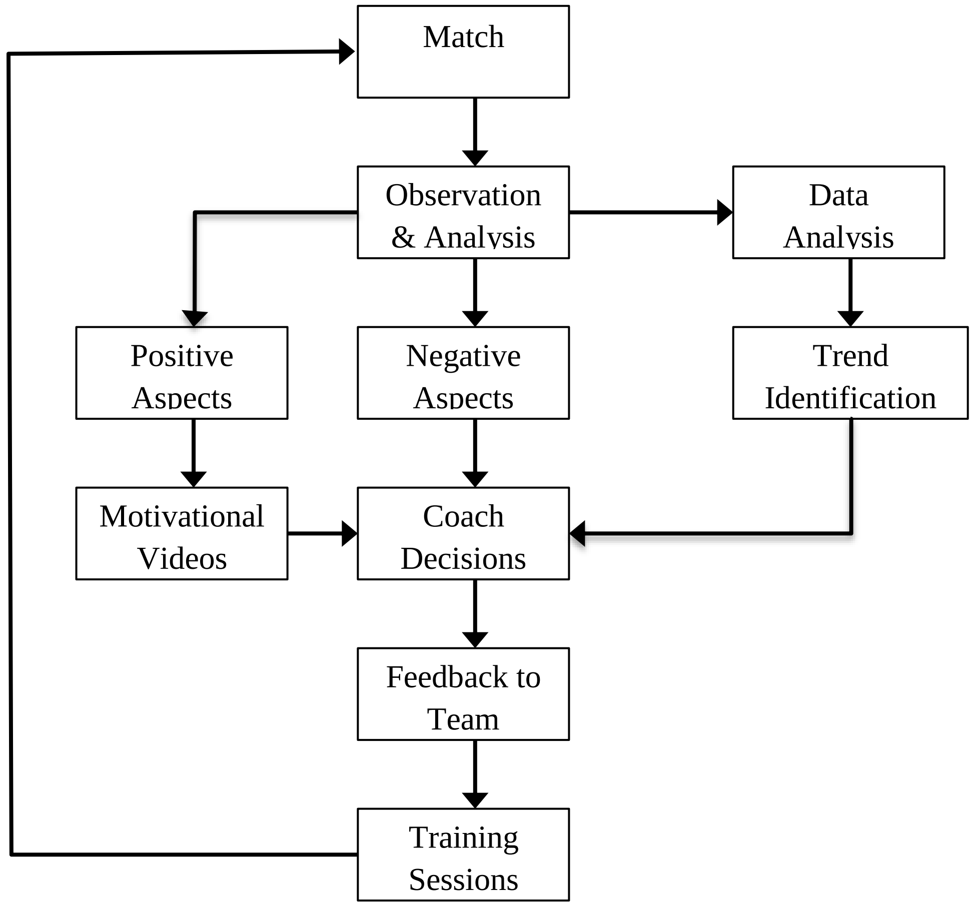


Figure 2.2: The application of performance analysis in elite sports (adapted from O'Donoghue, 2006b).

Modern performance analysis, and sports science as a whole, is a more widely integrated process with all sub-disciplines working together to improve performance, often collating and analysing data as a multi-disciplinary department, agreeing on a conclusion for the best method to improve performance before reporting the findings back to the coach or athlete (Figure 2.3).

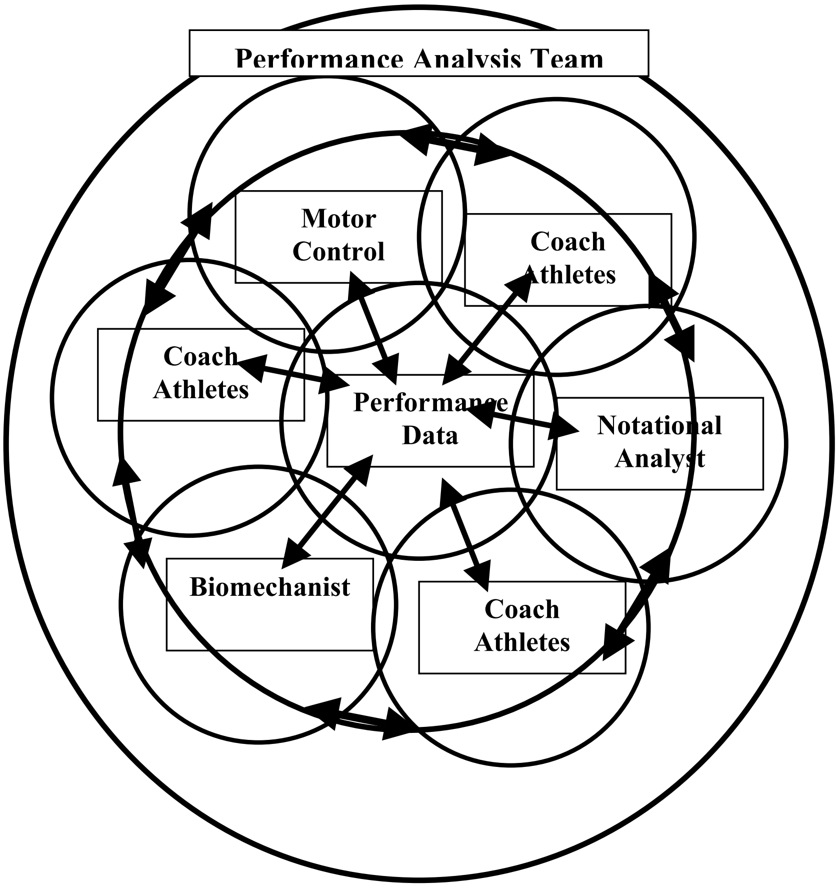


Figure 2.3: Modern multi-disciplinary approach to sport science feedback (Hughes, 2004b).

In order for an analysis system to be effective it must be able to analyse the area, or areas, of performance that needs to be assessed. A standard view by coaches and analysts has identified four key areas to consider; these include (1) the action being performed, (2) the individual performing the action, (3) the location on the playing area, and (4) the outcome (Hughes & Franks, 2004a). It is important to spend sufficient time deciding what aspects of performance are to be analysed in order to positively influence and inform playing practices and future performances (Carling et al., 2005; Liebermann & Franks, 2004; Liebermann et al., 2002; Smith, Hammond, & Gilleard, 2005). This can be based around monitoring the effectiveness of training practices and the application of specific actions within subsequent matches, or identifying weaknesses in performance thus replicating training practices to rectify the problem for future performances (Carling et al., 2005). It is possible to collect excessive data particularly with modern systems and the amount of information they record. If the data is not handled correctly, or large data sets are not required for the requirements of the coach, it may require too much time to analyse and therefore either provide ineffective/incomplete feedback or not provide feedback in a timely manner. Alternatively, with so much data, it is possible that the identified areas for improvement become obscured and therefore provide no effective feedback (Carling et al., 2005; Hughes & Franks, 2004a).

Once coaches have decided the area of performance which needs to be analysed, it is essential to develop universal understanding between coach and analyst, and therefore develop a set of operational definitions which define the areas for analysis (Hughes et al., 2012; Hughes & Bartlett, 2002; James, Mellalieu, & Jones, 2005). Without clear definitions it is easy for an analyst to record the incorrect information, therefore feeding insufficient or inaccurate data to the coach, which would then provide the wrong influences on the coaching process. As part of the process, the methods of collection must be taken into account. In the modern day, there are simple manual methods for collecting data or computer-based technologies which allow for automated or computer aided collection (Carling et al., 2005; Hughes, 2004b; Liebermann et al., 2002; Randers et al., 2010). Finally, once the coach has decided what needs analysing and how it is to be analysed, the final consideration is how, when and where feedback is provided. The advent of computer based displays and analysis systems have reduced the time between data collection, analysis and data representation. Nevertheless, either immediate or delayed feedback may not be beneficial for the individual players and therefore a coach must decide when to give feedback to maximise understanding and improvement (Figure 2.3; Liebermann & Franks, 2004).

### 2.1.2 Early Performance Analysis

The introduction of performance analysis is often suggested to have begun at the turn of the 20th Century when H.S. Fullerton first published work on the science behind baseball (Nevill et al., 2008). Although more recent research suggests there may have been a variety of sports analysis articles published in media reports rather than academic journals for many years prior to Fullerton's work (Eaves, 2015). These early articles may provide an understanding of the early development of sport as well as providing an essential underpinning to performance analysis. Although any of these findings need to be interpreted with caution as they would not be subjected to strict methodological processes or analysed through the use of rigorous statistical testing methods observed with modern day performance analysis research. The origins of performance analysis research can often be found in statistical and mathematical journals rather than sport specific journals and therefore the scientific area could be suggested to have emerged through statisticians' desire to understand the mathematics behind sporting performances rather than coaches developing methods of improving performance and using statistics to reinforce their opinions.

An interesting series of studies emerged from America in the mid-1900s regarding the distances covered by players during sporting performances (Fay & Messersmith, 1938; Messersmith, 1944; Messersmith & Bucher, 1939; Messersmith & Corey, 1931; Messersmith & Fay, 1932; Messersmith, Laurence, & Randels, 1940). This series of studies was the first attempt at quantifying the distances covered by American College level football and basketball players. The distances covered by players during the game was collated using a scaled replica sports pitch placed over a tin base electrified by battery power, with players' movements traced onto the tin base using a tracer wheel. Insulating tape was placed on the tracer wheel at regular intervals, breaking the electrical impulse between wheel and base allowing for a connected electrical impulse counter to measure the number of breaks in the electric circuit. With a calculated scale between the pitch and recording equipment and the total number contacts the researchers were able to calculate the distance covered by the players (Messersmith & Bucher, 1939). Given the rudimentary technology available in the mid-1900s this method was an acceptable technique to start measuring distance covered by players during a match, although it provides limited information and cannot calculate the speed of players or changes in acceleration/deceleration, which have recently been shown to be more beneficial measures of performance (Bangsbo, Iaia, & Krustrup, 2008; Bradley, Mohr, et al., 2011) and the impact running speed has on injury rates

(Daly, 2013; Opar, Williams, & Shield, 2012; Small, McNaughton, Greig, Lohkamp, & Lovell, 2009). In addition, due to the requirements of the testing equipment only one individuals' performance could be traced during a match, thus reducing the amount of data and providing limited evidence of it's accuracy. The method is also open to observer errors, which cannot be amended and although the authors highlight the systems accuracy over the whole pitch surface (Messersmith & Fay, 1932) it is not able to detect small movements during a match, both of which could positively or negatively affect the data obtained and therefore the total distance measured.

Early technical research was based around sports with clearly defined performance indicators such as soccer (Reep & Benjamin, 1968), squash (Sanderson, 1983; Sanderson & Way, 1979) and tennis (Downey, 1973). Due to match factors (such as match speed) and the frequency at which performance indicators occurred, analysts needed to quickly identify and rapidly record events in a method which could later be analysed post-match (Nevill et al., 2008; Sanderson & Way, 1979). As a result both Downey (1973) and Sanderson & Way (1979) adopted the use of symbols to identify and record shots played. This was due to the ease for recording, recollection and identification purposes at match speed. Through the use of pilot studies, it was identified that writing the shot type and outcome was a long and slow process and although possible, would not be viable as it took too long at match speed (Sanderson & Way, 1979). As an extension to this research, Sanderson and Way (1979) recorded each symbol on a court diagram to display where shots were played and the outcome of the shot, this allowed the identification of playing patterns and rally lengths/type with reasonable accuracy.

Hand based systems have a number of benefits in comparison to modern video based technologies. They can be developed relatively easily and can provide a vast amount of information to coaches. They are cheap, only requiring a pen and paper, and can be adapted depending on the changing requirements of the coach and/or team (Carling et al., 2005). Originally, simple hand notation systems were often used during play – live coding (Downey, 1973; Sanderson, 1983; Sanderson & Way, 1979), although with the advancements in video technologies can be used post-match (Carling et al., 2005). The decision to use either live or post match analysis if often based on the amount of information being recorded, if greater information is required it is easier to use video playback where the video can be paused or repeated in order to maximise the accuracy (Carling et al., 2005). Many hand notations systems are kept simple by using symbols or abbreviations to record events during games (Downey, 1973; Sanderson & Way, 1979). Alternatively simple tally charts or frequency tables can be an easy way to record the frequency of events (Hughes & Franks, 2004a). These symbols and abbreviations not only make recording events easier and quicker but can also be placed on pitch diagrams to enhance the detail recorded thus providing sufficient and effective feedback (Sanderson and Way, 1979; Hughes, 2004b). In addition, in sports such as soccer or rugby where players wear a shirt number during a game, these numbers can be used to identify which player is involved in the actions being recorded, whether on pitch diagrams, providing location, or within frequency tables

(Hughes & Franks, 2004a). Despite the advantages of hand notation systems compared to more complicated modern systems, they also have weaknesses. The systems themselves are only as solid as the performance indicators selected and their definitions as well as the understanding and ability of the analyst. Poor clarity in the operational definitions or a lack of understanding on the analyst's part can lead to inaccurate data being recorded and therefore insufficient feedback to the coaches/athletes (Hughes et al., 2012; O'Donoghue, 2006a). Another issue to consider is the time required to set up the system, for the analyst to become accustomed to the process and collection methods as well as the time to analyse the data. Even when matches are coded live, the vast amount of data collected takes time to analyse, and therefore feedback is not available immediately.

### 2.1.3 Technological Developments and Performance Analysis

The development of performance analysis feedback has occurred mainly due to the advances in technology. Originally back in the 1980s and 1990s, video cameras were expensive equipment and were often difficult to use. Videos were often on VHS (Hughes, 2004b) with analysis performed using simple hand notation systems (Reep & Benjamin, 1968; Sanderson & Way, 1979). Computers and digital data collection systems back in the 1980s and 1990s were still very complicated to use, with analysts often needing to understand software programming in order to develop analytical software (Hughes, 2004b; Hughes & Hughes, 2005; Hughes et al., 2007; James, 2006; O'Donoghue, 2006a, 2006b). However, technology has developed extensively over the last 30 years with development of digital cameras and computer tablets, allowing even coaches and athletes to record performance. Videos are often easily imported onto computers for analysis or playback on specially designed analytical software such as SportsCode Gamebreaker, Pro and Elite (Sportstec™), Dartfish™ and Focus X2 (Performance Innovation™). In addition, visual representation of data has progressed with basic graphics packages such as Microsoft Excel (Microsoft Corporation®) to more complex, sports specific graphical illustration such as Prozone (Prozone Sports™). As a result of the developments within technological systems, it is now not solely the analyst who captures and analyses the data, as both coaches and athletes now have a better understanding of the process behind analysing performance and the interpretation of results (Hughes, 2004b). Currently, this includes the coaches being able to use mobile applications on smart phones or tablets to code performances, allowing them to highlight key areas they identify for player feedback during matches.

Computer based analysis systems follow the same principles as hand based systems although can be designed to analyse greater detail on a relatively easy basis. Although computed based systems are similar to hand notation systems they generally have the added bonus of providing video footage for reinforcing coaching points as well as providing the potential for creating databases for long term analysis (Carling et al., 2005). With the continued expansion of computer capabilities, semi-automated and automatic tracking systems have been developed. These systems track player movement over the course of a match, particularly in sports such as rugby and soccer. These systems limit the interaction of individual observers and therefore reduce the probability of errors being made (Liebermann et al., 2002; Liebermann & Franks, 2004; Randers et al., 2010). In addition to measuring the total distance covered similar to Messersmith and colleagues in the 1930s and 1940s, these automated systems can calculate the distance covered at different speed thresholds, as well as the accelerations and decelerations of every player on the pitch. This information is far more vital for monitoring and implementing training regimes as it has more effect on match performance and injury rates (Andersson, Randers, Heiner-Møller, Krustrup, & Mohr, 2010; Bangsbo et al., 2006; Daly, 2013; Opar et al., 2012).

Many of these computer based analysis systems now use graphical packages to generate visual feedback compared to hand notation where the analyst would be required to develop alternative methods for presenting data (Hughes & Hughes, 2005). The video based technologies and analysis systems have principally been designed to provide qualitative, reliable and objective feedback to coaches and athletes, in quick time and in forms that would be understandable, aiding learning and development (Carling et al., 2005; Hughes & Hughes, 2005). Computer based software is more expensive and can be more time consuming compared to hand based notation depending on the amount of performance parameters analysed. Nevertheless, computer based systems can add to the traditional technical and tactical analysis and provide more accurate information on physical workloads along with biomechanical feedback, therefore providing a holistic and complete analysis on performance (Hughes & Hughes, 2005; Hughes et al., 2007; Liebermann & Franks, 2004). Although the progression of technology has allowed for greater depths of analysis, which therefore can take longer to complete, overall the ability to, and process of, recording and analysing sporting performances has become easier and quicker (Barris & Button, 2008; D'Orazio & Leo, 2010; James, 2006; Sarmento, Marcelino, et al., 2014).

### 2.1.4 Reliability and Validity Of Performance Analysis Systems

Upon the establishment of an analytical system, it is important to measure both the reliability (consistency and repeatability) and validity (accuracy) of the data collection procedures in order to assess its functionality. A plethora of research articles have been published in order to quantify either reliability and/or validity of performance analysis systems (Figure 2.4; Barbero-Alvarez, Coutts, Granda, Barbero-Alvarez, & Castagna, 2010; Bradley, O'Donoghue, Wooster, & Tordoff, 2007; Coutts & Duffield, 2010; Di Salvo, Collins, McNeill, & Cardinale, 2006; Hughes, Cooper, & Nevill, 2004; Hughes & Franks, 2004b; MacLeod, Morris, Nevill, & Sunderland, 2009; Portas, Harley, Barnes, & Rush, 2010; Randers et al., 2010; Redwood-Brown, Cranton, & Sunderland, 2012; Varley, Fairweather, & Aughey, 2012).

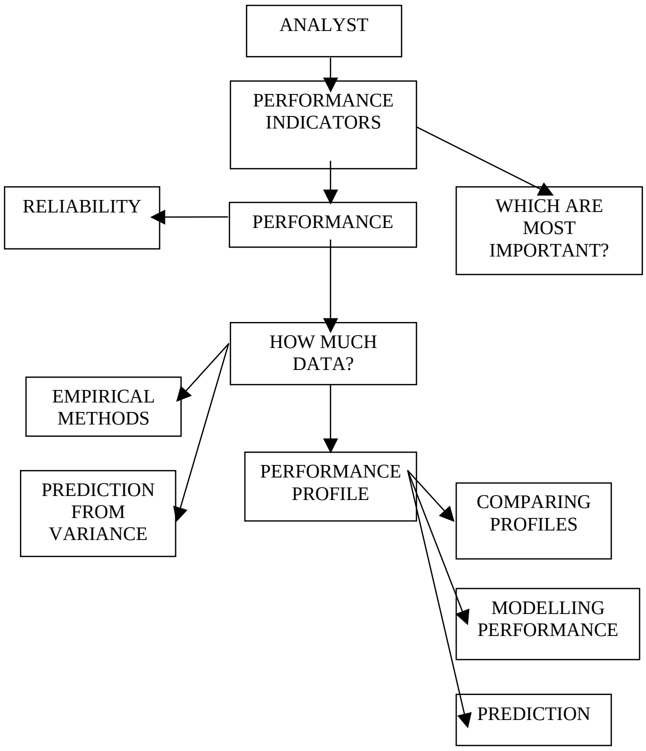


Figure 2.4: The development and validation process and use of performance analysis systems (Hughes, 2004a).

Validity testing measures a systems ability to measure what it is designed to. Assessing the validity of systems that measure physical performance is fairly simple. Common systems that measure physical workloads during sporting performance include global positioning systems (GPS) or semi-automated tracking systems such as Prozone™ or Amisco®, which can be compared against known measurements determined through the use of accurate equipment such as timing gates (Barbero-Alvarez et al., 2010; Di Salvo et al., 2006; MacLeod et al., 2009; Redwood-Brown, Cranton, et al., 2012). Both GPS and semi-automated tracking systems have been measured to accurately measure (near perfect) distance and speed covered over known distances ($r>0.970$) and are therefore able to validly measure distances covered during sport performances (Barbero-Alvarez et al., 2010; Di Salvo et al., 2006; MacLeod et al., 2009; Redwood-Brown, Cranton, et al., 2012). Alternatively, if an analyst knows the distances and dimensions of a pitch it is possible by using either stopwatches or video footage to manually calculate the distances and speeds covered by players during a sporting performance (Randers et al., 2010). Although this method gives an indication of the distances covered during a game, it is less accurate and more time consuming than GPS and semi-automated tracking systems but is a cheaper alternative for clubs or sports on a budget (Randers et al., 2010).

The assessment of the validity of technical parameters during match play is a more challenging aspect. Until now, coaches and analysts have not been able to come to a conclusion on the definition of variables which are analysed, particularly in soccer (Hughes & Franks, 2004b). Coaches and analysts at individual clubs have differing ideas on the definition of individual variables and as a result researchers or software developers must establish clear definitions for the variables which will be recorded before analysis begins to maximise the validity of data (Hughes & Bartlett, 2002), although this introduces errors when applying research findings in applied settings where operational definitions may differ.

Reliability testing assesses the test-retest capabilities, and therefore the objectivity, of analytical systems (Hughes et al., 2004; O'Donoghue, 2006a) and is often assessed on two levels; inter- operator reliability measures the ability of two observers, whilst intra-operator reliability assesses the ability of one observers' abilities to recorded data on multiple occasions. Both inter- and intra- operator reliability are essential for an effective analytical system as they measure the ability of the observers to understand and implement the operational definitions (Bradley et al., 2007; Hughes & Franks, 2005; Hughes & Hughes, 2005; Hughes et al., 2007; James, Mellalieu, & Hollely, 2002; O'Donoghue, Mayes, Edwards, & Garland, 2009; Sampaio & Janeira, 2003). Alternatively, when measuring the reliability of computer measuring devices (GPS, semi-automated systems), reliability is often measured through the use of coefficients of variation, measuring the testing devices on an identical test setup over multiple occasions and assessing the differences between tests (Coutts & Duffield, 2010; Portas et al., 2010; Varley et al., 2012). GPS systems have been identified as having less than 10% variability when assessed over repeated analysis. These results have been shown to be dependent on the speed of movement, with greater movement speeds recording greater differences between test results. In addition to the type of movement, the type of GPS unit and frequency rate of the units (1, 5 or 10Hz) can also affect unit reliability (Coutts & Duffield, 2010; Portas et al., 2010; Randers et al., 2010; Varley et al., 2012). Nevertheless, variability of less than 10% has been deemed acceptable for the measurement of sporting situations (Randers et al., 2010). Furthermore, environmental conditions and location can affect the communication between GPS units and the satellite receiver and therefore affect the results obtained (Portas et al., 2010). This is where semi-automated tracking systems can be more beneficial, although these systems need to be used in fixed positions such as stadiums where the dimensions of the measurement area remain constant. Nevertheless, semi-automated tracking systems are imperfect, for example, when two individuals come within close proximity of each other on the pitch, individual players' precise location can become obscured, despite the multiple camera set-up used. In these instances an observer is needed to manually input data to identify individual players, which can introduce operator errors (Di Salvo et al., 2006). When analysing the technical reliability, the closer to near perfect correlations between observer assessments, the more reliable and suitable the system is for analysing performance. It is the decision of the individual analysts as to whether the correlations are acceptable for the analysis the system will be used for. Independent systems developed for unique analysis in sport have previously been shown to provide high levels of reliability, often due to the clear definitions developed, allowing observers to identify events during analysis (Hughes & Franks, 2005; Hughes et al., 2007; Hughes & Hughes, 2005; Sampaio & Janeira, 2003; Smith, 2011; Tromp & Holmes, 2011). Fewer studies have been conducted on commercially available software, although the limited research that has been conducted has shown high levels of reliability between observers (Bradley et al., 2007). The research undertaken by Bradley et al. (2007) compared the results of two observer teams analysing the same game, this allowed for direct comparison between the observer groups using Cohen's kappa coefficient. Each observer team recorded all match events, the players involved, the time and location of each match event. The two teams of observers agreed on 2552 events, including event type and player involvement, demonstrating a kappa value of 0.990. In total the two teams disagreed on player involvement on 11 occasions for player 1 and 5 occasions for player 2, resulting in kappa values of 0.995 and 0.979 respectively. In addition to the high levels of agreement the two teams identified 95% of events occurred within one tenth of a second of each other. Commercially available software also requires a pitch location to be entered; the two observer groups identified 95% of match events occurring within 8.5 meters. These high correlations and the associated kappa values show a high level of agreement between observer groups and therefore demonstrate the software is reliable in measuring match performance, including the type of event, player involvement, match timing and event location. An alternative method has been proposed by Cooper, Hughes, O'Donoghue, & Nevill (2007) for analysing technical or frequency based data in analysis systems. The methods proposed suggest analysing the test-retest capabilities of the analyst and that at least 90% of recorded variables should fall within ±3 of a reference value, although there is some ambiguity regarding the formation of the reference value which is dependent upon the performance parameter and the context of the data being analysed. Due to the dynamical nature of sport, it is unlikely that perfect reliability will ever be observed, this is due to the different interpretations by analysts on the definitions of actions and the actions that occur during performance and therefore high levels of reliability which have been previously measured have been deemed to be acceptable (Bradley et al., 2007; Hughes et al., 2004, 2007; Hughes & Hughes, 2005; O'Donoghue, 2006a). Future research and applied practitioners need to be aware of the different software that is used to analyse performance. Taking physical performance as an example, many sports clubs use a variety of systems to measure physical output during training and matches, typically GPS and semi-automated tracking systems respectively. Due to different sample rates, even between different GPS units, variation can occur in the distances measured (Harley, Lovell, Barnes, Portas, & Weston, 2011; Randers et al., 2010), depending on the GPS device used, this variation can be up to 40% at higher intensities (Harley et al., 2011). Therefore, although these systems are reliable and valid as independent systems, when practitioners begin to compare results from different systems issues can occur which need to be taken into account before inferences are made.

## 2.2 Performance Analysis In Sporting Environments

### 2.2.1 Performance Analysis and the Feedback Process

Traditionally, coaches provide valuable external feedback to athletes on performance. This feedback is often been based on subjective observations formed during and after performance built on a coaches ability to recollect key events (Franks, 2004). However, despite this reliance on recollection, research has assessed coaching behaviour and identified coaches can recall a maximum of 40% of key events following a sporting performance (Laird & Waters, 2008). Although this could be as low as 20-30% depending on the number of key events that occur during a performance, with coaches more likely to remember events practiced during training, such as set plays, or events which precede goals compared to all other events (Franks & Miller, 1986). With the limited levels of recollection by coaches, any error or misperception on performance would lead to inappropriate feedback, which could have negative consequences on player development and subsequent performance (Carling et al., 2005). One reason for the development of performance analysis and video based feedback technologies was to help improve coach recollection, thus improve objectivity and reliability of the feedback given to athletes (James, 2006; Taylor et al., 2008; Taylor, Mellalieu, & James, 2005). The added presence of videos during feedback sessions between coaches and players also provides a form of visual reinforcement for coaching points thus providing additional information in the feedback process (Procyk, Neustaeder, & Schiphorst, 2015). With these justifications behind the development, particularly in elite sport where there are such high financial and reputational rewards, performance analysis has become an essential feature of sports science both in applied and research capacities (Franks, 2004; Liebermann & Franks, 2004; Lyons, Culhane, Hilton, Grace, & Lyons, 2005; Nevill et al., 2008; O'Donoghue, 2005).

The multi-disciplinary nature of performance sport has resulted in greater communication and understanding between coaches and sports scientists. This increased interaction has resulted in the development of essential performance indicators with clear and concise definitions, allowing sport scientists and analysts to focus on the areas performance coaches are most interested in or the areas which will help develop performance to the maximum (Bartlett, 2001; Hughes & Bartlett, 2002). Nowadays performance analysis is not just solely to record performance, generate data and statistics but also to monitor and analyse performance over longer periods of time, identifying trends and developing training interventions. Therefore performance analysis can be used for both positive and negative reinforcement, linking back to the training objectives and player development, as well as motivational purposes (for both individuals and/or teams), data analysis and trend identification (Figure 2.3; Carling et al., 2005;

Carling, 2011; O'Donoghue, 2006b). Thus, linking the coaching process into a complete and effective model, incorporating sport science and in particular performance analysis into the process as frequently as possible to maximise performance outcomes.

### 2.2.2 Coach and Athlete Perceptions on Performance Analysis

Coaches understand the main aim of their role is to help athletes improve and develop, in soccer this is generally in a technical or tactical sense, however coaches also understand that their success as a coach is judged on the success of their athletes (Abreham et al., 2006; Cushion, 2001; Groom & Cushion, 2004). Despite the purpose of coaching being to develop and improve an athlete's performance, the nature of modern coaching is far more multidisciplinary and incorporates knowledge on psycho-social, cultural, personal, physical and mental aspects of performance, even if the coach does not directly implement programmes on the above factors (Abreham et al., 2006; Cushion, 2001; Littlewood, Mullen, & Richardson, 2011). Although a coach understands his/her roles towards the athlete, less information is known regarding the methods in which coaches develop their own personal understanding and improve their sport specific knowledge in order to help maximise the athletes development (Cushion et al., 2010; Mackenzie & Cushion, 2013). The use of continuous professional development (CPD) has only recently come into focus and the application to coaching practices is relatively new in the literature (Cushion et al., 2010). Nevertheless this could become an important method for coaches to communicate and share ideas and a process to develop wider coaching practices, in greater detail the methods of undertaking CPD events and the availability of CPD materials for coaches to access is an important area for future research to investigate.

Performance analysis, and sport science in general, has constantly been identified as a key area to improve the quality of the coaching process and in particular the reflective ability of the players and coaches (Groom & Cushion, 2004; Groom et al., 2011; Liebermann & Franks, 2004; Mackenzie & Cushion, 2014; Martindale & Nash, 2013; Nelson et al., 2011). Despite the overwhelming belief of its importance, there has been a lack of research investigating the use of sport science in applied settings by coaches and/or players (Mackenzie & Cushion, 2013). Similarly, the development of the perceptions or skills of using performance analysis to maximise sporting performance and the feedback process has limited research. This often comes from a misunderstanding on the role and definition of sport science and the perception of how it can be used in coaching practice (Martindale & Nash, 2013). Although performance analysis can be an important part of the coaching process, it is possible that it has still not been accepted as a part of sport science due to the fact that most coaches work on intuition and previous experience rather than standardised models of coaching (Partington & Cushion, 2013). This is as a result of research analysing the processes a coach undertakes, and therefore observable coaching behaviours rather than methods of maximising coach effectiveness (Cushion, 2001). The lack of research between performance analysis and coaching may be due, in part, to the lack of research in coaching science as a whole. It is especially difficult to analyse the coaching sciences when the profession itself lies between concepts of art and science (Cushion, 2001). In addition, the lack of research may also be due to a difference in the perceptions of coaches and sport scientists on the important research questions and areas of research within the scientific literature (Gould, 2016; Martindale & Nash, 2013; Williams & Kendall, 2007). It is possible that coaches do not perceive investigations into coaching processes as important, especially as many coaches, particularly elite coaches, do not feel they could gain additional knowledge from the research literature despite research suggesting reaching elite level coaching is a long-term development process (Young, Jemczyk, Brophy, & Côté, 2009). This is in direct contrast to areas of psychology, biomechanics or physiology where coaches openly admit they have less knowledge and experience and require additional advice and expertise from scientific support staff (Williams & Kendall, 2007). The research that has investigated the coaching process has isolated individual areas of interest, and although this has provided some information on coaching procedures, it has not delivered a holistic understanding of the coaching role (Cushion, 2001) and instead has provided complex schematics of the coaching process, which are rarely applicable in real-life coaching situations or replicable across different sports (Abreham et al., 2006). These findings can be summarised in the coaches' perception of the coaching science literature. Research has identified the intentions of coaches is to replicate the findings of the research but without truly understanding the reason behind their actions or the ability to actually carry out the research suggestions (Partington & Cushion, 2013). One possible explanation is due to the inability of coaches to understand the complex language used in academic literature (Martindale & Nash, 2013). Coach perceptions and reluctance in engaging with performance analysis may also stem from the way performance analysis developed. As mentioned in the previous chapter, performance analysis began due to the statistical analysis of performance and was published in research papers with statistical backgrounds (Fullerton, 1912; Messersmith & Corey, 1931; Reep & Benjamin, 1968). It may be possible that this statistical viewpoint of performance analysis has overshadowed the coaches' perceptions and subsequent implementation within the coaching process.

The delivery of performance analysis sessions within the coaching process has previously been suggested to be unstructured and based around critical incidences during matches, primarily due to a reactive response from coaches (Groom et al., 2011). One potential reason for the lack of research on coach/player perceptions on performance analysis may be due to the processes involved with performance analysis itself. The athlete is both the purpose and receiver of the process, nevertheless both the coach and athlete have little involvement with the analysis of performance. The lack of involvement within the process along with previous negative experiences of feedback from performance analysis sessions may suggest that coaches and athletes have both negative feelings or a complete lack of understanding towards the use and application of performance analysis (Francis & Jones, 2014; Groom et al., 2011; Nelson et al., 2011). It is possible that CPD sessions, coaching courses and continued exposure to performance analysis may change current perceptions, nevertheless research should begin to investigate methods of developing and improving coach/athlete opinions on performance analysis in order to maximise its effectiveness.

Although players and coaches understand that performance analysis is aimed at improving technical ability and tactical knowledge (Francis & Jones, 2014), it is essential that the coaches and analysts understand the athletes they are interacting with and employ an athlete centred approach. It has been recommended that analysts/coaches should avoid large peer group performance reviews which discourage positive learning environments (Groom et al., 2011; Nelson et al., 2011), even though they can encourage team discussions and develop greater understanding and knowledge on team match-play and tactics (Nelson et al., 2011). In addition, athlete understanding and acceptance of coaching feedback through performance analysis relies heavily on the interaction and respect between coach and athlete (Nelson et al., 2011). Although rarely mentioned, let alone investigated, are the interactions between coach-analyst and athlete-analyst. In order to maximise the findings of any research or literature it is essential that the analyst also gain the trust and respect of the coaches/athletes similar to the coach-athlete relationships identified in the literature. In essence, analysts must quickly identify the most effective methods of communicating findings, in particular to coaches, who then decide which information is disseminated to athletes (Gould, 2016). Nevertheless, although coaches will have different learning styles, no research has attempted to analyse preferred methods of data visualisation for maximum understanding or where coaches go to attain data.

### 2.2.3 Issues To Consider in the Feedback Process

#### 2.2.3.1 Performance Variables and Definitions

The most important aspect of analysis is acquiring and developing clear definitions for performance indicators, this allows for universal understanding amongst coaches and analysts (Bartlett, 2001; Carling et al., 2005; Hughes & Bartlett, 2002). In team sports such as soccer, many clubs have playing philosophies that they use as a starting point for their analysis. The second area used to define analysis procedures is often the game plan organised by the coaches to defeat their opponents, including creating and stopping scoring opportunities (Hughes & Bartlett, 2002). The areas for analysis are organised and agreed between coaches and analysts although it is often the coaches who dictate to the analysts the final definition of the performance parameters (Carling et al., 2005). Nevertheless, the performance parameters selected for analysis and their respective definitions are subject to the software used to analyse performance (Bradley et al., 2007; Hughes & Franks, 2004a; Randers et al., 2010). Performance analysis systems are available which allow the analyst or coach to set up their own performance variables and associated definitions. However, software such as Prozone (Prozone Sports™) has built in performance variables and dictates the associated definitions to coaches and analysts who use the software. Although these fixed systems provide commonality for research purposes, and therefore increase the reliability of the data, they are less effective in applied settings as they cannot be easily adapted or modified to the specific needs of a club.

As there are different software used during analysis and different opinions between coaches and analysts there is a lack of clarity and universal acceptance of definitions. This lack of commonality amongst definitions is also caused in part due to each club adopting high levels of secrecy on the use of performance analysis and the definitions adopted at different clubs (Carling et al., 2005). The level of secrecy of data and of the processes adopted within clubs may be associated with the perceived intellectual property of the data gathered. The type of intellectual property associated with analytical work in sports science can be interpreted in different ways. The software used to analyse sporting performance is often registered trademarks or copyrighted, adopting a formal identification of intellectual property rights and therefore restricting the adaptability when using the software (Hall, Helmers, Rogers, & Sena, 2014). Alternatively, despite the vast amount of data that can be gathered from analytical software, the interpretation and implementation of the data is often down to individual analysts and coaches. It is often these processes which individual clubs want to keep undisclosed from other clubs, thus employing informal intellectual property rights (Hall et al., 2014). Due to the importance and value of the data, clubs may feel that sharing the data and the analysis procedures may allow other clubs to expand upon and enhance the shared ideas, therefore gaining a greater advantage in performance (Murray & Stern, 2007). Therefore, from an applied perspective it can be understood why clubs are reluctant to share resources. Nevertheless, from a research perspective the closed approach and level of secrecy from clubs often restricts research from identifying or analysing the information that is important for coaches or clubs in the professional sport arena and therefore limits the effectiveness of the research findings (Murray & Stern, 2007). In addition the formal intellectual property rights introduces methodological issues, where different research groups can use different software, believing they are using identical definitions or thresholds when in reality they can differ vastly.

#### 2.2.3.2 Dynamical Systems

Previously it was believed humans were controlled by a central mechanism, the brain, which acted similar to a computer and processed all movements (Handford, Davids, Bennett, & Button, 1997). Researchers believed movement patterns were stored in the brain, when an individual re-encountered a similar situation that they had been exposed to previously, the required movement patterns would be recalled to produce the necessary movement for a successful outcome (Handford et al., 1997). Variations that occurred in sporting performances were attributed to noise in the recording systems or variability in the motor control system (Bartlett, Wheat, & Robins, 2007; Davids, Glazier, Araújo, & Bartlett, 2003). More recently, researchers have begun to believe that human cognitive processes are a series of complex interactions between control mechanisms, including the brain, and the environment that interact in order to produce the required movement for the given situation (Chow, Davids, Hristovski, Araújo, & Passos, 2011).

The linear systems approach was proposed by physicists, robotic scientists, engineers and economists who were required to predict behaviours in the respective fields of research. The adoption of a closed-system approach enabled the researchers to reduce the uncertainty associated with investigating behaviour, therefore increasing the ability to predict actions and outcomes (Glazier & Davids, 2009). However, human movement scientists began to suggest movement was a combination of many individual neurobiological systems interacting to produce a successful movement outcome with respect to different constraints, based on the location of the human body in space and time (Stergiou, Jensen, Bates, Scholten, & Tzetzis, 2001).

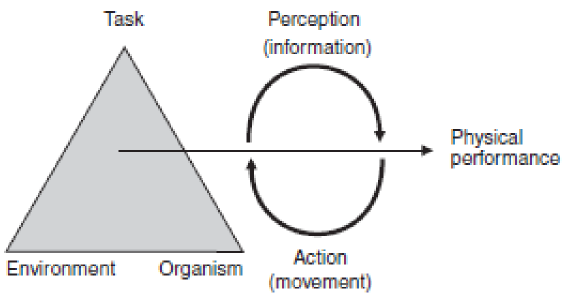


Figure 2.5: Newell's (1986) model of constraints showing the results of the decision making process.

The human decision making process is now seen as a series of complex interactions between the individual and the environment, based on task, environmental and organismic constraints, with variation in movement patterns originating when acquiring new skills (Figure 2.5; Newell, 1986; Stergiou et al., 2001; Vilar, Araújo, Davids, & Button, 2012). Whilst learning new skills individuals learn the basic movement patterns of a skill and subsequently will experience both success and failure. This experience will allow the individual to learn the boundaries, or degrees of freedom, their body is capable of achieving to perform the skill successfully whilst under different environmental and task constraints (Chow et al., 2011; Glazier & Davids, 2009). For example, the basics of passing a football around are constant, although will be dictated by the length of pass required, the positions of both the individuals team mates and opposition players in respect to the individuals starting position as well as the environment such as the type of ball, pitch conditions and weather conditions.

Many differences exist between linear and non-linear systems. In linear systems a change in the behaviour of a system leads to a proportionate change in the outcome, however in non-linear dynamics a small change in the behaviour can lead to a large change in the outcome or performance (Chow et al., 2011). A second difference is; a single input change within a linear system (task, environment or organism) can bring about one effect, yet in non-linear systems one input change can cause many different outcome effects, therefore making judgements or assumptions regarding an individual's behaviour extremely difficult (Glazier & Davids, 2009). In non-linear systems it is also possible to train an individual during the learning stage to identify the variability in movements to attain the same desired outcome; this training will in turn be functional to the individual as they learn new ways of overcoming tasks (Chow et al., 2011).

In team sports there is the presence of coupled oscillators, this can be either intra (within team) or inter (between teams). Within a team, players have a direct effect on the options and choices made by the player next to them in the formation they hold, either lateral or longitudinal (Figure 2.6). These can also be known as dyads, which can be formed or broken depending on the changing situational requirements during the game

(McGarry, Anderson, Wallace, Hughes, & Franks, 2002; Vilar et al., 2012). For example, in a standard 4-4-2 formation in soccer, the centre backs have an impact on the full backs, centre midfielders and goalkeepers, whilst attackers would generally have impact on the centre midfielders alone, although could also impact on the wide midfielders, depending on the game situation. Inter-couplings exist between teams, for example, in soccer one team's attackers, alongside the intra-couples with their team's midfielders, form relationships with the opposition defenders. This is where team formations begin to have an effect on playing styles. For example, if two teams adopt a traditional 4-4-2 players on opposing teams for couplings with the player directly opposite them, however if one team adopts a 4-4-2 and the other players a 3-5-2 or 4-4-1-1, the three defenders will have a more challenging game against 2 attackers compared to having 4 defenders. In addition in a 3-5-2 and a 4-4-1-1, an extra player in midfield occurs, therefore causing more couplings and decisions needing to be made from the team playing 4-4-2.

Both the intra- and inter-couplings are formed by the pursuit of a common goal, the defending team wish to stop the opponents from scoring whilst the attacking team try to break down the defence to score goals (McGarry et al., 2002). Gréhaigne, Bouthier, & David (1997) suggested that soccer players make decisions based on both team's position, movement and speed, and suggest that the ball holder can cause perturbations or disorder in the defending and attacking rhythm of the game, purely by selecting the appropriate decision. If one team scores a goal, they have been able to sufficiently break the inter-system dyads and have caused the equilibrium in the match to become unbalanced (Gréhaigne et al., 1997). A similar example can be provided in rugby, where attackers and defenders form dyads, both being attracted to gain ground in front of the position. During some game actions such as rucks, mauls, scrums or lineouts the dyad is stable and in equilibrium, however if the attacker managers to break the opponents defensive line, a perturbation is caused, breaking the dyads formed and causing the system to become de-stabilised, from this point on the defending team must try to re-gain order and reorganise the defence in order to stop the attacking team from scoring, if the defending team cannot reorganise the defensive formations or cannot complete it rapidly the attacking team will achieve a scoring opportunity (Gréhaigne et al., 1997; McGarry et al., 2002).

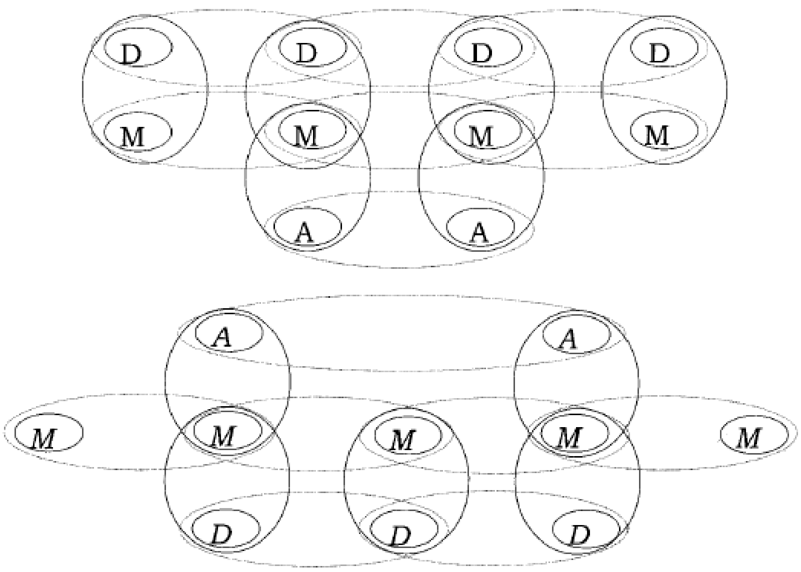


Figure 2.6: An example of dyads formed during a team game (McGarry, Anderson, Wallace, Hughes and Franks, 2002).

#### 2.2.3.3 Contextual Effects On Performance

The different situations and contexts surrounding matches have been extensively analysed, in particular looking at the advantages of playing at a team's "home ground" (Bradley, Lago-Peñas, et al., 2014; Jacklin, 2005; Lago et al., 2010; Lago-Ballesteros et al., 2012; Lago-Peñas & Lago-Ballesteros, 2011; Pollard, 2008; Poulter, 2009; Redwood-Brown, Bussell, et al., 2012; Sánchez et al., 2009; Taylor et al., 2008). In addition to analysing the advantage of playing at home stadiums, research has also investigated the effect of playing against different standards of opposition and the effect of match result (winning, losing or drawing).

Out of all the contextual factors, match location has the largest influence on match outcome than any other contextual factors (Bradley, Lago-Peñas, et al., 2014; Jacklin, 2005; Lago et al., 2010; Pollard, 2008; Pollard & Pollard, 2005). Home team advantage in sport has been evident since the early days of sport itself (Jacklin, 2005; Pollard, 2008; Pollard & Pollard, 2005; Sánchez et al., 2009). However, recent research has shown that the advantage for the home team playing in their own stadium is diminishing and is less prevalent in modern sports compared to previous years (Jacklin, 2005; Pollard & Pollard, 2005; Sánchez et al., 2009). Back in the 1940's, soccer teams were likely to win two home games for every one away game, by the 1970's this had increased to approximately 2.5 homes games for one away game win, although by the early 2000's this had reduced to being approximately 1.5 home wins for one away win (Jacklin, 2005). Interestingly, this is despite changes in the points system where teams are awarded three points for a win compared to two points for a win pre-1981 (Jacklin, 2005). This decrease in home advantage is most prevalent in ice hockey, although has also been measured in American football, soccer, basketball and baseball (Pollard & Pollard, 2005). The causes for home advantage are less clear than the effects; nevertheless there have been some proposals as to the causes. Territoriality and familiarity have been proposed as major factors in home advantage due to the nature of humans protectionism and the feeling of the away team invading the home teams territory, as well as the feeling of comfort playing in familiar surroundings (Pollard, 2008; Pollard & Pollard, 2005). This is plausible as teams who transfer to play in a new stadium often see a reduction in home advantage (Pollard, 2002). Familiarity and territoriality may be further supported by the reduction observed in home advantage in recent years. Football clubs in England are seeing ever increasing numbers of non-native players performing (BBC, 2013), and as a result the feelings of protecting territory and familiarisation will be less prevalent in non-native players compared to native players (Pollard & Pollard, 2005). Other potential factors include the effects of the crowd, where home teams traditionally have greater support than the away teams, thus with the close proximity of the crowd at football grounds, the additional noise providing a sense of greater support for the home team (Pollard, 2008). In addition, the crowd noise has been shown to influence a further factor of referee bias, where referee decisions have been shown to favour the home team as a result of the increased crowd noise (Nevill, Balmer, & Williams, 2002; Unkelbach & Memmert, 2010). The change in points system in English soccer is also an important factor, even though it is isolated to one example. It is possible that the change in points system has increased the importance of winning matches for away teams rather than drawing or losing, purely down to the factor of the increased number of points for a win (Jacklin, 2005). Teams now need to draw three matches to gain the same number of points for a single win, thus increasing the incentive for teams to win matches instead of setting for a draw. It is unlikely to be a single factor that encourages home advantage but it more likely to be a combination of all of the factors above, as well as other potential factors, which cause home teams to win a greater number of matches (Pollard, 2008).

The effects of match location has been more widely reported for technical performance variables compared to physical performance, although the total distance covered by away teams is approximately 260 metres less than the home team (Lago et al., 2010). Nevertheless, as the majority of this deficit for away teams is observed at low intensities, and as the high-intensity running distance strongly influences match result in football, the differences in total distance covered between home and away teams is unlikely to impact match result (Bangsbo et al., 2006; Bradley, Carling, et al., 2013; Lago et al., 2010; Mohr et al., 2003). In contrast, home teams have consistently been measured to perform better technical performances than away teams, including performing fewer fouls, losing possession fewer times, and receiving fewer cards (yellow and red), whilst also performing more passes, successful passes, crosses, possession regains as well as key variables such as the number of shots, shots on target and goals (Lago-Peñas & Lago-Ballesteros, 2011; Poulter, 2009).

Match status (winning, drawing or losing) and opposition standard has less of an effect on match parameters compared to match location although still had a minor effect on technical performance (Bradley, Lago-Peñas, et al., 2014; Lago et al., 2010). Matches played against strong opposition (typically those that finish in the top places in their respective league) result in the weaker team traditionally having fewer ball possession, fewer shots, passes, final third entries and goals scored compared to matches played against middle and low placed teams in the league (Lago-Peñas & Lago-Ballesteros, 2011; Redwood-Brown, Bussell, et al., 2012; Taylor et al., 2008). When teams are losing, they cover greater distances at high-intensities compared to teams who are winning, this is in addition to differences in technical factors where losing teams perform more shots, although there is no difference in the accuracy of these shots (Lago et al., 2010; Lago-Peñas & Dellal, 2010; Taylor et al., 2008), it is unclear for the reasoning behind these changes although it is possible that losing teams perform more high-intensity actions and take more shots in order to equalise and therefore avoid defeat (Lago, 2009). Although there is clear evidence of match context affecting both technical and physical performance, some match contexts are easier to account for than others. For example, match location is fairly simple to monitor and take into account compared to evolving match score or final result that are simple to measure but more random to control. Despite the ease of measuring some contextual factors, research generally negates factoring these within the methodological process. It is possible that research groups fail to account for these factors, as they do not see the need to include them in the analysis or fail to refer to the impact or effects they may have on the results identified. Alternatively, researchers may not feel the need, have the time or the abilities to carry out resampling procedures in order to mitigate or reduce potential interpretation errors when analysing data with varying samples for contextual factors. The reasons behind research not accounting for these factors is unclear, nevertheless given the results highlighting the impact of contextual factors it should become an essential element of all research articles. This could be as simple as research recording the different sample sizes for contextual factors, or a resampling process which takes contextual factors into account and minimises data interpretation errors.

### 2.3 Performance Analysis in Soccer

Analysis in invasion games such as soccer can be broken into 3 categories; technical, tactical and physical performance. Analysis of tactical information includes factors such as time in possession or playing formations (Figure 2.7; Bradley, Lago-Peñas, Rey, & Diaz, 2013; Collet, 2013; Eaves, Hughes, & Lamb, 2005; James et al., 2002; Lago & Martin, 2007). Basic technical analysis provides information on passing, shooting and tackling variables (Castellano et al., 2012; Lago-Ballesteros et al., 2012; Laird & Lorimer, 2004; Passos et al., 2008; Vaz, van Rooyen, & Sampaio, 2010). Research has attempted to analyse some of these factors in greater detail investigating attacking factors such as shots to goals ratios, possession to goals scored, penalty area entries to the number of shots attempted (Hughes & Franks, 2005; Lago-Ballesteros et al., 2012; Mara, Wheeler, & Lyons, 2012; Reep & Benjamin, 1968; Tenga, Ronglan, & Bahr, 2010). These complex forms of analysis provide a more detailed investigation on the chances of success although less evidence is available on the impact these findings have had on performance.

Analysis of physical performance details information on factors including total distance run, high-intensity and sprint distances covered, distance per sprint and the number of sprint or high-intensity actions in a game which shown to affect the success of performances (Bradley et al., 2009; Bradley, Carling, et al., 2013; Deutsch, Kearney, & Rehrer, 2007; Di Salvo et al., 2010, 2013, Duthie, Pyne, & Hooper, 2003, 2005). The effects of fatigue on physical performance have also been widely reported (Bangsbo et al., 2006; Bradley & Noakes, 2013; Mohr et al., 2003; Mohr, Nybo, Grantham, & Racinais, 2012). Research has more recently identified different positional requirements within the technical and physical requirements of sports (Bradley, Carling, et al., 2011, 2013; Di Salvo et al., 2007; Taylor, Mellalieu, & James, 2004).

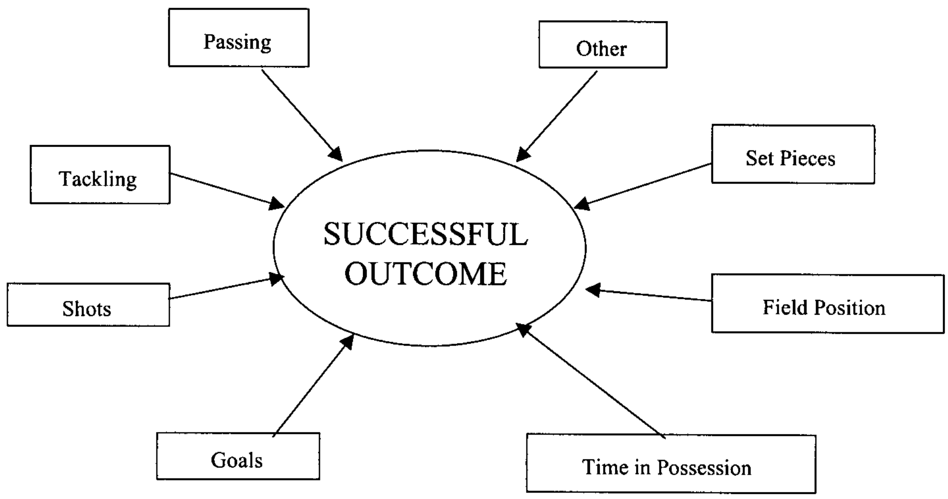


Figure 2.7: Categories of performance indicators for invasion sports (Hughes & Bartlett, 2002).

### 2.3.1 Physical Performance

The physical demands of soccer match-play have been widely researched (Andersson et al., 2010; Barnes, Archer, Hogg, Bush, & Bradley, 2014; Bradley et al., 2009; Bradley, Carling, et al., 2013; Bradley, Dellal, et al., 2014; Di Salvo et al., 2010, 2013; Krustrup, Mohr, Ellingsgaard, & Bangsbo, 2005), position-specific requirements of match-play (Bloomfield, Polman, & O'Donoghue, 2007; Di Salvo et al., 2007, 2010) along with the effects of fatigue on performance (Bradley & Noakes, 2013; Carling, 2013; Carling et al., 2008; Carling & Dupont, 2011; Mohr et al., 2003, 2012; Weston, Batterham, et al., 2011; Weston, Castagna, Impellizzeri, Rampinini, & Abt, 2007). It is widely accepted that players cover a minimum of 10 km during a match, irrespective of position, although players can cover up to 13-14 km (Barros et al., 2007; Bradley, Carling, et al., 2013; Di Salvo et al., 2007; Drust et al., 2007). The majority of the total distance is covered at low intensities, ≈80% is performed when standing, walking, jogging or at low running intensities (Bradley, Carling, et al., 2013; Bradley, Dellal, et al., 2014; Dellal et al., 2011; Di Salvo et al., 2013). Information on the total distance covered during soccer matches provides an understanding of the total physical workload, nevertheless research has identified that work at low intensities has little to no impact on match outcome. In contrast, the physical work completed at higher intensities and whilst sprinting has greater impact on match outcome (Akenhead, Hayes, Thompson, & French, 2013; Andersson et al., 2010; Bradley et al., 2009; Bradley, Carling, et al., 2013; Di Salvo et al., 2009; Faude, Koch, & Meyer, 2012). Although academic researchers agree on the proportions of low-intensity vs. high-intensity work completed during matches, the data must be handled with caution as different research papers and analytical software use differing speed thresholds to measure movements (Bradley et al., 2009; Bradley, Carling, et al., 2013; Dellal et al., 2011; Di Salvo et al., 2007; Mackenzie & Cushion, 2013). Although the differences between some of these speed thresholds are minor, over the course of a match, or multiple matches, there will be measureable effect on the distances covered in different speed categories. More importantly variations in speed categories will affect the ability to compare and contrast findings between different articles and the respective participant groups (Mackenzie & Cushion, 2013). In addition, more clarification and greater universal acceptance is required for the classification of speed thresholds (Table 2.1 and 2.2), for example some articles classify high-intensity to be >14 $km{\cdot}h^{-1}$, thus including classifications of medium-speed running, high-speed running and sprinting (Andersson, Raastad, et al., 2008; Bradley et al., 2009; Bradley, Carling, et al., 2011; Bradley & Noakes, 2013; Carling & Dupont, 2011; Krustrup & Bangsbo, 2001; Mohr et al., 2003; Rampinini et al., 2007), whilst others use a threshold at 19 $km{\cdot}h^{-1}$ (Barnes et al., 2014; Di Salvo et al., 2007, 2009, 2013; Gregson et al., 2010; Weston, Batterham, et al., 2011; Weston et al., 2007) and other articles choose not to categorise into high-intensity categories for methodological purposes (Barros et al., 2007; Bradley, Dellal, et al., 2014). There have been proposals to adopt more individualised speed thresholds for each player based on the transition between moderate to high-intensity actions around the second ventilatory threshold ($VT_{2;}$ Abt & Lovell, 2009). Nevertheless researchers have not widely adopted this strategy due to the complexity, time required and lack of access to players in order to measure ventilatory thresholds. As a result some research articles suggest players cover as much as ≈2500 m (20-25% of total distance) at high-intensity (Bradley et al., 2009; Bradley, Carling, et al., 2011), although the majority of research indicates players cover ≈1000 m (5-11% of total distance) at running speeds >19 $km \cdot h^{-1}$ (Barros et al., 2007; Bradley et al., 2009; Bradley, Carling, et al., 2011; Bradley, Dellal, et al., 2014; Carling et al., 2012; Weston et al., 2007), although these results are also dependant upon the data collection methods (Akenhead et al., 2013; Portas et al., 2010; Randers et al., 2010; Varley et al., 2012).

Table 2.1: Summary of Physical Match performance findings.

| Source | Nationality | N | Total Distance (m) | HIR Distance (m) | Number of HIR actions | HIRwp (m) | HIRwop (m) | Sprint Distance (m) | Number of Sprints | Speed Thresholds |
|---|---|---|---|---|---|---|---|---|---|---|
| Akenhead et al. (2013) | English | 36 | 10451±760 | 505±209 | – | – | – | 194±101 | – | HSR >20 $km \cdot h^{-1}$<br>SD >24 $km \cdot h^{-1}$ |
| Andersson et al. (2008a) | Swedish | 93 | 10190-10330 | 1860-1870 | 185 | – | – | 310-320 | 21-22 | HIR >18 $km \cdot h^{-1}$<br>SD >25 $km \cdot h^{-1}$ |
| Barnes et al. (2014) | English | 14700 | 10679-10881 | 890-1151 | 118-176 | 373-478 | 451-589 | 232-350 | 31-57 | HIR >19.8 $km \cdot h^{-1}$<br>SD >25.1 $km \cdot h^{-1}$ |
| Barros et al. (2007) | Brazilian | 55 | 10012 | 1128 | – | – | – | 437 | – | HIR >19 $km \cdot h^{-1}$<br>SD >23 $km \cdot h^{-1}$ |
| Bradley et al., (2009) | English | 370 | 10700±990 | 900±290 | – | – | – | 250±60 | | HIR >19 $km \cdot h^{-1}$<br>SD >23 $km \cdot h^{-1}$ |
| Bradley, Carling, et al., (2011) | English | 153 | ≈10700±1000 | ≈900±300 | ≈120±35 | ≈400 | ≈400 | – | – | HIR >19.8 $km \cdot h^{-1}$ |
| Bradley, Carling, et al., (2013) | English | 947 (EPL)<br>261 (Championship)<br>867 (League 1) | ≈10700-11500 | ≈930-1240 | – | ≈390-510 | ≈480-620 | ≈250-360 | – | HIR >19.8 $km \cdot h^{-1}$<br>SD >25.1 $km \cdot h^{-1}$ |
| Bradley, Lago-Peñas, et al., (2013) | English | 810 | 10700 | ≈930 | ≈120 | ≈400 | ≈450 | ≈250 | – | HIR >19.8 $km \cdot h^{-1}$<br>SD >25.1 $km \cdot h^{-1}$ |
| Bradley, Dellal, et al., (2014) | European | 54 – Male<br>59 - Female | 11142<br>10754 | | | | | | | |

Table 2.2: Summary of Physical Match performance findings continued

| Source | Nationality | N | Total Distance (m) | HIR Distance (m) | Number of HIR actions | HIRwp (m) | HIRwop (m) | Sprint Distance (m) | Number of Sprints | Speed Thresholds |
|---|---|---|---|---|---|---|---|---|---|---|
| Dellal et al., (2011) | English/ Spanish | 1896 (La Liga) 4704 (EPL) | 10500-11800 | 220-340 | – | 50-180 | 90-180 | 190-280 | – | HIR 21-24 $km{\cdot}h^{-1}$ SD >24.1 $km{\cdot}h^{-1}$ |
| Di Salvo et al., (2007) | European | 300 | 11393 | 400-740 | – | – | – | 200-450 | – | HSR 19.1-23 $km{\cdot}h^{-1}$ SD >23 $km{\cdot}h^{-1}$ |
| Di Salvo et al., (2013) | European | 26449 | ≈10900 | ≈720 | – | – | – | ≈260 | – | HSR 19.9-25.2 $km{\cdot}h^{-1}$ SD >25.2 $km{\cdot}h^{-1}$ |
| Lago-Peñas, Rey, et al., (2011) | Spanish | 172 | ≈10900 | ≈700 | – | – | – | ≈245 | – | HIR >19.1 $km{\cdot}h^{-1}$ SD >23 $km{\cdot}h^{-1}$ |
| Lago et al., (2010) | Spanish | 182 | 10719 | 618 | – | – | – | 302 | – | HIR >19.1 $km{\cdot}h^{-1}$ SD >23 $km{\cdot}h^{-1}$ |
| Mohr et al., (2003) | Italian/Danish | 42 | 10860 | 1900-2430 | 171-217 | – | – | 400-650 | 26-39 | HIR >15 $km{\cdot}h^{-1}$ SD >30 $km{\cdot}h^{-1}$ |
| Rampinini et al., (2007) | European | 188 | ≈11000 | ≈2500 | ≈4500 | ≈350 | ≈450 | – | – | HIR >14.4 $km{\cdot}h^{-1}$ |
| Scott et al., (2014) | Australian | 57 | – | 16344m/hour | 55 efforts/hour | – | – | 120m/hour | 15 efforts/hour | HIR>14.4 $km{\cdot}h^{-1}$ |
| Vigne et al., (2010) | Italian | 388 | ≈8500 | ≈700 | ≈100 | – | – | ≈800 | ≈80 | HIR 16-19 $km{\cdot}h^{-1}$ SD >19 $km{\cdot}h^{-1}$ |
| Weston et al., (2007) | English | 254 | ≈11000 | ≈800 | – | – | – | – | – | HIR >19.8 $km{\cdot}h^{-1}$ |

In extension to the distances covered at both high-intensity and whilst sprinting, the acceleration profiles in attaining these high speeds has been identified as a key factor within match performance and training, particularly in identifying and minimising injury risk (Daly, 2013; Opar et al., 2012; Petersen, Thorborg, Nielsen, Budtz-Jørgensen, & Hölmich, 2011; Small et al., 2009). Research groups have noted that players cover, on average, 20-40 sprints per game (Andersson, Ekblom, et al., 2008; Ingebrigtsen, Dalen, Hjelde, Drust, & Wisløff, 2015), averaging less than 10 m per sprint, thus suggesting short, sharp sprint actions (Barnes et al., 2014). However, measuring sprint distances only measures the physiological requirements once players attain the speed threshold and does not take into account the physical work they must complete to attain the speeds, nor does it take into account the sudden, sharp movements which causes velocity changes but without causing changes in speed thresholds (Castellano & Casamichana, 2013). In contrast to the low number of sprints, players can perform over 100 accelerations, or up to 8 times the number of sprints in a game (Bradley, Di Mascio, Peart, Olsen, & Sheldon, 2010; Ingebrigtsen et al., 2015; Varley, Gabbett, & Aughey, 2014). This high number of accelerations can result in players covering over 1000 m and spend over 500 seconds accelerating during matches, with a similar profile when players decelerate (Akenhead et al., 2013; Osgnach, Poser, Bernardini, Rinaldo, & Di Prampero, 2010). The majority of accelerations by players (>90%) begin from low running speeds (Bradley et al., 2010; Varley & Aughey, 2013; Varley et al., 2014), whilst a high proportion of accelerations do not result in players breaking the high-speed running thresholds (Varley et al., 2014). Players in wide positions (full backs and wide midfielders) demonstrate a higher number of accelerations compared to other positions whilst attackers demonstrate the highest number of hard accelerations (>3 $m \cdot s^{-2}$), (Ingebrigtsen et al., 2015; Varley & Aughey, 2013; Wehbe, Hartwig, & Duncan, 2014). In addition, the recovery time between high-intensity bouts is lowest in soccer compared to other football codes (Varley et al., 2014), with players often having moderate (30-120 seconds) to long (>120 seconds) recovery times between high-intensity bouts (Bradley et al., 2010; Varley et al., 2014). These findings show it is important to take into account the rapid and explosive movements conducted by soccer players when analysing the physical output during soccer matches. Without taking these factors into account a true representation of physical output is not accounted for, nor is it possible to design training programmes which replicate match performance to maximise physical preparation of players. Negating this information could lead to ineffective preparation and training programmes as well as an increased injury risk for players.

The information on sprints needs to be analysed with caution. As with the speed thresholds used to calculate distances covered during a match, researchers use differing acceleration thresholds when analysing changes in speed. Some researchers have classified accelerations into low (1-2 $m \cdot s^{-2}$), moderate (2-3 $m \cdot s^{-2}$) and high (>3 $m \cdot s^{-2}$), (Akenhead et al., 2013; Hodgson, Akenhead, & Thomas, 2014), whilst other research groups have used thresholds of medium (2.5-4 $m \cdot s^{-2}$) and high (>4 $m \cdot s^{-2}$), (Bradley et al., 2010). These differences in classifications add difficulties when analysing and comparing data, with the importance of the data and the practical findings, it is essential that researchers begin to use common thresholds. In addition to these issues, the method of collecting data needs to be accounted for. Some research articles have used 1Hz (Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010; Castagna, Manzi, Impellizzeri, Weston, & Barbero Alvarez, 2010; Mendez-Villanueva, Buchheit, Simpson, Peltola, & Bourdon, 2011) and 5Hz (Varley & Aughey, 2013) GPS devices to analyse accelerations. This is compared to other research that have used 10Hz GPS devices (Akenhead et al., 2013; Hodgson et al., 2014), automated motion tracking devices which typically record at 25Hz (Bradley et al., 2010; Osgnach et al., 2010) and accelerometers measuring at 100Hz (Castellano & Casamichana, 2013). The 1Hz and 5 Hz GPS systems have been shown to be less sensitive to sports movements (Barbero-Alvarez et al., 2010; Coutts & Duffield, 2010; Harley et al., 2011; Randers et al., 2010; Varley et al., 2012) and therefore may not accurately measure changes in velocities. In addition, the variability of GPS devices can affect the data recorded depending upon the number of satellites available during capture and location of capture (indoors vs. outdoors and obstructions) and must be taken into account (Portas et al., 2010; Randers et al., 2010; Varley et al., 2012).

### 2.3.2 Fatigue in Soccer Performance

Together with the analysis of the physical demands of match play, researchers have also analysed the potential presence and effects of fatigue on performance. Multiple methods for assessing fatigue have been proposed, these include analysing the high-intensity running distance or sprint distance during the most physically intense 5 minute period of the game and comparing it to the following 5 minute period and the average values for the remaining 5 minute periods of the match (Carling & Dupont, 2011; Mohr et al., 2003). Other research has divided match time into 15 minute segments (Carling & Dupont, 2011; Edwards & Noakes, 2009; Mohr et al., 2003; Weston, Batterham, et al., 2011), or examined the differences between physical work load in the first and second halves (Bradley & Noakes, 2013; Edwards & Noakes, 2009; Rampinini et al., 2008; Weston et al., 2007). Alternatively, a limited number of research articles have analysed the fatigue effects of multiple games being played over a short time period (Carling et al., 2015; Carling & Dupont, 2011).

The research on congested fixture periods, i.e. playing multiple matches over a short time span, suggests that there is no differences in the total distance or high-intensity running distance completed during each match when 3 matches are played within 7 days (Carling et al., 2012; Dellal, Lago-Peñas, Rey, Chamari, & Orhant, 2013), although decrements in performance may begin to be seen when 5 or 6 matches are played within the space of 2-3 weeks (Dellal et al., 2013). These findings would suggest that the current recovery protocols adopted by professional clubs are adequate at helping players recover during congested fixture periods where recovery is expected to take approximately 72 hours. However when extended periods of fixture congestion occur other factors appear to affect player recovery, which may increase the time required for an individual's body to fully recover by another 24 hours (Nédélec et al., 2012).

In the case of fatigue occurring during a match, methods analysing performance over 5 minute periods, over 15 minute periods and between halves have noted reductions in the physical output when comparing the early stages of a match compared to latter stages and between the peak 5 minute exercise period and the following 5 minute period. The results suggest that fatigue potentially occurs, either on a temporary basis (peak 5 minutes) before players use the following 5 minutes to recover. Alternatively, research suggests fatigue can occur on a longer term basis over the course of a match where players cover less total distance, high-intensity running distance and sprint distance during the second half when compared to the first (Bradley & Noakes, 2013; Carling & Dupont, 2011; Edwards & Noakes, 2009; Mohr et al., 2003; Nédélec et al., 2012; Rampinini et al., 2008; Weston, Batterham, et al., 2011; Weston et al., 2007). As the amount of high-intensity running distance has been correlated with match outcome it is important for players to be able to minimise the detrimental effects of fatigue in order to perform effectively for the entire match (Carling & Dupont, 2011). It is therefore important that training regimes mimic those of match play in order to reduce recovery time and enable players to minimise fatigue effects. Nevertheless, although physical decrements in performance occur, other factors much also be taken into account which may cause changes in physical output. Physical decrements may be caused by variations in contextual factors, pacing strategies and playing tactics. High-intensity actions have been shown to be a major factor in goal scoring opportunities (Faude et al., 2012). Therefore teams losing, particularly in latter stages of matches, may increase the intensity of the game in order to create scoring opportunities and as a result increase the high-intensity output, in contrast winning teams may attempt to slow the game down to reduce the opportunities of conceding in order to win the game (Wehbe et al., 2014). In addition to match score, the presence of player dismissals affect the high-intensity output of players during a match (Carling & Bloomfield, 2010). The tactics teams adopt, particularly the playing formation, affects the high-intensity output of individuals dependent upon playing positions. Attackers playing in a 4-3-3 formation cover greater high-intensity running distance compared to 4-4-2 and 4-5-1 formations. In contrast defenders in a 4-4-2 formation covered greater distances at high-intensities compared to defenders in other formations (Bradley, Carling, et al., 2011). Although research has identified these differences in performance, playing formations are not widely accounted for when analysing performance data.

In addition to the general findings of match play, researchers have also identified differences in the technical and physical performance of different positions (Bloomfield et al., 2007; Bradley, Dellal, et al., 2014; Bradley et al., 2009; Bradley, Carling, et al., 2013; Carling, 2010; Dellal et al., 2011; Di Salvo et al., 2007, 2010, 2013; Taylor et al., 2005, 2004). Players in central midfield positions and wide midfielders cover the greatest total distance over the course of a match (Bloomfield et al., 2007; Bradley, Carling, et al., 2011; Dellal et al., 2011; Di Salvo et al., 2007); this is due to the midfielders undertaking both attacking and defensive roles during a game and therefore cover greater distances in order to move into positions to complete their match roles. Barros et al. (2007) found that full backs in the top Brazilian league covered the greatest total distance, although this was only marginally greater than central and wide midfielders. Central defenders cover the least distance at both high-intensity and whilst sprinting, in contrast wide players, both wide midfielders and full backs, cover the greatest distance at high-intensity (>19 $km \cdot h^{-1}$) and whilst sprinting (Barros et al., 2007; Bradley et al., 2009; Di Salvo et al., 2007, 2010, 2009). The majority of research suggests players cover a minimum of 600 m at high-intensity (central defenders) and up to approximately 1200 m for wide midfielders and full backs (Barros et al., 2007; Bradley et al., 2009; Bradley, Dellal, et al., 2014; Di Salvo et al., 2009). Dellal et al. (2011) recorded players, in both the Spanish La Liga and EPL, covering less than 400 m at high-intensity for all positions, however used much higher speed thresholds for high-intensity (21 $km \cdot h^{-1}$) and sprinting (24 $km \cdot h^{-1}$), which would therefore affect the distance measured in these speed categories. This again highlights the challenges faced when analysing results using different data collection methods and different speed thresholds. The majority of high-intensity running is performed when out of possession except for attackers who perform more high-intensity running when the team is in possession and was consistent across playing standards and different leagues (Bradley, Carling, et al., 2011, 2013; Dellal et al., 2011; Di Salvo et al., 2009).

Mixed reasons have been proposed as to why these positional differences in locomotive patterns exist. Some research has found positional differences in $VO_{2max}$ and aerobic capacity for soccer players with central midfielders and full backs having greater $VO_{2max}$ results (Reilly, Bangsbo, & Franks, 2000), whist others found no differences (Haugen, Tønnessen, Hem, Leirstein, & Seiler, 2014). Central midfielders and full backs have consistently performed the greatest test results when assessed using intermittent running tests (Mohr et al., 2003; Reilly et al., 2000). Some research has identified players in central midfield and wide areas have greater physical capacity and $VO_{2max}$ scores compared to players in other positions (Haugen, Tønnessen,

& Seiler, 2012; Strøyer, Hansen, & Klausen, 2004; Tønnessen, Hem, Leirstein, Haugen, & Seiler, 2013). Nevertheless players from all positions have recorded $VO_{2max}$ scores between 50 and 65 $ml \cdot kg^{-1} \cdot min^{-1}$ (Aziz, Mukherjee, Chia, & Teh, 2007; Castagna, Impellizzeri, Chamari, Carlomagno, & Rampinini, 2006; Chamari et al., 2004; Haugen et al., 2014; Strøyer et al., 2004; Tønnessen et al., 2013). However, $VO_{2max}$ may provide a good understanding of an individual's physical capacity, however it has been shown to provide low correlations with soccer performance (Bangsbo et al., 2008; Krustrup et al., 2003).

Alternatively, Yo-Yo intermittent recovery (IR) tests have been measured as a more appropriate assessment for the physical preparation of players. The Yo-Yo IR tests analyse an individual's ability to perform repeated high-intensity actions and have become the most common tests used when assessing fitness testing in sporting environments (Bangsbo et al., 2008). The Yo-Yo IR tests include a two 20m shuttle runs separated by 10 second recovery periods, the speed of the test is progressively increased using audio signals until the individual cannot maintain speed and therefore deemed to have reached exhaustion (Bangsbo et al., 2008; Stølen et al., 2005). There are two forms of Yo-Yo IR tests, level 1 begins at a slower speed (≈10 $km \cdot h^{-1}$) and has more gradual increases in speed compared to the level 2 test, which begins at a higher speed (≈13 $km \cdot h^{-1}$) with greater increments between stages (Bangsbo et al., 2008; Krustrup et al., 2003, 2006; Stølen et al., 2005). Level 1 is designed to last between 10-15mins and aims to measure an individual's endurance capability, whilst level 2 is designed to last between 5-15 minutes and aims to measure an individual's ability to perform repeated high-intensity exercise (Bangsbo et al., 2008). Overall, during the tests the players will cover between 1200-2500 m during a level 1 test compared to 600-1600 m during a level 2 test (Bangsbo et al., 2008; Castagna, Abt, & D'Ottavio, 2005; Castagna, Impellizzeri, Chamari, et al., 2006; Krustrup et al., 2003, 2006; Rampinini et al., 2010), although some research has suggested individuals could cover up to 1800-2500 m during a level 2 test (Bradley, Bendiksen, et al., 2014; Bradley, Mohr, et al., 2011). Some of these values seem extremely high considering the intensity of the level 2 test, however test results are highly dependent on participant gender, age and training status (Bradley, Bendiksen, et al., 2014; Bradley, Mohr, et al., 2011; Castagna et al., 2005; Krustrup et al., 2003, 2006). When analysing player performance using Yo-Yo IR tests, players in centre midfield, full back and wide midfield positions record greater results, covering over 2200m in a level 1 test, whilst central defenders and attackers cover between 1700-2000 m (Bangsbo et al., 2008; Bradley, Bendiksen, et al., 2014; Bradley, Mohr, et al., 2011; Krustrup et al., 2003). The differences between positions in a level 2 test are more marginal, with central defenders often able to cover similar distances to full backs, central and wide midfielders, with attackers (≈100 m less) the only position recording noticeable differences (Bangsbo et al., 2008; Bradley, Bendiksen, et al., 2014; Bradley, Mohr, et al., 2011; Krustrup et al., 2006). Goalkeepers have rarely been analysed due to the different nature of the position, however the limited data available would suggest that goalkeepers have the lowest physical capacity of all positions and cover approximately 1700 m during a level 1 test and 600 m during a level 2 test (Bangsbo et al., 2008).

Nevertheless Yo-Yo IR test results are dependent on different factors, including player age, gender, playing standard and in particular playing position, with young midfielders and full backs have recorded greater test results compared to their senior counterparts (Bradley, Mohr, et al., 2011). In contrast, Krustrup et al. (2006) suggested that elite level u19s performed better in Yo-Yo IR tests than senior players in lower domestic leagues but worse than senior players of international standard. This research shows that it is not solely player age that affects testing performance but also playing standard where international players have greater physical endurance capability and the ability to perform repeated high-intensity actions compared to those who play in domestic leagues (Bangsbo et al., 2008; Bradley, Bendiksen, et al., 2014; Bradley, Mohr, et al., 2011; Krustrup et al., 2003, 2006). It has also been noted that the time of season where testing occurred has an impact on the results observed, where players, irrespective of standard or age, perform better during early stages of the season rather than the latter stages (Bradley, Bendiksen, et al., 2014; Bradley, Mohr, et al., 2011; Krustrup et al., 2006). It is no surprise that elite standard players or senior players have greater test performances compared to amateur or junior players as they have been exposed to a higher standard of training regimes, or over a longer period of time, thus helping to develop greater physical preparation. In addition at the start of the season players are at their peak physical fitness as they have been through rigorous physical preparation providing a foundation for the start of the forthcoming season. In contrast, at the end of the season players will generally be suffering from a level of fatigue, with training aimed at maximising recovery and maintaining performance, less focus is placed on developing or improving a player's physical capacity (Scott et al., 2014). As it has been shown that Yo-Yo IR test performances can be affected by a multitude of factors, it is imperative that research begins to provide greater information regarding the population tested as the current research limits comparisons between populations. It may therefore, be possible that current researchers are analysing test performances against different populations, i.e. elite junior international players in attacking positions against non-elite central midfielders. Thus, basing their conclusions on the findings of vastly different populations and as a result could have a direct, and potentially incorrect, impact on the training interventions.

### 2.3.3 Technical Match Performance

Team success is complex and multifactorial, technical indicators have been demonstrated to predict team success more accurately than physical indicators (Carling, 2013; Castellano et al., 2012). More specifically, ball possession, number of shots, shots on target, number of passes and pass completion rate all correlate with team success, particularly at domestic/league level (Castellano et al., 2012; Collet, 2013; Hughes & Franks, 2005; Lago-Ballesteros et al., 2012; Lago-Peñas & Lago-Ballesteros, 2011), although these factors are less distinguishable at the highest level of the game (Scoulding, James, & Taylor, 2004). Physical parameters do not appear to be as strongly associated with team success, however physical parameters have appeared to gain more focus within the research literature (Table 2.3; Bloomfield et al., 2007; Bradley & Noakes, 2013; Bradley et al., 2009; Bradley, Carling, et al., 2011, 2013; Carling & Dupont, 2011; Carling et al., 2012; Carling, 2013; Di Salvo et al., 2010; Haugen et al., 2014; Krustrup et al., 2005; Mohr et al., 2012; Weston et al., 2007; Weston, Batterham, et al., 2011). It is unclear why physical performance is more widely researched, although it is plausible that due to the advances in technology, i.e. GPS and semi-automated tracking systems, it is easier and quicker to analyse physical compared to technical performance (Barbero-Alvarez et al., 2010; Barris & Button, 2008; Bradley et al., 2007; Coutts & Duffield, 2010; Di Salvo et al., 2006; MacLeod et al., 2009; Portas et al., 2010; Redwood-Brown, Cranton, et al., 2012; Varley et al., 2012). It is also possible that physical performance is affected less by external and contextual factors compared to technical performance (Bradley, Lago-Peñas, et al., 2014; Castellano et al., 2011; Lago et al., 2010; Lago-Peñas & Lago-Ballesteros, 2011; Taylor et al., 2008). In contrast, analysing technical performance still requires a certain level of observer input and may therefore introduce more errors in the analysis, especially if definitions of performance indicators have not been established or understood correctly. In addition, the process of collecting and analysing the data can take longer and may be a restricting factor (Bartlett, 2001; Hughes & Bartlett, 2002; Hughes et al., 2004; Hughes & Franks, 2004b). Although physical indicators may not be as strongly associated with success as technical parameters, the physical workload of match-play appears to provide an essential underpinning for maintaining technical proficiency (Carling & Dupont, 2011; Rampinini et al., 2008), and therefore cannot be disregarded as contributors to overall performance. As previously mentioned with physical match performance, there is limited universal acceptance on the definitions of technical performance, some research publishes the operational definitions for technical variables, although the majority do not which makes direct comparison between articles challenging.

Despite there being less research on technical performance in football, it is clear that the ability to score goals is a key to being successful (Castellano et al., 2012; Reep & Benjamin, 1968). As a result, a lot of the research has focused on the objective of scoring goals and how to increase the chances of goal scoring. Early research suggested that the ability to get the ball into attacking areas of the pitch as quick as possible would provide the best chances of a goal being scored, therefore limiting the number of passes but maximising the number of shots would increase the chances of a team being successful (Reep & Benjamin, 1968). Later research has shown this is still more likely to result in a goal being scored but only when playing against an unbalanced defence, i.e. counter attacking a team when they are out of shape (Sarmento, Anguera, et al., 2014; Tenga, Holme, Ronglan, & Bahr, 2010; Tenga, Ronglan, et al., 2010). This is logical, given the fact that it is easier for teams to play forward and into space when their opponents are out of shape, providing opportunities to attack at goal when there is fewer defenders in position to restrict attacking play. It has also been identified that teams are more likely to score when regaining possession close to the opponents goal (Tenga, Holme, et al., 2010). These factors together are unsurprising, if teams are able to regain the ball closer to the opponent's goal it provides them with an opportunity to counter attack in a limited space before they are in an opportunity to score. If possession is regained further away from the opponents goal there is a greater opportunity for the opposition to recover and defend (Bangsbo & Peitersen, 2002). When the opponents are in a structured shape the opportunities to counter attack are limited (Sarmento, Anguera, et al., 2014). In these circumstances a more possession based strategy may be more effective at scoring goals (Bangsbo & Peitersen, 2004; Tenga, Ronglan, et al., 2010). These possession based strategies are aimed at disturbing the opposition structure in order to create opportunities to play through them and create goal scoring opportunities (Bangsbo & Peitersen, 2004). Long durations of possession-based football occur less frequently than counterattacking opportunities (Hughes & Franks, 2005; Tenga, Holme, et al., 2010), although when they do occur passing sequences of between five and seven passes are more likely to result in a goal being scored (Hughes & Franks, 2005). Goal scoring opportunities are also more likely to occur within the width of the 18 yard box, particularly within the box itself (Mara et al., 2012; Tenga, Holme, et al., 2010). This is inevitable given greater distances from goal will increase the number of defending players which could interfere with the path of the ball as well as the greater time a goalkeeper would have in order to save a shot, also the angles involved in creating scoring opportunities from wide areas of the pitch will reduce the size of the goal to aim for making it more difficult to aim at, as well as also making it easier for the goalkeeper to save given the visually smaller area in which they have to protect. Once a goal has been scored, it has been identified that the scoring team has a lower number of passes and a lower pass completion rate during the subsequent 5 minute period to the goal being scored (Redwood-Brown, 2008). Given the fact the conceding team regains possession from the kick-off the lower number of passes performed is unsurprising, however, the lower pass completion rate is. As the team has just scored the aim will be not to concede straight away, given this fact, it is important for the scoring team to regain and then keep possession, which then stops the opposition from creating goal-scoring opportunities. As a result it would be expected to increase the pass completion rate to reduce the chances of conceding a goal.

The results from Hughes and Franks (2005) led to teams adopting more possession based playing tactics in order to increasing the number of occurrences of goal scoring opportunities through passing sequences and therefore to score more goals. However, more recent research has identified these possession based playing styles to be successful for the best teams at domestic level (Collet, 2013), but less successful when those teams play in competitions such as the UEFA Champions League, where the best teams from each domestic competition play each other, or at international level, such as World Cups (Castellano et al., 2012; Collet, 2013). This suggests that possession does not affect the outcome or the success of a team. Instead, the results may be seen at domestic level as these teams are generally able to employ the best players from across the world, therefore having the ability to maintain possession compared to their opponents at domestic level. At international level and in competitions such as the Champions League, the best domestic and national teams play against each other, therefore negating any strengths as these levels see the most able players play against others that are equally as capable. Nevertheless, despite possession having little impact on the success of a team, different possession strategies have been observed between domestic competitions and those in European competitions such as the UEFA Champions League.

In domestic competitions, teams have been observed to maintain possession in more defensive areas of the pitch in an attempt to build play up from deep areas, before playing through wide areas into attacking positions on the pitch (James et al., 2005). In comparison in European competitions, teams try to maintain possession higher up the pitch and play through more central areas (James et al., 2005). This reinforces the fact that the best teams are able to maintain possession in domestic level, having the ability to play from deeper areas in the pitch before exposing their opponents in wide areas and having limited threats from their opponents as they keep possession closer to the defending goal. In contrast, when playing against equally capable teams, they look to keep possession away from defensive areas, trying to reduce the potential of conceding possession on the counterattack and therefore giving their opponents goal-scoring opportunities.

Research has also tried to quantify the technical expectations of a team during a match, as with physical performance, technical expectations are position and tactical dependent (Bradley, Carling, et al., 2011, 2013; Dellal et al., 2011; Fernandez-navarro et al., 2016). Differences have been observed between different leagues within one country (Bradley, Carling, et al., 2013), there are limited differences in technical performance between the highest domestic leagues in Europe (Bradley, Carling, et al., 2013; Dellal et al., 2011; Rampinini et al., 2009). The research surmises that players across positions require a minimum of 70% pass success rate to be successful (Dellal et al., 2011), although recent research has highlighted pass success rate has increased in the English Premier League (Barnes et al., 2014). Players across all outfield positions are expected to be able to perform and receive passes as well as win possession. However, players in attacker or wide midfield positions are expected to perform more shots compared to players in positions such as centre backs. Whilst players in defending positions are expected to perform technical actions such as tackles, interceptions, blocks and headers compared to other positions (Bradley, Carling, et al., 2013). In addition to the positional differences in technical performance, the tactical set up of a team also influences technical performance. Teams who play in a 4-4-2 formation perform and receive 10 more passes compared to teams who play in a 4-5-1 formation and marginally more passes than teams in a 4-3-3 formation. Teams who play in a 4-4-2 formation also show higher pass completion rates than a 4-3-3 or 4-5-1 formation, completing nearly 10% more passes. Although differences were observed in the passing variables, no differences between formations were found for attacking variables (the number of final third entries or the number of crosses) or for the number of times teams won or lost possession (Bradley, Carling, et al., 2011). Although each position has specific expectations within different teams and formations, the attacking and defensive playing styles adopted by each formation will likely affect the technical performance (Fernandez-navarro et al., 2016). For example, a 4-5-1 formation is inherently defensive, offering little attacking support for the lone striker, thus adopting a more defensive style of play and potentially a lower proportion of possession, the research by Bradley, Carling et al. (2011) suggests this may be the case with marginally lower numbers of crosses, final third entries and the lowest number of passes performed and received. In comparison, a 4-4-2 formation is generally more balance, providing support in attack and defence, thus providing more passing options in possession and providing the additional support in defence, increasing the opportunities to regain possession.

As well as physical parameters, technical parameters are also affected by contextual factors (Bradley, Lago-Peñas, et al., 2014; Taylor et al., 2008). Match location has an effect on most technical parameters including goals scored, shots taken, passes performed and the success rate of passes (Gómez, Gómez-Lopez, Lago, & Sampaio, 2012; Lago-Peñas & Lago-Ballesteros, 2011; Lago & Martín, 2007). Possession has been recorded to be higher for home teams, up to 7.6% higher than those of the away team when a match ends 0-0, although the predicted possession for the home team is dependent upon the score line of the match (Lago & Martín, 2007). Nevertheless, as referred to above, the possession statistic is less inclined to influence the game outcome compared to the defending and attacking technical performance in matches. Home teams have been identified to perform up to 40 more passes, with a similar number of successful passes dependent upon team standard (Lago-Peñas & Lago-Ballesteros, 2011). The strongest teams in the Spanish League recorded the greatest differences between playing at home and away whilst those that finished in the middle group, not only performed the lowest number of passes in the game but also the smallest differences between playing at home and away. The strongest teams in the league were the only team to record ball possession over 50% for both home and away games (Lago-Peñas & Lago-Ballesteros, 2011). It is unsurprising that the strongest teams perform the highest number of passes, but it is unclear why they record the greatest differences between home and away performances. It is possible that, as the biggest teams have the largest capacity stadiums, that the crowd support when playing at home provides a greater impact on player performances (Pollard, 2008; Sánchez et al., 2009), whilst also potentially influencing the referee decisions (Nevill et al., 2002; Unkelbach & Memmert, 2010).

Match outcome and evolving match score line has also been shown to affect match performances, with matches that are won recording the greatest performances with teams recording the highest number of passes performed and received, shots on and off target and goals scored. In contrast, the technical performance for matches that are lost or drawn show less variation (Gómez et al., 2012). Possession strategies change during a game depending on the score line and the time in the match when goals are scored (Lago-Peñas & Dellal, 2010; Lago, 2009). When winning teams are in possession, ball possession has been found to be higher in the defensive third and lower in the attacking third of the pitch, irrespective of match location (Lago, 2009). Interestingly, winning teams tend to play in the defensive third more when playing away compared to when winning at their home stadium. In contrast, when teams are losing or drawing ball possession is greater in the middle and attacking third of the pitch (Lago, 2009). This is unsurprising as teams need to play in the attacking areas in order to score to either equalise or take the lead. It is worthy to note that losing and drawing teams tend to play in the attacking areas more when playing at home (Lago, 2009), trying to use the support of the home crowd to create goal scoring opportunities, although play in the defensive third when playing away (Lago, 2009).

Table 2.3: Summary of Technical Match performance findings.

| Source | Nationality | N | Shots (On Target) | Pass | Pass Success (%) | Passes Received | Possession Won | Possession Lost | Tackles | Tackled |
|---|---|---|---|---|---|---|---|---|---|---|
| Andersson et al., (2008) | Swedish | 93 | 13 | ≈300 | – | 223 | – | – | – | – |
| Barnes et al., (2014) | English | 14700 | 1.2 | 29 | 79 | 22 | 19 | 22 | 3 | 3 |
| Bradley, Carling, et al., (2011) | English | 153 | – | ≈25 | ≈75 | ≈30 | 22 | 22 | – | – |
| Bradley, Carling, et al., (2013) | English | 947 (EPL)<br>261 (Championship)<br>867 (League 1) | – | ≈25 | ≈75 | ≈28 | – | – | – | – |
| Bradley, Lago-Peñas, et al., (2013) | English | 810 | ≈1 | ≈30 | ≈78 | ≈33 | 22 | 22 | 3 | 2.5 |
| Castellano et al., (2012) | International | 59 | 12 (5) | – | – | – | – | – | – | – |
| Lago-Peñas & Lago-Ballesteros, (2011) | Spanish | 380 | 13 (5) | 410 | 72 | – | 53 | 75 | – | – |
| Redwood-Brown, Bussell, & Bharaj (2012) | English | 29 | (1) | ≈30 | ≈84 | – | 14 | 19 | 3 | 3 |

Reep and Benjamin conducted the first major, detailed analysis of soccer in 1968. They reviewed over 3000 soccer matches between 1953 and 1967; matches were taken from around the world, from English domestic soccer to international level matches. The findings from Reep and Benjamin's research were the some of the most influential in the history of performance analysis (James, 2006). It was stated that 80% of goals in soccer were scored from a passing sequence consisting of 5 passes or less and that a goal was scored for every ten shots attempted (Reep & Benjamin, 1968). These findings led to the adoption of the "long ball" or "direct play" strategy for a number of teams, reducing the number of passes played and maximising the number of shots, thus hoping to score more goals than the opposition (Hughes & Franks, 2005).

In an attempt to reinvestigate the relationship between shots and passing sequences in soccer, Hughes & Franks (2005) assessed the 1990 and 1994 FIFA Soccer World Cups. They followed a similar methodological approach to that used by Reep and Benjamin (1968), although they applied a normalisation protocol to the data in an attempt to establish if the findings from Reep and Benjamin where accurate. Hughes and Franks (2005) suggested that Reep and Benjamin's results had been misinterpreted due to unequal frequencies in the length of passing sequences. The results showed shorter passing sequences leading up to a goal occurred more frequently than longer passing sequences therefore leading to a biased interpretation by the original authors. A process of normalisation, which in this study was achieved by dividing the number of occurrences (goals scored for a passing sequence) by the frequency of occurrence (number of times that passing sequence length occurs), would provide a more accurate understanding of the effects of passing sequence length on the number of goals scored. Initially the findings supported Reep and Benjamin, suggesting that 80% of goals are scored from passing sequences of 5 or less passes. However after applying the normalisation process results indicated goals were more likely to be scored from passing sequences consisting of 5-7 passes (Hughes & Franks, 2005). In addition, long passes distributed forward from the defensive half of the pitch have been identified to be the least likely method to provide a goal scoring opportunity and were more likely to result in a loss of possession (Mara et al., 2012). The results from Hughes and Franks (2005) suggest when trying to link an outcome (scoring goals) with a cause or process (passes preceding goals, possession regains or the number of penalty area entries), it is important to take into account the number of occurrences before suggesting a conclusion which changes the tactics of the game. For an analysis of goal scoring opportunities it may also be important to know the number of goals which came from set pieces or penalties (which may affect the number of goals scored from a passing sequence of zero passes), or access further information on the pitch location of the possession regain, for example, it may be speculated that shorter passing sequences occur when possession is regained closer to the opposition goal. This is essential information on build up play prior to goals being scored. An analysis of women's soccer has noted 61% of goals are scored from conventional passing sequences, compared to crosses, corners and free kicks (Mara et al., 2012). Crosses have been identified as having both a high chance of leading to a shot on goal and one of the primary sources of losing possession (Mara et al., 2012). Given the nature of set plays (corners and free kicks), and the number of both attacking and defending players in a confined area, it is unsurprising the majority of goals scored during set plays are distributed above waist height (Mara et al., 2012). In contrast, during open play, with fewer defending and attacking players in the same space, more crosses are scored below waist height (Mara et al., 2012).

In addition to the findings on goal scoring, the length of time possession is maintained has been extensively analysed and identified as a potential key to success. The longer a team maintains possession the greater number of points per match, which was evident in both domestic leagues and international competitions, in particular for European and South American teams (Bradley, Lago-Peñas, et al., 2013; Castellano et al., 2012; Collet, 2013). Teams with lower possession during a match perform greater physical workloads (Bradley, Lago-Peñas, et al., 2013), whilst teams with higher ball possession complete more technical actions, such as the number of passes and the number of shots (Bradley, Lago-Peñas, et al., 2013; Castellano et al., 2012), which often leads to greater success (Castellano et al., 2012; Collet, 2013; Redwood-Brown, 2008). In addition, although there is variability inherent between matches, the more successful teams displayed lower variability in the time they maintained possession in different matches (Lago-Peñas & Dellal, 2010). Nevertheless, possession and points per match was heavily influenced by the top clubs in domestic leagues, once teams that qualified for the UEFA Champions League were removed from the analysis, possession time did not predict the number of points per match (Collet, 2013). In these circumstances, although possession could not predict the number of points per match, it did show strong relationships with the number of shots, that is, greater ball possession was associated with a greater number of shots being taken. Although teams who maintained possession for longer periods performed more shots (Bradley, Lago-Peñas, et al., 2013; Castellano et al., 2012), no increase in the number of goals scored was observed (Collet, 2013). Possession strategies are not as straightforward as they appear to be, with more research required on the effects of contextual factors (Lago-Peñas & Dellal, 2010). For example, Collet (2013) analysed the link between possession and success without understanding or analysing the different contexts of matches. Teams have an average of ≈6% more possession when playing at home compared to playing away, that is, if a team has 50% of possession away from home, on average they would be in possession for approximately 56% of a match when playing at home (Lago & Martín, 2007). Nevertheless time in possession can also be affected by the score line (Bradley, Lago-Peñas, et al., 2014; Lago-Peñas & Dellal, 2010; Lago & Martín, 2007). If a home team is losing for the majority of the match, ball possession would still be greater than when playing away but would be reduced from ≈56% to ≈53% (Lago & Martín, 2007). Losing teams often have greater ball possession (≈8%) compared to their winning opponents, in particular immediately after the winning team has scored (Lago & Martín, 2007; Redwood-Brown, 2008). It is assumed that the losing team often retains possession in an attempt to create more shooting opportunities in order to equalise (Bradley, Lago-Peñas, et al., 2014; Lago & Martín, 2007; Redwood-Brown, 2008). In addition, the leading team will often assume defensive tactics in order to maintain their winning status depending on the time of the match when they took the lead. As a result, the proportion of passes to shots on goal may be more of an accurate and universal method for predicting the number of points scored, or the relative success of a team, where a lower pass to shot on goal ratio leads to greater success (Collet, 2013). Opposition standard has also been identified as a factor influencing time in possession, with teams observing an increase in possession time when playing against weaker opposition, whilst playing against stronger opposition decreases time possession of the ball (Bradley, Lago-Peñas, et al., 2014). Although differences have been observed in a team's time in possession, it is important to note the varying tactical styles. For example direct playing styles where teams intend on getting the ball into attacking areas quickly, usually result in lower time in possession, alternatively possession based playing styles where teams maintain possession trying to break down the opponents with intricate, high tempo passing moves. Depending on the tactical style employed by a team, this would have an effect on analysing possession statistics (Lago & Martín, 2007).

In the first study of its kind, James et al. (2002) analysed the possession strategies of an English soccer team, comparing playing styles in domestic (EPL) and European soccer matches (European Champions League). In order to assess passing and possession strategies the pitch was split into 12 equally sized areas, 4 horizontally across the pitch (offensive, pre-offensive, pre-defensive and defensive sections) and 3 vertically (left, right and central sections). The results displayed a greater number of possessions and attacking actions during domestic matches started and were maintained in wide areas of the pitch, leading to more balls playing into the central offensive area (in and around the opposition attacking area) compared to European matches. In comparison, more play was focused around the central defensive and pre-defensive areas during European competitions, suggesting teams adopt more central build up play in European competitions compared to domestic matches. Similar results were observed by Mara et al. (2012) who observed the majority of successful goal scoring opportunities were produced from wide areas of the pitch distributed ≈18 yards from the goal line (edge of the penalty box). Nevertheless, these are limited findings and have limited application due to the sample sizes analysed and therefore cannot be seen as a typical representation of playing strategy as each team will have different tactics and strategies dictated by coaches, players and competitions (Tucker et al., 2005). Therefore, a wider study should be conducted to analyse general possession strategies across teams in domestic and European matches. In addition, since there are many well-established leagues across the world; it would be interesting to note the varying possession strategies within different leagues and competitions.

Researchers have previously adopted a reductionist approach, analysing either physical or technical indicators in isolation (Mackenzie & Cushion, 2013). Although physical and technical performance parameters can be seen as individual aspects of match-play, success is a culmination of suitable tactics completed with the appropriate level of physical and technical performance. Analysing each match aspect in isolation restricts the context, understanding and application of the findings. Therefore, more research should adopt an integrated approach, analysing physical and technical and/or tactical match data in order to understand the overall development and successful factors of soccer match-play. Research is also needed to investigate whether there is interaction between physical and technical performance to analyse whether the individual aspects of performance influence or affect each other.

Table 2.4: Anthropometric Characteristics of Soccer Players.

| Source | Nationality | N | Height (cm) | Mass (kg) | Body Fat (%) | BMI (kg/m$^2$) | CMJ Height (cm) |
|---|---|---|---|---|---|---|---|
| Al-Hazzaa et al., (2001) | Saudi | 23 | ≈177 | ≈73 | ≈12 | | |
| Aziz et al., (2007) | | 37 | ≈170 | ≈70 | | | |
| Castagna, Impellizzeri, Chamari, et al., (2006) | | 24 | ≈178 | ≈75 | | | ≈47 |
| Chamari et al., (2004) | Tunisian | 34 | ≈178 | ≈71 | ≈12 | ≈23 | 51 |
| Chin, Lo, Li, & So, (1992) | Hong Kong | 24 | 173 | 68 | 7 | | |
| Fidelix et al., (2014) | Brazilian | 67 (youth) | 176 | 70 | | 22 | |
| Haugen, Tønnessen, & Seiler, (2013) | Norwegian | 939 (Female) | 182 | 79 | | 23 | 39 |
| Kulkarni, Levin, Peñailillo, Singh, & Singh, (2013) | Indian | 28 | 173 | 72 | 17 | 24 | 54 |
| Magalhães Sales et al., (2014) | UAE | 27 | 175 | 70 | 12 | 23 | |
| Ostojic, (2000) | Serbian | 16 (Elite)<br>16 (Amateur) | 182<br>181 | 77<br>74 | 11<br>10 | | 48<br>46 |
| Rebelo et al., (2013) | Portuguese | 190 | 174 | 75 | 10 | | 42 |
| Ueda et al., (2011) | Japanese | 82 | 174 | 68 | 13 | 23 | |

Table 2.5: Physical Characteristics of Soccer Players.

| Source | Nationality | N | $VO_{2max}$ (ml·kg$^{-1}$·min$^{-1}$) | $HR_{max}$ (beats·min$^{-1}$) | Resting Lactate (mmol·l$^{-1}$) | Peak Lactate (mmol·l$^{-1}$) | Peak Power (W·kg$^{-1}$) | Yo-Yo IE Test (m) |
|---|---|---|---|---|---|---|---|---|
| Al-Hazzaa et al., (2001) | Saudi | 23 | ≈57 | ≈190 | ≈1.5 | ≈10 | ≈12 | |
| Aziz et al., (2007) | | 37 | ≈54 | ≈195 | | | | |
| Bradley, Bendiksen, et al., (2014) | European | 199 | | ≈180 | | | | 1500 |
| Bradley, Mohr, et al., (2011) | European | 162 | | ≈200 | | | | ≈2500 |
| Castagna et al., (2005) | Italian | 42 | | 190 | | | | 1200-1900 |
| Castagna et al., (2006) | Italian | 18 | ≈50 | 190 | | | | ≈3000 |
| Castagna, Impellizzeri, Chamari, et al., (2006) | | 24 | ≈56 | | | | | 2100 (Level 1)<br>1300 (Level 2) |
| Chamari et al., (2004) | Tunisian | 34 | 61 | 191 | | 11.6 | | |
| Chaouachi et al., (2010) | Tunisian | 23 | | | | | | ≈2230 (Level 1) |
| Chin et al., (1992) | Hong Kong | 34 | 59 | 179 | | | 13.5 | |
| Fernandez-Gonzalo et al., (2010) | | 30 | 55 | 207 | | | | |
| Haugen et al., (2014) | Norwegian | 199 (Female) | 56 | | | | | |
| Krustrup & Bangsbo, (2001) | | 27 (Referees) | 47 | 190 | | | | 1100-2000 |

Table 2.6: Physical Characteristics of Soccer Players continued

| Source | Nationality | N | $VO_{2max}$ ($ml·kg^{-1}·min^{-1}$) | $HR_{max}$ ($beats·min^{-1}$) | Resting Lactate ($mmol·l^{-1}$) | Peak Lactate ($mmol·l^{-1}$) | Peak Power ($W·kg^{-1}$) | Yo-Yo IE Test (m) |
|---|---|---|---|---|---|---|---|---|
| Krustrup et al., (2003) | | 37 | 51 | 187 | 1.0 | 10.1 | | 1800 (Level 1) |
| Krustrup et al., (2006) | | 13 | 53 | 191 | 2.4 | 11.5 | | 590 (Level 2) |
| Kulkarni, Levin, Peñailillo, Singh, & Singh, (2013) | Indian | 28 | | 190 | | | | 2030 |
| Magalhães Sales et al., (2014) | UAE | 27 | 59 | 190 | | | 8 | |
| Rampinini et al., (2010) | | 13 (Pro)<br>12 (Amateur) | | 188<br>190 | 1 | 12 | | 2200/960 (Level 1/2)<br>1830/610 (Level 1/2) |
| Strøyer et al., (2004) | Danish | 26 | 59 | 199 | | | | |
| Tønnessen et al., (2013) | Norwegian | 1545 | 65 | | | | | |
| Ueda et al., (2011) | Japanese | 82 | 61 | | | | | 2400 (Level 1)<br>1000 (Level 2) |
| Veale, Pearce, & Carlson, (2010) | Australian | 60 (Junior) | | | | | | 1900 (Professionals)<br>1440 (Semi-pro)<br>770 (Non-athletes) |

### 2.3.4 Physiological and Anthropometric Data

The physiological and anthropometric requirements of soccer have been widely studied (Stølen et al., 2005). Goalkeepers are the tallest players on a team, on average >180 cm, whilst midfielders are the shortest players ≈170 cm and defenders and attackers a similar height >175 cm (Al-Hazzaa et al., 2001; Boone, Vaeyens, Steyaert, Vanden Bossche, & Bourgois, 2012; Kulkarni et al., 2013; Matković et al., 2003; Sporis, Jukic, Ostojic, & Milanovic, 2009). These results are unsurprising, particularly the similar heights between defenders and attackers as teams recruit taller players in order to compete in aerial challenges. Midfield players, in contrast, are often more technical players, using their skills with their feet rather than competing with the opposition in the air. The percentage of body fat in soccer players is dependent upon player nationality with Indian players recording greater body fats compared to European, Asian and South American players (Al-Hazzaa et al., 2001; Chamari et al., 2004; Chin et al., 1992; Kulkarni et al., 2013; Ostojic, 2000; Ueda et al., 2011). Indian players recorded body fats of 16-18% (Kulkarni et al., 2013), compared to 10-15% recorded in a European players (Al-Hazzaa et al., 2001; Boone et al., 2012; Matković et al., 2003; Sporis et al., 2009) and <10% in Asian players (Chin et al., 1992).

$VO_{2max}$ has been recorded to remain fairly stable across the last 20-30 years with the majority of elite male subjects recording a $VO_{2max}$ between 50 and 60 $ml \cdot kg^{-1} \cdot min^{-1}$ (Table 2.5 and 2.6), (Haugen et al., 2013, 2014, 2012; Tønnessen et al., 2013). With the differences observed in physical match performance both between individual players and between performances and with limited to no differences in $VO_{2max}$, it has been concluded that

$VO_{2max}$ does not influence match running performance (Reilly et al., 2000; Stølen et al., 2005). Alternatively, specific tests which measure intermittent endurance capacity have been developed which mimic match activities more closely and have been shown to correlate more strongly match with match performance (Bangsbo et al., 2008; Bradley, Bendiksen, et al., 2014; Bradley, Mohr, et al., 2011; Krustrup et al., 2003, 2006). Intermittent endurance capacity, measured through yo-yo tests (Bangsbo et al., 2008; Bradley, Bendiksen, et al., 2014; Castagna, Impellizzeri, Belardinelli, et al., 2006; Castagna et al., 2005; Krustrup et al., 2003, 2006) and soccer specific drills (Chamari et al., 2004), are dependent upon playing level, age, gender and nationality, and adapt following periods of training (Elferink-Gemser, Huijgen, Coelho-E-Silva, Lemmink, & Visscher, 2012).

Players have consistently been measured to perform well in squat and counter-movement jump tests. Goalkeepers again perform the best out of all positions, although all players have been recorded to perform over 40cm in both squat and counter-movement jumps (Boone et al., 2012; Haugen et al., 2013; Kulkarni et al., 2013; Sporis et al., 2009). Explosive power has been identified as a key factor and strong correlates strongly with sprint performance during matches (Wisløff, Castagna, Helgerud, Jones, & Hoff, 2004), this emphasises the importance of rapid movements in soccer and identifies alternative methods of monitoring explosive performance.

### 2.3.5 Evolution of Soccer

Until now research has often used data from multiple seasons in order to gather large amounts of data thus providing reliable and valid analysis (Barros et al., 2007; Bradley & Noakes, 2013; Carling & Dupont, 2011;

Castellano et al., 2012; Di Salvo et al., 2010; Gregson et al., 2010; Taylor et al., 2008). Nevertheless, this often occurs without analysing the changes or variation between seasons. These methodological approaches, although providing large sample sizes to identify playing styles, can desensitise information and disguise the visibility of trends or evolving patterns within the data and therefore may provide unreliable information to practitioners.

The limited research articles that have analysed the changes in soccer players have identified physiological and anthropometrical adaptations in soccer players. Soccer players are now taller and have greater body mass when compared to previous decades (Nevill, Holder, & Watts, 2009; Norton & Olds, 2001; Wong et al., 2008), although BMI and skinfolds appear to be fairly stable measurements over the same time period (Nevill et al., 2009; Norton & Olds, 2001; Wong et al., 2008). In addition to the changes in the physiological capabilities, both strength and power have also been measured to increase over the last 20-30 years, with players now capable of performing greater counter-movement jump heights as well as performing better at sprint testing during initial acceleration (0-20 m) and over greater distances (20-40 m), (Haugen et al., 2013, 2012). These changes in sprint and acceleration of players is combined with increases in the intermittent endurance capacity (Elferink-Gemser et al., 2012) and are potentially a result of increased quantity and quality of training (Elferink-Gemser et al., 2012). The increase in quantity of training and the respective increases in the physical capabilities of soccer players would be expected to have a direct impact on performance during matches, although the effects of these changes on physical performance has received little attention in research disciplines.

Despite the fact some research papers have examined multiple seasons in order to provide a large sample size for analysis, there has been a lack of research papers analysing the seasonal trends and the evolution in match play (Mackenzie & Cushion, 2013). The limited research across the football codes has recorded a reduction in the overall ball in play time, as well as the continuous ball in play time (Eaves, Lamb, & Hughes, 2008; Norton, Craig, & Olds, 1999; Wallace & Norton, 2014) whilst the intensity of match play has increased (Barnes et al., 2014). In the middle of the 20$^{th}$ Century, playing periods where the ball was in play for 2-3 minutes were frequently observed, however by the end of the 20$^{th}$ Century ball in play periods greater than 80 seconds were rarely seen (Norton et al., 1999). In contrast, duration of stoppages and rest periods were rarely over 30 seconds, although the frequency of short rest periods has decreased and the frequency of longer rest periods has increased (Norton et al., 1999).

The increase in match intensity is not only for physical variables, such as the number of sprints, high-intensity actions, or distance covered whilst running at high-intensities (Barnes et al., 2014; Burgess, Naughton, & Norton, 2012), but also in the technical aspects of match play, such as total passes performed, ratios of passes per minute and the average ball speed during a game (Barnes et al., 2014; Eaves et al., 2005, 2008; Wallace & Norton, 2014). Whilst the number of passes and the tempo of matches have increased the number of goals scored has decreased, particularly the number of goals scored from set plays (Prozone, 2014; Wallace & Norton, 2014).

English teams have previously adopted playing styles due to findings in the research by Reep and Benjamin (1968), the incorrect interpretation of these results led to a direct style of play which has since been shown to be less successful than possession based playing styles (Bradley, Lago-Peñas, et al., 2013; Castellano et al., 2012; Collet, 2013; Lago-Ballesteros et al., 2012; Lago-Peñas & Dellal, 2010). Though speculative, these modern research findings have led teams, particularly in the EPL, to change playing tactics from direct styles to more possession based playing styles although teams in the EPL are still more direct than their counterparts in other European leagues (Prozone, 2014). It has been observed that teams higher in the EPL (those performing against more possession based teams in the UEFA Champions League) adopt more possession based playing styles in the EPL, therefore possibly driving the evolution in playing styles, compared to the teams at the bottom of the league and those fighting relegation to the Championship (England's 2nd league) who still play more direct playing styles (Bradley, Carling, et al., 2013; Prozone, 2014). One possibility for this change in playing styles may be due to the teams qualifying and playing in European leagues each season and have been forced to adapt their playing styles in order to compete with the European teams. As a result, the English teams then bring the new playing tactics back to the EPL, thus maintaining playing tactics across formats. In contrast the teams fighting relegation adopt more direct styles in the lower divisions but do not develop playing styles when promotion to the EPL is achieved. An alternative reason could be that the EPL has seen rapid increases in the number of non-UK players and managers with greater experience playing possession-based football being employed in the EPL (BBC, 2013). These non-UK players are generally employed by the top teams in the EPL in order to compete in European competitions, as a result the top teams may have modified their playing styles in order to incorporate the non-UK players into their squads. In contrast the lower level teams are unable to afford non-UK players with the same level of experience and therefore may continue to adopt more direct playing styles as they have previously found them to be successful. However, these are only potential reasons for the changing playing styles, no clear evidence has been proposed for the changes in playing styles observed in the EPL.

The research that has analysed the evolution in the football codes provides limited information on the changes observed within playing practices. Greater research needs to be conducted in this area in order to understand the changes that are occurring within football and the potential causes for any changes observed.

#### 2.3.6 Variability in Soccer Performance

Performance variability can adopt different perspectives, it can refer to either the overall performance (technical or physical) on a match-to-match or even a half-by-half basis (Gregson et al., 2010; Rampinini et al., 2007; Weston, Drust, et al., 2011), or it can refer to a player’s ability to execute individual actions (Bartlett et al., 2007; Kellis, Katis, & Vrabas, 2006). Researchers have often assumed that inconsistency in performance, whether physical or biomechanical has been a result of errors or noise within the sampling process, i.e. methodological issues or errors in testing equipment (Bartlett et al., 2007), however more recently research has demonstrated that there is a level of variability inherent within sporting performances (Bartlett et al., 2007; Gregson et al., 2010), which can be affected by factors such as age and experience (Weston, Drust, et al., 2011), opposition and match variables (Mohr et al., 2003; Rampinini et al., 2007) and fatigue (Kellis et al., 2006).

The limited research available on movement variability suggests that variability is inherent within performance, irrespective of age or experience of the performer. This variability may be due to several factors, as suggested in dynamical systems theory, an experienced performer may introduce variability (minor changes in the movement patterns) in order to complete an identical task under differing circumstances with the maximal achievable result (Davids et al., 2003; Glazier & Davids, 2009; Newell, 1986). For example, passing a football may be affected by the location of the individual passing the ball, the individual receiving the ball, opposition player positioning and environmental and pitch conditions, thus changing the movement pattern in order to pass the ball from one player to another whilst taking the above factors into account. Alternatively, it has also been proposed that variability may be an involuntary measure to reduce repeated biomechanical loading on the same tissues which would potentially lead to overuse injuries over a period of time (Bartlett et al., 2007). In addition to overloading of tissues, biomechanical changes in both kicking and running can be caused by fatigue. Fatigue has been shown to induce changes in the strength, and therefore velocity, around the knee joint when performing kicking actions and whilst running at higher intensities (Kellis et al., 2006; Small et al., 2009). As previously discussed, fatigue can occur during a match, either temporarily or permanently, combining the biomechanical changes and the enduring technical requirements there is an increased injuries risk when fatigue occurs (Small et al., 2009). The occurrence of fatigue during a match may be one cause of the variability observed within performance and therefore must be taken into account when measuring variability.

Stability in sporting performance is essential for the reliable and accurate assessment of individual, unit and team performance (Hughes et al., 2001; Mytton, Archer, Gibson, & Thompson, 2014), stability is assumed when a level of consistency can be observed between multiple performances (Mytton et al., 2014). Comparative methods have been proposed to assess the stability between performances, including calculating coefficients of variation, 90 and 95% confidence limits and *t* tests (Atkinson & Nevill, 1998). A separate method was proposed by Hughes et al. (2001), who suggested calculating cumulative means for successive performances and measuring the number of matches required before performance ‘stabilised’. Once the cumulative means levelled within 10, 5 or 1% error limits it was assumed that performance has become consistent, the lower limits of error achieved the more accurate the assessment of performance (Hughes et al., 2001). The cumulative method has previously been applied in a variety of racket sports and team sports including rugby union (Hughes et al., 2001) as well as lap times in both swimming and running (Mytton et al., 2014). Although limited research has been conducted using stability measures, there has been general agreement in the findings. Typically performance parameters stabilise to within 10% limits of error after 2 or 3 matches, this includes parameters such as the number of shots per rally, the number of rallies per game and per match, the number of winners and errors per match (Hughes et al., 2001) and the lap times for 400 metre swimmers and 1500 metre runners (Mytton et al., 2014). However the rate of stabilisation is dependent upon the frequency of performance parameters, parameters which occur more often, or parameters which are ratios stabilise quicker than less frequent parameters (Hughes et al., 2001). This was displayed in the number of variables that rapidly stabilised to 10% error limits but took over 10 observations to stabilise to 5% or 1% error limits, alternatively other variables such as the total number of shots and rallies in a game do not stabilise to the lower error limits at all (see Figure 2.8). In contrast, Mytton et al. (2014) found all lap times for 400 metre swimmers and 1500 metre runners stabilised after 2 races, except the 1st lap of a 1500 metre event, which took 16 observations to stabilise to 5% error limits. The 400m swimming events also observed lap times stabilised to 1% error limits before 10 observations whilst lap times for 1500 metre runners took up to 45 observations to stabilise to the same error limits. The rate of stabilisation appeared to be reflected by the coefficients of variation (CVs), 400 metre swimmers recorded CVs less than 2% across all lap times, whilst 1500 metre runners recorded CVs up to 5%, in particular for the first lap of a race (Mytton et al., 2014). Interestingly, this was the same variable that took the longest to stabilise using the cumulative mean method. No research has attempted to apply this method of stability assessment to match parameters in soccer;

neither has research found empirical evidence for the relationship between stability and reliability.

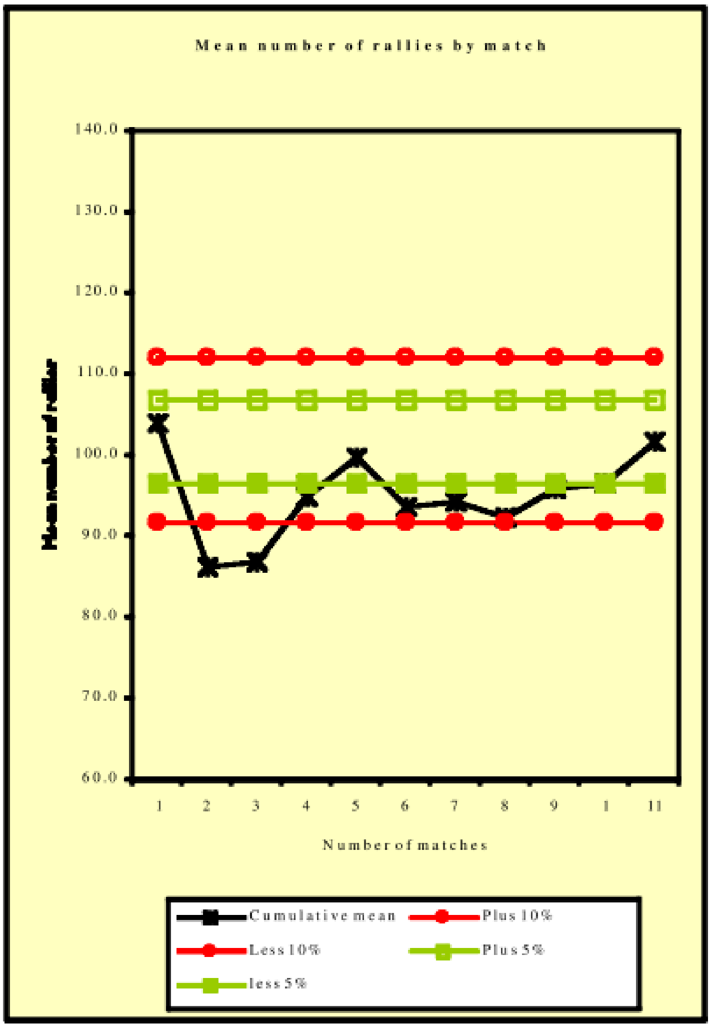


Figure 2.8: Example of stability profiles for the number of rallies per match in tennis (Adapted from Hughes, Evans and Wells, 2001)

Studies assessing performance variability, typically measured on a match-to-match basis through calculating coefficients of variation, have only measured the variability in physical performance and have not assessed the inherent variability of technical variables. Due to the vast distances covered during a match, total distance covered has been recorded to vary as little as 3% (Rampinini et al., 2007; Weston, Drust, et al., 2011), although it is unclear how positional changes affect the variability of total distance. The coefficient of variation for high-intensity running distance have been measured at approximately 15% (Gregson et al., 2010; Rampinini et al., 2007; Weston, Drust, et al., 2011), although this is affected by the distance covered at high intensities with and without possession of the ball, with the high-intensity running distance with possession recording match-to-match variability up to 40% (Gregson et al., 2010). Total sprint distance has recorded match-to-match variability ≈30% (Gregson et al., 2010), although the number of sprints show greater variability ≈50% (Weston, Drust, et al., 2011). Whilst the research has begun to analyse the variability on a match-to-match basis, so far research has given little focus to positional or contextual effects on physical or technical performance.

## 2.4 Migration of Soccer Players

Migration of soccer players has been a long-standing debate for the last decade or two, in particular for players coming to the big five European leagues (England, Spain, Germany, France and Italy). Teams in the EPL were recently found to play more non-native players, i.e. players not registered to play for UK countries, than native players (BBC, 2013). In the 2013-14 season native players were found to average approximately 30% of the total squad size in each of the two teams (Transfermarkt, 2014), native players played a similar percentage for the number of minutes played (32%; BBC, 2013). This is the reverse of the data from the mid-1990s when non-native players contributed approximately 30-40% of squad sizes in the EPL (Transfermarkt, 2014). Whilst English leagues are seeing increasing numbers of non-native players, the export opportunities for native players to perform in other European or Worldwide leagues is limited (Baur & Lehmann, 2007). Migration in sport has always been evident, nevertheless the movement of players to the EPL has increased every season since the Bosman ruling in 1995 (Binder & Findlay, 2012). The Bosman ruling had many implications for the transfers of players, with the main outcomes were the abolition of transfer fees for players out of contract as well as preventing the introduction of squad rotas for the number of native to non-native players (Binder & Findlay, 2012; Gardiner & Welch, 2011). The majority of the research on migration within soccer has analysed the financial and social aspects of migration (Free, 2007; Gardiner & Welch, 2011; Littlewood et al., 2011; Maguire & Pearton, 2000; McGovern, 2002; Richardson, Littlewood, Nesti, & Benstead, 2012). In contrast, there has been limited research analysing the impact of player migration on physical and technical performance. So far, research has found empirical evidence suggesting that player migration has positively influenced the spectator support at both national and domestic levels (Binder & Findlay, 2012; Littlewood et al., 2011; Maguire & Pearton, 2000; McGovern, 2002; Richardson et al., 2012). As a consequence of increased spectator support, the funding from sponsorship and financial rewards for performances have been driven higher, therefore placing more importance and greater need to win, in particular at domestic levels (Binder & Findlay, 2012; McGovern, 2002). This drives the need to acquire better players for domestic leagues and results in a vicious repetitive cycle where home-grown talent do not get playing time with their first team. Although this may develop the domestic game in the short term, in the long term this may have a catastrophic impact on domestic football and the sport as a whole where there are few home-grown players performing at the highest domestic level therefore gaining the experience and knowledge to play at the highest level on the international stage, which has previously been observed in other European leagues (Doidge, 2015).

A select number of research articles have analysed the effect of player imports and exports on national team and club performance (Baur & Lehmann, 2007; Binder & Findlay, 2012). Mixed outcomes have been found regarding the effects of increased import and exports of players on their respective national teams as well as the national team of the country in which their playing club is located. There are suggestions that increasing numbers of both imports and exports leads to stronger playing performance at both domestic and national team level (Baur & Lehmann, 2007; Binder & Findlay, 2012). This is a strong possibility, for example by both increasing the number of non-UK players performing in the EPL and the number of UK players playing in European leagues will expose UK players to some of the world's best players, against different formations and playing styles which should result in an improvement in their own game (Binder & Findlay, 2012). However the EPL is one of the biggest importers of non-UK players, whilst exporting one of the smallest numbers of native players to other leagues, either European or Worldwide (Baur & Lehmann, 2007). This imbalance between imports and exports leads to a reduced number of UK players being exposed to different playing styles and therefore potentially reduces the number of native players available to play for the national team with the experience of playing at the highest level. Therefore, for countries who have fairly balanced player import-exports the effects of the Bosman ruling are potentially positive, however for countries with domestic leagues with a stronger import to export ratio there appears to be a negative effect of the Bosman ruling. A stronger export to import player ratio appears to have less of an impact on the countries world ranking (Baur & Lehmann, 2007). A stronger import to export player ratio also suggests that native players become more of a valuable commodity for domestic clubs and therefore result in a more expensive but less effective national team (Baur & Lehmann, 2007). One suggestion on the effects of national team performance has been that national teams do not suffer from a lack of talented players but that players do not perform optimally when exposed to critical situations in a match (Binder & Findlay, 2012), it is unclear how much following this suggestion has, or the evidence behind it, but if this is the case it may be a result of the players lacking the required experience in similar situations, in particular with the experience of environmental factors, to perform the required response.

In the modern game it has become normal practice for all domestic clubs to import non-native players with the view to facilitate squad strength. It is often the big clubs in each domestic league that attract the world's greatest players, and as a result each of the top five European leagues (England, France, Germany, Spain and Italy) are often segregated into two leagues themselves. The top clubs in each domestic league providing one league season after season and thus have created a super league in terms of the UEFA Champions League, there is then the remaining teams who fight for the remaining places in the league (Binder & Findlay, 2012). Nonetheless it is unclear how this has affected match play, nor can it predict the future effects on both domestic and national teams. Despite the evidence analysing the effect of player migration on national and domestic clubs, the research so far has only analysed the effects on broad outcome-based variables, for example the effect of imports and exports on FIFA ranking (Baur & Lehmann, 2007). No research has tried to quantify the physical and technical performance effects of non-native players performing in domestic leagues.

# *Chapter 3* : Study 1: Stability and Variability of Technical and Physical Performance Parameters in the English Premier League

### 3.1 Introduction

There is an inherent level of variability within physical and technical performance due to the dynamical nature of sport (Chow et al., 2011; Davids et al., 2003; Gréhaigne et al., 1997; McGarry et al., 2002). During a match players will form relationships, or dyads, with other players, both with team mates as well as the opposition and these relationships break at the end of a game and will be reformed against the next opponents (Davids et al., 2003; McGarry et al., 2002). Defining the variability within performance parameters can be a useful tool for coaches and analysts alike (Vilar et al., 2012), although thus far this has received limited research (Gregson et al., 2010; Mohr et al., 2003; Weston, Drust, et al., 2011). This information can be used to indicate the boundaries of a typical performance, which can then be applied to the coaching process in order to maximise the physical preparation of players and minimise the impact of fatigue. Multiple measures have been proposed to analyse the variability and accuracy of measuring performance variables (Gregson et al., 2010; Hughes et al., 2001; Mytton et al., 2014). Despite the importance of accurate and reliable performance data, very few research papers have analysed any method of stability or validity (Mackenzie & Cushion, 2013). Stability measures the number of matches required for performance to become consistent whilst coefficients of variation and limits of agreement estimate the variability between performances. Although it is unclear which method is more effective at assessing the inconsistency of match performance due to the lack of research. Total distance covered during a match has been shown to vary as little as 3% (Mohr et al., 2003), whilst high-intensity running distance and the number of high-intensity actions have been measured to vary between 9 and 30% (Gregson et al., 2010; Mohr et al., 2003). Variation in performance is higher for central defenders and midfielders than for wide midfielders and attackers (Gregson et al., 2010). However, no research has analysed physical variables such as the number of sprint actions or sprint distances covered, types or sprint (leading vs. explosive) or the average distance per sprint, nor has an examination of the technical variability in performance been undertaken.

Match context, in particular match location but also opposition standard and match evolving match score, has been identified as affecting both physical and technical performance of soccer players (Bradley, Lago-Peñas, et al., 2014; Jacklin, 2005; Lago et al., 2010; Lago-Ballesteros et al., 2012; Lago-Peñas & Dellal, 2010; Nevill, Balmer, & Wolfson, 2005; Pollard, 2008; Redwood-Brown, Bussell, et al., 2012; Sánchez et al., 2009; Taylor et al., 2008). Home teams not only have more success than away teams, but often perform better for both technical and physical factors, covering greater distances, in particularly at low intensities (Lago et al., 2010), but also perform fewer fouls, lose possession fewer times, receive fewer cards (yellow and red), perform more passes, successful passes, crosses, possession regains as well as key variables such as the number of shots, shots on target and goals (Lago-Peñas & Lago-Ballesteros, 2011; Poulter, 2009). Matches played against strong opposition result in the weaker team traditionally having less ball possession, fewer shots, passes and goals scored (Lago-Peñas & Lago-Ballesteros, 2011; Redwood-Brown, Bussell, et al., 2012; Taylor et al., 2008). Although these factors have been shown to impact performance, there is a possibility that the changes under match locations are due to changes in the variability when exposed to different environmental factors, however as limited research exists on variability alone, it is unclear how match context affects match-to-match variability.

In addition, no studies have been published to date that have used a combined approach (analysing both physical and technical variability), and taken into account the influence of several known contextual factors on match-to-match variability (e.g. team standard, match location and result), (Mackenzie & Cushion, 2013). This is surprising as numerous studies have found that context influences both physical and technical performance of teams (Lago, 2009; Lago-Peñas & Lago-Ballesteros, 2011; Taylor et al., 2008) and thus the variability in performance could be partly explained by some of these factors. Therefore, the first aim of this study was to analyse performance stability methods and their usefulness in assessing the number of matches required for analysing performance. A secondary aim this study aimed were provide a greater understanding of the inherent physical and technical variability within performance, with a further objective to analyse the effect of different match contexts on the variability in performance.

## 3.2 Methods

### 3.2.1 Match Analysis and Player Data

#### 3.2.1.1 Match-to-Match Variability

Match performance data were collected from multiple EPL seasons (2005-06 to 2012-13) and consisted of 451 individual players across 3016 observations (mean=7, range=2-93 observations per player). Data were analysed in five playing positions: central defenders (*n*=110, mean=8.3, range=2-60), full backs (*n*=99, mean=7.3, range=2-93), central midfielders (*n*=108, mean=6.1, range=2-45), wide midfielders (*n*=59, mean=7.3, range=2-36) and attackers (*n*=75, mean=6.7, range=2-55). Original data files were de-sensitized and included 20 teams in each season. Individual match data were only included for players that completed entire matches. Ethical approval was granted from the appropriate institutional ethics committee (Ethics code 182).

Data were obtained from a computerised multiple-camera tracking system (Prozone 3, Prozone Sports Ltd®, Leeds, UK). Players' movements were captured during matches by cameras positioned at roof level and analysed using proprietary software to produce a dataset on each players' physical and technical performance. The validity and reliability of this tracking system has been quantified to verify the capture process and data accuracy (Bradley, O'Donoghue, Wooster, & Tordoff, 2007; Di Salvo, Collins, McNeill, & Cardinale, 2006). Inter-operator reliability of technical performance parameters has been measured at 99.3% with 95% of variables coded within one tenth of a second by both observers (Bradley et al., 2007). The computerised-tracking system was tested in comparison to timing gates with almost perfect correlations measured for a variety of tests including straight sprints, angled runs and dribbles with the ball ($r>0.9$; Di Salvo et al., 2006).

#### 3.2.1.2 Stability of Match Performances

Due to the nature of the calculations for performance stability, inclusion criteria were set up from the data set to allow for accurate testing of performances. The inclusion criteria was set at a minimum of 8 match observations for each player, based on previous research by Hughes, Evans and Wells (2001). This limited the number of observations to 1833 across 108 players (mean=17, range = 8-93 observations per player). The breakdown of the data resulted in 35 centre backs (592 observations), 22 central midfielders (348 observations), 16 attackers (281 observations), 21 full backs (379 observations) and 14 wide midfielders (233 observations) being analysed for stability profiles.

**3.2.2 Match Performance Parameters**

Activities were coded into: standing (0-0.6 $km \cdot h^{-1}$), walking (0.7-7.1 $km \cdot h^{-1}$), jogging (7.2-14.3 $km \cdot h^{-1}$), running (14.4-19.7 $km \cdot h^{-1}$), high-speed running (19.8-25.1 $km \cdot h^{-1}$) and sprinting (>25.1 $km \cdot h^{-1}$), (Bradley & Noakes, 2013; Bradley et al., 2009, 2011; Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007). Total distance represented the summation of distances covered in all categories. High-intensity running consisted of the combined distance in high-speed and sprinting (>19.8 $km \cdot h^{-1}$) and was separated into three subsets based on teams possession status: with (WP) or without ball possession (WOP) and when the ball was out of play (BOP). Technical events included the number of passes attempted, passing success, number of passes received, interceptions, the number of tackles completed per player and the number of times the player was tackled, the number of possessions won/lost and the average number of touches per possession were selected for analysis. These performance parameters were selected based on the speed thresholds on the analysis software and due to the proportion of research articles adopting similar boundaries. Technical performance parameters were selected based on those which were performed by all positions allowing for comparisons.

### 3.2.3 Stability in Performance

Predicting future performance is a key aspect for practitioners and researchers within a sporting context, previously research has suggested that understanding the stability of performance indicators must be achieved in order to predict future performances accurately (Hughes et al., 2001). Despite this, few research papers have investigated, let alone quantified, the number of matches required for performance indicators to stabilise (i.e. the number of matches required where the cumulative mean remained within set limits of error), and therefore provide a number of matches required for accurate assessment of performance (Mackenzie & Cushion, 2013). Hughes et al. (2001) proposed a method of assessing the stability of match performance through the generation of cumulative means and used this process to calculate the minimum number of games required in order to supply a sample large enough to provide an accurate illustration of performance without becoming insensitive to changes in performance.

In order to calculate the stability of performance variables, Hughes et al. (2001) suggested a simple methodology to calculate the number of matches required to display a stable profile. This included calculating the cumulative mean by calculating the sum of the occurrences of the variables divided by the number of matches analysed. It was deemed that performance had stabilised once the cumulative mean was consistently within 10%, 5% or 1% of the total mean, the lower the limits of error the more accurate the stabilisation of the performance parameter (Figure 3.1). For example, analysing the stability for the number of passes made in a match would be calculated as follows: the number of passes in match 1 combined with the number of passes in match 2 divided by the number of matches (2), following on from this a third, fourth and fifth match would be added to the calculation until the cumulative mean reach within the set limits of error, thus producing the following equation:

If: ‘$x_1$’ = the frequency of occurrences (number denotes match)

‘n’ = number of matches analysed

‘$x_{T'}$ = overall average of occurrences

Cumulative mean = ($x_1$ + $x_2$…….) / n

Limits of error (10%) = $x_T \pm (x_T \times 0.1)$

(5%) = $x_T \pm (x_T \times 0.05)$

(1%) = $x_T \pm (x_T \times 0.01)$

Data are presented as mean±SD number of matches.

As seen in the example (Figure 3.1), the individuals sprint distance stabilises to within 10% and 5% of the mean after 6 matches, this is the first time the data is consistently within these limits of error. The data in the example does not stabilise to 1% of the mean until the penultimate observation. Due to the calculation of the cumulative mean, the stability profile will always converge on the last data point. As a result, the data for this participants sprint distance data does not stabilise to 1% of the mean.

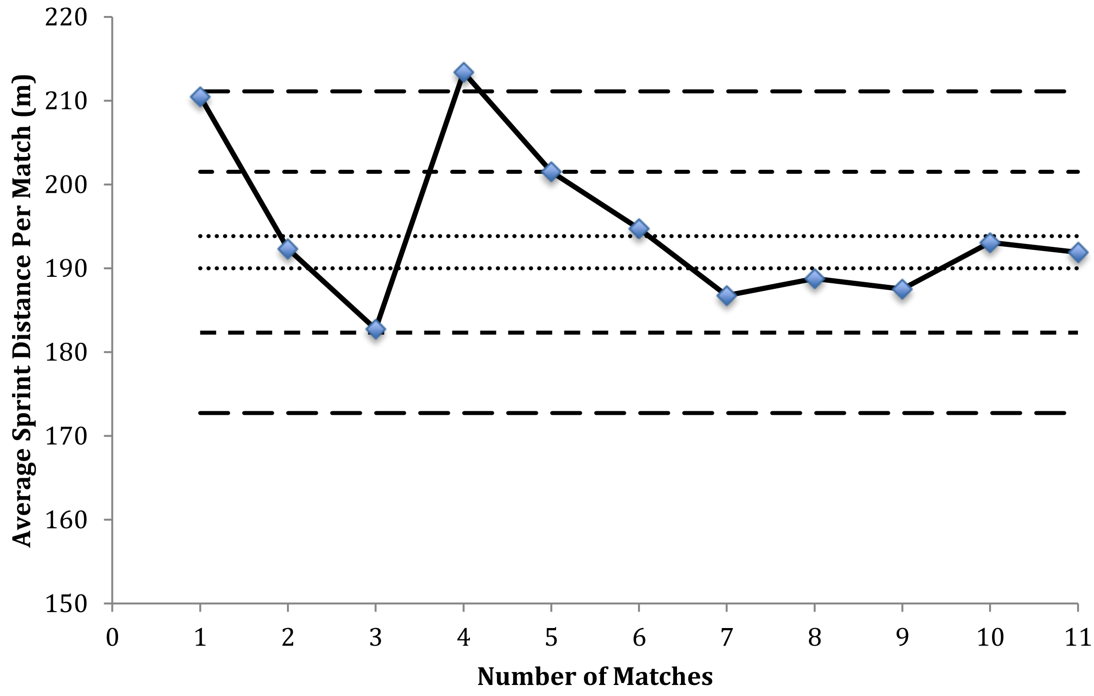


Figure 3.1: Example for the calculation of the stability profile for a players sprint distance, displaying the performance parameter (——), 10% error limits (– – – –), 5% error limits (- - -) and 1% error limits (· · ·).

### 3.2.4 Coefficients of Variation

Players' physical and technical performance measures were analysed to quantify the match-to-match variability using the coefficient of variation (CV) and subsets calculated for positional and contextual variables. This included total CV for each player; match location (home and away), standard of opposition (stronger/similar standard/weaker) and match result (won/lost/drawn). Parametric tests were conducted to highlight statistical differences between the means of the CVs. One-way ANOVAs were used to analyse differences in the recorded CVs between the five outfield positions (independent variables were set as position whilst dependent variables were set as the physical and technical CVs). Two-way ANOVAs were used to analyse differences between the contextual variables on the calculated CV (Independent variables were set as position and context whilst dependent variables were set as physical and technical CVs). The effect size (ES) was calculated to determine the meaningfulness of the difference (Cohen, 1988) and magnitudes classified as trivial (<0.2), small (>0.2-0.6), moderate (>0.6-1.2) and large (>1.2-2.0) using the recommendations of Batterham and Hopkins (2006). Relationships between the CV's for physical and technical indicators were evaluated using Pearson's product moment test. The correlation magnitudes were considered as trivial ($r$<0.1), small ($r$>0.1-0.3), moderate ($r$>0.3-0.5), large ($r$>0.5-0.7), very large ($r$>0.7-0.9), nearly perfect ($r$>0.9) and perfect ($r$=1.0) in accordance with Hopkins, Marshall, Batterham, & Hanin (2009). Match stability accumulative means were also used to calculate the number of games required for measures to stabilise to within 10% of the mean using the procedures of Hughes et al. (2000). Players were only included if they had completed a minimum of 8 games. All analyses were conducted using statistical software (SPSS, Chicago, USA) with significance set at $p<0.05$.

**3.2.5 Hypothesis**

$H_0$ – Variability between match performances will be low, with variability similar across all physical and technical performance measures

$H_0$ – Match-to-match variability will not be affected by the situation or the context of the match (match location, opposition standard, match result).

## 3.3 Results

### 3.3.1 Stability Results

The stability of match parameters depended on the parameter analysed and had minor effects according to playing position, all values reported are to within 10% of the mean unless otherwise stated. The results from the stability assessment indicated that total distance required the fewest number of matches (Figure 3.2) for analysis and stabilised to within both 10% and 5% of the mean after 2 matches (2.0±0.1 and 2.2±0.7 matches respectively), although required a greater number of matches to stabilise to within 1% of the mean (10.0±8.9 matches). Total high-intensity running distance stabilised within approximately 4 matches (4.4±3.5 matches), whilst the number of high-intensity actions and the recovery time between high-intensity actions stabilised within 5-6 matches (5.4±4.3 and 5.5±4.4 matches respectively). Sprint distance and high-intensity running distance covered with and without possession required 7-8 matches to stabilise on average (7.0±4.9, 8.0±6.4 and 6.7±6.0 matches respectively). Centre backs required the highest number of games to stabilise for physical parameters compared to all other positions. Centre backs required 9±7 matches for sprint distance, 6±6 matches for high-intensity running distance, 11±10 matches for high-intensity running distance with possession and 7±6 matches for recovery time to stabilise. Data for technical variables recorded a greater number of matches required before stabilisation occurred (Figure 3.3). The number of passes performed stabilised within approximately 7 matches (7.2±6.2 matches) whilst the number of passes received stabilised after 8.8±8.1 matches, nevertheless the pass completion rate stabilised after a small number of matches (3.2±2.0 matches). The number of possessions won per match stabilised after 8.0±6.0 matches, in contrast the number of possessions lost stabilised after 6.5±4.9 matches and the average number of touches per possession stabilised after 4.1±3.3 matches. Tackling variables recorded the highest number of matches required to stabilise within 10% of the mean our of all technical and physical variables, the number of tackles a player performed per match stabilised after 11.7±6.9 matches whilst the number of times a player was tackled per match stabilised after 11.8±7.8 matches. Centre backs required the highest number of games to stabilise for the number of passes made and passes received (9±6 and 11±11 respectively) compared to all other positions. In contrast, wide midfielders and full backs required the lowest number of matches to stabilise for the number of passes made (6±6 and 6±3 passes respectively) and the number of passes received (8±6 and 7±5 passes respectively). Attackers in contrast required more matches to stabilise for defensive parameters including the number of tackles made (15±11 tackles), interceptions (12±12) and the number of possessions won (11±11). All variables, except total distance covered, the percentage of successful passes and the average number of touches per possession, required more than 10 matches to stabilise to within 5% of the mean and more than 20 matches to stabilise to within 1% of the mean. The highest number of matches required to stabilise to within 1% of the mean was 26.3±9.7 matches, which occurred for the number of tackles a player performs in a match, although sprint distance (25.3±17.0 matches) and high-intensity running distance WP (25.5±14.2 matches) also displayed high numbers of matches required for the highest level of accuracy.

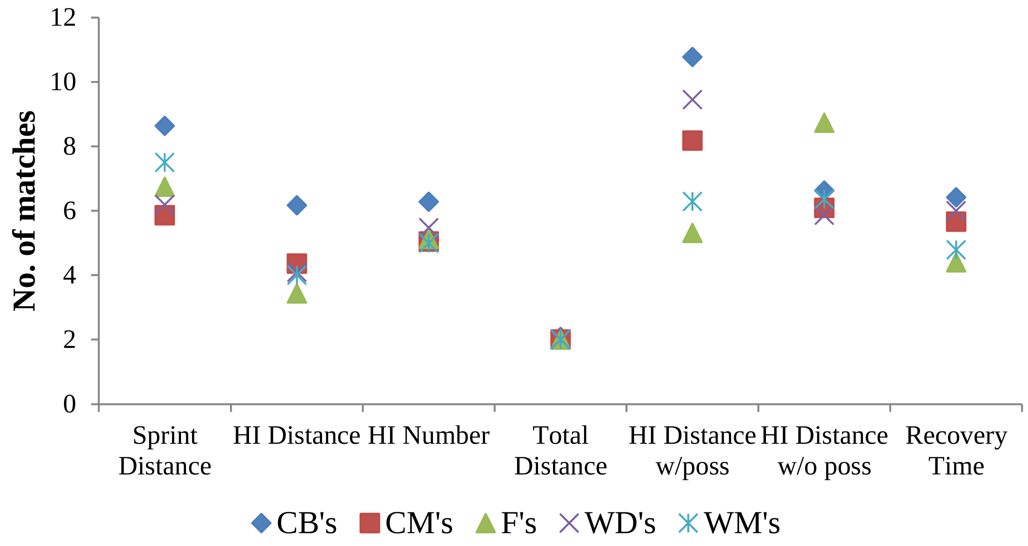


Figure 3.2: The mean number of matches required for physical performance variables to stabilise to within 10% error limits for outfield positions.

Limited research has been conducted into the stability of match data. Hughes et al. (2001) proposed a cumulative means method of investigating match stability although no research has subsequently used this or any method to establish the number of matches required to provide an accurate indication of performance. Hughes et al. (2001) concluded that stabilisation of performance indicators depended on the indicators being analysed and the standard of the match being played (i.e. international, national or non-professional). In racket sports, events which occurred more frequently such as shots and rallies in a game stabilised to within 10% of the mean quickest (<4 matches). These indicators would equate to passing events in soccer, which stabilised after 7±6 for the number of passes performed and 9±8 for the number of passes received. All physical performance parameters stabilise to within 10% of the mean within 8 matches, although took up to 25 matches to stabilise within 1% of the mean. Indicators which are also normalised such as average touches per possession (4±3) or percentage of successful passes (3±2) also stabilised to within 10% of the mean quicker, this was supported by Hughes et al. (2001) who suggested indicators such as the number of shots per rally stabilised quicker than non-normalised indicators, nevertheless, these factors took up to 16 matches to stabilise to within 1% of the mean.

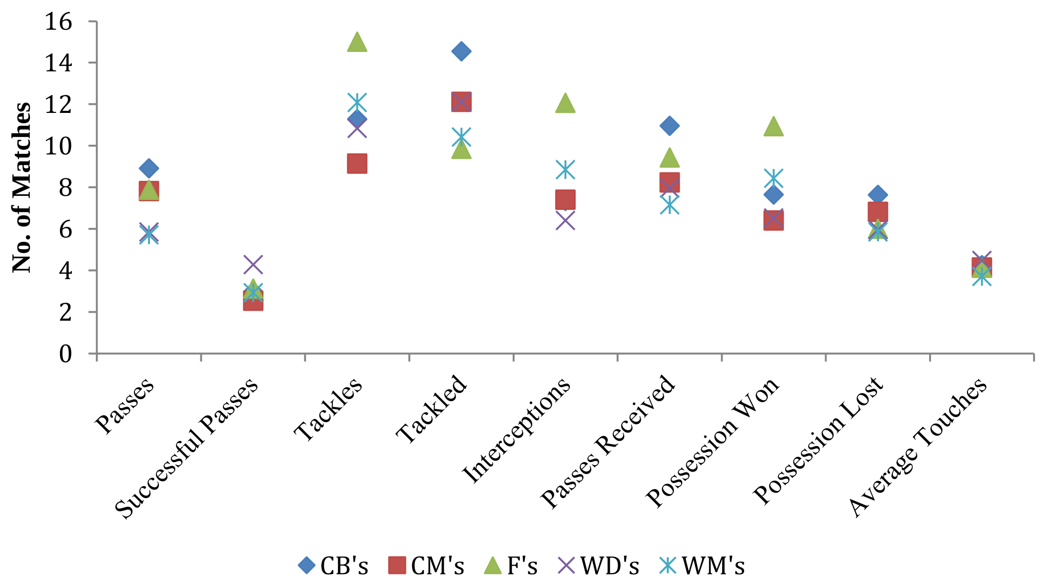


Figure 3.3: The mean number of matches required for technical variables to stabilise to within 10% error limits for outfield positions.

The high numbers of matches required, and the very large variability (SDs) in the number of matches required, even to stabilise to within 10% of the mean, suggest that this method is less than ideal in quantifying the number of matches required for accurate assessment of performance. The method of applying a cumulative mean to the data is similar to adding an expanding moving average filter to the data, as a result the data will eventually stabilise towards the arithmetic mean irrespective of the range of data or the number of matches analysed (Table 3.1). The data were highly susceptible to both minor and major changes in the performance variables, which then affected and effectively reset the stability profile, resulting in the requirement of a high number of matches to be analysed, especially for the highest level of accuracy. The nature of the data, and the multitude of interacting factors during a soccer game may lead to the data to be too variable for this method to be applicable and therefore appears unsuitable in this context. The method may have uses when analysing case studies, when analysing isolated movements, or sports that are manipulated less by external factors or are less inherently variable. Alternatively, a second proposal has recently been proposed by Gregson and collegues (2010) who applied the use of coefficients of variation to calculate the variability of performance parameters between matches, which may be a more appropriate calculation as the results are less susceptible to extremes in performance as CV calculations take into account the means and standard deviations of the data.

Table 3.1: The number of matches required to reach 10%, 5% and 1% error limits (mean±SD).

| | Number of matches | | |
|---|---|---|---|
| | **10%** | **5%** | **1%** |
| **Total Distance** | 2.0 ± 0.1 | 2.2 ± 0.7 | 10.0 ± 8.9 |
| **High-intensity Running Distance** | 4.4 ± 3.5 | 8.3 ± 6.0 | 19.5 ± 13.9 |
| **Sprint Distance** | 7.0 ± 4.9 | 10.9 ± 6.9 | 25.3 ± 17.0 |
| **High-intensity WP** | 8.0 ± 6.4 | 12.8 ± 10.2 | 25.5 ± 14.2 |
| **High-intensity WOP** | 6.7 ± 6.0 | 11.2 ± 8.5 | 20.1 ± 13.2 |
| **Number of HI actions** | 5.4 ± 4.3 | 8.8 ± 6.3 | 18.3 ± 14.0 |
| **Number of Passes** | 7.2 ± 6.2 | 12.1 ± 8.6 | 20.3 ± 12.9 |
| **Pass Success** | 3.2 ± 2.0 | 6.0 ± 4.7 | 15.7 ± 11.6 |
| **Number of Passes Received** | 8.8 ± 8.1 | 12.3 ± 10.5 | 16.1 ± 8.9 |
| **Number of Tackles** | 11.7 ± 6.9 | 14.6 ± 11.7 | 26.3 ± 9.7 |
| **Number of Times Tackled** | 11.8 ± 7.8 | 16.5 ± 11.6 | 22.4 ± 16.4 |
| **Number of Possessions won** | 8.0 ± 6.0 | 12.2 ± 7.8 | 22.7 ± 10.8 |
| **Number of Possessions lost** | 6.5 ± 4.9 | 10.5 ± 7.2 | 22.2 ± 14.2 |
| **Average Touches Per Possession** | 4.1 ± 3.3 | 7.9 ± 6.3 | 16.1 ± 11.1 |

### 3.3.2 Physical Match-to-Match Variability

Wide midfielders had the largest CVs for total distance covered, while central midfielders illustrated the smallest CVs. However, no meaningful differences were found for total distance covered between positions, with all positions demonstrating CVs ≤5% (central defenders: 4.7±3.9%; central midfielders:

3.9±1.4%; full backs: 4.0±1.3%; wide midfielders: 4.0±1.1%; attackers: 5.4±2.0%, p>0.05; ES: 0.01-0.3 [CI: -0.19-0.6). Central defenders produced the most variation from match-to-match for high-intensity running distance compared to all other positions (Figure 3.4; central defenders: 22.6±6.3%; central midfielders: 17.8±5.6%; full backs: 16.4±5.0%; wide midfielders: 15.0±4.9%; attackers: 18.0±5.5%, p<0.05 and ES: 0.4-0.8 [CI: 0.1-1.0]). This was particularly seen in high-intensity running distance WP (central defenders: 51.3±26.3%; central midfielders: 34.0±10.0%; full backs: 33.4±12.0%; wide midfielders: 21.7±7.9%; attackers: 24.5±14.7%, p<0.001; ES: 0.6-1.0 [CI: 0.4-1.3]). CVs for recovery time between high-intensity actions were also higher for central defenders (20.0±11.9%) compared to wide positions (full backs: 14.9±9.1% and wide midfielders: 14.9±8.7%, p<0.05, ES: 0.5 [CI: 0.1-0.8]) and non-significantly greater than central midfielders and attackers (centre midfield: 16.9±12.0%; attackers: 16.4±10.9%, p>0.05, ES: 0.3 [CI: -0.01-0.6]). However, CVs for high-intensity running distance WOP were greatest for attackers (27.6±16.6%) compared to central positions (central defenders: 21.8±10.1%; central midfielders: 21.9±11.3%, p<0.05; ES: 0.4 [CI: -0.1-0.7]) and full backs (18.6±9.1%, p<0.001, ES: 0.7 [CI: -0.4-1.0]). Nevertheless, no differences were observed with wide midfield positions for high-intensity running distance WOP compared to attackers (24.3±7.9%, p>0.05, ES: 0.3 [CI: -0.03-0.7]). CVs for sprint distance were greater for central defenders (32.3±13.8%) compared to attackers (25.5±13.5%), full backs (26.0±12.0%, p<0.05; ES: 0.5 [CI: 0.2-0.8]) and wide midfielders (22.6±11.2%, p<0.01; ES: 0.7 [CI: 0.4-1.1]), although recorded similar CVs for sprint distance to central midfielders (28.0±12.5%, $p>0.05$, ES: 0.3 [CI: 0.1-0.6]).

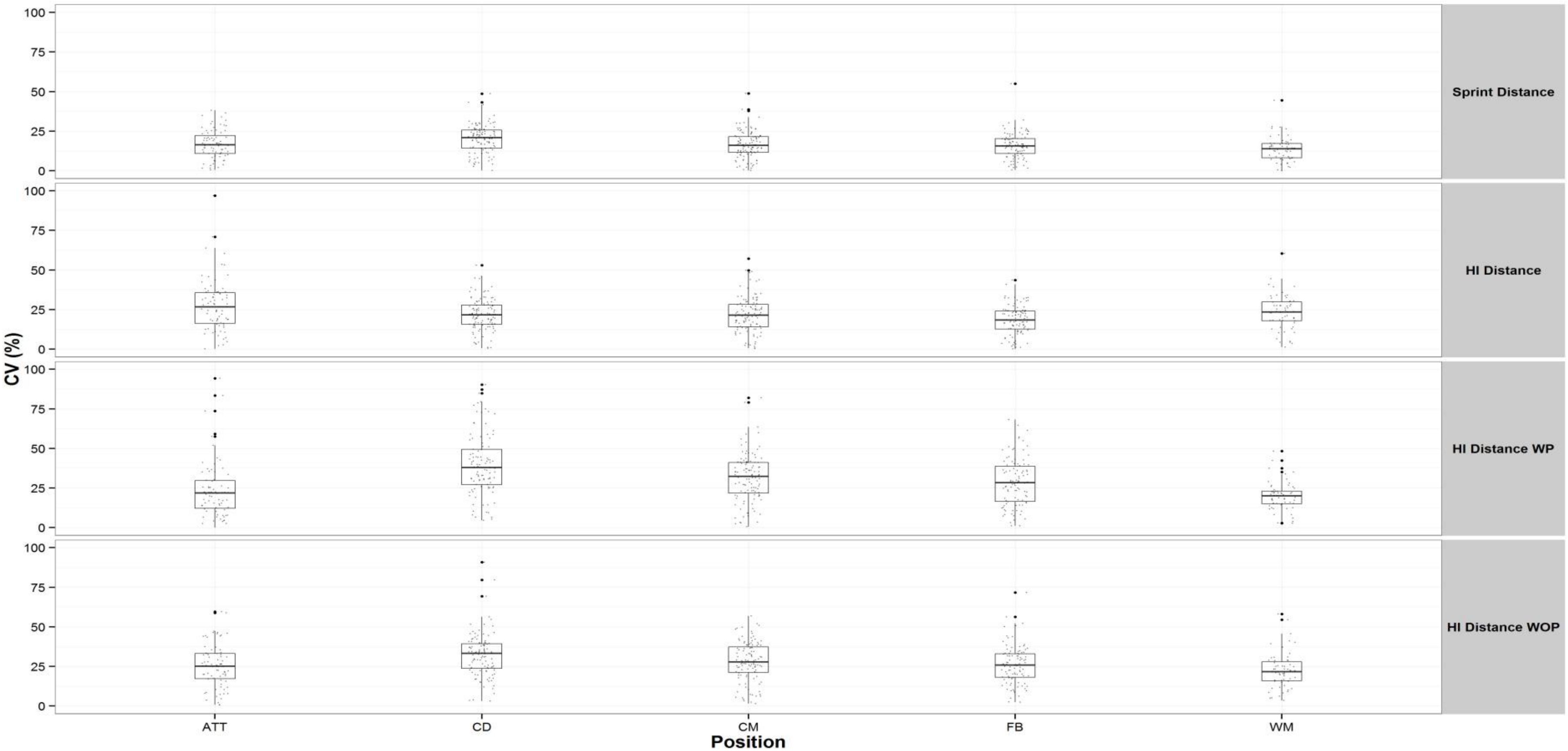


Figure 3.4: Total CVs for physical performance parameters across all positions. The Box and Whisker plot displays median values, interquartile ranges and outliers for the physical performance in matches in the English Premier League. Each player's observation is jittered and is included as a small dot around the box. The larger dots at the top and bottom of boxes are outliers.

### 3.3.3 Technical Match-to-Match Variability

Central defenders produced the highest CVs for passes (39.2±17.5%), passes received (46.9±20.2%) and the number of times they were tackled per match (144.9±58.3%) compared to other positions (Figure 3.5; $p<0.01$; ES: 0.6-0.7 [CI: 0.3-1.0], 0.7-1.2 [CI: 0.4-1.5] and 1.4-2.2 [CI: 1.1-2.6] respectively). In contrast, attackers demonstrated the smallest CVs for the number of times they were tackled per match (35.4±25.6%) but the largest CVs for the number of tackles per match (83.6±42.3%), number of possessions won (47.2±28%, $p<0.01$; ES: 0.3-0.9 [CI: -0.02-1.2], 0.4-1.1 [CI: 0.1-1.3]) and interceptions (59.1±37.3%, $p<0.05$; ES: 0.4-1.1 [CI: 0.1-1.5]) compared to other positions. Full backs illustrated higher CVs for the number of times tackled per match (76.0±36.4%) compared to central midfielders (56.5±29.4%), attackers (41.5±22.7%) and wide midfielders (37.7±21.4%, $p<0.05$, ES: 0.6-1.2 [CI: 0.3-1.6]). Wide midfielders demonstrated higher CVs for the number of interceptions (45±24.1%) and possessions won (36.9±19%) than central defenders (29±14.3% and 26±12.1%), central midfielders (31.6±19.1% and 26±14.4%) and full backs (30.2±19.7% and 26.9±17.6%, $p<0.05$; ES: 0.6-1.0 [CI: 0.3-1.3] and 0.6-0.7 [CI: 0.2-1.1] respectively).

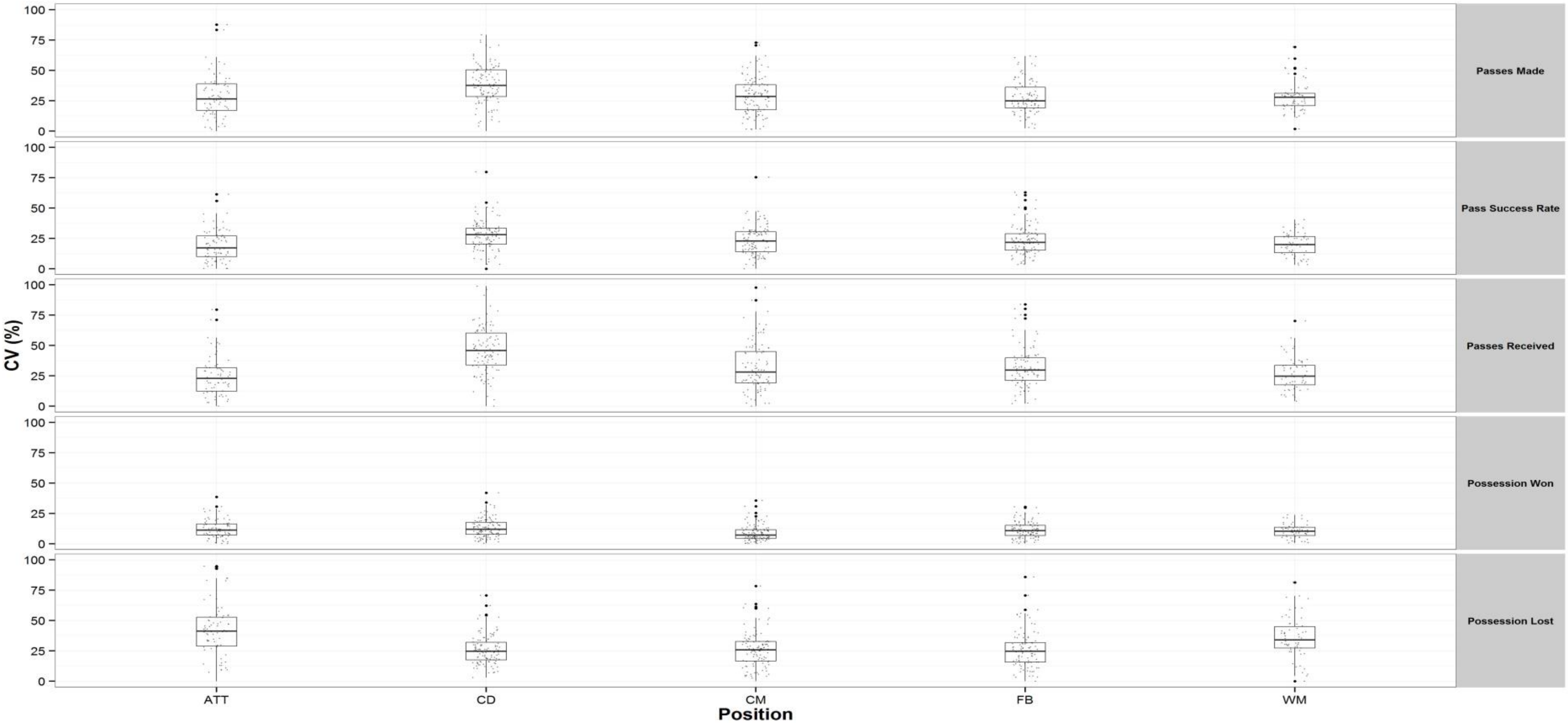


Figure 3.5: Total CVs for technical performance parameters across all positions. The Box and Whisker plot displays median values, interquartile ranges and outliers for the technical performance in matches in the English Premier League. Each player's observation is jittered and is included as a small dot around the box. The larger dots at the top and bottom of boxes are outliers.

### 3.3.4 Contextual Match-to-Match Variability

Marginal but no meaningful differences were observed across physical and technical parameters for match location ($p>0.05$, ES: <0.4). All positions, except attackers, tended to record lower CVs for high-intensity running distance WOP when playing away (central defenders: 22.1±9.3 vs. 20.1±11.6%; central midfielders: 23.5±11.4 vs. 20.5±9.8%; full backs: 20.1±8.1 vs. 19.1±10.3%; wide midfielders: 24.1±11.2 vs. 23.5±12.3%, $p>0.05$, ES: 0.1-0.5 [CI: -0.37-0.84]. In contrast, attackers recorded lower variability for high-intensity running distance WOP when playing at home (29.8±15.5 vs. 33.2±14.4%, $p>0.05$, ES: 0.22 [CI: -0.24-0.68]). High-intensity running distance WP recorded lower variability for all positions, except wide midfielders, when playing at home (central defenders: 41.7±25.7 vs. 48.3±31.6%; central midfielders: 28.9±17.2 vs. 33.6±14.5%; full backs: 29.1±15 vs. 32.9±18.5%; attackers: 19.1±14.4 vs. 28.0±23.0, $p>0.05$, ES: 0.2-0.5 [CI: -0.15-0.91]), wide midfielders in contrast demonstrated lower variability when playing away (22.2±15.7 vs. 19.2±10.0%, $p>0.05$, ES: 0.2 [CI: -0.2-0.64]). Centre backs recorded small differences for the number of passes, with lower variability recorded for home games compared to away (35.6±18.8 vs. 40.9±19.9%, $p>0.05$, ES: 0.3 [CI -0.04-0.57]), all other positions displayed no differences ($p>0.05$, ES: 0-0.16 [CI: -0.43-0.54]). Both attackers and wide midfielders showed lower CVs for the number of possessions won when playing at home (attackers: 37.7±16.1 vs. 48.8±21.6%; wide midfielders: 33.4±17.9 vs. 37.8±17.8%, $p>0.05$, ES: 0.6 [CI: 0.1-1.03] and 0.3 [CI: -0.2-0.7]), whereas all other positions showed no differences between home and away ($p>0.05$, ES: <0.1 [CI: -0.33-0.44]).

One way ANOVA revealed Central defenders produced lower CVs for high-intensity running distance WP when playing against stronger opposition (48.9±19.3%) compared to playing similar standards (54.5±40.2%, p>0.05, ES; 0.2 [CI: -0.7-1.0]) and weaker opposition (61.9±32.8%, p>0.05, ES: 0.4 [CI: -0.5-1.2]); although high-intensity running was marginally less variable against weaker opposition (21.8±12.4 vs. stronger: 22.1±7.6 and equal standard: 25.4±9.8, p>0.05, ES: 0.02-0.2 [CI: -0.8-1.1]). Wide midfielders produced lower variation when playing against weaker opposition for all physical parameters (p>0.05, ES: 0.2-1.2), in particularly for total high-intensity running distance (stronger: 18.1±3.9%; equal standard: 16.2±6.3%; weaker: 13.3±4.1%, p<0.05, ES: 1.2 and 0.6 respectively). Central defenders (62.1±20.1%), attackers (52.2±28.5%) and wide midfielders (46.4±26.0%) displayed larger CVs for the number of passes received when playing weaker opposition (p>0.05, ES: 0.4-1.2). In addition, full backs, attackers and wide midfielders demonstrated larger CVs for the number of passes made when playing weaker opposition (34.6±19.9%, 53.7±50.1% and 32.7±10.9% respectively, p>0.05, ES: 0.4-1.2). For match result, the number of high-intensity efforts and recovery time between high-intensity actions showed significantly lower CVs for wide midfielders when matches were won (12.4±7.3%) compared to matches that were lost (16.0±4.1%) or drawn (18.7±6.8%, p<0.05; ES: 0.5-0.9). Full backs were found to have greater CVs for the number of tackles made in matches that were won (70.9±40.1%) compared to matches that were lost (40.4±19.5%) or drawn (54.2±35.7%, p>0.05, ES: 0.9).

### 3.3.5 Correlations Between Physical and Technical CVs

Correlation analysis between the CVs for physical and technical variables mainly produced small magnitude correlations (Figure 3.6; $r<0.20$). The variability in the number of times tackled displayed the highest correlations with sprint distance ($r=0.25$, $p<0.01$), high-intensity running ($r=0.25$, $p<0.01$) and high-intensity distance WP ($r=0.37$, $p<0.01$). Nevertheless none of the CV correlations between physical and technical variables illustrated associations of greater than a moderate magnitude. Analysis of physical parameters identified very large magnitude correlations between the variability of high-intensity running and sprint distance ($r=0.75$, $p<0.01$) and moderate correlations with high-intensity running distance WP and WOP ($r=0.42$, $p<0.01$). The CVs for the number of high-intensity activities displayed near perfect correlations with recovery time between high-intensity activities ($r=0.96$, $p<0.01$) and large magnitude correlations with high-intensity running distance ($r=0.66$, $p<0.01$). Moderate-large magnitude correlations were observed for CVs between sprint distance and high-intensity distance WP ($r=0.37$, $p<0.01$), recovery time ($r=0.41$, $p<0.01$) and high-intensity running distance ($r=0.66$, $p<0.01$). Analysis of technical parameters identified very large magnitude correlations for CVs between possessions won and the number of interceptions ($r=0.85$, $p<0.01$) and moderate magnitude correlations with the average number of touches per possession ($r=0.34$, $p<0.01$). Moderate magnitude correlations were observed for CVs between the number of passes attempted with pass success, and the number of passes received ($r=0.30$-$0.50$, $p<0.01$).

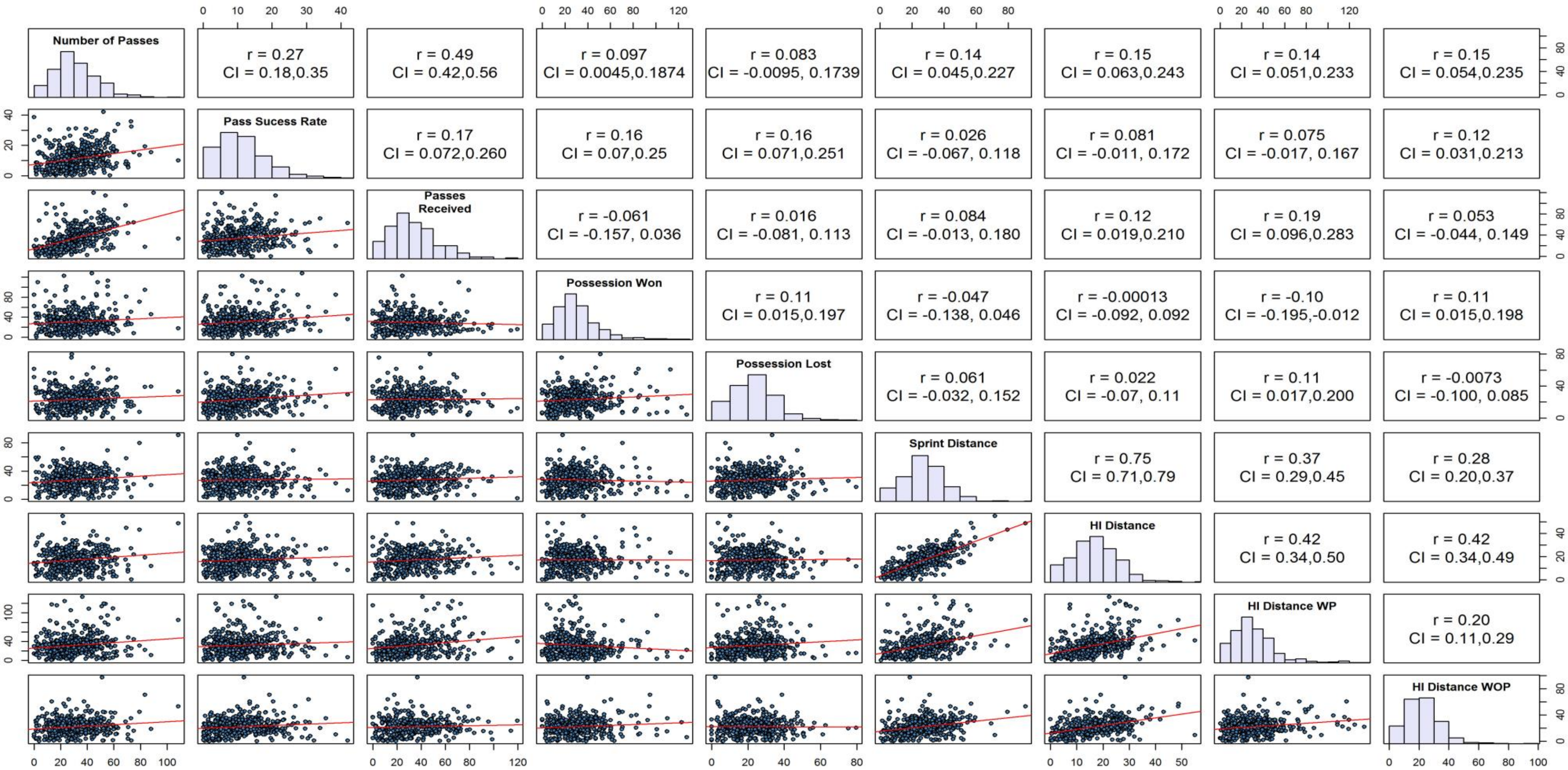


Figure 3.6: A correlation matrix between physical and technical CVs. Data are presented as Pearson's correlations (*r* values) except the central panel, which includes a histogram of distribution.

### 3.4 Discussion

The present study was the first to quantify the inconsistency of physical and technical parameters across both position and context. As a pilot study, the data were used to analyse the minimum number of matches required for performance to stabilise, before the data were subjected to the calculation of coefficients of variation in order to analyse which method is more applicable to sporting performances. The data demonstrated that a high number of matches are required for performance to stabilise, particularly for technical parameters that occur less frequently and as a result were highly susceptible to variations in performance. When analysing coefficients of variation, technical parameters varied more from match-to-match than physical parameters. Defensive players displayed higher CVs for offensive technical variables, whilst offensive players exhibited higher CVs for defensive technical variables. Both physical and technical performance parameters were equally variable, irrespective of match context (match location, opposition standard or match result).

Although an attractive proposition, it is clear from the results of this study that calculating the stability of performance is far less valuable and applicable compared to using coefficients of variation. Calculating the stability of performance has previously come under scrutiny due to many assumptions being made on the sample data, and assuming it represents a typical performance, thus potentially introducing sampling errors (Lames & McGarry, 2007). In addition, the method effectively employs an expanding filter on the data, therefore the expanding mean will always tend to the overall mean, irrespective of the number of samples included (O'Donoghue, 2005). The results also depend upon the level of stability the analyst or coach requires, with a greater number of matches required for greater levels of stability (Hughes et al., 2001; O'Donoghue, 2005). The pilot study identified a high number of matches was required for performance to stabilise to within 10% error limits, especially for technical variables, this combined with the high standard deviations show that even the number of games identified shows high variability and therefore may not provide an accurate number of matches required for stability to be present. Given the level of variability within performance it is possible that, irrespective of the number of observations, these error limits may never be reached.

In order to gain an appropriate level of stability within performance a high number of matches is required, nevertheless when analysing the results it was noted one extreme performance (either above or below the average) could have a large, negative effect on the stabilisation process and therefore affect the number of games required for performances to become stable. A single performance can be affected by a number of factors (Newell, 1986; Passos et al., 2008; Travassos, Araújo, Davids, Esteves, & Fernandes, 2012), including within match changes in tactics depending on the score and the success of the game plan (Lames & McGarry, 2007). In contrast to the thoughts of Hughes, Evans and Wells (2001), it is possible that calculating stability profiles and the minimum number of games or observations required to provide and accurate and reliable assessment of performance may not be applicable, particularly in team sports (Lames & McGarry, 2007). This can be attributed to the use and calculations of frequency-based statistics and the complex interactions between performers, which make this method highly susceptible to changes in performance and therefore researchers may need a high number of matches for performance to stabilise without being affected by highly abnormal performances. This is in contrast to time based and individual sports where continuous data is used as well as the presence of fewer interactions between performers (Vincent, 2005). In these instances the data are less susceptible to changes in performance and therefore can allow stability profiles to be used and the therefore calculate the minimum number of observations required for an accurate and stable performance (Mytton et al., 2014).

If it is not possible to measure the stability of sporting performances between matches, an alternative method is to analyse the inconsistency or variability between performances. One widely accepted method in sport science to calculate the instability of performance is to use coefficients of variation, thus analysing the spread of the data around a mean performance (Vincent, 2005). In this instance it is possible to generate the variation around a mean as a percentage and therefore provide benchmarks that represent typical performances. Given the generation of performance benchmarks from a suitable number of matches, performances that lie outside of these benchmarks may be seen as an outlier or an anomaly and may warrant further investigation.

Currently no exact measure of physical performance in elite soccer matches exists, the total distance covered and that performed at high-intensity provide useful indicators of physical performance (Bradley et al., 2009; Mohr, Krustrup, & Bangsbo, 2003). Both measures correlate with physical capacity but high-intensity running to a higher degree than total distance covered (Krustrup et al., 2003). This supports the existing contention that high-intensity running is a better indicator of match performance than total distance covered (Krustrup, Mohr, Ellingsgaard, & Bangsbo, 2005; Mohr et al., 2003). In the current study total distance covered varied little from match-to-match (CV<5%) which is in line with previous studies quantifying the match-to-match variability elite soccer (Gregson, Drust, Atkinson, & Di Salvo, 2010; Mohr et al., 2003; Rampinini et al., 2007). Central midfielders were found to have the lowest CV's for total distance, this is unsurprising considering central midfielders cover the greatest total distances in a match (Bradley et al., 2009; Bradley, Carling, et al., 2013; Di Salvo et al., 2007). This is due to being required to play an active role in both attacking and defensive match-play, the continuous link between defenders and attackers, may result in the low variation observed in total distance covered. The present study found CVs for high-intensity running distance ranged from 14% for wide midfielders to 20% for central defenders and thus compares well with values reported for the same positions (13-19%), (Gregson et al., 2010) and the average variability for all positions (14%), (Rampinini et al., 2007). The greater variability for central positions is probably indicative of the higher player density in central regions of the pitch in the modern game (Barnes et al., 2014; Wallace & Norton, 2014). Previous research demonstrated that CVs for sprint distance were greater than high-intensity running distance (Gregson et al., 2010), whereas these two parameters produced similar CVs in the present study. This finding is reflected in the large magnitude of the correlations between the CVs for the two variables. The high variability of these parameters has a direct impact on the assessment and evaluation of intervention strategies on match running performance, this is especially important as high-intensity running and sprint bouts usually occur during significant moments in the game (Faude, Koch, & Meyer, 2012).

This study was the first to quantify match-to-match variability of technical performance parameters. We identified that indicators such as possession won, possession lost and average touches tended to be higher, although non-significantly, for attackers compared to all other positions. Attackers generally receive the ball in the offensive third of the pitch, often within sight of goal. Thus, attackers are required to take many touches to hold the ball up to retain possession in densely populated areas of the pitch (Bangsbo & Peitersen, 2004; Carling et al., 2005). Nevertheless an attacker's ability to hold-up play will be affected by the number and quality of possession won along with the aptitude and tactics of the opposition defenders, thus affecting the variability in performance. The low CVs observed for the number of possessions won and lost indicate the number of turnovers of possession within the modern game are fairly consistent on a match-to-match basis and may suggest once teams have possession of the ball they attempt to maintain possession for as long as possible. Recent research has found that the number of short and medium passes performed during matches has increased since 2006-07 (Barnes et al., 2014). Although this current study did not measure the variability of passing distance, the previous findings combined with the current data demonstrating low match-to-match variability for possession won and lost supports the notion that teams now adopt possession based playing styles rather than the direct playing styles previously embraced (Carling et al., 2005). Further information is needed regarding the number of possession turnovers in a match, although combined with the results of the present study, it is likely teams now adopt possession based playing styles, therefore once a team regains possession they are more likely to maintain possession of the ball.

The number of passes and percentage pass success for each position showed variability to be <40%. Passes made and consequent pass success occur when the team is in possession. Although we have previously suggested that there is low variability in the change of possession (possession won/lost), the variability in passing variables occur due to the amount of possession a team holds. High levels of ball possession provide greater opportunity to perform passes, in contrast matches with low-ball possession will reduce the time available to perform passes. Over the course of a season teams will encounter or adopt varying playing styles and tactics (Fernandez-navarro et al., 2016), which could potentially explain the variability in passing measures. In contrast, the number of tackles made and the number of times they were tackled demonstrated the highest CVs out of the technical parameters (>50%). Attackers and wide midfielders had lower variability for the number of times they were tackled. Players in these positions gain the ball in attacking areas, and are thus more likely to be tackled to reduce the attacking threat. In contrast, defenders (wide and central) experienced a more variable number of times they were tackled as they are less likely to pose a threat to the opposition goal; as a consequence opposition strategy is more of an influence on these technical indicators. For example, some teams try to regain possession high up the pitch applying pressure on players in defensive positions; whilst other teams will allow defenders to keep possession. As a result, depending on a team's strategy on regaining possession the number of tackles completed between attackers and defenders will be affected and may explain the high CVs observed (Fernandez-navarro et al., 2016).

The relatively high CVs discovered for the number of tackles made and times tackled may be due to the low frequency of occurrences in matches. As a result small changes in the frequency of occurrences can have large impacts on the CVs observed (Castellano et al., 2012; Lago, 2009; Lago-Peñas & Lago-Ballesteros, 2011; Taylor et al., 2008). In contrast, the numbers of passes attempted and successful passes made are more frequent and hence stable technical parameters. A 70% pass success statistic is deemed a minimum requirement for elite soccer (Dellal et al., 2011) and thus the potential range of this measure is low, resulting in relatively low variability. The high variability observed for the majority of technical parameters highlights the difficulties in assessing the effectiveness of interventions or coaching adaptations on technical performance. The implications of the present study are that large subject numbers would be required to determine whether improvements during match-play would be due to interventions or the inherent variability in performance. In addition, although researchers have previously analysed the parameters that are important for success (Castellano et al., 2012; Lago, 2009; Lago-Ballesteros, Lago-Peñas, & Rey, 2012; Lago-Peñas & Lago-Ballesteros, 2011), the high CVs observed for technical parameters in this study would suggest that success cannot be defined by a small list of elements, but is a combination of factors. Success in one game could be as a result, of a high turnover in possession (high number of tackles, possession won/lost), low pass success rate and a high number of shots on/off target. In contrast, success in a different game may be a result of high numbers of passes made and pass success rate and a low turnover of possession, but low number of shots on/off target.

One of the key findings of this study was the higher match-to-match variability observed for technical variables when compared to physical variables. The physical data trends found in the present study are similar to previous findings on EPL populations (Gregson et al., 2010; Rampinini et al., 2007) suggesting that physical variability has remained relatively constant over recent seasons. Although there is inherent match-to-match variability observed in the physical performance of soccer players, the CVs observed may provide further evidence for the adoption of pacing strategies by players to ensure game completion (Bradley & Noakes, 2013). For instance, sparing low-intensity activity such as walking and jogging in an attempt to preserve essential high-intensity running, could the reason why total distance covered remains the similar between match periods but high-intensity is highly variable (Drust, Atkinson, & Reilly, 2007; Edwards & Noakes, 2009). In contrast, the variability of technical performance has not previously been analysed. In the present study the contextual factors examined had minimal influence on the variability of player’s physical or technical performance. Therefore, the results suggest that the changes in absolute technical performance previously identified (Lago, 2009; Lago-Ballesteros et al., 2012; Lago-Peñas & Lago-Ballesteros, 2011; Taylor et al., 2008) are as a result of different contexts rather than the variability in performance parameters. Technical performance in matches is not only affected by player ability or capacity, but is highly dependent on team and opposition tactics as well as contextual factors, (Lago, 2009; Lago-Ballesteros et al., 2012; Lago-Peñas & Lago-Ballesteros, 2011; Taylor et al., 2008). Consequently greater variability in technical compared to physical parameters may be partially explained by external factors having greater influence on players' technical rather than physical performance.

Rampinini et al. (2007) found that physical indicators were less variable when playing against the same opposition, suggesting that playing styles, fitness and tactics could influence variability in match-play. Surprisingly, match location, standard and match result had little effect on overall match-to-match variability of physical and technical parameters in this study. Central defenders, full backs and central midfielders displayed lower variability, although non-significant, when playing at home compared to away matches for high-intensity running distance WP. Although previous research has highlighted differences in match indicators (Lago, 2009; Lago-Ballesteros et al., 2012; Lago-Peñas & Lago-Ballesteros, 2011; Sánchez, García-Calvo, Leo, Pollard, & Gómez, 2009), performance would be expected to vary a similar amount whether matches are at home or away, won or lost or whether playing against a higher or lower standard of opposition. The limited influence of contextual factors on match-to-match CVs would suggest that the game is intrinsically variable and that could be driven by tactics and playing strategies.

Although previous research has started to analyse both technical and physical performance parameters within the same articles (Barnes et al., 2014; Bradley, Lago-Peñas, Rey, & Diaz, 2013; Bradley et al., 2011; Bradley, Carling, et al., 2013), researchers have not analysed the relationships between performance measures (Mackenzie & Cushion, 2013). The correlation analysis performed in this study found small-moderate magnitude associations ($r=0.22-0.37$, $p<0.001$) between CV values for the number of times tackled per match and the distance covered at high-intensity, high-intensity distance WP, sprint distance and recovery time between high-intensity actions. All other correlations were less than trivial ($r<0.2$). The low correlations observed in this study would suggest that physical match-to-match variability is not related to technical variability, although the influence of tactical factors may warrant further study.

The moderately-large CV's observed will also partially be caused by the dynamical nature of the sport (Gréhaigne et al., 1997; Hughes, Bürger, Hughes, Murray, & James, 2013; McGarry et al., 2002). Over the course of a season teams will play a variety of squads according to player availability, injuries and abilities, and although any individual team will have a playing style, player selection will ultimately affect the ability to accomplish any given playing style, both physically and technically. In addition, the variety of opposition a team will play in a season will also have an effect on the ability of a team to play. During each game a team will have to form both intra- and inter-player coupling (McGarry et al., 2002). These relationships will have an impact on the on-field interactions between players and teams and therefore the ability of a team to play at the desired level of the coach (Chow et al., 2011; McGarry et al., 2002; Newell, 1986). As a result of the dynamical nature of the sport there will always be a level of variability present within performance, however there has previously been limited attempt at quantifying this variability. Though this influence must be acknowledged, the present study has attempted quantified the variability within performance, both physical and technical, in order to gain a better understanding of the level of unpredictability present within performance. In addition the results of the study can be used to calculate the boundaries of a typical performance with respect to contextual changes.

Despite the novel data presented and analysed, there are some limitations in the present study. The range of observations for each player was high and data was sampled over a multi-season period in order to provide enough data points for analysis. These methodological issues could have influenced the variability observed. Furthermore, the study was restricted by the number of contextual variables available for analysis and the number of observations for each context. Therefore, future research could take into account more contextual variables such as the severity of match won/lost and the effect of tactical variables and formations. Future research could also investigate the interaction of the contextual variables on match-to-match variability, i.e. matches at home played against weaker opposition compared to matches played away against stronger opposition, which would require larger sample sizes than the present study. In addition, research has identified the presence of fatigue occurring during the second half of matches and thus reducing the physical workload undertaken, it may be useful for research to analyse the variability between 1$^{st}$ half compared to the 2$^{nd}$ half performance, therefore gaining a clearer understanding of fatigue and the effects on performance.

The findings of this study provide useful information on the variability of match-play for practitioners in elite soccer. Specifically, it extends previous research, demonstrating that several important contextual factors (match location, standard of opposition, match result) do not influence match-to-match variability. It also presents data for the variability of important technical factors. Moreover, this study provides an alternative method for analysing performance, providing a method for developing player benchmarks based on player position and match context compared to the more traditional mean and standard deviation calculations used in previous research. Although these methods may take time for practitioners to understand and adopt, they offer more detail to practitioners and coaches by allowing for the calculation of a minimum and maximum performance, thus allowing analysts to identify where a performance sits along a continuum, rather than suggesting a performance is lower or greater than a mean. This information could help with interpreting interventions and provide practitioners with an indication of the number of matches required to gain an accurate assessment of a player's physical and technical performance during match-play. Whilst the variability data can be used to provide valuable information, the previous methods suggested for determining performance stability was shown to be inapplicable for football performance, in particular for technical performance variables. This is most likely due to the higher variability observed in the technical parameters and as a result a greater number of matches would be required to account for this variability.

This is the first study to demonstrate the match-to-match variability of technical as well as physical performance parameters in elite soccer. Positional analysis showed attackers had high variability for defensive variables such as possession lost and the number of tackles made per match. In contrast defensive positions demonstrated higher CVs for attacking variables such as the number of times tackled per match and the number of passes received. Despite the considerable knowledge base linking technical performance and success, the findings from this study highlight the large variability in technical performance and therefore may suggest a cautious approach must be taken when making these associations. In addition, match contexts (match location, match result and opposition standard) had limited influence on match-to-match variability for either technical or physical parameters. The effect of match contexts on match performance as found in previous research is potentially a result of different playing strategies rather than the inherent variability between matches.

# ***Chapter 4*** **: General Methods for Following Studies**

## 4.1 Methods

### 4.1.1 Match Analysis and Player Data

Match performance data were collected from seven consecutive EPL seasons (2006-07 to 2012-13) using a computerised multiple-camera tracking system (Prozone Sports Ltd®, Leeds, UK). Players' movements were captured during matches by cameras positioned at roof level and analysed using proprietary software to produce a dataset on each player's physical and technical performance. The validity and reliability of this tracking system has been quantified to verify the capture process and data accuracy (Bradley et al., 2009, 2007, Di Salvo et al., 2006, 2009). Ethical approval was obtained from the University of Sunderland (Ethics Code 182) with Prozone Sports Ltd® supplying the data and granting permission to publish.

### 4.1.2 Match Performance Parameters

Data were derived from Prozone's Trend Software and consisted of 1036 individual players across 22846 player observations. Original data files were de-sensitised and included 33 different teams overall with all 20 teams evaluated in each season. Individual match data were only included for outfield players that had completed the entire 90 min, matches were excluded if a player dismissal occurred (Carling & Dupont, 2011). The total number of observations were substantially different across season (2006-07 to 2012-13), phase of season (Aug-Nov, Dec-Feb, Mar-May), position (Attackers, Central defenders, Central midfielders, Full backs, Wide midfielders), location (Home and Away) and team standard based on final league ranking (A: 1$^{st}$-4$^{th}$, B: 5$^{th}$-8$^{th}$, C: 9$^{th}$-14$^{th}$, D: 15$^{th}$-20$^{th}$). The original data were re-sampled using a stratification algorithm in order to balance the number of samples in each of the time periods (season and phase of season), match location and relative proportions of playing position thus minimising errors when applying statistical tests. The re-sampling was achieved using the stratified function in the R package “devtools” (R Development Core Team) using the procedures of Wickham & Chang (2013), the complete breakdown of the sample is shown in Table 4.1. Positions were categorised as central defenders (*n*=3792), full backs (*n*=3420), central midfielders (*n*=3200), wide midfielders (*n*=2136) and attackers (*n*=2152). Outfield positions were defined by the location of players primary actions on the pitch (Di Salvo et al., 2007).

Activities were coded into the following: standing (0-0.6 $km \cdot h^{-1}$), walking (0.7-7.1 $km \cdot h^{-1}$), jogging (7.2-14.3 $km \cdot h^{-1}$), running (14.4-19.7 $km \cdot h^{-1}$), high-speed running (19.8-25.1 $km \cdot h^{-1}$) and sprinting (>25.1 $km \cdot h^{-1}$). Total distance represented the summation of distances in all categories. High-intensity running consisted of the combined distance in high-speed running and sprinting (≥19.8 $km \cdot h^{-1}$) and was separated into three subsets based on the teams’ possession status: with (WP) or without ball possession (WOP) and when the ball was out of play (BOOP). Sprinting was divided into two subsets: explosive (entry into sprint category with no incursion into the high-speed category in the previous 0.5 s) and leading (entry into sprint category immediately after an incursion into the high-speed zone for 0.5 s or more; Di Salvo et al., 2010). Coding of technical events according to playing position was also conducted (Di Salvo et al., 2007). All positions included match events of passing variables (number of passes, passes received, pass distance and pass success), average touches per possession and possession won/lost. Clearances were included in the analysis for wide and central defenders while shots and final 3rd entries were included for attackers, wide and central midfielders and full backs. Pass distance referred to the overall length of pass, split into short (<10 m), medium (11-24 m) and long (>25m).

Table 4.1: Data breakdown prior to the re-sampling process.

| Season | 2006-07 | 2007-08 | 2008-09 | 2009-10 | 2010-2011 | 2011-12 | 2012-13 | Total |
|---|---|---|---|---|---|---|---|---|
| **Month** | | | | | | | | |
| Aug-Nov | 815 (31) | 926 (36) | 1042 (38) | 1270 (35) | 1218 (38) | 1220 (36) | 1723 (36) | **8214 (36)** |
| Dec-Feb | 1047 (40) | 880 (34) | 853 (31) | 1290 (36) | 1144 (36) | 982 (30) | 1608 (34) | **7804 (34)** |
| Mar-May | 742 (29) | 802 (30) | 847 (31) | 1025 (29) | 831 (26) | 1118 (34) | 1463 (31) | **6828 (30)** |
| **Location** | | | | | | | | |
| Home | 1314 (51) | 1323 (51) | 1368 (49) | 1803 (50) | 1600 (50) | 1656 (50) | 2383 (50) | **11447 (50)** |
| Away | 1290 (49) | 1285 (49) | 1374 (51) | 1782 (50) | 1593 (50) | 1664 (50) | 2411 (50) | **11399 (50)** |
| **Position** | | | | | | | | |
| AT | 414 (16) | 384 (15) | 415 (15) | 471 (13) | 466 (15) | 459 (14) | 581 (12) | **3190 (14)** |
| CB | 635 (24) | 650 (25) | 712 (26) | 902 (25) | 786 (25) | 831 (25) | 1239 (26) | **5755 (25)** |
| CM | 593 (23) | 561 (22) | 622 (23) | 829 (23) | 707 (22) | 779 (24) | 1216 (25) | **5307 (23)** |
| FB | 575 (22) | 631 (24) | 614 (22) | 826 (23) | 732 (23) | 760 (23) | 1051 (22) | **5189 (23)** |
| WM | 387 (15) | 382 (14) | 379 (14) | 557 (16) | 502 (15) | 491 (14) | 707 (15) | **3405 (15)** |
| **Standard** | | | | | | | | |
| A ($1^{st}$-$4^{th}$) | 377 (15) | 323 (13) | 420 (15) | 628 (18) | 653 (21) | 666 (20) | 920 (19) | **3987 (17)** |
| B ($5^{th}$-$8^{th}$) | 641 (25) | 525 (20) | 541 (20) | 643 (18) | 687 (22) | 541 (16) | 1011 (21) | **4589 (20)** |
| C ($9^{th}$-$14^{th}$) | 618 (23) | 892 (34) | 876 (32) | 1221 (34) | 916 (28) | 1035 (31) | 1452 (30) | **7010 (31)** |
| D ($15^{th}$-$20^{th}$) | 968 (37) | 868 (33) | 905 (33) | 1093 (30) | 937 (29) | 1078 (33) | 1411 (29) | **7260 (32)** |
| **Overall** | **2604** | **2608** | **2742** | **3585** | **3193** | **3320** | **4794** | **22846** |

Table 4.2: Data breakdown following re-sampling process.

| **Season** | **2006-07** | **2007-08** | **2008-09** | **2009-10** | **2010-2011** | **2011-12** | **2012-13** | **Total** |
|---|---|---|---|---|---|---|---|---|
| **Month** | | | | | | | | |
| Aug-Nov | 700 (33) | 700 (33) | 700 (33) | 700 (33) | 700 (33) | 700 (33) | 700 (33) | **4900 (33)** |
| Dec-Feb | 700 (33) | 700 (33) | 700 (33) | 700 (33) | 700 (33) | 700 (33) | 700 (33) | **4900 (33)** |
| Mar-May | 700 (33) | 700 (33) | 700 (33) | 700 (33) | 700 (33) | 700 (33) | 700 (33) | **4900 (33)** |
| **Location** | | | | | | | | |
| Home | 1083 (52) | 1078 (51) | 1050 (50) | 1069 (51) | 1051 (50) | 1049 (50) | 1019 (49) | **7399 (50)** |
| Away | 1017 (48) | 1022 (49) | 1050 (50) | 1031 (49) | 1049 (50) | 1051 (50) | 1081 (51) | **7301 (50)** |
| **Position** | | | | | | | | |
| AT | 315 (15) | 310 (15) | 309 (15) | 308 (15) | 306 (15) | 306 (15) | 298 (14) | **2152 (15)** |
| CB | 534 (25) | 527 (25) | 523 (25) | 539 (26) | 554 (26) | 546 (26) | 569 (27) | **3792 (26)** |
| CM | 459 (22) | 463 (22) | 465 (22) | 464 (22) | 454 (22) | 452 (22) | 443 (21) | **3200 (22)** |
| FB | 475 (23) | 489 (23) | 493 (23) | 487 (23) | 491 (23) | 487 (23) | 498 (24) | **3420 (23)** |
| WM | 317 (15) | 311 (15) | 310 (15) | 302 (14) | 295 (14) | 309 (15) | 292 (14) | **2136 (15)** |
| **Standard** | | | | | | | | |
| A (1st-4th) | 319 (15) | 245 (12) | 339 (16) | 360 (17) | 424 (20) | 446 (21) | 386 (18) | **2519 (17)** |
| B (5th-8th) | 509 (24) | 436 (21) | 407 (19) | 385 (18) | 459 (22) | 347 (17) | 422 (20) | **2965 (20)** |
| C (9th-14th) | 486 (23) | 719 (34) | 656 (31) | 713 (34) | 587 (28) | 636 (30) | 651 (31) | **4448 (30)** |
| D (15th-20th) | 786 (37) | 700 (33) | 698 (33) | 642 (31) | 630 (30) | 671 (32) | 641 (31) | **4768 (32)** |
| **Overall** | **2100** | **2100** | **2100** | **2100** | **2100** | **2100** | **2100** | **14700** |

# *Chapter 5* : Study 2: Correlations between Physical Performance Parameters and Technical Parameters

## 5.1 Introduction

Research and analysis into physical and technical soccer performance is now well established, including distances covered at various speeds and the effects of fatigue on physical performance (Bradley et al., 2009; Bradley, Carling, et al., 2011, 2013; Bradley & Noakes, 2013; Carling, 2010; Carling & Dupont, 2011; Di Salvo et al., 2007, 2010, 2013, Rampinini et al., 2009, 2008). Technical performance, including the frequency of passing and shooting variables, ball possession strategies and the effects of technical standards on team success have all been analysed (Castellano et al., 2012; Collet, 2013; Hughes & Franks, 2005; James et al., 2002; Lago-Ballesteros et al., 2012; Lago & Martín, 2007; Redwood-Brown, 2008).

Previous research, nevertheless, has not analysed the interaction of physical and technical performance parameters. Selected research articles have investigated the effects of physical variables, including the effects of fatigue, on selected but limited technical (Bradley, Carling, et al., 2013; Bradley, Lago-Peñas, et al., 2013; Carling & Dupont, 2011; Mohr et al., 2003; Rampinini et al., 2008) or tactical parameters (Bradley, Carling, et al., 2011; Lago et al., 2010). Bradley et al. (2011) previously reported the effects of formation on physical and technical performance, identifying players across all positions cover greater distances at high-intensities (>19.8km$\cdot$h$^{-1}$) when playing in 4-4-2 or 4-3-3 formations compared to 4-5-1. The same study found the number of passes made and received was higher when playing in a 4-4-2 formation. A further study by Bradley, Carling, et al. (2013) analysed the technical and physical differences between the top three divisions in English football. The results of the study demonstrated greater distances covered in lower leagues of English football, in particular at high-intensity and sprint speeds, whilst technical variables such as the total number of passes, forward passes and pass success were greater in the EPL compared to lower leagues, irrespective of position.

Despite the growing research evidence present in soccer, few articles have investigated the associations between physical performance and technical execution (Mackenzie & Cushion, 2013). One study to investigate the interaction of physical and technical performance was conducted by Rampinini et al. (2008). In this study the authors found a decrease in players' ability to perform short passing after the occurrence of fatigue in a match, and after an isolated bout of fatigue in junior soccer players. In addition, Carling & Dupont (2011) conducted a similar study and found a reduction in the number of passes and passing tempo in the final 5 minutes of a match compared to the first 5 minutes, this was in association with a decrease in the distance covered at high-intensities during later stages of a match. These results suggest that fatigue has a direct impact on the ability to carry out technical actions, however, these articles are somewhat limited in that they only measure the impact of high-intensity activities, and thus consequent fatigue, on passing variables. In addition, these studies do not provide evidence for the degree of impact of physical parameters on technical variables, for example whether covering greater distances at high-intensities has a larger impact on technical performance than smaller magnitude increases. As a consequence the aim of this study was to gain an understanding of how differences in physical performance affect technical ability and as a result the interaction between physical and technical performance of soccer players.

## 5.2 Methods

### 5.2.1 Statistical Analysis

Relationships between selected physical and technical indicators were evaluated using Pearson's product moment test with significance set at $p<0.05$. The magnitudes of the correlations were considered as trivial (<0.1), small (>0.1-0.3), moderate (>0.3-0.5), large (>0.5-0.7), very large (>0.7-0.9), nearly perfect (>0.9) and perfect (1.0) (Hopkins et al., 2009). All analyses were conducted using statistical software (R Development Core Team).

### 5.2.2 Hypothesis

$H_0$ – There will be no interaction between physical and technical performance of matches.

## 5.3 Results

### 5.3.1 Season-by-season analysis

The data was also analysed on a season-by-season basis. No clear trends for the correlations were observed for any of the variables assessed, or for any of the five positions analysed. Instead, the results for the season-by-season analysis indicated fluctuating correlations centred on the collapsed data presented in the result section below.

### 5.3.2 Overall correlations

Correlations between physical and technical variables ranged from <0.1 to 0.6 when analysing all positions collectively. The highest correlations were observed between the high-intensity running distance WP and the number of passes received (r=0.38, p<0.001), the number of times tackled (r=0.52, p<0.001), possession won (r=-0.63, p<0.001) and the number of short passes made (r=0.48, p<0.001). Moderate correlations were also observed between the number of short passes made and the number of high-intensity activities (r=0.41, p<0.001), recovery time between high-intensity actions (r=-0.41, p<0.001), total distance (r=0.37, p<0.001) and high-intensity running distance (r=0.38, p<0.001). The number of possessions won displayed moderate, negative, correlation with sprint distance and the number of sprint actions (r=-0.37 and -0.35 respectively, p<0.001), and high-intensity running distance (r=-0.38, p<0.001).

Physical performance variables showed near perfect correlations when correlated against other physical performance factors. High-intensity running distance displayed very large and greater correlations to the number of high-speed activities, sprint distance and the number of sprints performed (r≥0.9, p<0.001), as well as recovery time between high-intensity activities (r=-0.82, p<0.001). Total distance also showed large correlations with high-intensity running distance (r=0.7, p<0.001). The number of leading and explosive sprints showed moderate correlations with total distance covered (r=0.51 and 0.50, p<0.001).

Technical performance parameters followed similar trends with the number of passes made demonstrated large-near perfect correlations to the number of passes received (r=0.91, p<0.001), the number of short passes (r=0.67, p<0.001), the number of medium passes (r=0.95, p<0.001) and the number of long passes performed (r=0.57, p<0.001). The number of passes performed also showed moderate correlations with the number of final third entries (r=0.45, p<0.001) and pass success (r=0.37, p<0.001). The number of passes received showed medium-very large correlations with the number of short passes performed (r=0.72, p<0.001), medium passes (r=0.85, p<0.001) and long passes (r=0.40, p<0.001). The number of possessions won displayed moderate correlations with the number of tackles made (r=0.41, p<0.001) and the number of times tackled (r=0.47, p<0.001). The length of passes showed moderate correlations (short vs. medium: r=0.49, p<0.001, and medium vs. long: r=0.45, p<0.001), although the number of short passes displayed trivial correlations with the number of long passes (r=0.02, p<0.05). The percentage of successful passes displayed moderate correlations with the proportion of medium passes made (r=0.401, p<0.001) and small negative correlations with the proportion of long passes (r=-0.381, p<0.001). Although the proportion of short passes displayed no correlations with the percentage of successful passes (r=0.015, p>0.05).

### 5.3.3 Positional correlations

Total distance recorded weak correlations for attacking positions (attackers and wide midfielders) with the number of possessions won (r=0.289 and 0.236 respectively, p<0.001). Defenders recorded weak correlations between total distance and passes made (central defenders: r=0.202, p<0.001) and the number of passes received (central defenders: r=0.202; full backs: r=0.204, p<0.001). Central midfielders recorded very weak correlations between total distance covered and all technical variables (r<0.147, p<0.05).

The strongest correlations between physical and technical variables were found for players in defensive positions. For both centre backs and full backs high-intensity running distance WP displayed moderate-large correlations with the number of passes performed (CB: r=0.53, p<0.001; FB: r=0.43, p<0.001), the number of passes received (CB: r=0.52, p<0.001; FB: r=0.50, p<0.001), and the number of short (CB: r=0.38, p<0.001; FB: 0.41, p<0.001) and medium passes (CB: r=0.51, p<0.001; FB: 0.43, p<0.001). Centre backs also displayed moderate correlations with high-intensity running distance WP and the number of long passes performed (r=0.35, p<0.001). Central midfielders were the only other position to demonstrate moderate correlations for the number of possessions won compared the to the high-intensity running distance WP (r=-0.382, p<0.001). High-intensity running distance WOP displayed weak correlations with the number of possessions won for attackers and wide midfielders (r=0.290 and 0.247 respectively, p<0.001). In addition wide midfielders recorded weak negative correlations between the number of passes received and high-intensity running distance WOP (r=-0.283, p<0.001), whilst attackers were the only position to record correlations for the number of tackles made with high-intensity running distance WOP (r=0.245, p<0.001).

Sprint distance recorded weak negative correlations with the number of possession won for central midfield positions (r=-0.226, p<0.001), whilst it recorded weak but positive correlations with pass success (r=0.241, p<0.001), the number of passes received (r=0.298, p<0.001) as well as the number of short and medium passes (r=0.264 and 0.252 respectively, p<0.001) for players in full back positions. Central defenders, wide midfielders and attackers recorded very weak correlations between sprint distance and all technical variables (r<0.159, p<0.001). Central defenders and full backs recorded weak correlations between the number of explosive sprints and the number of passes received (r=0.277 and 0.275, p<0.001), the number of short passes performed (r=0.218 and 0.246, p<0.001) and the number of medium passes made (r=0.255 and 0.231, p<0.001). The number of leading sprints performed showed small to weak correlations with the number of passes made (r=0.247, p<0.001), the number of passes received (r=0.303, p<0.001), the number of short (r=0.274, p<0.001) and medium passes made (r=0.253, p<0.001) in full back positions. Central midfielders displayed weak negative correlations between the number of leading sprints and the number of possessions won (r=-0.212, p<0.001). Attackers and wide midfielders recorded no correlations between the number of leading or explosive sprints and technical variables (r<0.154, p<0.001).

## 5.4 Discussion

There is continuing expansion of data collection and analysis within professional soccer. Nevertheless researchers often analyse data on either a technical, tactical or physical basis without analysing different aspects of play. With this in mind the main aim of this study was to analyse the interaction between physical and technical performance in EPL matches in order to gain an understanding of how variations in physical performance affect technical ability.

There are few research articles that have investigated the interaction between physiological performance factors and the technical performance during match play. However the majority of this research is based either on the influence of training protocols or on the effects of short-term fatigue (Da Silva et al., 2011; Dellal et al., 2013; Katis & Kellis, 2009; Lago-Peñas et al., 2011; Rampinini et al., 2008; Rostgaard, Iaia, Simonsen, & Bangsbo, 2008). So far, research has not analysed the correlations between physical parameters on technical performance. It is unsurprising that both physical and technical indicators displayed near perfect correlations when analysed against physical and technical variables respectively as many of the variables are linked, for example total distance is a summation of all movement distances (high-speed, sprinting, walking and jogging), it would therefore be surprising if no correlations were observed as the measures are not truly independent. The number of passes made is the sum of short, medium and long passes performed, and should therefore correlate quite highly. Similarly, although more independent, the number of tackles made appeared to contribute to the number of possessions won, and the number of possessions lost is affected by the number of times the player is tackled and the pass success rate.

Physiological factors such as $VO_{2peak}$ ($ml \cdot kg^{-1} \cdot min^{-1}$) have been found to record moderate positive correlations with technical actions in youth soccer players, including variables such as such as shooting (r=0.671), passing (r=0.601), dribbling (r=0.519) and ball control (r=0.573), (Fernandez-Gonzalo et al., 2010). Given these results are measured in young soccer players it may be plausible to assume physical parameters such as high-intensity running distance may show similar moderate correlations with technical variables such as shooting, dribbling, passing and ball control in senior soccer players. However, the results from the current study suggest that high-intensity running distance is not correlated with any technical parameter except small correlation with the number of passes made (r=0.257). When reported per position, high-intensity running distance correlated with the number of short (r=0.275) and medium passes (r=0.265) performed and the number of passes received (r=0.318) by full backs and the number of times possession was won by centre midfielders (r=0.220) and attackers (r=0.289). This would suggest that the running distance covered at high-intensity is not associated with technical performance. One possible explanation is difference in population groups and the factors assessed. This chapter analysed the match running performance in relation to technical performance of senior players compared to Fernandez-Gonzalo et al. (2010) who assessed physiological tests compared with technical performance in youth players. As a result, the variability of match running performance may reduce the correlations observed with technical performance, in comparison physiological testing is a more stable assessment, which may explain why correlations were observed in previous research. Another potential factor to consider is fatigue, which has previously been identified as having a negative effect on passing ability (Rampinini et al., 2008; Rostgaard et al., 2008). These effects on short passing ability are thought to be a result of the biomechanical changes of ball striking brought on by both peripheral and muscular fatigue (Kellis et al., 2006). If fatigue had a measurable impact on passing ability it might be expected to manifest itself as a negative correlation, of any magnitude in the current study, between high-intensity running distance or sprint distance and the number of passes made (including short and/or medium passes performed), which was not observed for any of the five outfield positions. This may be due to the whole match assessment adopted in the current study compared the to the assessment of intense 5 minute periods measured by Rampinini et al. (2008) and the simulated running protocols adopted by Kellis et al. (2006) and Rostgaard et al. (2008). The differing time periods examined and the real versus simulated environment examined may partially explain why poor correlations between high-intensity running distance and technical parameters were found in the current study. In addition, the categorisation of passes into short (<40 meters) or long (>40 meters), by Rampinini et al. (2008) differs markedly from the classifications adopted by semi-automated tracking systems which generally classify short passes as <10 meters, medium passes between 10-25 meters and long passes >25 meters. This difference in pass classification could have had a direct impact on Rampinini and colleagues conclusions of the associations between fatigue and technical proficiency.

Previous research has highlighted the correlation between lower limb strength and sprinting performance during matches (Wisløff et al., 2004; Wisløff, Helgerud, & Hoff, 1998) whilst also reporting moderate-strong correlations between limb strength and shooting, passing and ball control skills (Fernandez-Gonzalo et al., 2010). It could therefore be assumed that there would be a correlation between sprint performance and technical parameters in matches. However, the results of the current study suggest that there is no link between these variables during match play, with only full backs reporting weak correlations between sprint performance and the number of passes made, pass completion rate and the number of passes received. It is therefore possible that the controlled environments of testing in previous research have highlighted interactions that are not visible during matches due to the impact of situational factors such as match result and match lcoation. However limited analysis has been conducted during training sessions where information on the interaction of physical and technical parameters could be most useful. Information on the technical and physical demands of different training situations could prove useful in monitoring and establishing training workloads and training regimes. This may be particularly useful when training with small sized games which have previously been identified to cause increases in both technical and physical workloads when compared to full size and sided games (Da Silva et al., 2011; Dellal et al., 2012; Katis & Kellis, 2009).

Although some moderate-strong correlations were observed, in particular for high-intensity running distance WP, the variability between performances will affect the observed correlations on physical and technical variables (Bates, Zhang, Dufek, & Chen, 1996; Bush, Archer, Hogg, & Bradley, 2015). High variability has been previously been identified for tackling variables across all positions, as a consequence it is not surprising that these variables demonstrated very few correlations with physical variables (Bush et al., 2015). Attackers displayed a weak correlation between the distance covered at high-intensities and the number of tackles made and the number of possessions won. This may reflect the strategies adopted by teams to regain possession since possession is often lost in attacking areas of the pitch, and as a result attackers have the first opportunities to regain possession. In contrast defenders are often the last source of goal protection, where the majority of possession regains occur before defenders have the opportunity to tackle the opponent (Bangsbo & Peitersen, 2002; James et al., 2002). Alternatively, since central midfielders act as link between the defenders and attackers, when a team is in possession for longer periods of time central midfielders, often receive more ball possessions, thereby increasing the opportunities to be tackled (Bangsbo & Peitersen, 2004; Bush et al., 2015; James et al., 2002). Interestingly, parameters that show a high level of consistency (i.e. total distance covered, pass success rate) demonstrate the lowest correlations when comparisons were made between physical and technical variables. It appears that one parameter with low variability correlated a second parameter with high variability results in low overall correlation between the two parameters, and therefore may mask any trends between physical and technical parameters (Bates et al., 1996).

The results of the correlation analysis indicate that high-intensity running distance correlates strongest with technical variables; these correlations were more evident in for high-intensity running distance WP in central (centre back and centre midfield) and defensive (centre back and full back) positions ($r \approx 0.5$). In contrast, wide midfielders and attackers displayed greater correlations between high-intensity running distance WOP and technical parameters. It can be noted that certain fitness test results can produce similar correlation levels and could be a more accurate performance predictor for both physical (Yo-Yo intermittent recovery tests) and technical (drop jumps, repeated jump test protocols, $VO_{2max}$ tests) match performance measures, rather than direct comparisons between physical and technical parameters.

Until now research has treated physical and technical performance parameters as independent samples. The results of this study suggest that there is limited interaction between physical and technical match variables and therefore support the independent analysis of technical and/or physical parameters irrespective of playing position. Nevertheless, the research in this study analysed data over a full match, greater emphasis on temporal factors (i.e. analysing data over specific match time periods) may identify greater correlations and expand on the current knowledge base. Previous research has identified multiple ways of analysing temporal match data. One simple method would be to analyse correlations between first half and second half performances. Previous analysis of half-by-half data has highlighted reduced physical output in the second half when compared to the first (Barros et al., 2007; Bradley, Carling, et al., 2013; Bradley & Noakes, 2013; Vescovi, 2012; Vigne et al., 2010), it would be interesting to note whether this reduced output would affect the interaction between physical and technical performance. This information can be important for practitioners, it demonstrates there are limited associations between physical and technical match parameters when analysing data across a full match although does not identify if there are associations during key moments, or specific time frames during matches. In addition, this information can also be used to monitor and assess training and match workloads.

# *Chapter 6* : Study 3: Positional Evolution of Physical and Technical Performance Parameters in the English Premier League

## 6.1 Introduction

The EPL has long been considered one of the most physically demanding leagues in professional soccer, players have been measured performing a greater physical workload in the EPL compared to the physical performance in the top leagues in other countries worldwide (Barros et al., 2007; Bradley et al., 2009; Bradley, Carling, et al., 2011; Carling, 2010; Dellal et al., 2011; Di Salvo et al., 2010, 2009). The effect of league location on technical variables is less clear as fewer research studies have been conducted on technical variables. Overall, the research that has been conducted in this area has been focused mainly on the EPL (Bradley, Carling, et al., 2011, 2013; Bradley, Dellal, et al., 2014; Collet, 2013; Rampinini et al., 2009). It is widely accepted that players cover between 10-13 km per match, although only 1-1.5 km of this distance is covered at intensities over 19.8 $km \cdot h^{-1}$, the majority of the remaining distance is covered at low intensities (<14.4 $km \cdot h^{-1}$). Nevertheless the distance covered by players is dependent upon playing position, with central midfielders covering the greatest total distance, whilst full backs and wide midfielders cover the most distance at high-intensities (Bangsbo et al., 2006; Barros et al., 2007; Bradley et al., 2009; Bradley, Carling, et al., 2011, 2013; Bradley, Dellal, et al., 2014; Carling et al., 2012; Di Salvo et al., 2013, 2007, 2010, 2009; Mohr et al., 2003). Players generally perform around 20-30 passes per game, the majority of these are short to medium distance passes (<25 m), with less emphasis on long distance passing (Bradley, Carling, et al., 2013; Hughes & Franks, 2005; Rampinini et al., 2009). In addition to the number of passes, players are expected to successfully complete a minimum of 70% of passes (Dellal et al., 2011) and whilst in possession players typically touch the ball an average of 2-3 times during each interaction with the ball (Bradley, Carling, et al., 2011, 2013; Bradley, Dellal, et al., 2014). Although there are some research groups that have analysed the technical performance during soccer matches, the information is limited and is not current data. As a result greater understanding is required on overall technical performance in soccer to provide greater reliability and clarity in the interpretation of results.

Despite substantial research into the physical and technical performance of players in the EPL there is limited evidence of the existence or direction of performance evolution in either the physical or technical demands of the EPL. Researchers often gather data over numerous seasons in order to analyse a large sample and therefore provide statistically reliable results (Barros et al., 2007; Bradley & Noakes, 2013; Carling & Bloomfield, 2010; Carling et al., 2012; Collet, 2013; Di Salvo et al., 2010, 2013), however this is often conducted without the understanding of evolving match patterns and therefore may not provide an accurate assessment of current performance. Recent research has begun to identify evolving match patterns and has identified that high-intensity running and sprint distance have increased by 30-50% in the EPL while the overall number of passes have increased by 40% over a seven-year period (Barnes et al., 2014). These changes in the EPL mirrored longitudinal increases in FIFA World Cup Final matches over a 44 year period, where an increase in ball out of play time was observed and an increase in match intensity and passing tempo was measured (Wallace & Norton, 2014). Nevertheless, these previous studies failed to account for specific positional evolutionary trends (Bradley et al., 2009; Di Salvo et al., 2007, 2010; Gregson et al., 2010). Central midfielders have consistently been found to cover the greatest total distance whilst full backs, central midfielders and wide midfielders covered greater distances at high-intensities (Barros et al., 2007; Bradley et al., 2009; Di Salvo et al., 2007, 2009). Given the evolutionary changes highlighted previously in elite soccer (Barnes et al., 2014; Wallace & Norton, 2014), it would be of interest to track longitudinal positional changes to gain insight into physical and technical requirements of modern players. Thus, this study aimed to investigate the position-specific evolution of physical and technical parameters in the EPL using one of the largest controlled samples published to date.

## 6.2 Methods

### 6.2.1 Statistical Analysis

One-way independent-measures analysis of variance (ANOVA) tests were used to compare each season for each of the five outfield positions (five independent tests) with Dunnet's *post hoc* tests used to verify localised differences in comparison to the 2006-07 season. Independent variables were set as playing position and season, whilst dependent variables were set as the physical and technical performance parameters. Statistical significance was set at $p<0.05$. The effect size (ES) was calculated to determine the meaningfulness of the difference with magnitudes classified as trivial (<0.2), small (>0.2-0.6), moderate (>0.6-1.2) and large (>1.2-2.0), (Batterham & Hopkins, 2006). All analyses were conducted using statistical software (R Development Core Team) and data visualisation was carried out using the “ggplot2” package accessed via the Deducer Interface for the R statistical programming language.

### 6.2.2 Hypothesis

$H_0$ – There will be no differences in the physical and technical performance measures between positions in the EPL

$H_0$ – There will be no evolution or change in performance measures on a season by season basis between 2006-07 and 2012-13.

## 6.3 Results

### 6.3.1 Physical Parameters

Total distance covered during matches showed small changes between 2006-07 and 2012-13, increasing for central midfielders, central defenders, full backs and attackers (200-300 m, $p<0.001$, ES: 0.3 [CI: 0.2-0.4], 0.5 [CI: 0.4-0.7], 0.3 [CI: 0.2-0.4] and 0.4 [CI: 0.3-0.6] respectively). Wide midfielders displayed no change across the seven seasons (11385±725 m vs. 11389±742 m, $p>0.05$, ES: 0.01 [CI: -0.15-0.16]). Figure 6.1 demonstrates the total distance profiles of the five outfield positions, the figure clearly shows players in central midfield cover the highest total running distance whilst centre backs cover the lowest total distance. The figure also clearly displays the small and continual increases in total distance observed over the seven seasons analysed. It is worthy to note a minor anomaly observed for all positions in the 2007-08 season where the software developers changed definitions slightly altering the values recorded.

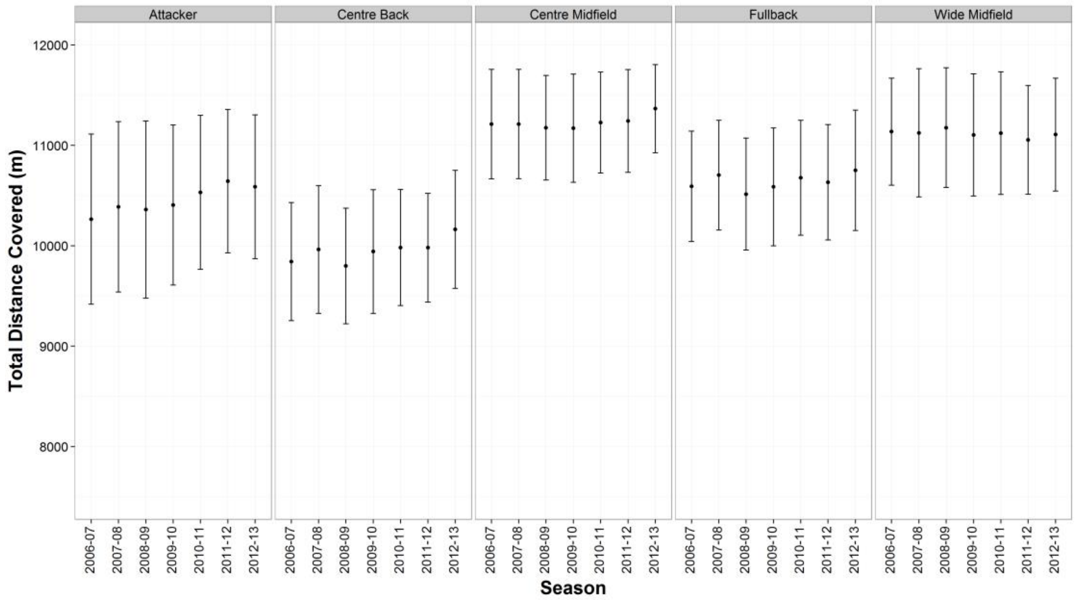


Figure 6.1: Plot for mean and standard deviation of total distance covered per match across the seven seasons in the English Premier League. Each plot is split to represent the five outfield positions analysed.

Full backs showed the greatest change in high-intensity running distance (Figure 6.2; 35% increase, p<0.001, ES: 1.3 [CI: 1.1-1.4]), nevertheless all positions demonstrated moderate increases in high-intensity running distance over the seven seasons (central defenders: 33%; wide midfielders: 27%; central midfielders: 30%; attackers: 24%, p<0.05, ES: 1.1 [CI: 1.0-1.2], 1.1 [CI: 1.0-1.3], 1.0 [CI: 0.9-1.2] and 0.9 [CI: 0.7-1.0]). Although high-intensity running distance for full backs increased across all seasons figure 6.2 clearly shows a large increase between the 2011-12 to 2012-13 seasons, this is compared to the other positions which show a constant increase in high-intensity running distance across all seasons, nevertheless the reason for this change is unclear. Central defenders, full backs and wide midfielders demonstrated moderate increases in high-intensity running distance covered

WP (central defenders: 114±61 vs. 193±86 m, p<0.001, ES: 1.1 [CI: 0.9-1.2]; full backs: 355±159 vs. 503±181 m, p<0.001, ES: 0.9 [CI: 0.7-1.0]; wide midfielders: 591±178 vs. 710±171 m, p<0.01, ES: 0.8 [CI: 0.6-1.0]). In contrast, central midfielders and attackers showed small increases for high-intensity running distance WP (≈100 m, p<0.05, ES: 0.5 and 0.6 [CI: 0.4-0.7]). All positions showed moderate increases in high-intensity running distance WOP between 2006-07 and 2012-13, central defenders increased from 438±120 to 533±138 m (p<0.001, ES: 0.7 [CI: 0.6-0.9]), full backs increased from 498±133 to 657±150 m (p<0.001, ES: 1.1 [CI: 1.0-1.3]), central midfielders increased from 519±166 to 697±213 m (p<0.001, ES: 0.9 [CI: 0.8-1.1]), wide midfielders increased from 480±168 to 624±200 m (p<0.001, ES: 0.8 [CI: 0.6-0.9]) and attackers increased from 278±124 to 386±148 m (p<0.05, ES: 0.8 [CI: 0.6=1.0]). All positions recorded moderate-large increases in sprint distances (Figure 6.3), full backs displayed the greatest increase (250±105 m vs. 405±125 m, 62%, p<0.001, ES: 1.3 [CI: 1.2-1.5]) compared to wide midfielders (≈160 m, 53%, p<0.001, ES: 1.3 [CI: 1.2-1.5]), central positions (≈80-120 m, ≈53%, p<0.001, ES: 1.1 [CI: 0.9-1.3]) and attackers (276±117 m vs. 375±121 m, 36%, p<0.001, ES: 0.8 [CI: 0.7-1.0]).

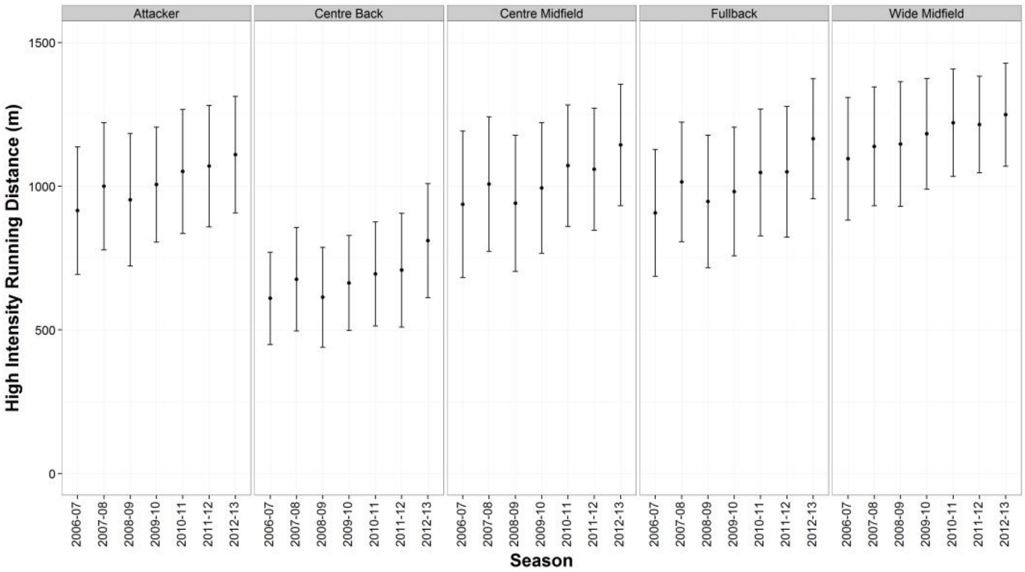


Figure 6.2: Plot for mean and standard deviation of high-intensity running distance covered per match across the seven seasons in the English Premier League. Each plot is split to represent the five outfield positions analysed.

The number of high-intensity actions and the number of sprints performed increased for all positions between 2006-07 and 2012-13 (Figure 6.4 and 6.5; ES: 1.6-2.0 [CI: 1.4-2.1], 1.6-2.0 [CI: 1.4-2.2], respectively). For both parameters, attackers exhibited the smallest increases (high-intensity actions: 121±32 vs. 174±35, $p<0.001$, ES: 1.6 [CI: 1.4-1.8]; sprint actions: 35±13 vs. 59±17, $p<0.001$, ES: 1.6 [CI: 1.4-1.8]), whereas wide positions exhibited the greatest (high-intensity actions: ≈60, $p<0.001$, ES: 1.8-2.0 [CI: 1.6-2.1]; sprint actions: ≈30, $p<0.001$, ES: 2.0 [CI: 1.8-2.2]). The number of explosive sprints increased by very large magnitudes for all positions (central defenders: 7±5 vs. 19±8, ES: 1.8 [CI: 1.6-1.9]; full backs: 11±6 vs. 28±10, ES: 2.0 [CI: 1.9-2.2]; central midfielders: 11±7 vs. 29±10, ES: 2.1 [CI: 1.9-2.2]; wide midfielders: 14±7 vs. 33±11, ES: 2.1 [CI: 1.9-2.3]; attackers: 12±6 vs. 27±9, p<0.001, ES: 2.0 [CI: 1.8-2.2]). Leading sprints showed moderate-large increases for all positions (central defenders: 13±5 vs. 20±7, full backs: 22±8 vs. 35±10, central midfielders: 20±9 vs. 30±10, wide midfielders: 27±9 vs. 41±11, p<0.001), whereas attackers showed the smallest increase (p<0.01) from 23±9 to 32±11 (ES: 1.1 [CI: 1.0-1.3], 1.4 [CI: 1.3-1.6], 1.1 [CI: 0.9-1.2], 1.4 [CI: 1.2-1.6] and 0.9 [CI: 0.7-1.1], respectively).

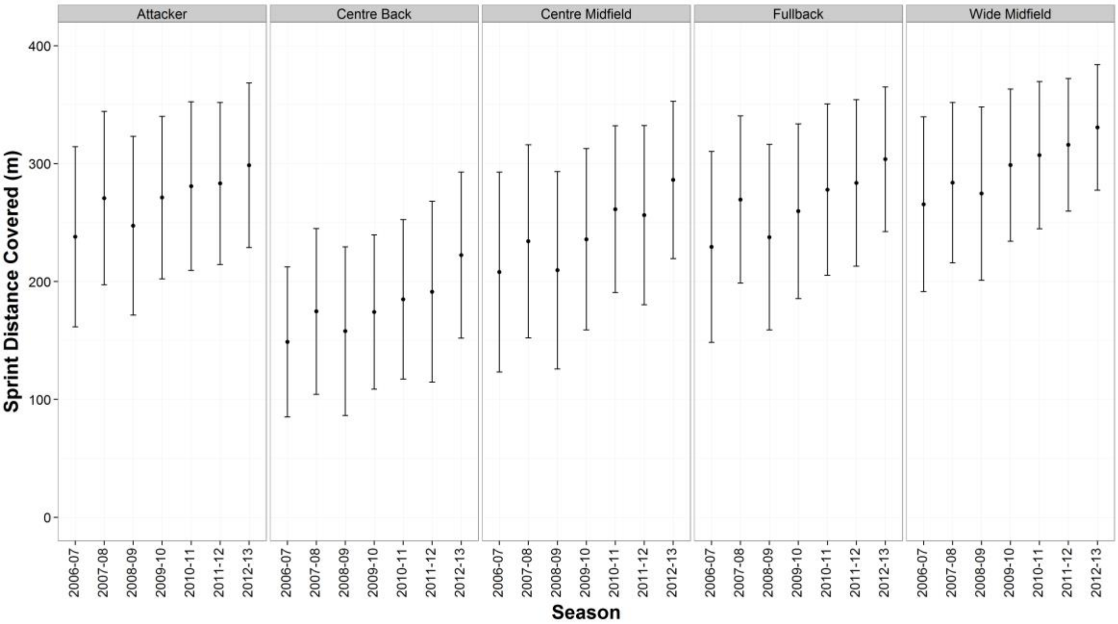


Figure 6.3: Plot for mean and standard deviation of sprint covered per match across the seven seasons in the English Premier League. Each plot is split to represent the five outfield positions analysed.

### 5.3.2 Technical Parameters

Moderate-large increases were observed for central players (central defenders and midfielders) in the total number of passes performed between 2006-07 and 2012-13 compared to wide players (full backs and wide midfielders) and attackers who showed small increases (Figure 6.6). Figure 6.6 displays the number of passes performed increased for central players over the seven seasons analysed compared to wide players, this is shown in the width of each of the density plots. For central positions the plot width expands, the plot width for wide players in contrast stays similar over the seven seasons, representing the increase in the number of passes performed. In contrast, displayed by the tails observed in each density plot, the pass completion rate by both wide and central players increases (plot tail shrinks) over the course of the seven seasons. Central defenders increased the number of passes by ≈70% (19±12 vs. 32±16), central midfielders increased ≈50% (33±15 vs. 49±18, $p<0.001$, ES: 0.9 [CI: 0.8-1.1]). Full backs, wide midfielders and attackers showed similar increases (≈25%) in the number of passes over the seven seasons (full backs: 28±12 vs. 35±14; wide midfielders: 27±11 vs. 33±15; attackers: 19±8 vs. 24±12, $p<0.001$, ES: 0.5 [CI: 0.3-0.7]). Although wide players showed small increases in the number of passes over the seven seasons, similar increases in the pass success rate compared to central players were observed (all positions increased by ≈7%, $p<0.01$, ES: 0.6-0.8 [CI: 0.5-0.9]). No differences were identified for the pass success rate for attackers ($p>0.05$, ES: 0.3 [CI: 0.1-0.4]).

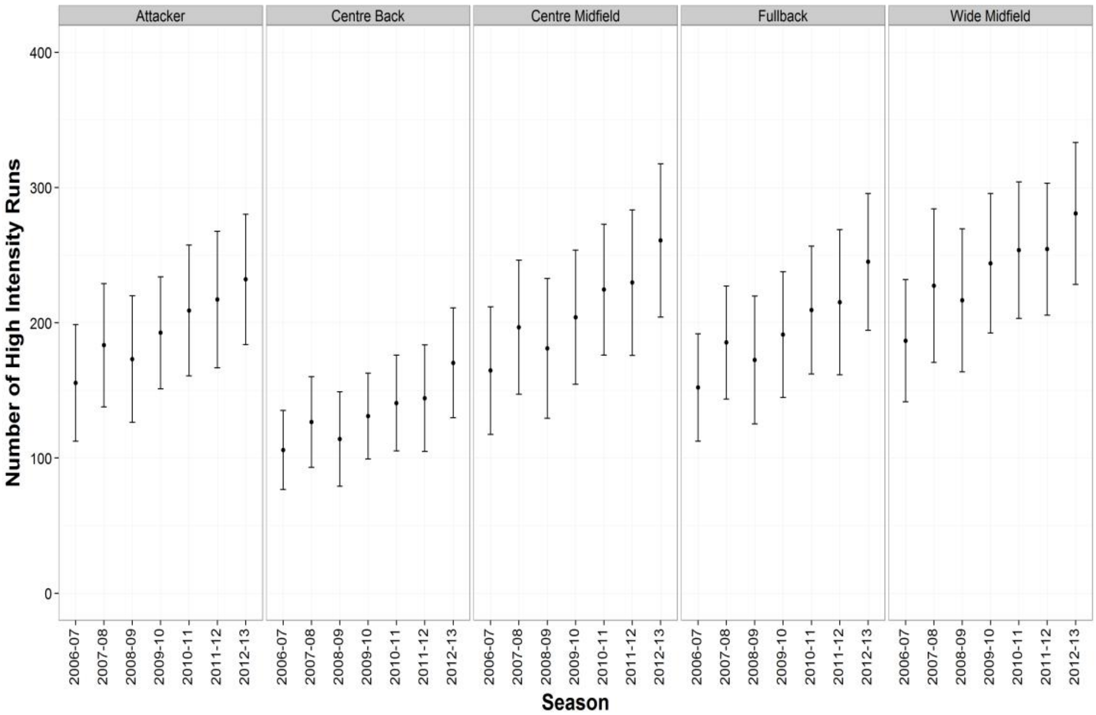


Figure 6.4: Plots to represent the mean and standard deviation changes in the number of high-intensity actions in the English Premier League across the seven seasons analysed. Each plot is split to represent the five outfield positions.

Central midfielders and full backs performed 5 more short distance passes between 2006-07 and 2012-13 ($p<0.001$, ES: 0.9 [CI: 0.7-1.0]). All other positions displayed small-moderate increases in the number of short distance passes performed (central defenders: 2.6±2.5 vs. 4.5±3.3; full backs: 6±4 vs. 10±5; wide midfielders: 8.6±4.5 vs. 12±6.5, $p<0.001$, ES: 0.7 [CI: 0.6-0.9], 0.9 [CI: 0.8-1.0] and 0.6 [CI: 0.5-0.8] respectively). Central midfielders performed 10 more medium distance passes in 2012-13 compared to 2006-07 ($p<0.001$, ES: 0.8 [CI: 0.7-1.0]), whilst central defenders performed 9 more medium distance passes ($p<0.001$, ES: 0.9 [CI: 0.8-1.0]) and full backs performed 5 more medium distance passes in 2012-

13 (p<0.001, ES: 0.6 [CI: 0.5-0.7]). Central defenders performed more long distance passes in 2012-13 (p<0.001, ES: 0.6 [CI: 0.4-0.7]), whereas full backs and wide midfielders performed fewer long distance passes over the seven seasons (p<0.05, ES: 0.4 [CI: 0.2-0.6]). Attackers showed trivial-small non-significant changes in the number of short, medium and long distance passes performed over the seven seasons (p>0.05, ES: 0.6 [CI: 0.5-0.8], 0.5 [CI: 0.3-0.6] and 0.04 [CI: -0.1-0.2] respectively).

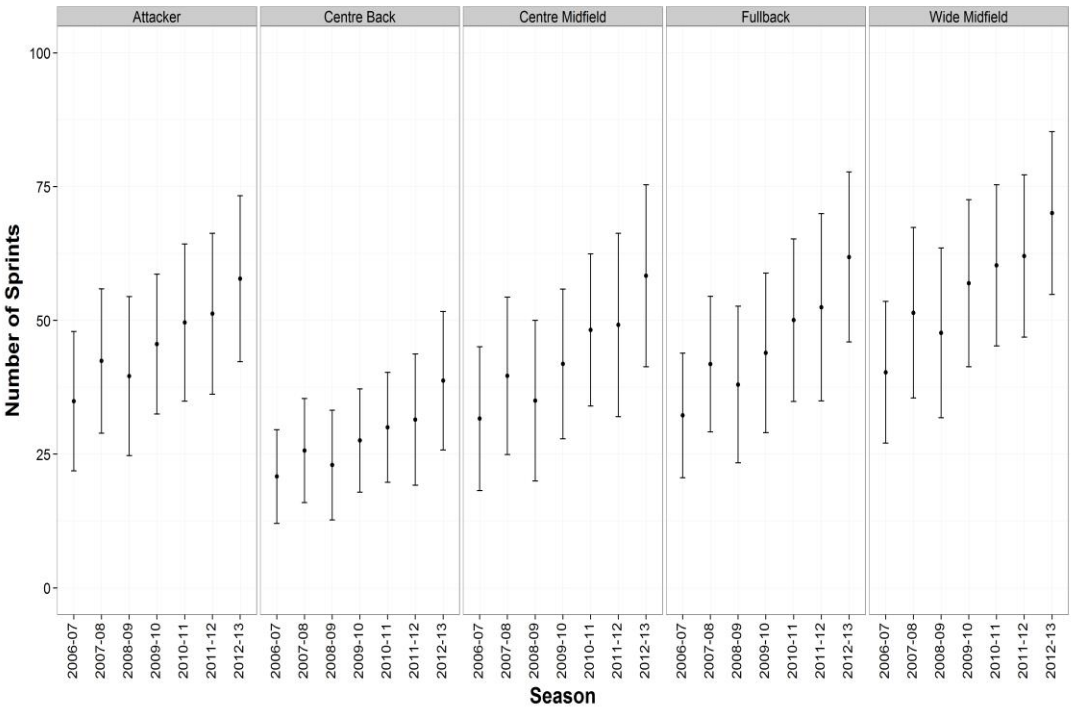


Figure 6.5: Plots to represent the mean and standard deviation changes in the number of sprint actions in the English Premier League across the seven seasons analysed. Each plot is split to represent the five outfield positions.

All positions displayed small-moderate decreases in the number of possessions won across the seven seasons. Central defenders showed the greatest decrease (28±7 vs. 22±6, p<0.001, ES: 0.9 [CI: 0.8-1.0]) compared to full backs (22±6 vs. 18±5, p<0.001, ES: 0.7 [CI: 0.6-0.8]), central midfielders (20±7 vs. 17±6, $p<0.001$, ES: 0.5 [CI: 0.3-0.6]), and wide midfielders (14±5 vs. 11±5, $p<0.001$, ES 0.6 [CI: 0.4-0.8]). Whilst attackers showed a decrease in the number of possessions won although statistically the reduction was non-significant (7±4 vs. 6±3, $p>0.05$, ES: 0.3 [CI: 0.1-0.4]). Decreases were observed for all positions in the number of possessions lost between 2006-07 and 2012-13 (central defenders: 20±6 vs. 16±6, $p<0.001$, ES: 0.7 [CI: 0.6-0.8]; full backs: 23±7 vs. 20±7, $p<0.001$, ES: 0.6 [CI: 0.4-0.7]; central midfielders: 21±6 vs. 19±6, $p<0.05$, ES: 0.4 [CI: 0.2-0.5]; wide midfielders: 26±6 vs. 22±6, $p<0.05$, ES: 0.7 [CI: 0.6-0.9]; attackers: 23±7 vs. 21±6, $p<0.05$, ES: 0.4 [CI: 0.3-0.6]).

Small decreases in the number of final third entries were identified for full backs and wide midfielders between 2006-07 and 2012-13 (9±5 vs. 7±4, $p<0.001$, ES: 0.7 [CI: 0.5-0.8]; 5±3 vs. 4±3, $p<0.05$, ES: 0.5 [CI: 0.3-0.7] respectively). None of the five positions showed changes in the number of tackles made between 2006-07 and 2012-13, respectively (Central defenders: 3±2 vs. 3±2; full backs: 3±2 vs. 4±2; central midfielders: 4±3 vs. 4±3; wide midfielders: 3±2 vs. 3±2 and attackers: 2±2 vs. 2±1, $p>0.05$, ES: 0-0.5) or tackled events over the seven seasons (central defenders: 1±1 vs. 1±1; full backs: 2±2 vs. 2±2; central midfielders: 3±2 vs. 3±2; wide midfielders: 5±3 vs. 4±3; attackers: 5±3 vs. 5±3; $p>0.05$, ES: 0-0.2 [CI: -0.2-0.4]).

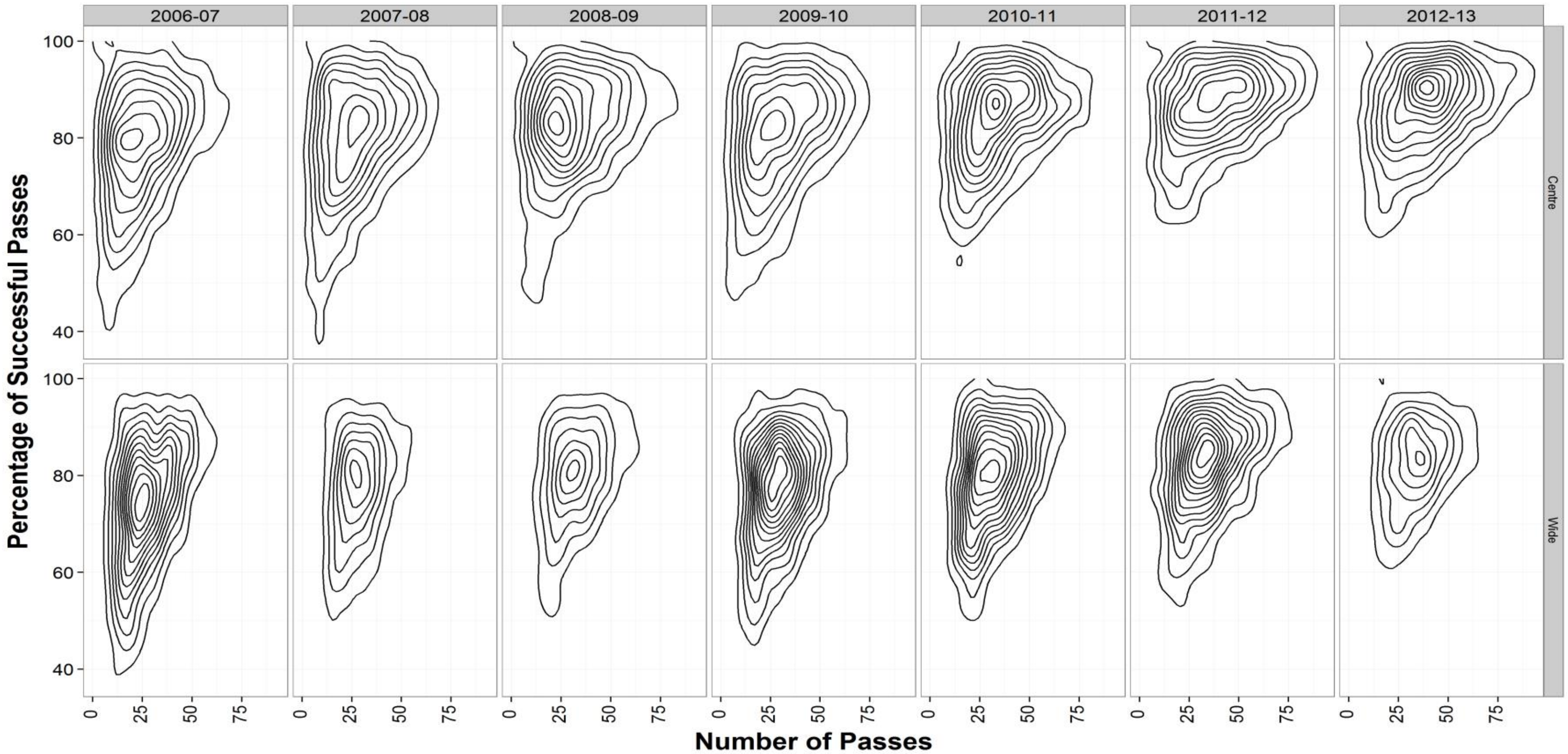


Figure 6.6: Two-dimensional kernel density plots representing the number of passes and the pass success rate of central (central defenders and central midfielders) and wide players in the EPL (full backs and wide midfielders). The plot displays a similar number of passes performed by wide players, while central players increase the number of passes over the seven seasons (plot width). Nevertheless both wide and central players increased the success rate of passes (plot length).

## 6.4 Discussion

This study investigated the position-specific evolution of physical and technical parameters in the EPL. Previous large-scale studies have not controlled for seasonal, tactical or contextual factors (Di Salvo et al., 2013; Gregson et al., 2010). These factors have been found to influence the physical and technical performance of elite players and thus should be accounted for in the methodological design (Bradley et al., 2009; Castellano et al., 2012; Di Salvo et al., 2009; Lago et al., 2010). Our study is the first to re-sample data using a randomised stratification algorithm to account for seasonal and contextual factors (match location, opposition standard, month of match). Thus, this analytical approach will allow more appropriate generalisations to be made regarding the longitudinal performance characteristics of various playing positions.

Our research group recently reported that total distance covered in EPL matches had typically increased by 2% across seven seasons (Barnes et al., 2014) although position-specific trends were not reported. Interestingly, the current study identified an increase in total distance covered for central players only (central defenders and midfielders), with wide players (full backs and wide midfielders) and attackers demonstrating negligible changes. These observed changes were, however, within the inherent match-to-match variability for total distance covered by all positions in the EPL (Bush et al., 2015; Gregson et al., 2010) and as such should be treated with care. It may therefore be possible the changes were due to the natural variation in soccer performance rather than long-term changes in the physical requirements of soccer.  It has been reported that the distance covered at high-intensity seems a superior, more sensitive indicator of performance than total distance covered as it correlates better with physical capacity (Bradley, Carling, et al., 2011; Krustrup et al., 2005) and is a distinguishing variable between competitive standard and gender (Andersson et al., 2010; Bradley, Carling, et al., 2013; Mohr, Krustrup, Andersson, Kirkendal, & Bangsbo, 2008; Mohr et al., 2003). The findings of the current study revealed pronounced increases for high-intensity running distance for all positions (24-36%), the magnitude of these changes were greater than the inherent match-to-match variability previously reported for high-intensity running (Gregson et al., 2010). This could suggest that the elevation in high-intensity running over the seven seasons is due to evolving game patterns as opposed to natural variability.

Our findings suggest that the physical requirements of modern soccer, particularly for high-intensity running, have evolved more for defenders (central defenders and full backs) and central midfielders (30-36%) than for attacking players (wide midfielders and attackers, 24-27%). This trend in physical performance could potentially be attributed to improvements in the players' physical capacity through enhanced physical preparation, or via an influx of players with innately higher levels of physical fitness. Evidence would suggest maximal oxygen uptake ($VO_{2max}$) of elite soccer players has stayed relatively stable over the last two decades (Tønnessen et al., 2013) although this may not be the most appropriate measure of physical capacity in elite team sports, with intermittent exercise capacity identified as a more sensitive measure of training adaptations than $VO_{2max}$ (Iaia, Rampinini, & Bangsbo, 2009; Krustrup & Bangsbo, 2001). Data from our laboratory indicates that the average distance covered by elite soccer players during the Yo-Yo Intermittent Endurance Level 2 Test has increased minimally (Bradley, Carling, et al., 2011, 2013) in contrast to the dramatic increases in high-intensity running distances in EPL matches across a similar time period (Barnes et al., 2014). Thus, if the physical capacity of EPL players has remained stable across this time then these findings could be the result of players working at a higher proportion of their physical capacity in games. In support of this notion Bradley et al. (2013) reported no differences in the intermittent exercise capacity of players in the top three tiers of the English games but found that the lower tier players covered more distance at high-intensity compared with top tier players. Thus, it is plausible that current EPL players are expected to work at a higher relative intensity compared to nearly a decade ago, possibly driven by changes in tactics and playing systems. For example, when in possession, modern tactics often require wide midfielders to play in more central positions attracting defenders inside and creating space for full backs to move into, thus introducing more players into attacking positions (Bangsbo & Peitersen, 2004; Tipping, 2007). When possession is lost players must quickly recover from attacking positions into defensive positions, increasing the number of defensive players behind the ball and therefore reducing the space for attacking play (Bangsbo & Peitersen, 2002; Wallace & Norton, 2014). These tactical changes support the finding that full backs demonstrated the most pronounced increases in high-intensity running and sprinting across the seven seasons. This tactical change has arisen from changes in the traditional rigid playing systems (4-4-2, 4-3-3 and 4-5-1) to move to more dynamic contemporary systems (4-2-3-

1, 4-1-4-1). Although is it difficult to discuss the impact of playing formations on physical performance as limited studies exist, the increasing popularity of the compact 4-2-3-1 system in the EPL could be one potential reason why full backs now cover more high-intensity and sprinting distances, but more research needs to be undertaken to verify this. Ultimately, if players are working at higher proportions of their physical capacity it is possible that eventually players will reach a maximum work rate in respect to the $VO_{2max}$, and therefore increases in physical aspects of gameplay will plateau unless respective increases in player's physical capabilities also occur.

Overall sprint distances increased by ≈50% between 2006-07 and 2012-13, however when analysed by position interesting differences were observed. The greatest increases were observed in full backs (63%), followed by central defenders, central midfielders and wide midfielders increased sprint distance (all 54%) and attackers (36%). In 2012-13 players in wide (full backs and wide midfielders) and attacking positions covered a higher percentage of total distance by sprinting (3.5-4.2%) than central defenders or central midfielders (2.3-2.9%). These findings have implications in terms of the physical preparation of players. This could be achieved through individual drills for each position or ideally during soccer simulations that incorporate all 5 positions working in tandem with specific instructions provided where tactical and technical aspects are merged with the unique physical demands of each position (e.g. full backs sprint whilst creating overlaps with wide midfielders followed by recovery runs).

Previous research has reported that the absolute number of explosive and leading sprints is dependent on playing position (Di Salvo et al., 2009).

Across the timeframe of this study, all positions showed increases in the number of leading (39-59%) and explosive sprints (125-171%). For both types of sprints attackers showed the smallest relative change whilst full backs and central defenders demonstrated the greatest. Although differences were observed in the absolute number of leading and explosive sprints the proportions of explosive sprints remained comparable amongst all positions (44-49%). Increases in the number of sprints and in particular the proportion of explosive sprints would suggest an increase in match intensity whilst at the same time players must maintain technical abilities (Bangsbo & Peitersen, 2004). In addition, players in defensive positions showed higher increases in the number of explosive and leading sprints, suggesting that the evolution in sprints is due to changes in strategies and tactics. When in possession, modern tactics mean wide midfielders play in more central positions attracting defenders inside and creating space for full backs to move into, thus introducing more players into attacking positions (Bangsbo & Peitersen, 2004). This has been identified to occur more in stronger teams where wide midfielders have been shown to contribute with attacking and passing opportunities in the final third but contributed less to crosses (Hongyou Liu, Gómez, Gonçalves, & Sampaio, 2016). When possession is lost players must then recover from attacking positions into defensive positions, increasing the number of defensive players behind the ball and therefore reducing the space for attacking play (Bangsbo & Peitersen, 2002; Wallace & Norton, 2014). The increase in the number and type of sprints performed in soccer match-play has been proposed as one causative factor for increased injury propensity, in particular groin and hamstring strains

(Junge & Dvorak, 2010). Changes in injury rates are unclear over a comparable time period (Ekstrand, Hägglund, & Waldén, 2011b), but are based on a small sample across Europe, and not purely on the EPL. The aetiology of muscle injuries in soccer is complex, however there is currently widespread use of pre-habilitation and preventative programmes utilising exercises such as Nordic lunges to reduce injury risk (Daly, 2013; Opar et al., 2012). The absolute numbers of leading and explosive sprints as well as the distance covered at high-intensity and maximal speeds in 2012-13 were greater than previous studies conducted on players competing in the UEFA Champions League, Spanish La Liga and EPL (Bradley et al., 2009; Di Salvo et al., 2007; Lago et al., 2010), therefore supporting the general perception that the EPL has evolved into one of the most physically demanding leagues in soccer.

Soccer is based on a combination of physical, technical and tactical aspects of match play. Although the physical and tactical aspects are central to high-level soccer match performance (Bradley, Carling, et al., 2013; Lago-Ballesteros et al., 2012), players' and teams' technical ability have been identified as the best indicators of success (Castellano et al., 2012; Collet, 2013; Rampinini et al., 2009). The number of passes performed in FIFA World Cup final matches has been shown to have increased by 40% over a 44 year period (Wallace & Norton, 2014), a similar increase to that observed over a seven year period in the EPL (Barnes et al., 2014). When broken down by position we can show that passes performed increased by a greater extent in central defenders (≈66%) and central midfielders (44%), compared to full backs, wide midfielders and attackers (all ≈25%). This increase in the number of passes is comprised primarily from increased short and medium distance passes (30-72% increases), whilst there was little or no increase in the number of long distance passes across all positions. A previous analysis of World Cup final matches identified an increase in passing tempo over a 44 year period (Wallace & Norton, 2014). Although this study did not directly analyse the number of passes per minute, the observed increase in passes over the course of a match, coupled with previous findings demonstrating increases in match stoppage time (Wallace & Norton, 2014) would infer an increase in passing tempo. The relatively greater increases in the number of passes by central players may be as a result of a change in positional roles. Previously central defenders were used purely in a defensive role, and although the defensive role of a central defender is unchanged (no differences in the number of tackles and interceptions), the attacking role has evolved. The increase in the number of passes could indicate an evolution of positional tactics, with many teams now focussing on possession based strategies, awaiting opportunities to exploit gaps in opposition defence. Teams use short to medium distance passes to increase the likelihood of pass success, essential for maintaining possession in areas of increased player density whilst still attempting to find weakness in the opposition defence (Bangsbo & Peitersen, 2004; Tipping, 2007). As a consequence defenders, in particular central defenders, provide extra passing options when in possession (Bangsbo & Peitersen, 2004; Tipping, 2007). This is supported in this current study with decreases observed in the number of possessions won and lost by players in all positions which suggests once a team has possession they are more likely to maintain possession and further supported by recent findings by Prozone (2014) who noted an increase in the number of passes per shot since 2006-07, suggesting more patient build up play by teams, probing at opposition defence before finding weaknesses which may lead to a shot on goal. Further evidence can be seen in the increases observed in the number of passes received with central defenders (109%) and central midfielders (70%) showing greater increases than colleagues in other positions.

Bradley et al. (2011) previously reported effects of playing formation on high intensity distance covered. Nevertheless, current research has not investigated the effects of playing formation on technical indicators, nor does research take into account formations when analysing data. In addition, playing formations have evolved from older traditional formations such as 4-4-2, 4-3-3 and 4-5-1 to more advanced and modern formations such as 4-2-3-1 and 4-1-4-1, the physical and technical evolution of match play needs to be coincided with the evolution in playing formations to gain a true representation and understanding of the evolution in soccer. With no changes in physical capacity of soccer players (Tønnessen et al., 2013), it is clear that there must be other driving forces behind the evolution of both physical and technical match performance. The modern formations result in compact midfield creating space in wider pitch areas for full backs to push forward in support of attacking play, therefore increasing the high-intensity distance covered in order to perform both the attacking and defensive aspects of a full backs game plan. The increased player density in the central areas has forced an increase in passes and pass success in order to maintain possession, due to the number of players in central areas the central defenders are required as additional passing options in order to pass around the opponents and build up attacking play (Bangsbo & Peitersen, 2004). It may also be plausible that the playing styles in the EPL, particularly in the earliest years are as a consequence of the direct style of play previously adopted following the findings of Reep & Benjamin (1968), and therefore EPL clubs may still be evolving and developing more passing based playing styles and tactics to those observed in other leagues across the world (Collet, 2013; Janković, Leontijević, Jelušić, & Pašić, 2011; Rampinini et al., 2009).

The technical findings of this study have implications for the scouting process, it is now important for scouts to find and recruit players who are able to play a similar system and style of play compared to the club which is looking to recruit them, possession based teams need to search for central defenders who are not only good defenders but also comfortable and confident on the ball with good passing ability. Direct style teams require central defenders who are good defenders with fewer requirements on passing ability.

This study demonstrates that players in wide and attacking positions have increased the distance covered at high-intensity and sprinting to a greater extent than central defenders and central midfielders between 2006-07 and 2012-13. In contrast, central players were found to have increased the number of passes and pass completion rates over the same period. These evolutionary trends could be attributed to tactical modifications with more teams playing possession-based football although more investigation into the evolution of tactics and playing styles is required. These findings provide useful data for benchmarking requirements of modern EPL players in each position and can therefore assist in player recruitment and development of position-specific training drills.

# *Chapter 7* : Study 4: Longitudinal Match Performance Characteristics of UK and Non-UK Players in the English Premier League

### 7.1 Introduction

There are frequent reports regarding the number of players who perform in the EPL, this is often associated with the number of non-UK players bought by clubs to add to their squads (BBC, 2013). However there is little research on player transfer in professional sport except articles published in the media, nonetheless, it is evident that there is an ever increasing number of non-UK players purchased and playing for English clubs in the EPL (BBC, 2013; Transfermarkt, 2014). Although increasing migration occurred before the mid-1990s, players coming to play in the top league in England were typically from commonwealth countries due to social and historical factors (McGovern, 2002; Taylor, 2006). However by the mid 1990's many changes had occurred in social and political world simultaneously, thus expanding the potential player markets, in particular across Eastern Europe and former Soviet Union countries but also across the world (Taylor, 2006).

The effect of the social and political changes were further enhanced by the introduction of the Bosman ruling in 1995, which enabled clubs to employ greater number of non-native players (Baur & Lehmann, 2007; BBC, 2013; Binder & Findlay, 2012; McGovern, 2002; Taylor, 2006; Transfermarkt, 2014). The Bosman ruling allowed the free transfer of out of contract players within the European Union, thus opening up the pool of available players for English clubs. In addition, the ruling prohibited the introduction of foreign player quotas and therefore allowed clubs to recruit as many non-UK players as they desired (Binder & Findlay, 2012). Since the introduction of the Bosman ruling National Governing Bodies and Continental Confederations within Europe have attempted to impose restrictions on the number of “home-grown” players within either a team’s starting line-up or the teams squad. However, these restrictions are constantly under scrutiny due to the legality of such restrictions (the European Union permits unimpeded employment migration between EU member states, and therefore prevents member countries restricting migration), as well as a reluctance by clubs in the EPL to agree on the introduction of player quotas (Gardiner & Welch, 2011; Soika, 2008). As a consequence of social and political changes, as well as the introduction of the Bosman ruling, the EPL saw an increase in the minutes played by non-UK players from 28.9% in 1994-95 to 67% in 2013-14 (BBC, 2013; Binder & Findlay, 2012).

The majority of research has focused on the social and historical effects and influences upon migration, both overall and sport specific, as well as the personal and professional consequences of migration (Free, 2007; Littlewood et al., 2011; Maguire & Pearton, 2000; McGovern, 2002; Taylor, 2006). There is little research focused on the impact of player migration on overall performance, let alone the physical or technical performance during match play on a country or continent basis. The limited research that has been conducted has analysed the number of imports and exports on national club performance (Baur & Lehmann, 2007; Binder & Findlay, 2012). The research has suggested there may be some small negative effects on national and domestic leagues, although these negatives effects generally impact lower ranked teams and do not impact greatly on the big European Leagues (England, France, Spain, Germany, Italy), (Binder & Findlay, 2012). Nevertheless, national teams who have a greater number of players performing in leagues abroad tend to perform better than teams with fewer exported players (Baur & Lehmann, 2007). In addition, it has been suggested that greater player imports has increased the playing standards within the imported league, with player imports occurring across all teams, not just the top teams, therefore maintaining the league's competitiveness (Baur & Lehmann, 2007; Binder & Findlay, 2012). Research has suggested that increases in playing standards occur, increasing the number of imports generally implies clubs are employing better players and therefore expect an increase in the technical and physical performance. However, these player recruitment patterns could lead to over-saturation of good non-native players performing in the top leagues and reducing the number of experienced native players available for the national side (Baur & Lehmann, 2007). There has been a general acceptance, both in the coaching and wider world that non-UK players have greater technical skills than their UK counterparts and therefore increase the playing standards. Despite this general perception, there is no evidence that physical, technical or tactical workloads of players have evolved or that the degree of increase in non-UK players has increased the rate of any changes in performance, therefore the aim of this study was to analyse UK and non-UK performances in order to find evidence that supports or disproves the general perceptions highlighted above. Further analysis was designed to analyse player performances between continents, which could provide information for possible future recruitment patterns.

## 7.2 Methods

### 7.2.1 Match Analysis and Player Data

In the current study, the national team an individual player was eligible to play for was dictated by the nationality of that individual. Players with an English, Scottish, Welsh or Northern Irish nationality were considered UK players, with all other nationalities considered non-UK (Maguire & Pearton, 2000). Due to historical political and social issues the Republic of Ireland was considered as a non-UK country (Free, 2007; McGovern, 2002). An extension to the protocol saw the data split in order to identify technical performance according to continental location according to player nationality; data were divided according to the official FIFA classifications regarding the location of the countries national governing bodies (Table 7.1; FIFA, 2014). These classifications caused some issues, Australia moved from the Oceanic Football Confederation to the Asian Football Confederation during the 2006-07 season and may have been adapting to tactical changes due to the change of opponents. Due to these changes, as well as the low number of observations for Oceanic players, the Asian and Oceanic confederations were combined into one category for all seasons examined.

### 7.2.2 Statistical Analysis

Independent t-test measures were used to compare UK and non-UK performance. Two-way independent-measures analysis of variance (ANOVA) tests were used to compare seasonal performance for UK and non-UK players for each of the five outfield positions (5 independent tests), with Dunnet's *post hoc* tests used to verify localised differences. Independent variables were set as player nationality and season, whilst dependent variables were set as physical and technical performance parameters. Further two-way analysis of variance (ANOVA) tests were carries out to analyse the effect of continent on player performance across the seven seasons analysed. Independent variables were set as season and continent while dependent variables were set as physical and technical performance parameters. Independent ANOVA tests were conducted for each of the five outfield positions. Statistical significance was set at $p<0.05$. The effect size (ES) was calculated to determine the meaningfulness of the difference and magnitudes classified as trivial (<0.2), small (>0.2-0.6), moderate (>0.6-1.2) and large (>1.2-2.0), (Batterham & Hopkins, 2006). Additionally, regression analyses were performed to quantify the relationship between selected variables across time and the uncertainty of the estimates using 95% confidence intervals. All analyses were conducted using statistical software (R Development Core Team) and data visualisation was carried out using the "ggplot2" package accessed via the Deducer Interface for the R statistical programming language.

Table 7.1: The breakdown in the number of observations according to playing position, player nationality and continent following resampling.

| | **CB** | **FB** | **CM** | **WM** | **Attackers** | **Total** |
|---|---|---|---|---|---|---|
| **European** | 3016 | 2854 | 2617 | 1712 | 1489 | 11 688 |
| **North-American** | 125 | 174 | 89 | 112 | 146 | 646 |
| **South American** | 107 | 122 | 160 | 136 | 167 | 692 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **African** | 439 | 193 | 272 | 120 | 303 | 1327 |
| **Asian** | 105 | 77 | 62 | 56 | 47 | 347 |
| **UK** | 1792 | 1649 | 1622 | 990 | 827 | 6880 |
| **Non-UK** | 2000 | 1771 | 1578 | 1146 | 1325 | 7820 |
| **Total** | 3792 | 3420 | 3200 | 2136 | 2152 | 14 700 |

### 7.2.3 Hypothesis

$H_0$ – There will be no differences in physical or technical performance measures between UK and non-UK players in the EPL.

$H_0$ – There will be no difference in the rate of change or evolution over the data set between UK and non-UK players.

$H_0$ – There will be no differences in performance between players from different continents.

## 7.3 Results

Overall there were a greater number of observations for non-UK players across all positions except central midfielders (Table 7.1). The number of observations for attackers across the seven seasons was continuously lower for UK compared to non-UK players with non-UK players recording 500 fewer observations in total (33-42% vs. 55-67%). UK centre backs recorded ≈200 fewer observations compared to non-UK centre backs in total (Table 7.2), the data set recorded non-UK centre backs having more observations in every season except 2009-10 (43%) and 2011-12 (45%). Overall non-UK full backs recorded ≈120 more observations, this resulted in a greater number of observations during each season except 2006-07 (51% vs. 49%) and 2012-13 (50%). Wide midfielders showed similar trends to full backs with non-UK players recording ≈150 observations more compared to UK wide midfielders, the breakdown for each season displayed non-UK players with greater number of observations in each season except the 2006-07 season (52% vs. 48%).

Table 7.2: Seasonal data sample (as percentages) of UK and non-UK in outfield positions after resampling.

| | 2006-07 | 2007-08 | 2008-09 | 2009-10 | 2010-11 | 2011-12 | 2012-13 | Total |
|---|---|---|---|---|---|---|---|---|
| **CB** | | | | | | | | |
| **UK** | 41 | 42 | 45 | 57 | 49 | 55 | 42 | 47 |
| **Non-UK** | 59 | 58 | 55 | 43 | 51 | 45 | 58 | 53 |
| **FB** | | | | | | | | |
| **UK** | 51 | 49 | 48 | 43 | 48 | 49 | 50 | 48 |
| **Non-UK** | 49 | 51 | 52 | 57 | 52 | 51 | 50 | 52 |
| **CM** | | | | | | | | |
| **UK** | 46 | 52 | 54 | 50 | 53 | 56 | 44 | 51 |
| **Non-UK** | 54 | 48 | 46 | 50 | 47 | 44 | 56 | 49 |
| **WM** | | | | | | | | |
| **UK** | 52 | 47 | 44 | 40 | 43 | 50 | 48 | 46 |
| **Non-UK** | 48 | 53 | 56 | 60 | 57 | 50 | 52 | 54 |
| **Attackers** | | | | | | | | |
| **UK** | 41 | 42 | 38 | 45 | 33 | 33 | 36 | 38 |
| **Non-UK** | 59 | 58 | 62 | 55 | 67 | 67 | 64 | 62 |

### 7.3.1 Physical parameters

UK players covered approximately 100 m more in total distance during matches compared to non-UK players, this difference was reflected in 2006-07 (10732±925 vs. 10634±979 m) and 2012-13 (10936±877 vs. 10837±890 m). Central defenders, both UK and non-UK displayed the greatest change in total distance compared to players in other positions. UK central defenders showed a greater change in total distance (9753±596 vs. 10163±584 m, ES: 0.69 [CI 0.53-0.85]) compared to non-UK central defenders (9912±587 vs. 10164±592 m, ES: 0.43 [CI 0.29-0.56]). Non-UK wide midfielders were the only position to record a marginal decrease in total distance covered between 2006-07 and 2012-13 (11414±741 vs. 11328±709 m, ES: 0.12 [CI -0.07-0.31]), although did not cover significantly different distance compared to UK players in 2012-13 ($p>0.05$, ES: 0.17 [CI -0.02-0.36]). All other positions displayed similar results between UK and non-UK players.

UK players covered marginally greater distances at high-intensities compared to non-UK players in 2006-07 (929±310 vs. 858±286 m, $p<0.001$, ES: 0.24 [CI 0.17-0.31]). However non-UK players recorded slightly greater increases over the seven seasons ($p<0.001$, ES: 0.91 [CI 0.83-0.97] vs. 0.73 [CI 0.65-0.80]), resulting in comparable high-intensity distance being covered by 2012-13 (UK: 1167±344 vs. non-UK: 1139±331 m, ES: 0.08 [CI 0.01-0.15]). These increases were equivalent to increasing their high-intensity running distance by 31 (CI 27-34) and 40 (CI 37-43) meters per match, per season ($m \cdot match \cdot season^{-1}$) for UK and non-UK players respectively (Figure 7.1). The greater increase in high-intensity running distance for non-UK players was evident in wide ($p<0.001$, ES: 1.33 [CI 1.12-1.53] vs. 0.97 [CI

0.76-1.16]), central midfield ($p<0.001$, ES: 1.22 [CI 1.06-1.38] vs. 0.86 [CI 0.68-1.03]) and attackers ($p<0.001$, ES: 1.15 [CI 0.96-1.33] vs. 0.42 [CI 0.2-0.64]). Players in central defensive positions were the only position to record greater increases in high-intensity running distance for UK players compared to non-UK players ($p<0.001$, ES: 1.18 [CI 1.01-1.35] and 1.05 [CI 0.91-1.19] respectively). UK and non-UK players in full back positions (ES: 1.32 [CI 1.16-1.49] vs. 1.22 [CI 1.06-1.39]) recorded similar increases in high-intensity running distance over the time period analysed.

Similarly, high-intensity running distance WP was marginally greater in UK players in 2006-07 (391±240 vs. 358±235 m, $p<0.05$, ES: 0.14 [CI 0.07-0.21]), but was identical (UK: 478±260 vs. non-UK: 478±261 m, ES: 0.0 [CI -0.07-0.07]) in 2012-13 and equivalent to 9 (CI 7-12) and 19 (CI 17-21) m·match·season$^{-1}$ for UK and non-UK players respectively. The greater increases in high-intensity running distance WP were evident in non-UK central midfielders and non-UK attackers compared to UK players in the equivalent positions (ES: 0.65 [CI 0.49-0.8] vs. 0.37 [CI 0.2-0.53] and 0.86 [CI 0.68-1.04] vs. 0.06 [CI -0.15-0.28] respectively). The magnitude of change for central defenders and full backs were similar between UK and non-UK players (ES: 1.13 [CI 0.96-1.29] vs. 1.06 [CI 0.92-1.19] and 0.88 [CI 0.72-1.03] vs. 0.85 [CI 0.7-1.01] respectively).

UK players covered marginally greater high-intensity running distance WOP in 2006-07 compared to non-UK players (468±164 vs. 437±159 m, $p<0.001$. ES: 0.19 [CI 0.12-0.26]), but these differences were trivial in 2012-13 (599±192 vs. 581±202 m, $p>0.05$, ES: 0.09 [CI 0.02-0.16]), being equivalent to 18 (CI 17-20) and 19 (CI 17-20) m·match·season$^{-1}$ for UK and non-UK players respectively. In addition, the number of high-intensity actions was similar for UK vs. non-UK across the seasons, increasing from 121±37 and 115±35 in 2006-07 to 178±47 and 174±46 (ES: 1.3-1.4), for UK and non-UK players respectively.

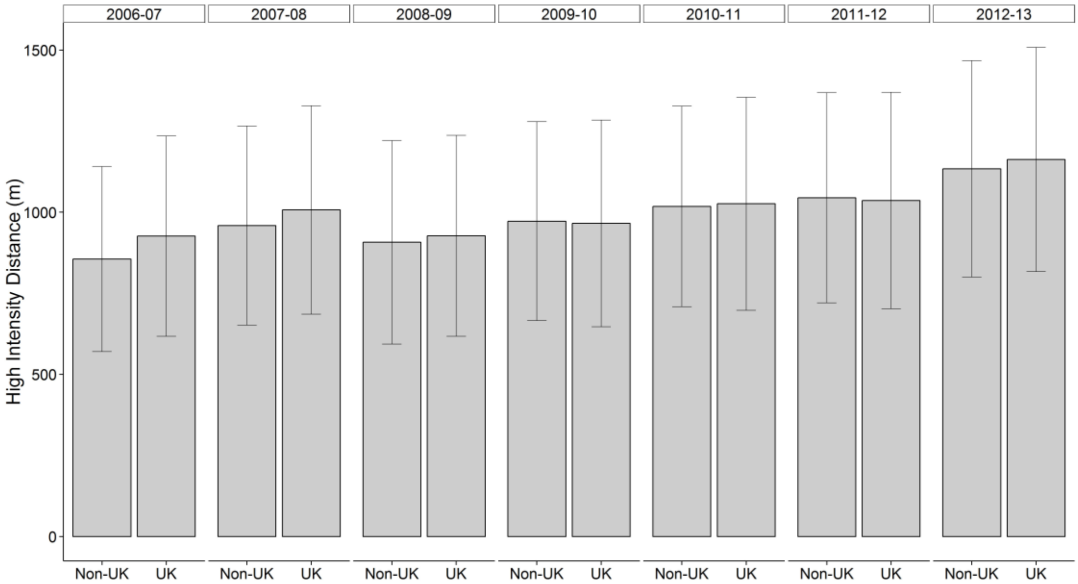


Figure 7.1: Bar chart demonstrating means and standard deviations for high-intensity running distance in the English Premier League for each season analysed. Each season is split between Non-UK players (left) and UK players (right).

Similar patterns were observed for sprinting with UK players covering marginally greater sprint distances in 2006-07 compared to non-UK players (243±117 vs. 222±110 m, $p<0.001$, ES: 0.19 [CI 0.11-0.26]), but the same distance in 2012-13 (UK: 355±147 vs. non-UK: 346±133 m, ES: 0.06 [CI -0.01-0.14]). Sprint distance increased by 15 (CI 14-17) and 18 (CI 17-19) $m \cdot match \cdot season^{-1}$ for UK and non-UK players respectively (Figure 7.2). No differences were observed between UK and non-UK players, respectively, for both the number of sprints performed (2006-07: 32±15 vs. 30±14; 2012-13:

57±21 vs. 56±20, ES: <0.15 [CI -0.02-0.21]) and the average distance per sprint (2006-07: 6.9±1.3 vs. 6.9±1.4 m; 2012-13: 5.9±0.9 vs. 5.9±0.8 m, ES: 0.0 [CI -0.07-0.07]), with similar changes across the seasons. The number of sprints performed increased by 3.5 (CI 3.4-3.7) and 4.0 (CI 3.8-4.1) per season in UK and non-UK players respectively, whereas the average distance covered per sprint decreased annually by 0.2 (CI 0.1-0.2) $m \cdot match \cdot season^{-1}$ in both groups. In addition, the number of leading (2006-07: 21±10 vs. 20±9, ES: 0.11 [CI 0.03-0.18]; 2012-13: 31±13 vs. 30±12, ES: 0.08 [CI 0.01-0.15]) and explosive sprints (2006-07: 11±7 vs. 10±6, ES: 0.15 [CI 0.08-0.23]; 2012-13: 27±11 vs. 26±10, ES: 0.1 [CI 0.02-0.17]) were identical between UK and non-UK in both seasons, these having increased annually by a similar magnitude for leading (1.2 [CI 1.1-1.4] and 1.5 [CI 1.4-1.6]) and explosive sprints (2.3 [CI 2.2-2.4] and 2.5 [CI 2.4-2.5]), respectively.

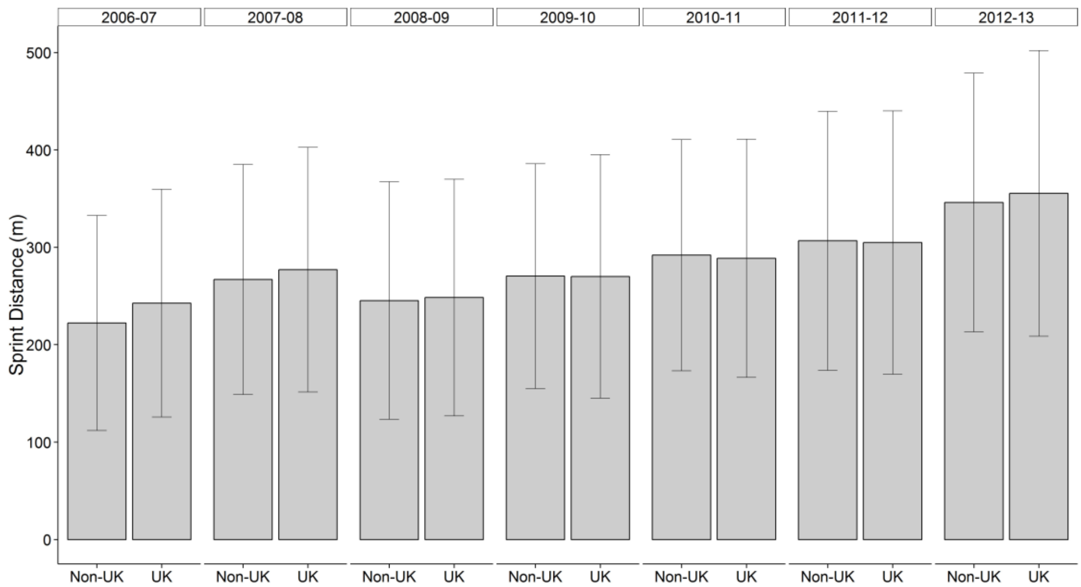


Figure 7.2: Bar chart demonstrating means and standard deviations for sprint distance in the English Premier League for each season analysed. Each season is split between Non-UK players (left) and UK players (right).

### 7.3.2 Technical parameters

Technical data revealed trivial to small differences between UK and non-UK players (Table 7.3). Non-UK players performed three more passes per match in 2006-07 (27±14) compared to UK players (24±12, ES: 0.23 [CI 0.16-0.3]), however by 2012-13 this marginal difference had reduced to a single pass (non-UK 36±17 vs. UK: 35±17, ES: 0.05 [CI -0.01-0.13]). This was equivalent to an increase of 1.8 (CI 1.6-1.9) and 1.7 (CI 1.6-1.9) passes·match·season$^{-1}$ made by UK and non-UK (Figure 7.3). The increased number of passes performed by UK players was observed in central midfielders (ES: 1.19 [CI 1.01-1.37] vs. 0.71 [CI 0.56-0.87]), full backs (ES: 0.78 [CI 0.62-0.93] vs. 0.51 [CI 0.36-0.67]) and attackers (ES: 0.75 [CI 0.53-0.98] vs. 0.39 [CI 0.22-0.56]). In contrast, UK and non-UK players in central defenders and wide midfielders increased the number of passes performed by similar magnitudes (ES: CD: 0.9 and 0.92 [CI 0.73-1.06] and WM: 0.54 and 0.48 [CI 0.29-0.73]).

When broken down, the number of short passes increased from 6±4 in 2006-07 to 9±5 (ES: 0.61 [CI 0.53-0.68]) for UK players and from 7±5 to 10±6 (ES: 0.54 [CI 0.47-0.61]) for non-UK players, annual changes of 0.5 (CI 0.5-0.6) passes·match·season$^{-1}$. Over the same time period the number of medium passes for both UK (12±8 to 19±11, ES: 0.73 [CI 0.65-0.80]) and non-UK players (14±9 to 20±12, ES: 0.56 [CI 0.49-0.63]), increasing annually to a similar degree (1.1 [CI 1.0-1.2] passes·match·season$^{-1}$). The greater increase in the distance of passes performed for UK players was observed in full back (ES: Short: 1.1 [CI 0.94-1.26] vs. 0.78 [CI 0.62-0.93]; Medium: 0.79 [CI 0.64-0.95] vs. 0.44 [CI 0.29-0.59]), central defender (ES: Short: 0.77 [CI 0.61-0.93] vs. 0.66 [CI 0.53-0.80]; Medium: 0.9 [CI 0.74-1.06] vs. 0.79 [CI

0.66-0.92]), wide midfielder (ES: Short: 0.79 [CI 0.6-0.99] vs. 0.49 [CI 0.3-0.68]; Medium: 0.57 [CI 0.38-0.76] vs. 0.44 [CI 0.25-0.63]) and attacker positions (ES: Short: 0.99 [CI 0.76-1.21] vs. 0.66 [CI 0.48-0.83]; Medium: 0.6 [CI 0.38-0.81] vs. 0.33 [CI 0.16-0.5]).

Non-UK players recorded a marginally greater pass success rate in 2006-07 (UK: 75±13 vs. non-UK: 77±12%, ES: 0.16 [CI 0.09-0.23]); nevertheless by 2012-13 both UK and non-UK had similar pass success rates (UK: 83±10 vs. non-UK: 84±10%, ES: 0.10 [CI 0.03-0.17]). Pass success rate increased seasonally by 1.3 (CI 1.2-1.4) and 1.1 (CI 1.0-1.2)% for UK and non-UK players, respectively. The number of passes received was marginally greater for non-UK compared to UK players in 2006-07 (20±13 vs. 18±11, ES: 0.17 [CI 0.09-0.24]), though were the same in 2012-13 (UK: 29±15 vs. non-UK: 30±15, ES: 0.07 [CI -0.01-0.14]), increasing by 1.8 (CI 1.7-1.9) passes·match·season$^{-1}$.

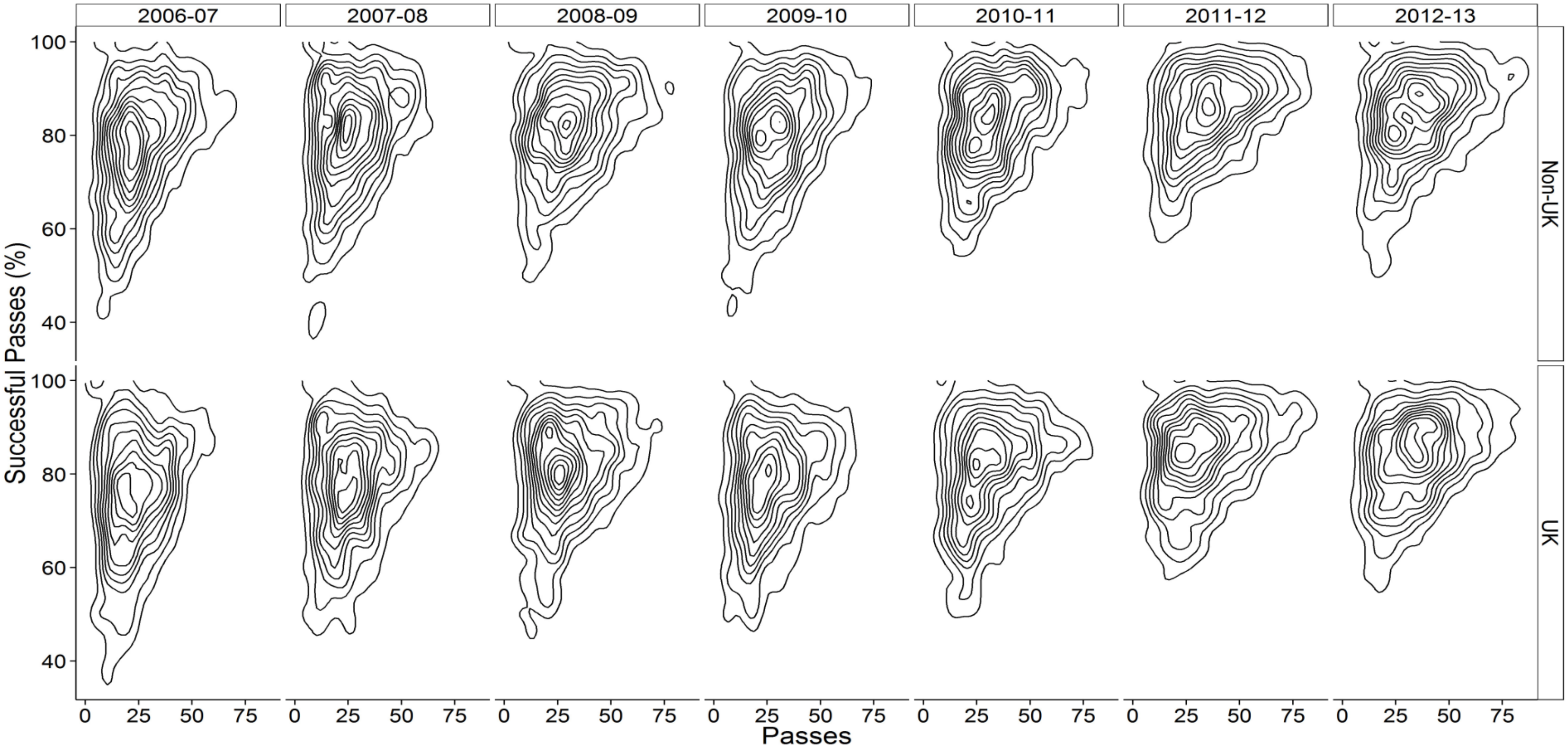


Figure 7.3: Two-dimensional kernel density plots representing the number of passes and the pass success rate of the UK and non-UK players across 7 seasons. The plot displays an increasing number of passes for both the UK and non-UK (plot width), while the UK players show a greater change in pass completion rate over the 7 seasons (plot length).

Table 7.3: Match passing performance for both UK and Non-UK players in the English Premier League across seven seasons. The table demonstrates the total passes, the contribution of small, medium and long passes as well as the pass completion rate.

| | **Short Pass** | | **Medium Pass** | | **Long Pass** | | **Total Pass** | | **Pass Completion (%)** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **UK** | **Non-UK** | **UK** | **Non-UK** | **UK** | **Non-UK** | **UK** | **Non-UK** | **UK** | **Non-UK** |
| **2006-07** | 5.7±3.9 | 6.6±4.5 | 12.3±7.9 | 14.3±9.3 | 5.9±4.0 | 5.6±4.0 | 23.8±12.4 | 26.5±14.2 | 75.3±13.4 | 77.2±12.1 |
| **2007-08** | 6.7±4.4 | 7.3±5.0 | 13.8±8.3 | 14.7±9.2 | 6.1±4.1 | 5.4±3.8 | 26.6±13.1 | 27.4±14.2 | 77.0±12.3 | 78.9±11.9 |
| **2008-09** | 7.2±4.8 | 8.5±5.7 | 15.9±9.7 | 17.5±10.8 | 6.6±4.5 | 5.9±4.5 | 29.7±15.0 | 31.8±16.8 | 79.8±11.4 | 81.4±10.5 |
| **2009-10** | 7.0±4.8 | 8.1±5.4 | 14.7±9.3 | 16.3±9.4 | 6.2±4.5 | 5.7±4.0 | 27.9±14.7 | 30.0±14.4 | 77.1±12.5 | 79.2±11.2 |
| **2010-11** | 7.6±4.8 | 8.8±5.4 | 17.3±10.2 | 18.0±9.9 | 6.8±4.4 | 5.7±4.0 | 31.7±15.7 | 32.5±14.6 | 80.4±11.0 | 81.8±9.9 |
| **2011-12** | 8.8±5.9 | 10.3±6.8 | 18.8±12.0 | 20.6±11.6 | 6.3±4.5 | 6.2±4.7 | 33.9±18.2 | 37.1±18.1 | 83.6±9.9 | 84.5±9.3 |
| **2012-13** | 9.1±5.7 | 9.6±6.2 | 19.3±11.1 | 20.2±11.5 | 6.2±4.6 | 6.2±4.4 | 34.7±16.8 | 36.9±17.3 | 83.0±10.0 | 83.5±10.2 |

### 7.3.3 Continental analysis

Players from African countries showed the greatest increases in total distance covered (10088±836 vs. 10732±831 m, $p<0.001$, ES: 0.8) whilst European and North American players showed small increases ($p<0.01$, ES: 0.2 and 0.5 respectively). Asian and South American players showed trivial but non-significant decreases in total distance covered (Asian: 10673±1066 vs. 10456±877 m; South American: 10876±985 vs. 10840±818 m, $p>0.05$, ES: 0.2 and 0.04). Players from all continents recorded moderate-large increases in high-intensity running distance over the seven seasons. African (753±243 vs. 1102±303 m) and Asian players (875±313 vs. 1281±332 m) displayed the largest increases for high-intensity running distance ($p<0.001$, ES: 1.3), whilst European players recorded the small increase (911±304 vs. 1152±345 m, $p<0.001$, ES: 0.7). Similar findings were observed for high-intensity running distance WP, African players demonstrated the largest increase (298±218 vs. 534±266 m, $p<0.001$, ES 1.0), whilst the players from the European, North and South American continents recorded small increases in high-intensity running distance WP ($p<0.001$, ES: 0.4-0.5). In contrast players from the Asian continent recorded small, non-significant, decreases in high-intensity running distance WP (379±213 vs. 290±211 m, $p>0.05$, ES: 0.4). Players from all continents recorded moderate increases in high-intensity running distance WOP, African players recorded the smallest increase (≈100m, $p<0.001$, ES: 0.6), whilst North American players displayed the largest increase (≈200 m, $p<0.001$, ES: 1.1). Players from the South American continent displayed the largest increase in sprint distance (231±91 vs. 388±132 m, $p<0.001$, ES: 1.4), whilst players from the African, North

American and European continents demonstrated moderate increases in sprint distance (≈110-150 m, $p<0.001$, ES: 1.2, 1.2 and 0.9 respectively).

Players from all continents showed moderate-large increases in the number of high-intensity and sprint activities ($p<0.001$, ES: 1.0-1.8 and 1.2-2.0). Players from the African continent completed the least number of high-intensity and sprint efforts in the 2006-07 season, (101±30 and 26±12) although recorded greater magnitudes of change over the seven seasons ($p<0.001$, ES: 1.8 and 1.8), by 2012-13 players from the Asian continents covered the fewest number of high-intensity and sprint actions and recorded the lowest magnitude of change across the seasons analysed (High-intensity: 117±35 vs. 156±42; Sprint: 30±14 vs. 47±15, $p<0.001$, ES: 1.0 and 1.2). The change in the number of sprints was largely down to the number of explosive sprints, where all continents showed large-very large increases ($p<0.001$, ES: 1.6-2.2). African and North American players demonstrated the largest increase in explosive sprints (African: 9±5 vs. 26±10; North American: 11±6 vs. 28±9, $p<0.001$, ES: 2.2) whilst European players showed the smallest change (11±7 vs. 26±11, $p<0.001$, ES: 1.7). Although of a smaller magnitude, all continents demonstrated moderate-large increases in leading sprints ($p<0.001$. ES: 0.9-1.1), although players from the Asian continent recorded small increases in leading sprints (20±10 vs. 24±9, $p>0.05$, ES: 0.4). Whilst the number of sprints increased, the average distance per sprint decreased. Players from the North American continent showed the greatest decrease in average sprint distance (7.1±1.3 vs. 5.9±0.7 m, $p<0.001$, ES: 1.3 and 1.2 respectively). In contrast, players from South American and African continents showed the smallest decrease in average sprint distance (South American: 7.0±1.5 vs. 6.1±0.8 m; African: 6.9±1.4 vs. 5.9±1.0 m, $p<0.001$, ES: 0.8).

Players from African, European and North American continents showed the greatest changes in technical indicators. Players from these continents showed moderate-large increases in the number of passes made and passes received ($p<0.001$, ES: 0.6-1.3), whilst the pass completion showed small-moderate increases for African, Asian and European players ($p<0.001$, ES: 0.7-0.8). Players from South American continent showed no increases in the number of passes made or the pass completion rate ($p>0.05$, ES: $<0.2$) and small changes in the number of passes received ($p<0.05$, ES: 05). Although players from the South American continent showed limited changes in passing variables across the seven seasons they still performed and received similar number of passes to their counterparts from the other continents in the 2012-13 season. African and North American players showed the greatest increase in short and medium passes ($p<0.001$, ES: 0.9 and 1.0-1.1 respectively) whilst European players' showed small increases in the number of short and medium passes (6.3±4.4 vs. 9.3±6 and 13.5±8.9 vs. 19.8±11.3, $p<0.001$, ES: 0.6). Players from the Asian continent showed increases in medium length passes (14.2±6.8 vs. 17.9±11.0, $p<0.05$, ES: 0.4), although showed no increase in short passes. Small increases were observed for the number of long passes for players from the North American continent ($p<0.01$, ES: 0.6). All other continents showed trivial to no differences in the number of long passes ($p>0.05$, ES: ≤0.2).

## 7.4 Discussion

The main aim of this study was to investigate the effect of non-UK players in the EPL in comparison to UK players. The study included one of the largest sample sizes used in research to date and develops on previous findings in the literature (Barnes et al., 2014; Dellal et al., 2011). Research on the role and involvement of UK and non-UK players in the EPL has focussed on migration patterns (Maguire & Pearton, 2000; Richardson et al., 2012), the legal aspects of player movement (Gardiner & Welch, 2011) and the impact of migration on the number and nationality of players in the EPL (Binder & Findlay, 2012; Maguire & Pearton, 2000), to our knowledge, although some research has analysed the differences between different leagues (Dellal et al., 2011; James et al., 2002) no research has previously examined the effect of nationality or player migration on playing styles and match performance.

Information available has identified UK players contributing to ≈30% of the total number of players in the EPL (BBC, 2013; Transfermarkt, 2014). This study took nationality into account during the resampling process, therefore UK players represented 46% of the data set, closer to the value observed in 2007/08 season (BBC, 2013), which also provides comparable data sets for comparison to non-UK players (Barnes et al., 2014). Nevertheless Maguire & Pearton (2000) identified that there was 122 players from other confederations working at UEFA clubs in 1998, however by 2012-13, 117 players from other confederations made appearances in the EPL alone, contributing to 221% of the total number of players in the EPL. Another 185 players (35%) in the EPL were from other UEFA countries, thus a total of 302 players (56%) working in the EPL during the 2012-13 seasons were non-UK players. A total of 235 players from UK countries made appearances during the 2012-13 season (44%), nevertheless of that 235 less than 170 UK players made regular appearances (>10 appearances) for their club during the 2012/13 season (Transfermarkt, 2014).

Previous research has identified an increase of ≈2% in total distance covered during the seven seasons analysed in this study (Barnes et al., 2014). Total distance in this study was observed to increase a similar amount for both UK and non-UK players (≈2%). In the third study of this thesis it was found that total distance increased primarily through central players. When positions were taken into account in the present study we found total distance increases were greatest for UK centre backs (≈4%). Nevertheless, all positions showed smaller increases in total distance over the seven seasons than the inherent match variability previously measured in study 1.

Maguire & Pearton (2000) suggested that one reason for the increase in non-UK players in the EPL was due to managers requiring experienced players in their teams in order to increase the chances of success. Teams in the EPL during the 2012-13 season had an average age of 24.8 years (range: 15-41 years), nevertheless the majority of players at the higher range were goalkeepers rather than outfield players (Transfermarkt, 2014). The data for the current study was desensitised before analysis, thus we could not analyse any respective age differences between UK and non-UK players. Although this study does not distinguish age according to nationality, an average players' age of 24.8 years would tend to contradict the proposals by Maguire & Pearton (2000), though the frequency of appearances may complicate this. For example, an 18-year-old appearing once would have equal weight to a 35-year-old appearing 30 times in 2012-13. If managers are turning to non-UK players to fulfil their requests this will decrease the number of young UK players given opportunities in the EPL despite the results of the present study suggesting that there is little difference between UK and non-UK player performances. As a result UK football is at risk of entering a vicious cycle where increasing non-UK players are bought to provide experience, consequently reducing the number of and experience for UK players. Currently there is a restriction on the number of home-grown players in an EPL squad, out of the 25-man squad at least 8 must be classed as home-grown players. There have been radical new proposals by the English FA to increase this to 12 home-grown players in a 25 man squad. However, it is also worthy of note that a home-grown player does not have to be of UK nationality. Players gain home-grown status if they have been affiliated to a UK based football association for 3 years before the age of 21, although under the new proposals the age restriction will be reduced to 18 years of age (The FA, 2015). Nevertheless, it is important to note that the new playing quotas are currently proposals and have not been accepted or implemented at this stage.

Although the current number of non-UK players performing in the EPL may be reducing the number of match playing opportunities for UK players, non-UK players may also be helping drive evolution. Non-UK players were found to show greater percentage increases for physical parameters in this study compared to UK players (Sprint distance: 47.3% vs. 55.4%; high-intensity distance: 26.7% vs. 32.6%; high-intensity distance WOP: 27.4% vs. 35.4%; leading sprints: 45.5% vs. 52.3%; explosive sprints: 140.9% vs.

146%). For most physical parameters, non-UK players recorded greater increases over the course of the seven seasons. However by 2012-13 UK and non-UK players performed similar physical performance. It is possible that the UK players were more conditioned to working at higher intensities in 2006-07 compared to non-UK players, although after playing for EPL teams the non-UK players have increased their physical conditioning. Alternatively, improvements in the recruitment process may have allowed clubs to employ non-UK players who are able to work at higher intensities. In contrast, UK players demonstrated greater percentage increases for passing variables compared to non-UK players (passes: 47.8% vs. 33.8%; passes received: 63.1% vs. 49.6%; short passes: 67.6% vs. 47.3%; medium passes: 55.5% vs. 38.4%). The results from this study may suggest that non-UK players were accustomed to more technically-based playing styles as they displayed greater numbers of passes and pass success rates in 2006-07 compared to their UK counterparts. In contrast, UK players have continued the evolution of the EPL in terms of physical performance, whilst the growing presence of non-UK players may have assisted improvements in the UK players' technical performance within the EPL.

The EPL has often been proposed and shown to be one of the most intense and physically demanding leagues in professional soccer (Barnes et al., 2014; Bradley et al., 2009; Bradley, Carling, et al., 2011). As a result, non-UK players who play in the EPL will be required to achieve the physical performance managers have come to expect. Whilst performing greater physical workloads during matches, non-UK players must replicate the technical ability they were recruited for. In the previous study in this thesis, it was summarised that central players recorded greater evolution in technical match performance compared to wide players who displayed greater change in physical performance. This current paper took player nationality into account in addition to player position, the results displayed fewer clear trends. Nevertheless, the main trend visible was the converging of data for both physical and technical performance in UK and non-UK players. The distances covered (both the total distance and distances at high-intensity and sprinting) in the EPL across the seven seasons analysed in this study are consistently higher than those measured in other leagues in Europe or Worldwide (Barros et al., 2007; Dellal et al., 2011).

Players from the Asian continent who play in the EPL displayed the greatest increases across both physical and technical performance when compared to players from all other continents. The number of observations for Asian, North American and African players decreased between the 2006-07 and 2012-13 seasons (Asian: 76 vs. 29; North American: 106 vs. 77 and African: 264 vs. 136). European (1597 vs. 1706) and South American (50 vs. 133) were the only continents to demonstrate increases in the number of observations. Although the original data was subjected to a re-sampling process, continental data was not included within the algorithm. This may have marginally affected the proportional representation of each continent in the re-sampled data set, nevertheless we assume that the data is representative of the trends present in the original data set. Players from southern hemisphere continents displayed greater change over the seven seasons for physical parameters compared to northern hemisphere continents (Sprint distance: 66-79% vs. 33-52%, high-intensity distance: 32-

46% vs. 24-32%, high-intensity running distance WP: 31-79% vs. 4-25%), high-intensity running distance WOP was the only physical parameter that displayed greater change for Northern hemisphere continents (North American: 41% and Asian players: 43%). North American players demonstrated the greatest change in technical parameters (number of passes: 78%; number of passes received: 100%; medium distance passes: 89% and long distance passes: 50%). However, the number of short distance passes (120%) and the number of possessions won (38%) displayed greater change for players from the African continent. Previously players performing in other countries have been recorded covering lower total and high-intensity running distances compared to players in the EPL (Barros et al., 2007; Dellal et al., 2011). In contrast, despite extensive research examining the physiological profiles of soccer players from different countries across the world, no differences in the $VO_{2max}$ in middle eastern or Asian players have been identified in comparison to UK players (Al-Hazzaa et al., 2001; Aziz et al., 2007; Castagna, Impellizzeri, Chamari, et al., 2006; Chamari et al., 2004; Chin et al., 1992; Strøyer et al., 2004; Ueda et al., 2011). This may be due to the poor correlations between $VO_{2max}$ and match performance (Bangsbo et al., 2008; Bradley, Bendiksen, et al., 2014). In contrast, fitness tests such as the Yo-Yo intermittent recovery tests have been shown to correlate more accurately with physical match performance (Bradley, Bendiksen, et al., 2014; Krustrup et al., 2003). Results of previous research has identified very limited differences in the results of intermittent endurance tests or the ability to perform repeated high-intensity bouts in Middle Eastern, Asian and African players in comparison to UK players

(Chaouachi et al., 2010; Kulkarni et al., 2013; Ueda et al., 2011). It therefore appears, although players from different continents are performing lower physical workloads during matches, that these lower workloads are due to reductions in the requirements of the respective leagues rather than the individual capabilities to perform intensive workloads. This can be observed by the results in the present study, which has identified the ability of players from different continents to increase physical workloads when performing in the EPL. There is less research-based analysis on the technical performance from different leagues across the world, with the majority of information attained from European based countries. Despite the lack of evidence, the information available suggests that there is limited differences between the technical performances of different European countries (James et al., 2002; Janković et al., 2011; Tenga, Ronglan, et al., 2010).

It is also worthy of note that despite the number of non-UK players performing in the EPL, evidence of the number of UK players migrating to playing in other European or World leagues is limited (Gardiner & Welch, 2011). There has recently been an increase in large profile players migrating to the MLS in the USA, however these moves are typically during the later stages of a players career and are still a small minority within the wider transfer market. In addition, due to the low number of transfer exports from the UK it is difficult to assess the benefits for either the individual player or for the importing country/league and therefore does not provide enough data for a meaningful comparison. There are a number of reasons proposed for the lack of UK player exports, although these are mainly summarised into three factors: social (psychological, language etc.), financial (limited revenues in other leagues to purchase UK players) and political (Gardiner & Welch, 2011; Littlewood et al., 2011; Maguire & Pearton, 2000; McGovern, 2002; Richardson et al., 2012; Taylor, 2006).

Due to modern transfer market activity, playing quotas and restrictions are once again in the spot light. Despite national, continental and world governing bodies attempting to implement different playing quotas it is likely that the debate over nationality representation within a squad will always be on the agenda due to the political and financial issues associated with them (Gardiner & Welch, 2011; Soika, 2008). Although playing quotas would have an effect on the number of players migrating to play in different leagues, it would provide home-grown players with a chance to play at the highest level and potentially increase their countries performance. It may also have the effect of increasing the transfer cost of both UK and non-UK players as more clubs become embroiled in the competition of attracting the best UK and non-UK players (Gardiner & Welch, 2011; Littlewood et al., 2011; Soika, 2008). This is especially the case in the EPL where the revenues associated with success, and in particular those associated with media deals, are now much higher and therefore tempt agents, players and clubs demanding higher fees, mainly for personal gain, with the big clubs willing to pay higher fees in an attempt to secure greater revenues (Maguire & Pearton, 2000; McGovern, 2002).

Although suggested as an impacting factor on migration, one area which has received limited research focus, is the psychological effect of migration on the athlete (Richardson et al., 2012). The limited research has identified challenges and difficulties when migrating to a new country for sporting reasons, in particular at young ages. These issues included acculturation issues, settling into new living accommodation and adapting to new cultures and languages (Richardson et al., 2012). It would be surprising if these issues had no negative impacts on performance, at least until the individual had adapted to the new environments. Unfortunately this study was unable to account for the length of time the non-UK players had been performing in the EPL and therefore could not take into account the duration of playing effects in the EPL. Future research should analyse the psychological and psycho-social effects of migration to a greater extent as well as assessing the impact of club's actions in order to help non-UK players adapt and the subsequent effects on performance.

The results of the present study are presented over a limited number of seasons. Thus, in order to gain a greater understanding of the influx of non-UK players and their effects on the EPL a more historic comparison would be required. Nevertheless, this would be challenging, as this would predate the introduction of semi-automated tracking systems. In addition, some of the physical and technical developments may be driven by altered tactics or playing styles, for example, playing formation can influence some physical and technical performance metrics during a match (Bradley, Carling, et al., 2011). Due to the nature of the dataset and the fluidity of these factors, it was not factored into the analysis. Moreover, due to the nature of the desensitised data, it was impossible to discriminate between non-UK players who had played in the EPL for consecutive seasons and those in their first season (repeated measures design needed). Armed with this information, it could be assessed whether non-UK players have encouraged the technical increases seen in the EPL or whether non-UK players adapt after playing a number of seasons in the EPL. Neither could players who had transferred between teams in the EPL be identified, which may have influenced performance. It must also be noted that player nationality was classified by the player's eligibility for a national side, however this does not acknowledge the fact a player can be eligible for a national side but can play their entire domestic career in a different country, nor does this acknowledge a player's true place of birth, as players can play for a national side dependent upon their relatives registered birth country.

In conclusion, small differences were observed in the physical and technical performance of a large sample of UK and non-UK players in 2006-07, namely UK players covering greater high intensity distances but with lower numbers of passes being made when compared to non-UK players. However, by the 2012-13 seasons, these small differences are no longer present. It can be speculated that the non-UK players have increased their physical performance to match their UK counterparts over the seasons in question, either through individual adaptation or altered player recruitment policies. The UK players' relative improvements in technical performance may also have been due to similar factors, but these changes may also be partly explained due to altered playing styles or tactics adopted by EPL teams over this period. Therefore this study begins to investigate the potential effect of transfers on playing performance although further analysis is required. Future studies should take into account player experience playing in their non-native leagues as well as further investigation on the psycho-social effects of transferring to a foreign league. It would also be worth comparing data between the EPL and other leagues across Europe and the World to investigate the wider effects of player migration.

# *Chapter 8* : Epilogue

## 8.1 Discussion

The research within this thesis examined the current trends in both physical and technical match performance parameters in the EPL. The thesis aimed to focus on the development of trends over a number of playing seasons and the potential causes. The research expanded on previous research by Barnes et al. (2014) on the evolution of performance in the EPL, by analysing the changes in performance by position. Full backs demonstrated the largest increase in high intensity running distance (35%) compared to all other positions, whilst full backs and wide midfielders showed even greater increases in the distance covered whilst sprinting (62 and 53% respectively). Whilst wide players demonstrated the greatest increases in physical performance, centre backs and central midfielders demonstrated the largest increases in the number of passes performed in a match, 70% and 50% increases respectively. These results suggest that whilst players of all positions have recorded increases over the seasons analysed, players in wide areas have seen the greatest increases in physical match outputs whilst central players have demonstrated more technical based increases. The changes in performance between 2006-07 and 2012-13 are now well documented, however the cause of the evolution is less clear. One anecdotal theory suggested, particularly in the media, is the increases of non-UK players performing in the EPL may have contributed to the increases observed. This was one theory investigated in this thesis, the results suggesting this theory can be doubted. In 2006-07, UK players covered greater distances in all speed thresholds compared to non-UK players, however by 2012-13 non-UK players had increased the physical performance and covered similar distances to UK players. In contrast, the opposite was highlighted for technical variables, where non-UK players covered higher numbers of passes and a greater pass success rate compared to UK players in 2006-07 although by 2012-13 the differences were negligible. These results may suggest non-UK players have contributed to the development of UK players technical performance, it does not highlight causes of the overall evolution as both UK and non-UK players showed increases in physical and technical performance over the seasons analysed. It is possible some of the evolution in performance may be due to the inherent variability of the sport, however when calculating performance benchmarks, increases in performance are still visible. The results on variability also show the high levels of variability for technical variables in comparison to physical performance, this may suggest that technical performance is affected more by the tactics adopted compared to physical performance. The research within this thesis has provided an alternative method for setting both physical and technical performance benchmarks, which will develop greater understanding of the current playing performance in the EPL. The generation of performance benchmarks is a key application of the thesis, this information and the method used for calculating them can be used across all formats of the game, including different leagues and different age groups. Another key application of the thesis is the requirement to continuously update performance benchmarks rather than rely on means and standard deviations based on previous literature, based on the assumption that performance remains relatively constant.

### 8.1.1 Evolution In Performance

The main aim of this thesis was to assess the evolution of technical and physical match performance in the EPL over a number of seasons, thus analysing whether the evolution previously observed in a small number of international performances is replicated in the most financially successful domestic soccer competition. Previous research has highlighted changes in match play in international, particularly World Cup matches in modern tournaments compared to those in the middle of the 20th Century (Wallace & Norton, 2014). Wallace and Norton (2014) discovered increases in the intensity of match play with a reduction in overall playing time combined with increases in the number of actions performed. Stoppages in play such as throw ins, corners, free kicks now take longer in duration than previously, suggesting players use these stoppages to recover from the increased intensity (Wallace & Norton, 2014). These changes in performance may potentially be caused by changes observed in the physical and physiological characteristics of soccer players. Power output and sprint performance has been shown to increase between the mid 1990s and 2010, in particular peak sprint speed has increased from 8.8$m{\cdot}s^{-1}$ to over 9$m{\cdot}s^{-1}$ (Haugen et al., 2013). In addition, players have been recorded to be taller and have greater body mass in modern day soccer players compared to the in the middle of the 20th Century (Elferink-Gemser et al., 2012; Haugen et al., 2013; Nevill et al., 2009; Norton & Olds, 2001). Intermittent endurance performance tests have been shown to increase over the last few decades (Elferink-Gemser et al., 2012). This is an important finding as these have been shown to correlate more closely with physical match performance compared to $VO_{2max}$ (Bradley, Bendiksen, et al., 2014; Bradley, Mohr, et al., 2011; Castagna et al., 2005; Krustrup et al., 2006). Evolution of football has not been isolated to soccer, but has been shown to be displayed across many football codes (Burgess et al., 2012; Norton et al., 1999; Norton & Olds, 2001; Olds, 2001). The result of previous research provides some support for the improvement and effectiveness of the application of sport science and the research findings. These results may suggest that professional clubs are applying these results to improve performance and may be partially why increases in match intensity and performance have been recorded. Nevertheless, these results have frequently been identified in international level athletes. The evolution of match performance has not been conducted at a domestic league level and therefore it is not known if these changes in performance have been replicated in domestic leagues.

The limited research based on the changes in the EPL has identified increases in the average number of passes preceding a goal, increasing from 16 to 25 between 2006-07 and 2013-14 (Prozone, 2014). In addition, a reduction in the number of fouls committed and the number of goals scored from set plays is proposed to reflect a change from direct playing styles in the EPL to more possession based playing styles observed in other European leagues (Dellal et al., 2011; Prozone, 2014). Research on the physical and technical performance has identified increases of 30 and 35% for high-intensity and sprint distance covered, respectively, and increases of up to 80% in the number of high-intensity and sprint actions performed during a game (Barnes et al., 2014). In addition, the number of passes performed has been noted to have increased by 40% as well as increases in the pass success rate (Barnes et al., 2014). Other research has demonstrated a closing gap between those finishing in the top 4 places (Tier A) in the EPL and those finishing in the following 4 league places (Tier B) and between the bottom 6 teams (Tier D) and the 6 teams above them (Tier C) across both physical and technical performance. This would suggest that the requirements to stay in the EPL or to qualify for European Competitions are becoming more challenging (Bradley et al., 2015). These research findings suggest that teams in the EPL are adopting more possession based playing styles, similar to those observed in other European leagues (Prozone, 2014). It is unclear as to the driving force behind the adoption of possession-based strategies in the EPL, nevertheless a strong possibility is the increase in both non-UK players and non-UK managers employed in the EPL. These players and managers are often employed in the EPL after acquiring their trade in European leagues, therefore bringing their knowledge and experience to the EPL and adopting their playing strategies in English clubs. A further possibility is the amount of young managers now employed in the EPL who may be more influenced by the findings of academic research and therefore adopting possession based playing styles as they have been shown to be more successful compared to the old direct playing styles. Possession based playing styles may in turn be more appealing to clubs who believe this is a more attractive and appealing style of play for their spectators, although may contradict the results driven expectations of the spectators who want to see their team win. As a result managers and club executives may try to adopt possession based playing styles they observe and believe to be successful but without have the squad capable of succeeding. Nevertheless, the results of the research to date have been focused on team performance and have not analysed the evolution in different positions or player nationality as potential causes of the changes in performance related parameters, in addition there is no clear identification of the causes of evolution.

The results from this thesis suggest that the evolution is evident across all playing positions. Results indicated greater increases in physical performance for players in wide areas (full backs and wide midfielders) compared to all other positions. Full backs recorded the greatest increase in high-intensity and sprint distances covered (~36 and 63% respectively). In contrast, players in attacking positions recorded the lowest increases across physical performance parameters (high-intensity running distance ~24%; sprint distance ~36%). Central positions (central defenders and central midfielders) demonstrated greater increases in technical performance, particularly the number of passes performed (~70 and ~50% increases respectively) and pass success rate (~7%), compared to all other positions. These changes in performance suggest alterations in the modern game within the EPL, similar to those observed in international competitions. The increase in the number of passes performed, particularly through players located in central areas suggests teams are trying to adopt more possession based playing styles, maintaining possession over longer periods in order to create scoring opportunities, this compared to previous long ball playing styles (Barnes et al., 2014; Prozone, 2014).

Following the findings of Chapter 6, the subsequent chapter focused on a possible cause for the evolution observed in the EPL. Ever since the introduction of the Bosman ruling in 1995, allowing movement of European players between European leagues, there has been a continuous increase in the number of non-UK players being imported to play for teams in the EPL (BBC, 2013; Binder & Findlay, 2012; McGovern, 2002). Given the performances observed in other European leagues compared to the EPL (Dellal et al., 2011), it may be postulated that the increase in non-UK players performing in the EPL may lead to these greater performances transferring into the English game. The findings from Chapter 7 highlighted that although there was an increase in the number of non-UK players performing in the EPL over the seasons analysed (BBC, 2013), there were very few differences in the technical and physical performance between UK and non-UK players. In 2006-07, UK players performing in the EPL recorded marginally greater physical performances compared to their non-UK counterparts, this was identified particularly in high-intensity and sprint distances and actions performed and were most prominent in wide positions. Nevertheless, by the last season analysed, 2012-13, non-UK players had displayed a greater increase in physical performance and thus recorded similar performances compared to their UK counterparts. In contrast, non-UK players tended to record greater technical performances in 2006-07 compared to UK players, although by 2012-13 differences in performance between UK and non-UK players was negligible. Although speculative, these findings may suggest that despite non-UK players performing greater technical performance in other leagues (Dellal et al., 2011), when non-UK players transfer into the EPL, they are not used to performing to the required physical demands. As a result, it appears that the presence of increasing numbers of non-UK players in the EPL may potentially have required UK players to increase their technical match performances to match those of the non-UK players, whereas non-UK players have needed to increase their physical performance in order to compete in the EPL. Similar results were identified in the positional analysis of UK and non-UK players, suggesting these results are not position dependent and therefore the overall evolution observed in performance and playing positions are caused by other factors and not changes in player nationality. Nevertheless, it is also worthy of note that these changes may not be restricted to the evolving numbers of non-UK players performing in the EPL, but are likely to be due to a combination of factors including but not restricted to changes in playing styles, formations, coaching styles as well as the improvements in sport science to enhance player recovery strategies.

Further analysis was conducted in order to analyse the effect of the observed evolution by continent, and therefore see if there were any visible trends across the seasons analysed. These series of comparisons highlighted that players from European countries performing in the EPL evolved the least for many physical and technical variables over the seasons analysed, although still performing comparable performances in the 2012-13 season compared to players from other continents. In contrast, players from Asian countries demonstrated lower increases compared to other continents and often performed lower match performances on physical and technical performance parameters and therefore may not be as capable performing the demands required for the EPL, or may be less adaptable or slower to evolve compared to players from other continents. It is also possible that these results are due to the lower sample sizes, particularly for players from the Asian continent who recorded low player numbers in the EPL. Outliers in these small population groups could have larger impact of the evolution observed and therefore effect the comparisons available.

Given that the magnitude of differences between UK and non-UK players are small in comparison to the overall increases observed over the seasons analysed, further investigation is required into other influencing factors driving the evolution observed in Chapter 6. It is also unknown whether the evolution observed will continue into future seasons or whether players' physical and technical capabilities will be reached and the evolvement in the game will plateau. It may also be worthy of investigating whether UK or non-UK players are recruited for specific positions and therefore whether coaches and managers believe players from different nationalities offer differing strengths for differing positions. Here it is also worth taking into account the potential effects of tactical and formation changes. Whilst more difficult to measure and in its relative infancy (Fernandez-navarro et al., 2016), tactical changes can have a dramatic affect on both physical and technical performance and would provide a greater holistic understanding of match performances and the changes observed over time.

### 8.1.2 Applications To Performance

#### 8.1.2.1 Predicting Performance

One common trend identified within the literature is the lack of papers analysing the physical and technical performance in unity, with the majority of papers choosing to focus on either physical or technical performance parameters independently (Mackenzie & Cushion, 2013). It is unclear as to the reasons behind this isolated analysis, although one potential reason may be due to publishers of journal articles and the constraints associated to word limits, researchers often have to compromise between detail and the expanse of the research question. In an attempt to answer whether future research would need to adopt a multifaceted approach to soccer, one study in this thesis was aimed at analysing the interaction between physical and technical variables. The limited research available has identified the importance of physical performance when completing specific technical tasks such as scoring goals (Faude et al., 2012), as well as the negative effects of fatigue on the ability to perform technical parameters (Carling & Dupont, 2011; Rampinini et al., 2008). Nevertheless, these studies have analysed selective physical variables on individual technical parameters over limited match periods, there is currently no research that has analysed a variety of physical variables on multiple technical parameters. This thesis appears to be the first study to analyse the interaction of a number of performance parameters over the full 90 minutes of a match. Taking previous research into account, it may be speculated that selected physical and technical parameters influence the other over small match incidents, nevertheless results from this thesis (Chapter 4) suggest there are only small correlations ($r<0.3$) between overall physical and technical performance across a full match. These results suggest that predicting performance in elite soccer based on their physical or technical attributes is extremely difficult due to the high levels of variability (Chapter 3). Nevertheless, this thesis was one of the first to look at correlations between physical and technical performance, future research could consider correlations around key moments within in football. Previous research has highlighted the 5 minutes prior to goals being scored as key moments within a game (Faude et al., 2012), it would be interesting to investigate whether there were increased correlations between physical and technical performance for the goal scoring team during these 5 minute periods. In addition, previous research has identified a reduction in physical output during the second half of matches (Bradley & Noakes, 2013; Mohr et al., 2003, 2005), however it is unclear how these reductions in physical performance effect technical performance. Carling & Dupont (2011) noted a reduced technical performance during the last 5 minutes of games and speculated this may be down to a reduction in high-speed physical out put, although presented no data to support this argument. It would, therefore, be interesting to analyse the correlations between physical and technical performance differ between halves or 5 minute periods of a match and whether the decrement in physical performance observed effects technical performance, and what performance parameters this is observed in.

Previously, research has highlighted contextual effects on performance, particularly match location (Jacklin, 2005; Lago-Peñas & Lago-Ballesteros, 2011; Nevill et al., 2005; Pollard, 2008; Pollard & Pollard, 2005), playing standard or quality of the opposition and match result (Lago-Peñas & Lago-Ballesteros, 2011; Lago, 2009; Redwood-Brown, Bussell, et al., 2012; Taylor et al., 2008). Nevertheless, research has assumed these differences are due to the effects of the situational factors and have not factored the match-to-match variability as a possible implicating facet. As a result, the initial study of this thesis (Chapter 3) attempted to analyse the effects of situational variables on match-to-match variability. The results observed in Chapter 3 suggest that there is minimal effect of the situational factors examined on match-to-match variability, with similar coefficients of variation observed between match location (home vs. away), match result (won, lost or drawn) and playing standard (playing against a higher standard, similar standard or weaker standard of opposition). These findings would suggest the differences observed in previous research papers are due to the effects of the situational variables and not due to the effects of match-to-match variability. Therefore teams performing at home perform greater technical and physical performance compared to teams playing away from home (Castellano et al., 2011; Lago-Peñas & Lago-Ballesteros, 2011; Taylor et al., 2008). The results obtained in Chapter 3, provided the evidence for the resampling process used in the later studies. This process was selected in order to balance out the effects of the situational factors and provide a consistent and representative sample for analysis. In addition, it is also imperative that applied sport scientists and analysts use this data when reviewing and analysing performances as the data collected will vary depending on the location, result and quality of the opposition. If the applied sport scientists do not use this information, it is likely that the wrong interpretation of the data will occur and therefore, incorrect information will be returned to the coaching staff.

The results from this thesis and previous literature (Hughes et al., 2001; O'Donoghue, 2005; O'Donoghue et al., 2009; Reed & O'Donoghue, 2005) suggest that predicting performance in soccer is difficult, mainly due to the unpredictable nature of the game (Gregson et al., 2010; Mohr et al., 2003; Weston, Drust, et al., 2011). This is particularly the case when assessing performance stability using methods previously suggested by Hughes et al., (2001). The methods proposed effectively suggested using an expanding moving average filter to the data until the results level to acceptable predetermined error limits. However, study 1 attempted to use this method but discovered results were highly susceptible to changes in performance. As a result, this method does not appear to be an accurate or acceptable method for predicting performance due to the high number of matches required to establish an acceptable level of stability. In addition, the situational factors of games can have an effect on the performances observed and therefore must be taken into account, but also make predicting performance more difficult. As a result an alternative method must be identified for measuring expected performances, one potential method is to adopt performance benchmarks using CVs based around a mean collected over a number of performances (Gregson et al., 2010; Mohr et al., 2003).

#### 8.1.2.2 Performance Benchmarks

The average performances observed across playing positions has been well established within the literature (Barros et al., 2007; Bradley, Carling, et al., 2011, 2013; Bradley, Dellal, et al., 2014; Bradley et al., 2010; Dellal et al., 2011; Di Salvo et al., 2010, 2009, 2013; Rampinini et al., 2009) and has now been found to have increased over a number of seasons (Barnes et al., 2014; Bradley et al., 2015). Nevertheless, the accepted boundaries of a typical performance are not known. For this to be calculated the initial study in this thesis was used to calculate coefficients of variation across physical and technical performance parameters, these CVs could then be used to calculate performance benchmarks, therefore providing typical and expected levels of performance. Although CVs are an established method for statistical analysis, their application to football performance has been limited. Until now, researchers and applied practitioners have used more traditional statistical reporting such as means and standard deviations (Bishop, 2008). Arguably this offers little practicality, as practitioners will generally only take the means into account and refer to a performance as above or below the mean. Given the dynamic nature of the sport and the contextual effects on performance, it is unlikely means are an accurate method of assessing performance over successive matches. CVs, in contrast, can offer more detail to the information provided. Practitioners can use CVs to calculate minimum and maximum performance benchmarks and then analyse where a performance occurs on the continuum. If the practitioner has enough information it is also possible to generate benchmarks that are individualised for a specific player taking into account contextual factors, thus providing more effective information to coaches.

The level of variability observed on a match-to-match basis for physical performance was similar to those reported previously in the literature (Gregson et al., 2010; Weston, Drust, et al., 2011). The similarity between variability measures in the present thesis and previous research suggests that variability within performance is well characterised and is relatively constant over time. As a result, the findings of the first study, combined with previous research can be used to identify performance benchmarks, providing values of a typical performance that allows coaches, analysts and players to prepare for, monitor and assess individual performance. In order to calculate benchmarks, we must assume CVs are the equivalent of 1 standard deviation around a mean, thus representing approximately 69% of occurrences, therefore to represent 95% of occurrences, 2 standard deviations either side of the mean is suggested in research (Vincent, 2005). On average players cover 11000 metres per match, taking the 5% variation into account, most players would cover between 9900-12100 metres in a match (Barros et al., 2007; Bradley, Carling, et al., 2011, 2013; Bradley, Lago-Peñas, et al., 2013; Di Salvo et al., 2007; Weston et al., 2007). Due to the large distances covered a 5% variation in match performance could be seen as an insignificant change in performance. Players complete an approximate 900 metres of high-intensity running and 300 metres whilst sprinting during matches, a match-to-match variation of 20% and 30% respectively would result in a player covering between 540-1260 metres of high-intensity running distance and 120-480 metres of sprinting per match. If an average number of 30 passes per player and a pass success rate of 79% is standard during a match, variability measured at 40% and 25% respectively would suggest 6-48 passes and a pass success rate of 39.5-100% might be expected by the majority of soccer players in the EPL (Bradley, Carling, et al., 2013). Given a pass success rate of 70% has been identified as essential for success in the EPL (Dellal et al., 2011), it is possible the lower end of this benchmark is less accurate, or slightly skewed due to the data, although it is likely there will be some occurrences over the course of the season. These benchmarks provide evidence of the high match-to-match variability associated with soccer performance, particularly for technical parameters. Less information is known regarding variables such as the number of tackles a player performs per match, or the number of possessions won or lost, as they are highly dependent on playing position. Central defenders recorded variability >140% for the number of times they were tackled and attackers recorded variability ≈80% for the number of tackles made per match. Due to the requirements of these positions it is unsurprising these results were observed, the research that has reported these variables suggest an average of 2 observations during a match, thus resulting in between 0-11 tackles made by attackers and 0-7 times central defenders are tackled during matches. Nevertheless, no research until now has attempted to analyse the variability within technical performance parameters and therefore the novelty of the variability study can be used in future assessment of performance. In addition, the physical and technical performance variability results can be used to predict possible future evolution, results indicating consistent performances higher or lower than the boundaries generated using these results would suggest performance has evolved. Sports scientists and analysts should be aware of these values for various reasons; 1) in order to make sure players are capable of performing the required level, this would typically by built up over the course of preseason, reaching the upper boundary levels at the end of preseason; 2) in order to monitor training programmes and matches in order to make sure players are performing at a level comparable to other teams and therefore performing the physical and technical performances that are required within the league they are competing in. The research on evolution of soccer, both in this thesis and the wider research base has shown the vast changes in performance, particularly within the last decade in the EPL, therefore when both researchers and applied sport scientists use benchmarks for predicting performance it is essential to use up to date benchmarks rather than using previous data which may be out of date. One interesting and potential use for benchmarks, which the author is currently investigating, is the use of performance benchmarks in the development of younger soccer players. The thesis has investigated performance at a senior professional status, however less information is known about the use or application in youth sport. Once the author has sufficient data, they are hoping to investigate whether performance benchmarks differ between those of a senior professional status compared to younger players at different stages of development and how these benchmarks change through the development process.

#### 8.1.2.3 Effects On Injury Rates

A common issue in professional sport is the prevalence of players getting injured and therefore missing training and/or match time (Arnason et al., 2004; Hawkins, Hulse, Wilkinson, Hodson, & Gibson, 2001; Henderson, Barnes, & Portas, 2010). Research has highlighted many predispositions to and causes of injuries within soccer and has consequently adapted training regimes in order to minimise the risks associated with the injuries occurred (Arnason, Andersen, Holme, Engebretsen, & Bahr, 2008; Bengtsson, Ekstrand, & Hägglund, 2013; Ekstrand, Hägglund, & Waldén, 2011a; Ekstrand et al., 2011b; Junge & Dvorak, 2004; Opar et al., 2012). Nevertheless, research has recently highlighted complications and miscommunication between sport science and medical departments and the associated differing objectives between them (Gabbett & Whiteley, 2016).

Medical staff are often associated with reducing training workload to reduce injury risk whilst sport science staff aim to increase the physical capabilities of players in preparation for games. However, Gabbett and Whiteley (2016) suggest that working independently will result in players not being prepared for games and therefore expose players to greater risks of injuries.

Soft tissue injuries are some of the most common injuries in soccer, generally muscle tears or strains, particularly to the hamstring and quadriceps muscle groups (Daly, 2013; Ekstrand et al., 2011a; Hägglund, Waldén, Magnusson, et al., 2013; Hawkins et al., 2001; Junge & Dvorak, 2004; Opar et al., 2012; Small et al., 2009). Other common injury types include; ligament strains, overuse injuries, contusions and non-contact injuries (Arnason et al., 2004). Due to the contact nature of the sport a level of injuries must be expected, including contusions or soft tissue damage. Nevertheless, it is the medical staff at clubs that must attempt to reduce the number of non-contact and soft tissue injuries and the severity of the injury in order maximise player availability for both training and matches. The occurrence of muscle strains are increased during particular actions, particularly high-intensity and sprint actions (Daly, 2013; Small et al., 2009). In addition to the greater physical impact of soccer matches, technical actions have also been noted to pose injury risk, even simple actions such as striking the ball can lead to injuries, greater injury risks are associated with technical actions such as tackles for both the tackler and the player making the tackle (Rahnama, Reilly, & Lees, 2002). Given the propensity of injuries during high-intensity actions and the noted increases in high-intensity and sprint distance and actions during a game it is possible that clubs will notice an increase in the number of muscle strains which occur in Premier League players. As a result, medical and sport science staff members need to account for and be more aware of the predispositions leading to greater injury risks and monitor players who are at greater risk. Research has highlighted the effect of preseason training in building a foundation for the forthcoming season, developing the necessary strength as well as cardiovascular conditioning and should be tailored across the preseason phase so players are prepared for the intensity required for the start of the playing season (Heidt, Sweeterman, Carlonas, Traub, & Tekulve, 2000).

It has been suggested that sport science staff prepare players using mean performance values, but do not provide players with the ability to complete performances above average values, as a result players will be exposed to increase injury risks, particularly soft tissue injuries, in half of all games played in (Ekstrand, Waldén, & Hägglund, 2016; Gabbett & Whiteley, 2016). This assumption can be seen in the research that has highlighted increases in match-play demands whilst also recording increases in injury rates (Ekstrand et al., 2011b, 2016; Hägglund, Waldén, Magnusson, et al., 2013). The main cause of increased soft tissue injuries has been proposed to be due to the increased exposure to high-intensity activity during a game (Duhig et al., 2016; Ekstrand et al., 2016). As a result, previous and possibly current prehabilitation and medical routines are not sufficient to reduce the risk and threat of soft tissue injuries given the increase in high-intensity and sprint activity during games and training. Previous research has claimed positive effects on hamstring injuries when exercises such as Nordic lunges are incorporated into training programmes to improve players muscle flexibility (Brukner, 2015; Daly, 2013; Opar et al., 2012). In addition to specific exercises to help muscle flexibility, other factors have been identified which cause increased risk of hamstring injuries, including increased neural tension, previous or current lumber disorders, fatigue, insufficient warm ups and strength imbalances (Bengtsson et al., 2013; Brukner, 2015; Ekstrand et al., 2011a, 2011b; Hägglund, Waldén, Magnusson, et al., 2013; Hägglund, Waldén, & Ekstrand, 2013; Hui Liu, Garrett, Moorman, & Yu, 2012). Monitoring and modifying training regimes can reduce the effect these risk factors have on hamstring injuries and therefore it is essential for support staff to consider these when developing training programmes. There are further factors which increase the likelihood of hamstring injuries, including player age, race and muscle composition, as well as the previous medical history of that player (Brukner, 2015; Ekstrand et al., 2011a; Hui Liu et al., 2012). As these cannot be changed or affected, it is more important that medical and conditioning staff consider these factors when developing training programmes, and as a result these programmes should be individualised taking into account the factors above, thus minimising the risks placed on the player whilst developing the robustness in order for the player to sustain the higher levels of modern day match requirements (Gabbett & Whiteley, 2016). Nevertheless, further research needs to be continued within this area, particularly taking into account the increases in match demands and the effects these have on injury rates and whether the proposed actions and exercises have sufficient affect to minimise injury rates, or whether other exercises or combination of exercises have greater impact on reducing injuries. Another factor that should be accounted for in future studies is the size of playing squads and the ability to rotate match day squads in order to maximise recovery protocols and minimise injury risks.

One further consideration that needs to be taken into account by clubs is the effect of socio-cultural factors on potential injury rates, particularly with the increases in non-UK players performing in the EPL. Research has recently identified players who fast during religious events such as Ramadan to suffer an increase in non-contact and overuse injuries compared to players who do not fast (Chamari, Haddad, Wong, Dellal, & Chaouachi, 2012). Socio-cultural factors need to be taken into account, particularly where they will be affected by the increasing multicultural nature of teams. The previous research has mainly focused on single cultural teams, which take into account the social-cultural factors by changing training times, or matches in order to accommodate these factors (Chamari et al., 2012). However, teams in the EPL frequently do not, or cannot, modify timing due to external factors and therefore may predispose players to greater injury risk due to less effective recovery procedures including sleep patterns and nutrition intake.

## 8.2 Limitations of the Thesis

Whilst this thesis has provided more context and understanding of soccer performance, there are limitations that need addressing. The author accepts the descriptive nature of the thesis itself is a limitation as it does not provide mechanistic evidence or laboratory data. Nevertheless, the initial and continuing aims of the thesis was to develop understanding of current competition data in the EPL and how this data had evolved over a number of seasons. In addition, the sample size used in the thesis is greater than those used in previous studies and adopted a resampling process in order to balance sample sizes in order to minimise errors when statistical tests were applied which is previously unused in research. Therefore, although there are limitations to descriptive natured research projects (Bishop, 2008), this thesis adds greater understanding to the current knowledge of performances in the EPL.

Other factors to consider as limiting factors for the thesis are some of the data handling methods. The fact the data was de-sensitised meant there would have been repeated measures within the statistical tests that could not be accounted for by the independent ANOVAs performed. Due to the size of the data set it is unlikely to have a substantial impact on the outcome of the results, although could be included in future research in order to minimise the effects if desensitised data was provided. In addition, this research selected the major key performance indicators and performance parameters to assess, further research could analyse metrics that this thesis could not analyse, such as shots on target, the number of final third entries or the number of fouls committed and received, that were not provided in the data set (Bradley, Carling, et al., 2011, 2013; Castellano et al., 2012; Rampinini et al., 2009). The temporal nature of the data set also restricted the analysis in this thesis to full matches. Future research should analyse data in match segments (half by half, or 15 minute segments etc.), particularly for investigations on the interactions between physical and technical parameters, which may highlight interactions during performances compared to the limited results found over complete matches.

### 8.3 Future Directions

This thesis provides important and essential information for coaches, a final study was in preparation to analyse the preferred methods to disseminate this information to coaches, however due to time constraints this final study was not completed. As a result, an imperative future direction should be to begin to investigating methods of supplying this information to coaches. Although it is clear that coaches and sport science support staff are becoming more receptive to the information gained through analysing performance, a majority of the research base is written in a language designed to maximise the chances of publication rather than to maximise interpretation by coaches (Bishop, 2008). In addition, the research does not attempt to answer the question of which method is more effective at developing the understanding between analysts and coaches, and therefore maximising player improvement. The result of this academic writing and lack of understanding on information transmission, coaches are extremely reluctant to use peer reviewed journals and analysts continue to use what may be inappropriate methods to pass on information to coaches (Cushion et al., 2010; Reade, Rodgers, & Hall, 2009). The limited utilisation of peer reviewed journal articles reduces the impact any research findings have on future performances, as there is a limited application to coaching sessions and coaching practice.

Further research is needed into the causes of the seasonal increases observed in this thesis. The increase in non-UK players performing in the EPL was one speculative cause. Although UK players appear to have driven physical changes and non-UK players impacted in technical changes, the impact of this factor appeared to be minimal and evolution in performance was being caused by other factors. It would be interesting to note the effect more modern formations and playing styles have had on playing performance and whether this has potentially caused the changes in performance. Some previous research has investigated older, more traditional formations, such as 4-4-2, 4-5-1 and 4-3-3 formations and have highlighted positional differences in the physical workloads completed during matches (Bradley, Carling, et al., 2011). Since then teams have developed 4-2-3-1, 4-1-4-1 and 4-1-3-2 formations, developing specific positions such as holding midfield players. It would be interesting for future research to investigate the effects these positions have on both technical and physical parameters. In addition, all these results would focus on more traditional defending formations that adopt two central defenders and two full backs. However, in the modern game managers are increasingly adopting formations which adopt three central defenders and wing backs, i.e. 5-3-2, 3-5-2 or 3-4-3 formations, nevertheless it is not widely known in how these formations affect the physical and technical performance. It would be worthy to continue the work begun within this thesis to investigate whether these increases in performance are continuing to be observed in the following seasons and whether continued exposure to high-intensity and high-quality coaching continues to help develop player’s capabilities. Alternatively, does performance reach a plateau where players cannot increase physical and/or technical performance any further irrespective of the amount of coaching received or increased players’ physical capacities? Further investigation could also look into the development of youth soccer and whether, with the current investment in academy soccer in England, similar rates of development are visible or whether the professional game is developing while the youth game is stationary. If academy soccer is stationary whilst senior performance in the EPL is evolving, it would suggest a growing gap between senior and academy match play which would have significant impact on player's stepping up from youth football, particularly in terms of the potential injury risks associated with performing at the higher levels. It is also possible that the gulf between academy and professional levels would mean players stepping up to senior team performance may not be able to perform at the required physical or technical performance levels. Therefore, greater investigation is required in order to assess whether youth performance is developing at a similar rate to senior team performance or whether there is a growing gap between senior and academy performance.

The research conducted in this thesis can also be used and expanded to monitor and understand the performance within other leagues, both in England as well as other countries worldwide. This would provide both the research community and the applied community with the appropriate information within individual leagues. This would provide greater information on comparing leagues and would provide greater contextual information for player transfers.

## 8.4 Conclusion

The results of this thesis are an important development in the understanding of match performance, particularly within the EPL, as well as soccer in general. Whilst there has been a vast research history analysing soccer performance, a large proportion of these research studies have not accounted for changes in physical or technical performances, particularly in domestic leagues. Previously research has combined data over consecutive seasons to provide sufficiently large sample sizes for analysis. Results from this thesis suggest that combining data collected over a number of seasons may act as masking or confounding factors as both physical and technical performance evolves over time. Research groups need to factor these findings into future investigations in order to maximise the application of their findings.

Research has analysed a small number of physical variables comprehensive understanding of physical and technical parameters has not been conducted. Technical variables recorded greater CVs compared to physical variables and could vary as much as 70-80% for tackling variables, whereas parameters that occurred more frequently such as passes (performed and received) varied less (≈40-50%). The majority of physical parameters were recorded with CVs <30% and in some cases were as low as 5-10%. These results suggest physical performance is a relatively constant factor compared to technical parameters. The variability appeared to affect the interaction of physical and technical parameters, with low correlations (r<0.4) across full match analysis of performance parameters, suggesting predicting match values is extremely difficult. The following study expanded previous research, investigating the positional evolution of technical and physical performances. This investigation highlighted developments in the technical performance of central players (centre backs and central midfielders) compared to players in wide positions, although the opposite was observed for physical variables, which saw the most prominent increases in wide (full backs and wide midfielders) and attacking positions. In an attempt to investigate the causes of the increases in performance, the final study investigated the impact of the increases in player migration to the EPL. This investigation highlighted the marginally greater technical proficiency of non-UK players (passes performed and received, pass completion rate) in the first season analysed (2006-07), although by 2012-13 these differences were eliminated. The opposite was identified for physical variables, where UK players performed greater physical workloads in 2006-07, but non-UK players had increased their physical output over the seasons analysed, therefore performing similar physical workloads compared to UK players in 2012-13.

These results have important applications across the football spectrum, the results can be used to calculate performance benchmarks, both within a team and across multiple teams, thus identifying the limits of a typical performance. This can be used from recruitment perspectives, identifying players who perform within the expected boundaries of a team, and should therefore be able to perform to the coach's desire. It is also possible for these results to be used in injury rehab programs, identifying when a player is able to perform to the standard required to fit back into training and/or matches following injury. There are areas of research that this thesis has not been able to cover, including looking at the effects these results have on coach understanding and application which should be investigated in the near future for researchers to help apply their findings in an applied setting. In addition, due to the large de-sensitised data used in this study there were methodological weaknesses which could be removed in future investigations.

## 8.5 Summary of Key Findings

- The main outcome of this thesis is the proposal of an alternative method for calculating performance benchmarks using coefficients of variation.
- Stability calculations previously proposed by Hughes, Evans and Wells (2001) may have limited impact on football due to the low frequency of occurrences, particularly in technical performance parameters.
- There is a need for practitioners to continually updating performance benchmarks and expectations as they evolve over time.
- Due to the evolution, researchers need to be aware of the implications of analysing multiple seasons within single data sets.
- Physical performance (5-30%) is less variable than technical performance (25-80%).
- Match context did not appear to affect match-to-match variability. Therefore previous research on contextual effects on performance appears to show match context does affect physical and technical performance.
- High-intensity and sprint performance (no. of actions and distance covered) as well as passing performance (no. of passes and completion rate) have increased in the EPL between 2006-07 and 2012-13.
- Evolution in the EPL does not appear to be due to increasing numbers of non-UK players performing in the EPL. Further research is required to provide additional information.

## References


Abreham, A., Collins, D., & Martindale, R. (2006). The coaching schematic validation through expert coach consensus. *Journal of Sports Sciences*, *24*(6), 549–564.

Abt, G., & Lovell, R. (2009). The use of individualized speed and intensity thresholds for determining the distance run at high-intensity in professional soccer. *Journal of Sports Sciences*, *27*(9), 893–8.

Akenhead, R., Hayes, P. R., Thompson, K. G., & French, D. (2013). Diminutions of acceleration and deceleration output during professional football match play. *Journal of Science and Medicine in Sport*, *16*(6), 556–561.

Al-Hazzaa, H. M., Almuzaini, K. S., Al-Rafaee, A., Sulaiman, M. A., Dafterdar, M. Y., Al-Ghamdei, A., & Al-Khuraiji, K. N. (2001). Aerobic and anaerobic power characteristics of Saudi elite soccer players. *Journal of Sports Medicine and Physical Fitness*, *41*, 54–61.

Andersson, H., Ekblom, B., & Krustrup, P. (2008). Elite football on artificial turf versus natural grass: movement patterns, technical standards, and player impressions. *Journal of Sports Sciences*, *26*(2), 113–22.

Andersson, H., Raastad, T., Nilsson, J., Paulsen, G., Garthe, I., & Kadi, F. (2008). Neuromuscular fatigue and recovery in elite female soccer: effects of active recovery. *Medicine and Science in Sports and Exercise*, *40*(2), 372–380.

Andersson, H., Randers, M. B., Heiner-Møller, A., Krustrup, P., & Mohr, M. (2010). Elite Female Soccer Players Perform More High-Intensity Running When Playing in International Games Compared With Domestic League Games. *Journal of Strength and Conditioning Research*, *24*(4), 912–919.

Arnason, A., Andersen, T. E., Holme, I., Engebretsen, L., & Bahr, R. (2008). Prevention of hamstring strains in elite soccer: An intervention study. *Scandinavian Journal of Medicine and Science in Sports*, *18*(1), 40–48.

Arnason, A., Sigurdsson, S. B., Gudmundsson, A., Holme, I., Engebretsen, L., & Bahr, R. (2004). Risk Factors for Injuries in Football. *American Journal of Sports Medicine*, *32*(90010), 5S–16.

Atkinson, G., & Nevill, A. (1998). Statistical Methods for Assessing Measurement Error (Reliability) in Variables Relevant to Sports Medicine. *Sports Medicine*, *26*(4), 217–238.

Aziz, A. R., Mukherjee, S., Chia, M. Y. H., & Teh, K. C. (2007). Relationship between measured maximal oxygen uptake and aerobic endurance performance with running repeated sprint ability in young elite soccer players. *Journal of Sports Medicine and Physical Fitness*, *47*(4), 401–407.

Bangsbo, J., Iaia, F. M., & Krustrup, P. (2008). The Yo-Yo Intermittent Recovery Test. *Sports Medicine*, *38*(1), 37–51.

Bangsbo, J., Mohr, M., & Krustrup, P. (2006). Physical and metabolic demands of training and match-play in the elite football player. *Journal of*

*Sports Sciences*, *24*(7), 665–674.

Bangsbo, J., & Peitersen, B. (2002). *Defensive Soccer Tactics: How to stop players and teams from scoring*. Champaign, IL: Human Kinetics.

Bangsbo, J., & Peitersen, B. (2004). *Offensive Soccer Tactics: How to control possession and score more goals*. Champaign, IL: Human Kinetics.

Barbero-Alvarez, J. C., Coutts, A., Granda, J., Barbero-Alvarez, V., & Castagna, C. (2010). The validity and reliability of a global positioning satellite system device to assess speed and repeated sprint ability (RSA) in athletes. *Journal of Science and Medicine in Sport*, *13*(2), 232–235.

Barnes, C., Archer, D., Hogg, B., Bush, M., & Bradley, P. S. (2014). The Evolution of Physical and Technical Performance Parameters in the English Premier League. *International Journal of Sports Medicine*, *35*(13), 1095–1100.

Barris, S., & Button, C. (2008). A review of vision-based motion analysis in sport. *Sports Medicine*, *38*(12), 1025–1043.

Barros, R., Misuta, M., Menezes, R., Figueroa, P., Moura, F., Cunha, S., … Leite, N. (2007). Analysis of the distances covered by first division Brazilian soccer players obtained with an automatic tracking method. *Journal of Sports Science and Medicine*, *6*, 233–242.

Bartlett, R. (2001). Performance analysis: can bringing together biomechanics and notational analysis benefit coaches? *International Journal of Performance Analysis in Sport*, *1*, 122–126.

Bartlett, R., Wheat, J., & Robins, M. (2007). Is movement variability important for sports biomechanists? *Sports Biomechanics*, *6*(2), 224–243.

Bates, B. T., Zhang, S., Dufek, J. S., & Chen, F. C. (1996). The effects of sample size and variability on the correlation coefficient. *Medicine and Science in Sports and Exercise*, *28*(3), 386–391.

Batterham, A. M., & Hopkins, W. G. (2006). Making meaningful inferences about magnitudes. *International Journal of Sports Physiology and Performance*, *1*(1), 50–57.

Baur, D. G., & Lehmann, S. (2007). Does the Mobility of Football Players Influence the Success of the National Team? *IIIS Discussion Paper*, (April).

BBC. (2013). State of the Game Premier League now less than one third English. Retrieved 12 October 2015, from http://www.bbc.co.uk/sport/0/football/24467371

Bengtsson, H., Ekstrand, J., & Hägglund, M. (2013). Muscle injury rates in professional football increase with fixture congestion: an 11-year follow-up of the UEFA Champions League injury study. *British Journal of Sports Medicine*, *47*(12), 743–747.

Binder, J., & Findlay, M. (2012). The Effects of the Bosman Ruling on National and Club Teams in Europe. *Journal of Sports Economics*, *13*(2), 107–129.

Bishop, D. (2008). An applied research model for the sport sciences. *Sports Medicine*, *38*(3), 253–63.

Bloomfield, J., Polman, R., & O'Donoghue, P. (2007). Physical demands of different positions in FA Premier League soccer. *Journal of Sports Science and Medicine*, *6*, 63–70.

Boone, J., Vaeyens, R., Steyaert, A., Vanden Bossche, L., & Bourgois, J. (2012). Physical Fitness of Elite Belgian Soccer Players by Player Position. *Journal of Strength and Conditioning Research*, *26*(8), 2051–2057.

Bradley, P. S., Archer, D. T., Hogg, B., Schuth, G., Bush, M., Carling, C., & Barnes, C. (2015). Tier-specific evolution of match performance characteristics in the English Premier League: it's getting tougher at the top. *Journal of Sports Sciences*, *414*(October), 1–8.

Bradley, P. S., Bendiksen, M., Dellal, A., Mohr, M., Wilkie, A., Datson, N., … Krustrup, P. (2014). The Application of the Yo-Yo Intermittent Endurance Level 2 Test to Elite Female Soccer Populations. *Scandinavian Journal of Medicine and Science in Sports*, *24*(1), 43–54.

Bradley, P. S., Carling, C., Archer, D., Roberts, J., Dodds, A., Di Mascio, M., … Krustrup, P. (2011). The effect of playing formation on high-intensity running and technical profiles in English FA Premier League soccer matches. *Journal of Sports Sciences*, *29*(8), 821–830.

Bradley, P. S., Carling, C., Diaz, A. G., Hood, P., Barnes, C., Ade, J., … Mohr, M. (2013). Match performance and physical capacity of players in the top three competitive standards of English professional soccer. *Human Movement Science*, *32*(4), 808–821.

Bradley, P. S., Dellal, A., Mohr, M., Castellano, J., & Wilkie, A. (2014). Gender differences in match performance characteristics of soccer players competing in the UEFA Champions League. *Human Movement Science*, *33*, 159–71.

Bradley, P. S., Di Mascio, M., Peart, D., Olsen, P., & Sheldon, B. (2010). High-intensity activity profiles of elite soccer players at different performance levels. *Journal of Strength and Conditioning Research*, *24*(9), 2343–2351.

Bradley, P. S., Lago-Peñas, C., Rey, E., & Diaz, A. G. (2013). The effect of high and low percentage ball possession on physical and technical profiles in English FA Premier League soccer matches. *Journal of Sports Sciences*, *31*(12), 1261–1270.

Bradley, P. S., Lago-Peñas, C., Rey, E., & Sampaio, J. (2014). The influence of situational variables on ball possession in the English Premier League. *Journal of Sports Sciences*, *32*(20), 1–7.

Bradley, P. S., Mohr, M., Bendiksen, M., Randers, M. B., Flindt, M., Barnes, C., … Krustrup, P. (2011). Sub-maximal and maximal Yo-Yo intermittent endurance test level 2: Heart rate response, reproducibility and application to elite soccer. *European Journal of Applied Physiology*, *111*(6), 969–978.

Bradley, P. S., & Noakes, T. D. (2013). Match running performance fluctuations in elite soccer: indicative of fatigue, pacing or situational influences? *Journal of Sports Sciences*, *31*(15), 1627–38.

Bradley, P. S., O'Donoghue, P., Wooster, B., & Tordoff, P. (2007). The reliability of Prozone MatchViewer: a video-based technical performance analysis system. *International Journal of Performance Analysis in Sport*, *7*, 117–129.

Bradley, P. S., Sheldon, W., Wooster, B., Olsen, P., Boanas, P., & Krustrup, P. (2009). High-intensity running in English FA Premier League soccer matches. *Journal of Sports Sciences*, *27*(2), 159–168.

Brukner, P. (2015). Hamstring injuries: prevention and treatment—an update. *British Journal of Sports Medicine*, *49*(19), 1241–1244.

Buchheit, M., Mendez-Villanueva, A., Simpson, B. M., & Bourdon, P. C. (2010). Repeated-sprint sequences during youth soccer matches. *International Journal of Sports Medicine*, *31*(10), 709–716.

Burgess, D., Naughton, G., & Norton, K. (2012). Quantifying the gap between Under 18 and senior AFL Football: 2003 and 2009. *International Journal of Sports Physiology and Performance*, *7*(1), 53–58.

Bush, M., Archer, D., Hogg, R., & Bradley, P. S. (2015). Factors Influencing Physical and Technical Variability in the English Premier League. *International Journal of Sports Physiology and Performance*, *10*, 865–872.

Carling, C. (2010). Analysis of physical activity profiles when running with the ball in a professional soccer team. *Journal of Sports Sciences*, *28*(3), 319–326.

Carling, C. (2011). Match Analysis to Training. *Soccer Journal*, *May-June*, 42–44.

Carling, C. (2013). Interpreting Physical Performance in Professional Soccer Match-Play: Should We be More Pragmatic in Our Approach? *Sports Medicine*, *43*(8), 655–663.

Carling, C., & Bloomfield, J. (2010). The effect of an early dismissal on player work-rate in a professional soccer match. *Journal of Science and Medicine in Sport*, *13*, 126–128.

Carling, C., Bloomfield, J., Nelsen, L., & Reilly, T. (2008). The Role of Motion Analysis in Elite Soccer: Contemporary Performance Measurement Techniques and Work Rate Data. *Sports Medicine*, *38*(10), 839–862.

Carling, C., & Dupont, G. (2011). Are declines in physical performance associated with a reduction in skill-related performance during professional soccer match-play? *Journal of Sports Sciences*, *29*(1), 63–71.

Carling, C., Gregson, W., McCall, A., Moreira, A., Wong, D. P., & Bradley, P. S. (2015). Match Running Performance During Fixture Congestion in Elite Soccer: Research Issues and Future Directions. *Sports Medicine*, *45*(5), 605–13.

Carling, C., Le Gall, F., & Dupont, G. (2012). Analysis of repeated high-intensity running performance in professional soccer. *Journal of Sports Sciences*, *30*(4), 325–336.

Carling, C., Williams, M., & Reilly, T. (2005). *Handbook of Soccer Match Analysis*. Oxon, UK: Routledge.

Castagna, C., Abt, G., & D'Ottavio, S. (2005). Competitive-Level Differences in Yo-Yo Intermittent Recovery and Twelve Minute Run Test Performance in Socer Referees. *Journal of Strength and Conditioning Research*, *19*(4), 805–809.

Castagna, C., Impellizzeri, F., Belardinelli, R., Abt, G., Coutts, A., Chamari, K., & D'Ottavio, S. (2006). Cardiorespiratory responses to Yo-yo Intermittent Endurance Test in nonelite youth soccer players. *Journal of Strength and Conditioning Research*, *20*(2), 326–330.

Castagna, C., Impellizzeri, F., Chamari, K., Carlomagno, D., & Rampinini, E. (2006). Aerobic Fitness and Yo-Yo Continuous and Intermittent Tests Performances in Soccer Players: A Correlation Study. *Journal of Strength and Conditioning Research*, *20*(2), 320–325.

Castagna, C., Manzi, V., Impellizzeri, F. M., Weston, M., & Barbero Alvarez, J. C. (2010). Relationship between endurance field tests and match performance in young soccer players. *Journal of Strength and Conditioning Research*, *24*(12), 3227–3233.

Castellano, J., Blanco-Villaseñor, A., & Alvarez, D. (2011). Contextual variables and time-motion analysis in soccer. *International Journal of Sports Medicine*, *32*(6), 415–421.

Castellano, J., & Casamichana, D. (2013). Differences in the number of accelerations between small-sided games and friendly matches in soccer. *Journal of Sports Science and Medicine*, *12*(1), 209–210.

Castellano, J., Casamichana, D., & Lago, C. (2012). The Use of Match Statistics that Discriminate Between Successful and Unsuccessful Soccer Teams. *Journal of Human Kinetics*, *31*(March), 139–147.

Chamari, K., Hachana, Y., Ahmed, Y. B., Galy, O., Sghaïer, F., Chatard, J.-C., … Wisløff, U. (2004). Field and laboratory testing in young elite soccer players. *British Journal of Sports Medicine*, *38*(2), 191–196.

Chamari, K., Haddad, M., Wong, D. P., Dellal, A., & Chaouachi, A. (2012). Injury rates in professional soccer players during Ramadan. *Journal of Sports Sciences*, *30*(September), S93–S102.

Chaouachi, A., Manzi, V., Wong, D. P., Chaalali, A., Laurencelle, L., Chamari, K., & Castagna, C. (2010). Intermittent endurance and repeated sprint ability in soccer players. *Journal of Strength and Conditioning Research*, *24*(10), 2663–2669.

Chin, M., Lo, Y., Li, C., & So, C. (1992). Physiological profiles of Hong Kong élite soccer players. *British Journal of Sports Medicine*, *26*(4), 262–266.

Chow, J. Y., Davids, K., Hristovski, R., Araújo, D., & Passos, P. (2011). Nonlinear pedagogy: Learning design for self-organizing neurobiological systems. *New Ideas in Psychology*, *29*(2), 189–200.

Collet, C. (2013). The possession game? A comparative analysis of ball retention and team success in European and international football, 2007-2010. *Journal of Sports Sciences*, *31*(2), 123–136.

Cooper, S., Hughes, M., O'Donoghue, P., & Nevill, A. (2007). A simple statistical method for assessing the reliability of data entered into sport performance analysis systems. *International Journal of Performance Analysis in Sport*, *7*(1), 87–109.

Coutts, A. (2014). Evolution of football match analysis research. *Journal of Sports Sciences*, *32*(20), 1829–1830.

Coutts, A., & Duffield, R. (2010). Validity and reliability of GPS devices for measuring movement demands of team sports. *Journal of Science and Medicine in Sport*, *13*(1), 133–5.

Cushion, C. (2001). *The Coaching Process in Youth Football: An Ethnography of Practice*. Brunel University.

Cushion, C., Nelson, L., Armour, K., Lyle, J., Jones, R., Sandford, R., & O'Callaghan, C. (2010). *Coach Learning and Development: A Review of Literature*.

D'Orazio, T., & Leo, M. (2010). A review of vision-based systems for soccer video analysis. *Pattern Recognition*, *43*(8), 2911–2926.

Da Silva, C. D., Impellizzeri, F., Natali, A. J., De Lima, J. R., Bara-Filho, M. G., Silami-Garçia, E., & Marins, J. C. (2011). Exercise Intensity and Technical Demands of Small-Sided Games in Young brazilian Soccer Plaayers: Effect of Number of Players, Maturation, and Reliability. *Journal of Strength and Conditioning Research*, *25*(10), 2746–2751.

Daly, C. (2013). Sprint-related hamstring injuries the current state of play. *sportEX Medicine*, *58*, 20–27.

Davids, K., Glazier, P. S., Araújo, D., & Bartlett, R. (2003). Movement Systems as Dynamical Systems. *Sports Medicine*, *33*(4), 245–260.

Dawson, P., Dobson, S., & Gerrard, B. (2000). Estimating coaching efficiency in professional team sports: Evidence from English association football. *Scottish Journal of Political Economy*, *47*(4), 399–421.

Dellal, A., Chamari, K., Wong, D. P., Ahmaidi, S., Keller, D., Barros, R., … Carling, C. (2011). Comparison of physical and technical performance in European soccer match-play: FA Premier League and La Liga. *European Journal of Sport Science*, *11*(1), 51–59.

Dellal, A., Lago-Peñas, C., Rey, E., Chamari, K., & Orhant, E. (2013). The effects of a congested fixture period on physical performance, technical activity and injury rate during matches in a professional soccer team. *British Journal of Sports Medicine*, *49*(6), 390–4.

Dellal, A., Owen, A., Wong, D. P., Krustrup, P., van Exsel, M., & Mallo, J. (2012). Technical and physical demands of small vs. large sided games in relation to playing position in elite soccer. *Human Movement Science*, *31*(4), 957–969.

Deutsch, M. U., Kearney, G. a, & Rehrer, N. J. (2007). Time - motion analysis of professional rugby union players during match-play. *Journal of Sports Sciences*, *25*(4), 461–472.

Di Salvo, V., Baron, R., González-Haro, C., Gormasz, C., Pigozzi, F., & Bachl, N. (2010). Sprinting analysis of elite soccer players during European Champions League and UEFA Cup matches. *Journal of Sports Sciences*, *28*(14), 1489–1494.

Di Salvo, V., Baron, R., Tschan, H., Calderon Montero, F. J., Bachl, N., & Pigozzi, F. (2007). Performance characteristics according to playing position in elite soccer. *International Journal of Sports Medicine*, *28*(3), 222–227.

Di Salvo, V., Collins, A., McNeill, B., & Cardinale, M. (2006). Validation of Prozone: A new video-based performance analysis system. *International Journal of Performance Analysis in Sport*, *6*, 108–119.

Di Salvo, V., Gregson, W., Atkinson, G., Tordoff, P., & Drust, B. (2009). Analysis of High Intensity Activity in Premier League Soccer. *International Journal of Sports Medicine*, *30*(3), 205–212.

Di Salvo, V., Pigozzi, F., González-Haro, C., Laughlin, M. S., & Witt, J. K. De. (2013). Match Performance Comparison in Top English Soccer Leagues. *International Journal of Sports Medicine*, *34*, 526–532.

Doidge, M. (2015). *Football Italia: Italian Football in an Age of Globalization*. London: Bloomsbury Academic.

Downey, J. (1973). *The singles game*. London: E.P. Publications.

Drust, B., Atkinson, G., & Reilly, T. (2007). Future perspectives in the evaluation of the physiological demands of soccer. *Sports Medicine*, *37*(9), 783–805.

Duhig, S., Shield, A. J., Opar, D., Gabbett, T. J., Ferguson, C., & Williams, M. (2016). Effect of high-speed running on hamstring strain injury risk. *British Journal of Sports Medicine*, (September), bjsports-2015-095679. http://doi.org/10.1136/bjsports-2015-095679

Duthie, G., Pyne, D., & Hooper, S. (2003). Applied physiology and game analysis of rugby union. *Sports Medicine*, *33*(13), 973–991.

Duthie, G., Pyne, D., & Hooper, S. (2005). Time motion analysis of 2001 and 2002 super 12 rugby. *Journal of Sports Sciences*, *23*(5), 523–530.

Eaves, S. J. (2015). A history of sports notational analysis: a journeyinto the nineteenth century. *International Journal of Performance Analysis in Sport*, *15*(3), 1160–1176.

Eaves, S. J., Hughes, M., & Lamb, K. L. (2005). The Consequences of the Introduction of Professional Playing Status on Game Action Variables in International Northern Hemisphere Rugby Union Football. *International Journal of Performance Analysis in Sport*, *5*(2), 58–86.

Eaves, S. J., Lamb, K. L., & Hughes, M. (2008). The Impact of rule and playing season changes on time variables in professional in rugby league in the United Kingdom. *International Journal of Performance Analysis in Sport*, *8*(2), 44–54.

Edwards, A. M., & Noakes, T. D. (2009). Dehydration: Cause of Fatigue or Sign of Pacing in Elite Soccer ? *Sports Medicine*, *39*(1), 1–13.

Ekstrand, J., Hägglund, M., & Waldén, M. (2011a). Epidemiology of Muscle Injuries in Professional Football ( Soccer ). *American Journal of Sports Medicine*, *39*(6), 1226–32.

Ekstrand, J., Hägglund, M., & Waldén, M. (2011b). Injury incidence and injury patterns in professional football: the UEFA injury study. *British Journal of Sports Medicine*, *45*, 553–558.

Ekstrand, J., Waldén, M., & Hägglund, M. (2016). Hamstring injuries have increased by 4% annually in men's professional football, since 2001: a 13-year longitudinal analysis of the UEFA Elite Club injury study. *British Journal of Sports Medicine*, *50*, 731–737. http://doi.org/10.1136/bjsports-2015-095359

Elferink-Gemser, M. T., Huijgen, B. C. H., Coelho-E-Silva, M., Lemmink, K. a. P. M., & Visscher, C. (2012). The changing characteristics of talented soccer players – a decade of work in Groningen. *Journal of Sports Sciences*, *30*(15), 1581–1591.

Faude, O., Koch, T., & Meyer, T. (2012). Straight sprinting is the most frequent action in goal situations in professional football. *Journal of Sports Sciences*, *30*(7), 625–31.

Fay, P., & Messersmith, L. (1938). The Effect of Rule Changes upon the Distance Traversed by Basketball Players. *Research Quarterly. American Association for Health, Physical Education and Recreation*, *9*(2), 136–137.

Fernandez-Gonzalo, R., De Souza-Teixeira, F., Bresciani, G., García-López, D., Hernández-Murúa, J. a, Jiménez-Jiménez, R., & De Paz, J. a. (2010). Comparison of technical and physiological characteristics of prepubescent soccer players of different ages. *Journal of Strength and Conditioning Research*, *24*(7), 1790–1798.

Fernandez-navarro, J., Fradua, L., Zubillaga, A., Ford, P. R., Mcrobert, A. P., Fradua, L., … Fernandez-navarro, J. (2016). Attacking and defensive styles of play in soccer : analysis of Spanish and English elite teams elite teams. *Journal of Sports Sciences*, *34*(24), 2195–2204. http://doi.org/10.1080/02640414.2016.1169309

Fidelix, Y. L., Berria, J., Ferrari, E. P., Ortiz, J. G., Cetolin, T., & Petroski, E. L. (2014). Somatotype of Competitive Youth Soccer Players From Brazil. *Journal of Human Kinetics*, *42*, 269–266.

FIFA. (2014). FIFA Associations and Confederations. Retrieved 28 September 2014, from http://www.fifa.com/associations/index.html

Fleming, P., Young, C., Dixon, S., & Carré, M. (2010). Athlete and coach perceptions of technology needs for evaluating running performance. *Sports Engineering*, *13*(1), 1–18.

Francis, J., & Jones, G. (2014). Elite rugby union players perceptions of performance analysis. *International Journal of Performance Analysis in Sport*, *14*(1), 188–207.

Franks, I. (2004). The need for feedback. In M. Hughes & I. Franks (Eds.), *Notational Analysis of Sport: Systems for better coaching and performance in sport* (2nd ed., pp. 8–16). Oxon, UK: Routledge.

Franks, I., & Miller, G. (1986). Eyewitness testimony in sport. *Journal of Sport Behaviour*, *9*, 39–45.

Free, M. (2007). Tales from the Fifth Green Field: The Psychodynamics of Migration, Masculinity and National Identity amongst Republic of Ireland Soccer Supporters in England. *Sport in Society*, *10*(3), 476–494.

Fullerton, H. (1912). The inside game: the science of baseball. *The American Magazine*.

Gabbett, T. J., & Whiteley, R. (2016). Two training-load paradoxes: can we work harder and smater, can physical preparation and medical be team-mates? *International Journal of Sports Physiology and Performance*.

Gardiner, S., & Welch, R. (2011). Nationality and protectionism in football: why are FIFA's '6+5 rule' and UEFA's 'home-grown player rule' on the agenda? *Soccer & Society*, *12*(6), 774–787.

Glazier, P. S., & Davids, K. (2009). Constraints on the complete optimization of human motion. *Sports Medicine*, *39*(1), 15–28.

Gómez, M. A., Gómez-Lopez, M., Lago, C., & Sampaio, J. (2012). Effects of game location and final outcome on game-related statistics in each zone of the pitch in professional football. *European Journal of Sport Science*, *12*(5), 393–398. http://doi.org/10.1080/17461391.2011.566373

Gould, D. (2016). Conducting Impactful Coaching Science Research: The Forgotten Role of Knowledge Intergration and Dissemination. *International Sport Coaching Journal*, *3*(2), 197–203.

Gregson, W., Drust, B., Atkinson, G., & Di Salvo, V. (2010). Match-to-match variability of high-speed activities in premier league soccer. *International Journal of Sports Medicine*, *31*(4), 237–242.

Gréhaigne, J. F., Bouthier, D., & David, B. (1997). Dynamic-system analysis of opponent relationships in collective actions in soccer. *Journal of Sports Sciences*, *15*(2), 137–149.

Groom, R., & Cushion, C. J. (2004). Coaches perceptions of the use of video analysis: A case study. *FA Insight*, *7*(3), 56–58.

Groom, R., Cushion, C., & Nelson, L. (2011). The Delivery of Video-Based Performance Analysis by England Youth Soccer Coaches: Towards a Grounded Theory. *Journal of Applied Sport Psychology*, *23*(1), 16–32.

Hägglund, M., Waldén, M., & Ekstrand, J. (2013). Risk Factors for Lower Extremity Muscle Injury in Professional Soccer: The UEFA Injury Study. *American Journal of Sports Medicine*, *41*(2), 327–335.

Hägglund, M., Waldén, M., Magnusson, H., Kristenson, K., Bengtsson, H., & Ekstrand, J. (2013). Injuries affect team performance negatively in professional football: an 11-year follow-up of the UEFA Champions League injury study. *British Journal of Sports Medicine*, *47*(12), 738–42.

Hall, B., Helmers, C., Rogers, M., & Sena, V. (2014). The choice between formal and informal intellectual property - A review. *Journal of Economic Literature*, *52*(2), 375–423.

Handford, C., Davids, K., Bennett, S., & Button, C. (1997). Skill acquisition in sport : Some applications of an evolving practice ecology Skill acquisition in sport : Some applications of an evolving practice ecology. *Journal of Sports Sciences*, *15*(6), 621–640.

Harley, J. A., Lovell, R. J., Barnes, C. A., Portas, M. D., & Weston, M. (2011). The Interchangeability of Global Positioning System and Semiautomated Video-Based Performance Data During Elite Soccer Match Play. *Journal of Strength and Conditioning Research*, *25*(8), 2334–2336.

Haugen, T. a., Tønnessen, E., & Seiler, S. (2013). Anaerobic performance testing of professional soccer players 1995-2010. *International Journal of Sports Physiology and Performance*, *8*(2), 148–156.

Haugen, T., Tønnessen, E., Hem, E., Leirstein, S., & Seiler, S. (2014). VO 2max Characteristics of Elite Female Soccer Players , 1989 – 2007. *International Journal of Sports Physiology and Performance*, *9*, 515–521.

Haugen, T., Tønnessen, E., & Seiler, S. (2012). Speed and Countermovement Jump Characteristics of Elite Female Soccer Players 1995-2010 Speed and CMJ in Female Soccer. *International Journal of Sports Physiology and Performance*, 340–349.

Hawkins, R. D., Hulse, M. A., Wilkinson, C., Hodson, A., & Gibson, M. (2001). The association football medical research programme: an audit of injuries in professional football. *British Journal of Sports Medicine*, *35*(1), 43–47.

Heidt, R. S. J., Sweeterman, L. M., Carlonas, R. L., Traub, J. A., & Tekulve, F. X. (2000). Avoidance of Soccer Injuries with Preseason Conditioning. *The American Journal of Sports Medicine*, *28*(5), 659–662.

Henderson, G., Barnes, C. A., & Portas, M. D. (2010). Factors associated with increased propensity for hamstring injury in English Premier League soccer players. *Journal of Science and Medicine in Sport*, *13*(4), 397–402.

Hodgson, C., Akenhead, R., & Thomas, K. (2014). Time-motion analysis of acceleration demands of 4v4 small-sided soccer games played on different pitch sizes. *Human Movement Science*, *33*(1), 25–32.

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*, *41*(1), 3–13.

Hughes, M. (2004a). Notational analysis – a mathematical perspective. *International Journal of Performance Analysis in Sport*, *4*(2), 97–139.

Hughes, M. (2004b). Performance analysis – a 2004 perspective. *International Journal of Performance Analysis in Sport*, *4*(1), 103–109.

Hughes, M., & Bartlett, R. (2002). The use of performance indicators in performance analysis. *Journal of Sports Sciences*, *20*(10), 739–754.

Hughes, M., Bürger, P., Hughes, M. T., Murray, S., & James, N. (2013). Profiling in sport using momentum and perturbations. *Journal of Human Sport and Exercise*, *8*(Proc2), 242–260.

Hughes, M., Caudrelier, T., James, N., Donnelly, I., Kirkbride, A., & Duschesne, C. (2012). Moneyball and soccer - an analysis of the key performance indicators of elite male soccer players by position. *Journal of Human Sport and Exercise*, *7*(2), 402–412.

Hughes, M., Cooper, S., & Nevill, A. (2004). Analysis of notation data: reliability. In M. Hughes & I. M. Franks (Eds.), *Notational Analysis of Sport: Systems for better coaching and performance in sport* (2nd ed.). Abingdon, UK: Routledge.

Hughes, M., Evans, S., & Wells, J. (2001). Establishing normative profiles in performance analysis. *International Journal of Performance Analysis in Sport*, *1*(1), 1–26.

Hughes, M., & Franks, I. (2004a). How to develop a notation system. In M. Hughes & I. Franks (Eds.), *Notational Analysis of Sport: Systems for better coaching and performance in sport* (2nd ed., pp. 118–140). Abingdon, UK: Routledge.

Hughes, M., & Franks, I. (2004b). Notational Analysis - a review of the literature. In M. Hughes & I. M. Franks (Eds.), *Notational Analysis of Sport: Systems for better coaching and performance in sport* (2nd ed.). Abingdon, UK: Routledge.

Hughes, M., & Franks, I. (2005). Analysis of passing sequences, shots and goals in soccer. *Journal of Sports Sciences*, *23*(5), 509–514.

Hughes, M., & Hughes, M. T. (2005). The Evolution of Computerised Notational Analysis Through the Example of Squash. *International Journal of Computer Science in Sport*, *4*(1), 5–20.

Hughes, M., Hughes, M. T., & Behan, H. (2007). The Evolution of Computerised Notational Analysis Through the Example of Racket Sports. *International Journal of Sports Science and Engineering*, *1*(1), 3–28.

Iaia, F. M., Rampinini, E., & Bangsbo, J. (2009). High-Intensity Training in Football. *International Journal of Sports Physiology and Performance*, *4*(3), 291–306.

Ingebrigtsen, J., Dalen, T., Hjelde, G. H., Drust, B., & Wisløff, U. (2015). Acceleration and sprint profiles of a professional elite football team in match play. *European Journal of Sport Science*, *15*(2), 101–110.

Jacklin, P. B. (2005). Temporal changes in home advantage in English football since the Second World War: what explains improved away performance? *Journal of Sports Sciences*, *23*(7), 669–679.

James, N. (2006). Notational analysis in soccer: past, present and future. *International Journal of Performance Analysis in Sport*, *6*(2), 67–81.

James, N., Mellalieu, S. D., & Hollely, C. (2002). Analysis of strategies in soccer as a function of European and domestic competition. *International*

*Journal of Performance Analysis in Sport*, *2*(1), 85–103.

James, N., Mellalieu, S. D., & Jones, N. M. P. (2005). The development of position-specific performance indicators in professional rugby union. *Journal of Sports Sciences*, *23*(1), 63–72.

Janković, A., Leontijević, B., Jelušić, V., & Pašić, M. (2011). Analysis of passes of Serbian football (soccer) team in qualifying for the World Cup 2010. *Anthropological Aspects of Sports, Physical Education and Recreation*, *2*(1), 235–244.

Junge, A., & Dvorak, J. (2004). Soccer injuries: A review on incidence and prevention. *Sports Medicine*, *34*(13), 929–938.

Junge, A., & Dvorak, J. (2010). Injury risk of playing football in Futsal World Cups. *British Journal of Sports Medicine*, *44*(15), 1089–1092.

Katis, A., & Kellis, E. (2009). Effects of small-sided games on physical conditioning and performance in young soccer players. *Journal of Sports Science and Medicine*, *8*, 374–380.

Kellis, E., Katis, A., & Vrabas, I. S. (2006). Effects of an intermittent exercise fatigue protocol on biomechanics of soccer kick performance. *Scandinavian Journal of Medicine and Science in Sports*, *16*(5), 334–344.

Krustrup, P., & Bangsbo, J. (2001). Physiological demands of top-class soccer refereeing in relation to physical capacity: effect of intense intermittent exercise training. *Journal of Sports Sciences*, *19*(11), 881–891.

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., … Bangsbo, J. (2003). The yo-yo intermittent recovery test: physiological response, reliability and validity. *Medicine and Science in Sports and Exercise*, *35*(4), 697–705.

Krustrup, P., Mohr, M., Ellingsgaard, H., & Bangsbo, J. (2005). Physical demands during an elite female soccer game: importance of training status. *Medicine and Science in Sports and Exercise*, *37*(7), 1242–1248.

Krustrup, P., Mohr, M., Nybo, L., Jensen, J. M., Nielsen, J. J., & Bangsbo, J. (2006). The Yo-Yo IR2 test: Physiological response, reliability, and application to elite soccer. *Medicine and Science in Sports and Exercise*, *38*(9), 1666–1673.

Kulkarni, K., Levin, G., Peñailillo, L., Singh, A., & Singh, S. J. (2013). Physical and Physiological Characteristics of Elite Indian National Football Players. *Journal of Athletic Enhancement*, *2*(6).

Lago-Ballesteros, J., Lago-Peñas, C., & Rey, E. (2012). The effect of playing tactics and situational variables on achieving score-box possessions in a professional soccer team. *Journal of Science and Medicine in Sport*, *30*(14), 37–41.

Lago-Peñas, C., & Dellal, A. (2010). Ball Possession Strategies in Elite Soccer According to the Evolution of the Match-Score: the Influence of Situational Variables. *Journal of Human Kinetics*, *25*, 93–100.

Lago-Peñas, C., & Lago-Ballesteros, J. (2011). Game location and team quality effects on performance profiles in professional soccer. *Journal of Sports Science and Medicine*, *10*, 465–471.

Lago-Peñas, C., Rey, E., Lago-Ballesteros, J., Casais, L., & Dominguez, E. (2011). The Influence of a Congested Calendar on Physical Performance in Elite Soccer. *Journal of Strength and Conditioning Research*, *25*(8), 2111–7.

Lago, C. (2009). The influence of match location, quality of opposition, and match status on possession strategies in professional association football. *Journal of Sports Sciences*, *27*(13), 1463–1469.

Lago, C., Casais, L., Dominguez, E., & Sampaio, J. (2010). The effects of situational variables on distance covered at various speeds in elite soccer. *European Journal of Sport Science*, *10*(2), 103–109.

Lago, C., & Martín, R. (2007). Determinants of possession of the ball in soccer. *Journal of Sports Sciences*, *25*(9), 969–974.

Laird, P., & Lorimer, R. (2004). An examination of try scoring in rugby union: a review of international rugby statistics. *International Journal of Performance Analysis in Sport*, *4*(1), 72–80.

Laird, P., & Waters, L. (2008). Eyewitness Recollection of Sport Coaches. *International Journal of Performance Analysis in Sport*, *8*(1), 76–84.

Lames, M., & McGarry, T. (2007). On the search for reliable performance indicators in game sports. *International Journal of Performance Analysis in Sport*, *7*(1), 62–79.

Liebermann, D., & Franks, I. (2004). The use of feedback-based technologies. In M. Hughes & I. Franks (Eds.), *Notational Analysis of Sport: Systems for better coaching and performance in sport* (2nd ed., pp. 40–58). Abingdon, UK: Routledge.

Liebermann, D., Katz, L., Hughes, M., Bartlett, R., McClements, J., & Franks, I. (2002). Advances in the application of information technology to sport performance. *Journal of Sports Sciences*, *20*(10), 755–769.

Littlewood, M., Mullen, C., & Richardson, D. (2011). Football labour migration: an examination of the player recruitment strategies of the ‘big five’ European football leagues 2004–5 to 2008–9. *Soccer & Society*, *12*(6), 788–805.

Liu, H., Garrett, W. E., Moorman, C. T., & Yu, B. (2012). Injury rate, mechanism, and risk factors of hamstring strain injuries in sports: A review of the literature. *Journal of Sport and Health Science*, *1*(2), 92–101.

Liu, H., Gómez, M.-A., Gonçalves, B., & Sampaio, J. (2016). Technical performance and match-to-match variation in elite football teams. *Journal of Sports Sciences*, *34*(6), 509–18.

Lyons, G. M., Culhane, K. M., Hilton, D., Grace, P. a., & Lyons, D. (2005). A description of an accelerometer-based mobility monitoring technique. *Medical Engineering and Physics*, *27*, 497–504.

Mackenzie, R., & Cushion, C. (2013). Performance analysis in football: a critical review and implications for future research. *Journal of Sports*

*Sciences*, *31*(6), 639–676.

Mackenzie, R., & Cushion, C. (2014). Performance Analysis in Professional Soccer: Player and coach Perspectives. In D. Peters & P. O'Donoghue (Eds.), *Performance Analysis of Sport IX*. Abingdon, UK: Routledge.

MacLeod, H., Morris, J., Nevill, A., & Sunderland, C. (2009). The validity of a non-differential global positioning system for assessing player movement patterns in field hockey. *Journal of Sports Sciences*, *27*(2), 121–128.

Magalhães Sales, M., Vieira Browne, R. A., Yukio Asano, R., dos Reis Vieira Olher, R., Vila Nova, J. F., Moraes, & Simoes, H. G. (2014). Physical fitness and anthropometric characteristics in professional soccer players. *Revista Andaluza de Medicina Del Deporte*, *7*(3), 106–110.

Maguire, J., & Pearton, R. (2000). The impact of elite labour migration on the identification, selection and development of European soccer players. *Journal of Sports Sciences*, *18*(9), 759–769.

Mara, J. K., Wheeler, K. W., & Lyons, K. (2012). Attacking Strategies That Lead to Goal Scoring Opportunities in High Level Women's Football. *International Journal of Sports Science and Coaching*, *7*(3), 565–578.

Martindale, R., & Nash, C. (2013). Sport science relevance and application: perceptions of UK coaches. *Journal of Sports Sciences*, *31*(8), 807–19.

Matković, B. R., Misigoj-Duraković, M., Matković, B., Janković, S., Ruzić, L., Leko, G., & Kondric, M. (2003). Morphological differences of elite Croatian soccer players according to the team position. *Collegium Antropologicum*, *27 Suppl 1*, 167–174.

McGarry, T., Anderson, D., Wallace, S., Hughes, M., & Franks, I. (2002). Sport competition as a dynamical self-organizing system. *Journal of Sports Sciences*, *20*(10), 771–781.

McGovern, P. (2002). Globalization or Internationalization? Foreign Footballers in the English League, 1946-95. *Sociology*, *36*(1), 23–42.

Mendez-Villanueva, A., Buchheit, M., Simpson, B., Peltola, E., & Bourdon, P. (2011). Does On-Field Sprinting Performance in Young Soccer Players Defend on How Fast Then Can Run or How Fast The Do Run? *Journal of Strength and Conditioning Research*, *25*(9), 2634–2638.

Messersmith, L. (1944). A Study of the Distance Traveled by Basketball Players. *Research Quarterly. American Association for Health, Physical Education and Recreation*, *15*(1), 29–37.

Messersmith, L., & Bucher, C. (1939). The Distance Traversed by Big Ten Basketball Players. *Research Quarterly. American Association for Health, Physical Education and Recreation*, *10*(3), 61–62.

Messersmith, L., & Corey, S. (1931). The Distance Traversed by a Basketball Player. *Research Quarterly. American Physical Education Association*, *2*(2), 57–60.

Messersmith, L., & Fay, P. (1932). Distances Traversed By Football Players. *Research Quarterly. American Physical Education Association*, *3*(1), 78–80.

Messersmith, L., Laurence, J., & Randels, K. (1940). A Study of Distances Traversed by College Men and Women in Playing the Game of Basketball. *Research Quarterly. American Association for Health, Physical Education and Recreation*, *11*(3), 30–31.

Mohr, M., Krustrup, P., Andersson, H., Kirkendal, D., & Bangsbo, J. (2008). Match Activities of Elite Women Soccer Players at Different Performance Levels. *Journal of Strength and Conditioning Research*, *22*(2), 341–349.

Mohr, M., Krustrup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Sciences*, *21*(7), 519–528.

Mohr, M., Krustrup, P., & Bangsbo, J. (2005). Fatigue in soccer: a brief review. *Journal of Sports Sciences*, *23*(6), 593–599.

Mohr, M., Nybo, L., Grantham, J., & Racinais, S. (2012). Physiological responses and physical performance during football in the heat. *PloS One*, *7*(6), e39202.

Murray, F., & Stern, S. (2007). Do formal intellectual property rights hinder the free flow of scientific knowledge?. An empirical test of the anti-commons hypothesis. *Journal of Economic Behavior and Organization*, *63*(4), 648–687.

Mytton, G. J., Archer, D. T., Gibson, A. S. C., & Thompson, K. G. (2014). Reliability and stability of performances in 400-m swimming and 1500-m running. *International Journal of Sports Physiology and Performance*, *9*(4), 674–679.

Nédélec, M., Mccall, A., Carling, C., Legall, F., Berthoin, S., & Dupont, G. (2012). Recovery in Soccer. *Sports Medicine*, *42*(12), 997–1015.

Nelson, L., Potrac, P., & Groom, R. (2011). Receiving video-based feedback in elite ice-hockey: a player's perspective. *Sport, Education and Society*, *1*(October), 37–41.

Nevill, A., Atkinson, G., & Hughes, M. (2008). Twenty-five years of sport performance research in the Journal of Sports Sciences. *Journal of Sports Sciences*, *26*, 413–426.

Nevill, A., Balmer, N., & Williams, A. (2002). The influence of crowd noise and experience upon refereeing decisions in football. *Psychology of Sport and Exercise*, *3*(4), 261–272.

Nevill, A., Balmer, N., & Wolfson, S. (2005). The extent and causes of home advantage: Some recent insights. *Journal of Sports Sciences*, *23*(4), 335–336.

Nevill, A., Holder, R., & Watts, A. (2009). The changing shape of 'successful' professional footballers. *Journal of Sports Sciences*, *27*(5), 419–426.

Newell, K. (1986). Constraints on the development of coordination. In M. Wade & H. Whiting (Eds.), *Motor Development in Children: Aspects of Coordination and Control*. Rotterdam, Netherlands: Springer.

Norton, K., Craig, N. P., & Olds, T. (1999). The evolution of Australian football. *Journal of Science and Medicine in Sport*, *2*(4), 389–404.

Norton, K., & Olds, T. (2001). Morphological evolution of athletes over the 20th century: causes and consequences. *Sports Medicine*, *31*(11), 763–783.

O'Donoghue, P. (2005). Normative Profiles of Sports Performance. *International Journal of Performance Analysis in Sport*, *5*, 104–119.

O'Donoghue, P. (2006a). Reliability Issues in Performance Analysis, 35–48.

O'Donoghue, P. (2006b). The use of feedback videos in sport. *International Journal of Performance Analysis in Sport*, *6*(2), 1–14.

O'Donoghue, P., Mayes, A., Edwards, K. M., & Garland, J. (2009). Performance Norms for British National Super League Netball. *International Journal of Sports Science and Coaching*, *3*(4), 501–511.

Olds, T. (2001). The evolution of physique in male rugby union players in the twentieth century. *Journal of Sports Sciences*, *19*(4), 253–262.

Opar, D., Williams, M. D., & Shield, A. J. (2012). Hamstring strain injuries: factors that lead to injury and re-injury. *Sports Medicine*, *42*(3), 209–226.

Osgnach, C., Poser, S., Bernardini, R., Rinaldo, R., & Di Prampero, P. E. (2010). Energy cost and metabolic power in elite soccer: A new match analysis approach. *Medicine and Science in Sports and Exercise*, *42*(1), 170–178.

Ostojic, S. M. (2000). Physical and physiological characteristics of elite Serbian soccer players. *Physical Education & Sport*, *1*(7), 23–29.

Partington, M., & Cushion, C. (2013). An investigation of the practice activities and coaching behaviors of professional top-level youth soccer coaches. *Scandinavian Journal of Medicine and Science in Sports*, *23*(3), 374–382.

Passos, P., Araújo, D., Davids, K., Gouveia, L., Milho, J., & Serpa, S. (2008). Information-governing dynamics of attacker-defender interactions in youth rugby union. *Journal of Sports Sciences*, *26*(13), 1421–1429.

Petersen, J., Thorborg, K., Nielsen, M. B., Budtz-Jørgensen, E., & Hölmich, P. (2011). Preventive effect of eccentric training on acute hamstring injuries in men's soccer: a cluster-randomized controlled trial. *The American Journal of Sports Medicine*, *39*(11), 2296–303.

Pollard, R. (2002). Evidence of a reduced home advantage when a team moves to a new stadium. *Journal of Sports Sciences*, *20*(12), 969–973.

Pollard, R. (2008). Home Advantage in Football: A Current Review of an Unsolved Puzzle. *The Open Sports Sciences Journal*, *1*(1), 12–14.

Pollard, R., & Pollard, G. (2005). Long-term trends in home advantage in professional team sports in North America and England (1876-2003). *Journal of Sports Sciences*, *23*(4), 337–350.

Portas, M. D., Harley, J., Barnes, C., & Rush, C. J. (2010). The validity and reliability of 1-Hz and 5-Hz global positioning systems for linear, multidirectional, and soccer-specific activities. *International Journal of Sports Physiology and Performance*, *5*(4), 448–458.

Poulter, D. R. (2009). Home advantage and player nationality in international club football. *Journal of Sports Sciences*, *27*(8), 797–805.

Procyk, J., Neustaeder, C., & Schiphorst, T. (2015). Amateur Ice Hockey Coaching and the Role of Video Feedback. In *Proceedings of the 41st Graphics Interface Conference* (pp. 179–186). Halifax, Nova Scotia: Canadian Information Processing Society.

Prozone. (2014). STYLE AND SUBSTANCE The Evolution of the Premier League - Prozone Sports. Retrieved from http://www.prozonesports.com/style-and-substance-the-evolution-of-the-premier-league/

Rahnama, N., Reilly, T., & Lees, A. (2002). Injury risk associated with playing actions during competitive soccer. *British Journal of Sports Medicine*, *36*(5), 354–359.

Rampinini, E., Coutts, A., Castagna, C., Sassi, R., & Impellizzeri, F. (2007). Variation in top level soccer match performance. *International Journal of Sports Medicine*, *28*(12), 1018–1024.

Rampinini, E., Impellizzeri, F., Castagna, C., Azzalin, A., Ferrari Bravo, D., & Wisløff, U. (2008). Effect of Match-Related Fatigue on Short-Passing Ability in Young Soccer Players. *Medicine and Science in Sports and Exercise*, *40*(5), 934–942.

Rampinini, E., Impellizzeri, F., Castagna, C., Coutts, A., & Wisløff, U. (2009). Technical performance during soccer matches of the Italian Serie A league: Effect of fatigue and competitive level. *Journal of Science and Medicine in Sport*, *12*(1), 227–233.

Rampinini, E., Sassi, A., Azzalin, A., Castagna, C., Menaspà, P., Carlomagno, D., & Impellizzeri, F. (2010). Physiological determinants of Yo-Yo intermittent recovery tests in male soccer players. *European Journal of Applied Physiology*, *108*(2), 401–409.

Randers, M. B., Mujika, I., Hewitt, A., Santisteban, J., Bischoff, R., Solano, R., … Mohr, M. (2010). Application of four different football match analysis systems: a comparative study. *Journal of Sports Sciences*, *28*(2), 171–182.

Reade, I., Rodgers, W., & Hall, N. (2009). Knowledge Transfer: How do High Performance Coaches Access the Knowledge of Sport Scientists? *International Journal of Sports Science and Coaching*, *3*(3), 319–334. http://doi.org/10.1260/174795408786238470

Rebelo, A., Brito, J., Maia, J., Coelho-E-Silva, M. J., Figueiredo, A. J., Bangsbo, J., … Seabra, A. (2013). Anthropometric characteristics, physical fitness and technical performance of under-19 soccer players by competitive level and field position. *International Journal of Sports Medicine*, *34*(4), 312–317.

Redwood-Brown, A. (2008). Passing patterns before and after goal scoring in FA Premier League Soccer. *International Journal of Performance Analysis in Sport*, *8*(3), 172–182.

Redwood-Brown, A., Bussell, C., & Bharaj, H. S. (2012). The impact of different standards of opponents on observed player performance in the English Premier League. *Journal of Human Sport and Exercise*, *7*(2), 341–355.

Redwood-Brown, A., Cranton, W., & Sunderland, C. (2012). Validation of a real-time video analysis system for soccer. *International Journal of Sports Medicine*, *33*(8), 635–640.

Reed, D., & O'Donoghue, P. (2005). Development and application of computed-based prediction methods. *International Journal of Performance Analysis in Sport*, *5*(3), 12–28.

Reep, C., & Benjamin, B. (1968). Skill and Chance in Association Football. *Journal of the Royal Statistical Society*, *131*(4), 581–585.

Reilly, T. (1996). *Science and Soccer*. (T. Reilly, Ed.). Abingdon, UK: Taylor & Francis Group.

Reilly, T. (1997). Energetics of high-intensity exercise (soccer) with particular reference to fatigue. *Journal of Sports Sciences*, *15*(3), 257–263.

Reilly, T., Bangsbo, J., & Franks, A. (2000). Anthropometric and physiological predispositions for elite soccer. *Journal of Sports Sciences*, *18*(9), 669–683.

Reilly, T., & Gilbourne, D. (2003). Science and football: a review of applied research in the football codes. *Journal of Sports Sciences*, *21*(9), 693–705.

Richardson, D., Littlewood, M., Nesti, M., & Benstead, L. (2012). An examination of the migratory transition of elite young European soccer players to the English Premier League An examination of the migratory transition of elite young European soccer players to the English Premier League. *Journal of Sports Sciences*, *30*(15), 1605–1618.

Rostgaard, T., Iaia, F. M., Simonsen, D. S., & Bangsbo, J. (2008). A Test to Evaluate the Physical Impact on Technical Performance in Soccer. *Journal of Strength and Conditioning Research*, *22*(1), 283–292.

Russell, M., & Kingsley, M. (2011). Influence of exercise on skill proficiency in soccer. *Sports Medicine*, *41*(7), 523–539.

Sampaio, J., & Janeira, M. (2003). Statistical analyses of basketball team performance: Understanding teams' wins and losses according to a different index of ball possessions. *International Journal of Performance Analysis in Sport*, *3*(1), 40–49.

Sánchez, P. a., García-Calvo, T., Leo, F. M., Pollard, R., & Gómez, M. (2009). An Analysis of Home Advantage in the Top Two Spanish Professional Football Leagues 1. *Perceptual and Motor Skills*, *108*(3), 789–797.

Sanderson, F. H. (1983). A notation system for analysing squash. *Physical Education Review*, *6*, 19–23.

Sanderson, F. H., & Way, K. I. (1979). The development of objective methods of game analysis in squash rackets. *British Journal of Sports Medicine*, *11*(4), 188.

Sarmento, H., Anguera, M. T., Pereira, A., Marques, A., Campanico, J., & Leitao, J. (2014). Patterns of Play in the Counterattack of Elite Football Teams - A Mixed Method Approach. *International Journal of Performance Analysis in Sport*, *14*(2), 411–427.

Sarmento, H., Marcelino, R., Anguera, M. T., Campaniço, J., Matos, N., & Leitão, J. C. (2014). Match analysis in football: a systematic review. *Journal of Sports Sciences*, *32*(30), 1831–1843.

Schmidt, R., & Lee, T. (2011). *Motor Control and Learning: A Behavioural Emphasis* (5th ed.). Champaign, IL: Human Kinetics.

Scott, B. R., Lockie, R. G., Davies, S. J. G., Clark, A. C., Lynch, D. M., & Janse de Jonge, X. A. K. (2014). The Physical Demands of Professional Soccer Players During in-season Field-based Training and Match-Play. *Journal of Australian Strength and Conditioning*, *22*(4), 7–15.

Scoulding, A., James, N., & Taylor, J. B. (2004). Passing in the Soccer World Cup 2002. *International Journal of Performance Analysis in Sport*, *4*(2), 36–41.

Small, K., McNaughton, L. R., Greig, M., Lohkamp, M., & Lovell, R. (2009). Soccer fatigue, sprinting and hamstring injury risk. *International Journal of Sports Medicine*, *30*(8), 573–8.

Smith, H. K. (2011). Penalty shots in International water polo: Regular opportunities with robust success despite greater impact on the game under current rules. *International Journal of Performance Analysis in Sport*, *11*(2), 335–343.

Smith, T., Hammond, J., & Gilleard, W. (2005). The use of performance analysis technology to monitor the coaching environment in soccer. *International Journal of Performance Analysis in Sport*, *5*(3), 126–138.

Soika, D. (2008). *Legal opinion upholds 6 + 5 rule Experts perceive no conflict with European law*. Dusseldorf.

Sporis, G., Jukic, I., Ostojic, S. M., & Milanovic, D. (2009). Fitness Profiling In Soccer: Physical and Physiologic Characteristics of Elite Players. *Journal of Strength and Conditioning Research*, *23*(7), 1947–1953.

Stergiou, N., Jensen, J. L., Bates, B. T., Scholten, S. D., & Tzetzis, G. (2001). A dynamical systems investigation of lower extremity coordination during running over obstacles. *Clinical Biomechanics*, *16*, 213–221.

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of Soccer. *Sports Medicine*, *35*(6), 501–536.

Strøyer, J., Hansen, L., & Klausen, K. (2004). Physiological profile and activity pattern of young soccer players during match play. *Medicine and Science in Sports and Exercise*, *36*(1), 168–174.

Taylor, J. B., Mellalieu, S. D., & James, N. (2004). Behavioural comparisons or positional demands in professional soccer. *International Journal of Performance Analysis in Sport*, *4*(1), 81–97.

Taylor, J. B., Mellalieu, S. D., & James, N. (2005). A Comparison of

Individual and Unit Tactical Behaviour and Team Strategy in Professional Soccer. *International Journal of Performance Analysis in Sport*, *5*(2), 87–101.

Taylor, J. B., Mellalieu, S. D., James, N., Shearer, D. A., Mallalieu, S. D., James, N., & Shearer, D. A. (2008). The influence of match location, quality of opposition, and match status on technical performance in professional association football. *Journal of Sports Sciences*, *26*(9), 885–895.

Taylor, M. (2006). Global players? Football , Migration and Globalization, c. 1930-2000. *Historical Social Research*, *31*(1), 7–30.

Tenga, A., Holme, I., Ronglan, L. T., & Bahr, R. (2010). Effect of playing tactics on goal scoring in Norwegian professional soccer. *Journal of Sports Sciences*, *28*(3), 237–244. http://doi.org/10.1080/02640410903502774

Tenga, A., Ronglan, L. T., & Bahr, R. (2010). Measuring the effectiveness of offensive match-play in professional soccer. *European Journal of Sport Science*, *10*(4), 269–277.

The FA. (2015). FA Chairman's update on England Commission. Retrieved 10 May 2015, from http://www.thefa.com/news/thefa/2015/mar/greg-dyke-england-commission-homegrown-players-work-permits-march-2015

Tipping, J. (2007). The 1-4-5-1 System. *Soccer Journal*, (April), 40–45.

Tønnessen, E., Hem, E., Leirstein, S., Haugen, T., & Seiler, S. (2013). Maximal aerobic power characteristics of male professional soccer players, 1989-2012. *International Journal of Sports Physiology and Performance*, *8*(3), 323–329.

Transfermarkt. (2014). Premier League Statistics. Retrieved 10 September 2014, from http://www.transfermarkt.co.uk/premier-league/gastarbeiter/wettbewerb/GB1#subnavi

Travassos, B., Araújo, D., Davids, K., Esteves, P. T., & Fernandes, O. (2012). Improving Passing Actions in Team Sports by Developing Interpersonal Interactions Between Players. *International Journal of Sports Science and Coaching*, *7*(4), 677–688.

Tromp, M., & Holmes, L. (2011). The effect of free-hit rule changes on match variables and patterns of play in international standard women ' s field hockey. *International Journal of Performance Analysis in Sport*, *11*(2), 376–391.

Tucker, W., Mellalieu, S. D., James, N., & Taylor, J. B. (2005). Game Location Effects in Professional Soccer: A Case Study. *International Journal of Performance Analysis in Sport*, *5*(2), 23–35.

Ueda, S., Yamanaka, A., Yoshikawa, T., Katsura, Y., Usui, T., Orita, K., & Fujimoto, S. (2011). Differences in Physiological Characterization between Yo-Yo Intermittent Recovery Test Level 1 and Level 2 in Japanese College Soccer Players. *International Journal of Sport and Health Science*, *9*, 33–38.

Unkelbach, C., & Memmert, D. (2010). Crowd noise as a cue in referee decisions contributes to the home advantage. *Journal of Sport & Exercise Psychology*, *32*(4), 483–498.

Varley, M. C., & Aughey, R. J. (2013). Acceleration profiles in elite Australian soccer. *International Journal of Sports Medicine*, *34*(1), 34–39.

Varley, M. C., Fairweather, I. H., & Aughey, R. J. (2012). Validity and reliability of GPS for measuring instantaneous velocity during acceleration, deceleration, and constant motion. *Journal of Sports Sciences*, *30*(2), 121–127.

Varley, M. C., Gabbett, T., & Aughey, R. J. (2014). Activity profiles of professional soccer, rugby league and Australian football match play. *Journal of Sports Sciences*, *32*(20), 1858–1866.

Vaz, L., van Rooyen, M., & Sampaio, J. (2010). Rugby game-related statistics that discriminate between winning and losing teams in IRB and super twelve close games. *Journal of Sports Science and Medicine*, *9*(1), 51–55.

Veale, J. P., Pearce, A. J., & Carlson, J. S. (2010). The Yo-Yo Intermittent Recovery Test (Level 1) to discriminate elite junior Australian football players. *Journal of Science and Medicine in Sport*, *13*(3), 329–331.

Vescovi, J. D. (2012). Sprint profile of professional female soccer players during competitive matches: Female Athletes in Motion (FAiM) study. *Journal of Sports Sciences*, *30*(12), 1259–1265.

Vigne, G., Gaudino, C., Rogowski, I., Alloatti, G., & Hautier, C. (2010). Activity profile in elite Italian soccer team. *International Journal of Sports Medicine*, *31*(5), 304–310.

Vilar, L., Araújo, D., Davids, K., & Button, C. (2012). The role of ecological dynamics in analysing performance in team sports. *Sports Medicine*, *42*(1), 1–10.

Vincent, W. J. (2005). *Statistics in Kinesiology* (3rd ed.). Champaign, IL: Human Kinetics.

Wallace, J. L., & Norton, K. (2014). Evolution of World Cup soccer final games 1966-2010: Game structure, speed and play patterns. *Journal of Science and Medicine in Sport*, *17*(2), 223–228.

Wehbe, G. M., Hartwig, T. B., & Duncan, C. S. (2014). Movement Analysis of Australian National League Soocer Players Using Global Positioning System Technology. *Journal of Strength and Conditioning Research*, *28*(3), 834–842.

Weston, M., Batterham, A. M., Castagna, C., Portas, M. D., Barnes, C., Harley, J., & Lovell, R. (2011). Reduction in physical match performance at the start of the second half in elite soccer. *International Journal of Sports Physiology and Performance*, *6*(2), 174–182.

Weston, M., Castagna, C., Impellizzeri, F., Rampinini, E., & Abt, G. (2007). Analysis of physical match performance in English Premier League soccer referees with particular reference to first half and player work rates. *Journal of Science and Medicine in Sport*, *10*(6), 390–397.

Weston, M., Drust, B., Atkinson, G., & Gregson, W. (2011). Variability of Soccer Referees' Match Performances. *International Journal of Sports*

*Medicine*, *32*(3), 190–194.

Wickham, H., & Chang, W. (2013). Tools to make developing R code easier. Retrieved from https://cran.r-project.org/web/packages/devtools/index.html

Williams, S. J., & Kendall, L. (2007). Perceptions of elite coaches and sports scientists of the research needs for elite coaching practice. *Journal of Sports Sciences*, *25*(14), 1577–1586.

Winter, D. (2009). *Biomechanics and Motor Control of Human Movement* (4th ed.). New Jersey: John Wiley & Sons.

Wisløff, U., Castagna, C., Helgerud, J., Jones, R., & Hoff, J. (2004). Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine*, *38*(3), 285–288.

Wisløff, U., Helgerud, J., & Hoff, J. (1998). Strength and endurance of elite soccer players. *Medicine and Science in Sports and Exercise*, *30*(3), 462–467.

Wong, D. P., Mujika, I., Castagna, C., Chamari, K., Lau, P. W. C., & Wisløff, U. (2008). Characteristics of World Cup Soccer Players. *Soccer Journal*, *1*, 57–62.

Young, B. W., Jemczyk, K., Brophy, K., & Côté, J. (2009). Discriminating Skilled Coaching Groups: Quantitative Examination of Developmental Experiences and Activities. *International Journal of Sports Science and Coaching*, *4*(3), 397–414.

## Appendices

### Appendix A: Copy of Study 1:

Bush, M.D., Archer, D.T., Hogg, R. and Bradley, P.S. (2015). Factors Influencing Physical and Technical Variability in the English Premier League. *International Journal of Sports Physiology and Performance, 10,* 865-872.

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Human Kinetics
ORIGINAL INVESTIGATION

# Factors Influencing Physical and Technical Variability in the English Premier League

**Michael D. Bush, David T. Archer, Robert Hogg, and Paul S. Bradley**

***Purpose:*** To investigate match-to-match variability of physical and technical performances in English Premier League players and quantify the influence of positional and contextual factors. ***Methods:*** Match data (N = 451) were collected using a multicamera computerized tracking system across multiple seasons (2005–06 to 2012–13). The coefficient of variation (CV) was calculated from match to match for physical and technical performances in selected positions across different match contexts (location, standard, and result). ***Results:*** Wide midfielders demonstrated the greatest CVs for total distance (4.9% ± 5.9%) and central midfielders the smallest (3.6% ± 2.0%); nevertheless, all positions exhibited CVs <5% ($P > .05$, effect size [ES] 0.1–0.3). Central defenders demonstrated the greatest CVs and wide midfielders the lowest for both high-intensity running (20.2% ± 8.8% and 13.7% ± 7.7%, $P < .05$, ES 0.4–0.8) and sprint distance (32.3% ± 13.8% and 22.6% ± 11.2%, $P < .05$, ES 0.5–0.8). Technical indicators such as tackles (83.7% ± 42.3%), possessions won (47.2% ± 27.9%), and interceptions (59.1% ± 37.3%) illustrated substantial variability for attackers compared with all other positions ($P < .05$, ES 0.4–1.1). Central defenders demonstrated large variability for the number of times tackled per match (144.9% ± 58.3%) and passes attempted and received compared with other positions (39.2% ± 17.5% and 46.9% ± 20.2%, $P < .001$, ES 0.6–1.8). Contextual factors had limited impact on the variability of physical and technical parameters. ***Conclusions:*** The data demonstrate that technical parameters varied more from match to match than physical parameters. Defensive players (fullbacks and central defenders) displayed higher CVs for offensive technical variables, while attacking players (attackers and wide midfielders) exhibited higher CVs for defensive technical variables. Physical and technical performances are variable per se regardless of context.

***Keywords:*** football, contextual, high-intensity, passing, variation

In the last 2 decades there has been substantial investment in computerized tracking systems in elite soccer in an attempt to evaluate and optimize team performance. Although some progress has been made in this research area, some caveats exist. For instance, researchers typically adopt a 1-dimensional approach analyzing individual aspects of soccer performance (physical, technical, or tactical) with the main intention of predicting future performance or identifying trends that lead to successful performances.[1–3] Thus, more research is needed that integrates multiple parameters that allow a more holistic understanding of the important facets of performance.

Assessing performance is essential to develop intervention programs and to improve performance. Nevertheless, without measuring the variability between performances it is impossible to evaluate the effectiveness and success of an intervention program.[1] One method proposed is to use the coefficient of variation (CV) to calculate inconsistency on a match-to-match basis. Mohr et al[4] demonstrated that players analyzed in 2 consecutive elite matches played within a 3-wk period produced CVs of 3% and 9% for the distance covered in total and at high intensity, respectively. Notably, the variability in high-intensity running across different stages of the season was much higher (CV = 25%) than across shorter periods of time. However, that study quantified variability of <20 elite players across 1 to 3 observations, thus restricting the application of the findings.[4] Gregson et al[5] used a large sample of elite players and demonstrated that high-intensity activities can vary by ~15% to 30% from match to match and that variability is higher for central defenders and midfielders than for wide midfielders and attackers.

Rampinini et al[6] found that physical parameters were reduced when playing against lower-standard opponents; nevertheless, this difference equated to approximately 100 m in total distance covered and 50 m at high intensity. Despite analyzing variation in performance Rampinini et al[6] examined performance across the season rather than on a match-to-match basis. Previous research has not investigated the effects of context on variability; however, there have been investigations into the effects of contexts on match performance. Teams finishing higher in competitive leagues were found to perform more passing and shooting than teams finishing lower in the leagues.[7] Home teams have been found to have greater technical performance than away teams for passing and shooting variables, as well as goals scored, while losing possession less.[7] In addition, teams spend less time in the attacking third and more time in the defensive third when playing away from their home ground.[8] However, no studies have been published to date that have used a combined approach (analyzed both physical and technical variability) and taken into account the influence of context on match-to-match variability (eg, team standard, match location, and result).[1] This is surprising as numerous studies have found that context influences both physical and technical performance of teams[7–9] and thus the variability in performance could be partly explained by some of these factors.

Thus, this study aimed to investigate match-to-match variability of physical and technical performances in English Premier League (EPL) players and quantify the influence of positional and contextual factors.

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# Method

## Players and Design

Match performance data were collected from multiple EPL seasons (2005–06 to 2012–13) and consisted of 451 individual players across 3016 observations (mean 7, range 2–93 observations per player). Data were analyzed in 5 playing positions: central defenders (n = 110), fullbacks (n = 99), central midfielders (n = 108), wide midfielders (n = 59), and attackers (n = 75). Original data files were desensitized and included 20 teams in each season. Individual match data were only included for players who completed entire matches. Ethical approval was granted from the appropriate institutional ethics committee.

## Methodology

Data were obtained from a computerized multiple-camera tracking system (Prozone 3, Prozone Sports Ltd, Leeds, UK). Players' movements were captured during matches by cameras positioned at roof level and analyzed using proprietary software to produce a data set on each player's physical and technical performance. The validity and reliability of this tracking system have been quantified to verify the capture process and data accuracy.[10,11] Interoperator reliability of technical-performance parameters has been measured at 99% with 95% of variables coded within 0.1 second by both observers.[10] The computerized tracking system was tested in comparison with timing gates with almost perfect correlations measured for a variety of tests including straight sprints, angled runs, and dribbles with the ball ($r > .9$).[11]

## Match Performance Parameters

Activities were coded into standing (0–0.6 km/h), walking (0.7–7.1 km/h), jogging (7.2–14.3 km/h), running (14.4–19.7 km/h), high-speed running (19.8–25.1 km/h), and sprinting (>25.1 km/h).[3,6,12,13] Total distance represented the sum of distances covered in all categories. High-intensity running consisted of the combined distance in high speed and sprinting (>19.8 km/h) and was separated into 3 subsets based on team-possession status: with (WP) or without ball possession and when the ball was out of play. Technical events selected for analysis included the number of passes attempted, passing success, number of passes received, interceptions, number of tackles completed per player and number of times the player was tackled, number of possessions won/lost, and average number of touches per possession.

## Data Analysis

All analyses were conducted using statistical software (SPSS v21, SPSS Inc, Chicago, IL, USA). CVs were used to quantify match-to-match variability of EPL players[14] and subsequently calculated for each playing position and context such as match location (home and away), standard of opposition (stronger/equal standard/weaker), and result (won/lost/drawn). One- and two-way analysis-of-variance tests were used to analyze CV differences between playing positions and contexts. Statistical significance was set at $P < .05$. The effect size (ES) was calculated to determine the magnitude of the effect and was classified as trivial (<0.2), small (>0.2–0.6), moderate (>0.6–1.2), large (>1.2–2.0), or very large (>2.0–4.0).[15] Relationships between selected physical and technical indicators were evaluated using Pearson product–moment correlation. The magnitudes of the correlations were considered trivial (<.1), small (>.1–.3), moderate (>.3–.5), large (>.5–.7), very large (>.7–.9), nearly perfect (>.9), or perfect (1.0).[16] Values are presented as mean ± SD unless otherwise stated.

# Results

## Physical Match-to-Match Variability

Wide midfielders illustrated the largest CVs for total distance covered, while central midfielders illustrated the smallest CVs; nevertheless, no meaningful differences were found for total distance covered between positions, with all demonstrating CVs <5% ($P >$ .05, ES 0.1–0.3). Central defenders produced the most variation from match to match for high-intensity-running distance compared with all other positions (Figure 1; $P < .05$, ES 0.4–0.8), particularly high-intensity-running distance WP ($P < .001$, ES 0.6–1.1). Sprint-distance CVs were greater for central defenders (32.3% ± 13.8%) than for attackers (25.5% ± 13.5%), fullbacks (26.0% ± 12.0%, $P < .05$, ES 0.5), and wide midfielders (22.6% ± 11.2%, $P < .01$, ES 0.8). The CVs for high-intensity-running distance without ball possession were greatest for attackers (27.6% ± 16.6%) compared with central positions (central defenders 21.8% ± 10.1%, central midfielders 21.9% ± 11.3%, $P < .05$, ES 0.4) and fullbacks (18.6% ± 9.1%, $P < .001$, ES 0.6).

## Technical Match-to-Match Variability

Central defenders produced the highest CVs for passes (39.2% ± 17.5%), passes received (46.9% ± 20.2%), and number of times they were tackled per match (144.9% ± 58.3%) compared with other positions (Figure 2; $P < .01$; ES 0.6–0.7, 1.4–2.4, and 0.7–1.2, respectively). In contrast, attackers demonstrated the largest CVs for the number of tackles per match (83.7% ± 42.3%), possessions won (47.2% ± 28%, $P < .01$; ES 0.3–0.8, 0.4–1.0), and interceptions (59.1% ± 37.3%, $P < .05$, ES 0.5–1.1) compared with other positions. Fullbacks illustrated higher CVs for the number of times tackled per match (76% ± 36.4%) than central midfielders (56.5% ± 29.4%), attackers (41.5% ± 22.7%), and wide midfielders (37.7% ± 21.4%, $P < .05$, ES 0.6–1.3). Wide midfielders demonstrated higher CVs for the number of interceptions (45% ± 24.1%) and possessions won (36.9% ± 19%) than central defenders (29% ± 14.3% and 26% ± 12.1%), central midfielders (31.6% ± 19.1% and 26% ± 14.4%), and fullbacks (30.2% ± 19.7% and 26.9% ± 17.6%, $P <$ .05; ES 0.6–0.8 and 0.5–0.7, respectively).

## Contextual Match-to-Match Variability

No meaningful differences were observed across physical and technical parameters for match location ($P > .05$, ES <0.4). Central defenders produced lower CVs for high-intensity-running distance WP when playing against stronger opposition than when playing similar standards and weaker opposition ($P > .05$, ES 0.2–0.5), although high-intensity running was less variable against weaker opposition ($P > .05$, ES 1.1–1.2). In contrast, wide midfielders produced lower variation when playing against weaker opposition for all physical parameters ($P > .05$, ES 0.2–1.2). Central defenders, attackers, and wide midfielders displayed larger CVs for the number of passes received when playing weaker opposition ($P > .05$, ES 0.4–1.2). In addition, fullbacks, attackers, and wide midfielders demonstrated larger CVs for the number of passes made when playing weaker opposition ($P > .05$, ES 0.4–1.2). For match result, the number of high-intensity efforts and recovery time between

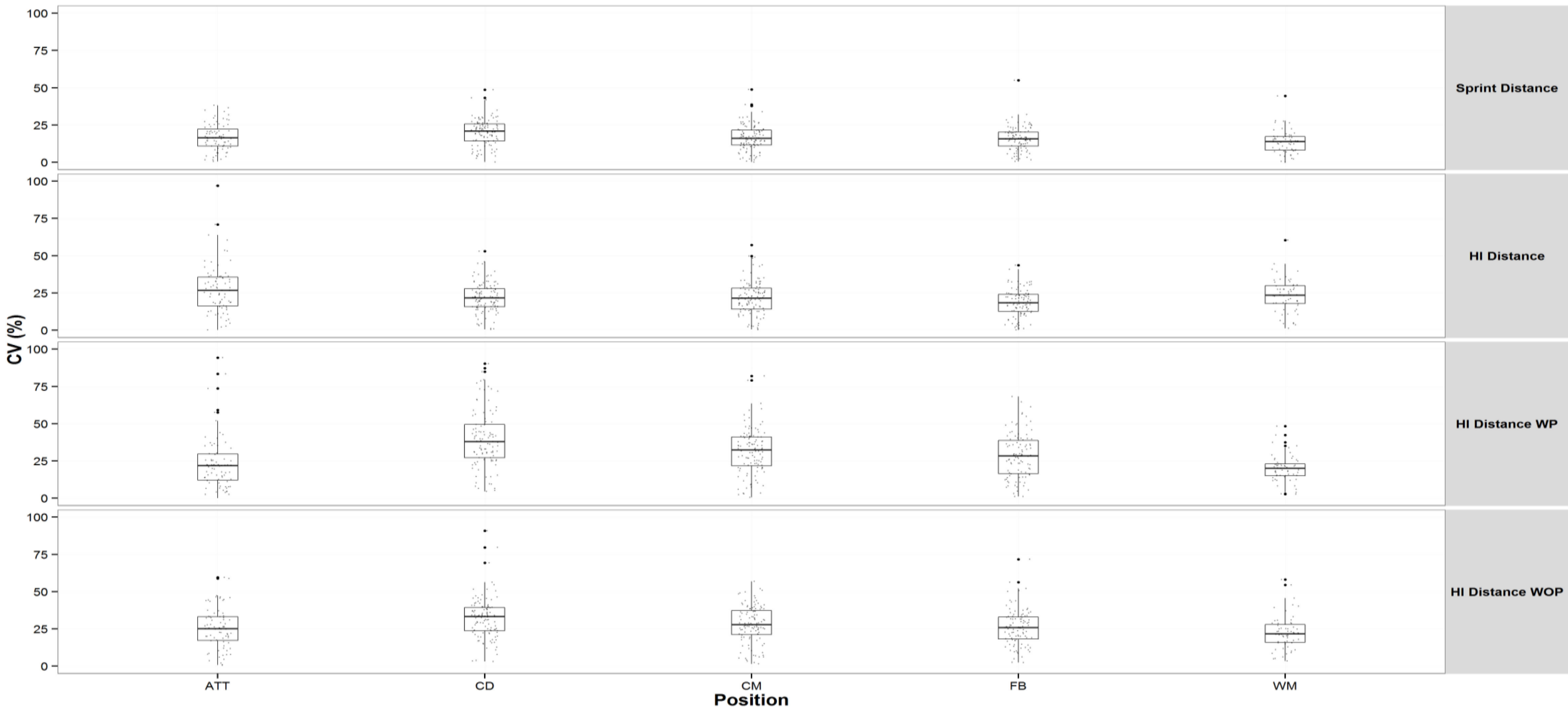


**Figure 1** — Total coefficients of variation (CVs) for physical-performance parameters across all positions. The box-and-whisker plot displays median values, interquartile ranges, and outliers for physical performance in matches in the English Premier League. Each player's observation is jittered and is included as a small dot around the box. The larger dots at the top and bottom of boxes are outliers. Abbreviations: HI, high-intensity; WP, with possession; WOP, without possession; ATT, attacker; CD, central defender; CM, central midfielder; FB, fullback; WM, wide midfielder.

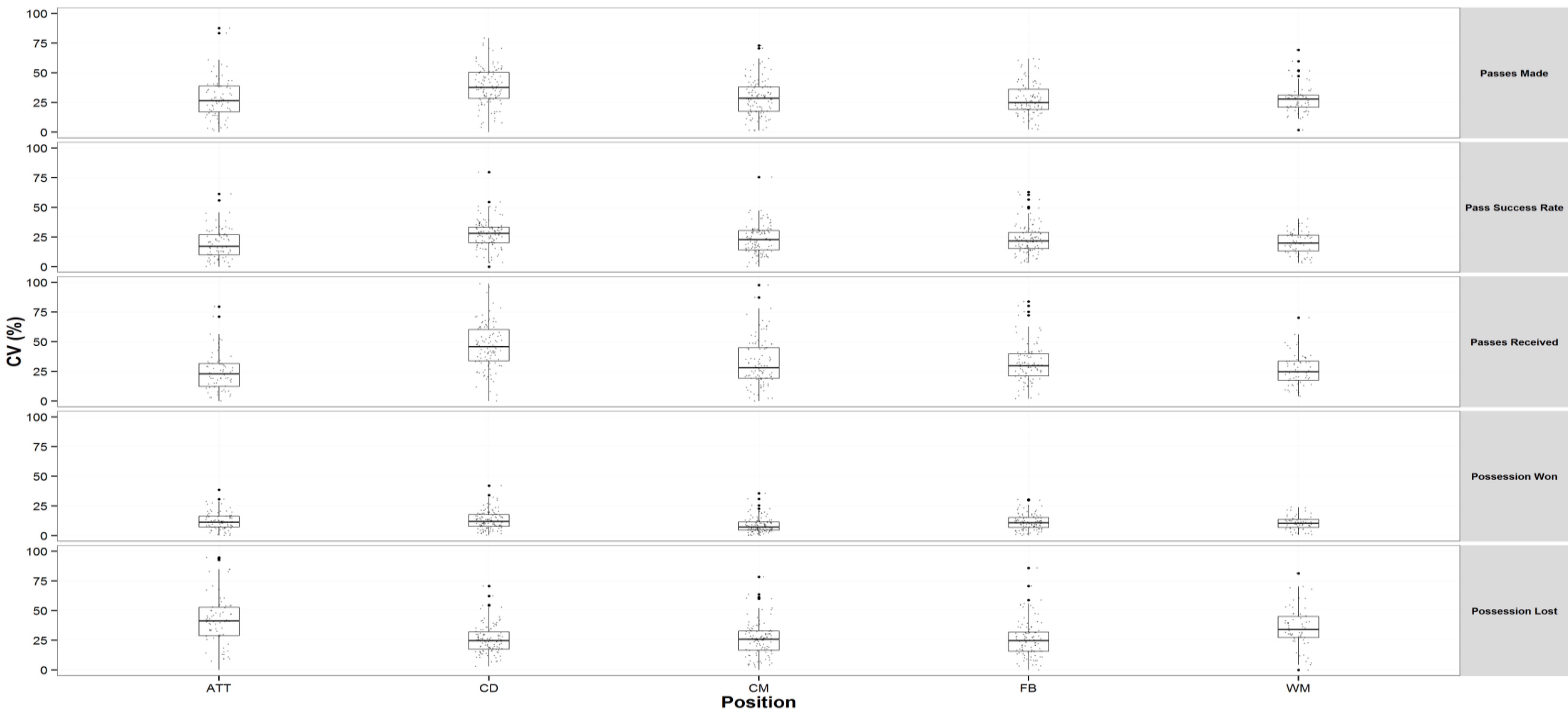


**Figure 2** — Total coefficients of variation (CVs) for technical-performance parameters across all positions. The box-and-whisker plot displays median values, interquartile ranges, and outliers for technical performance in matches in the English Premier League. Each player's observation is jittered and is included as a small dot around the box. The larger dots at the top and bottom of boxes are outliers. Abbreviations: ATT, attacker; CD, central defender; CM, central midfielder; FB, fullback; WM, wide midfielder.

them showed significantly lower CVs for wide midfielders when matches were won than in matches that were lost or tied ($P < .05$, ES 0.5–0.9). Fullbacks were found to have greater CVs for the number of tackles made in matches that were won than in matches that were lost or tied ($P > .05$, ES 0.9).

### Correlations Between Physical and Technical CVs

Correlation analysis between the CVs for physical and technical variables mainly produced small-magnitude correlations (Figure 3; $r < .20$). The variability in the number of times tackled displayed the highest correlations with sprint distance ($r = .25$, $P < .01$), high-intensity running ($r = .25$, $P < .01$), and high-intensity distance WP ($r = .37$, $P < .01$). Nevertheless, none of the CV correlations between physical and technical variables illustrated associations greater than moderate in magnitude. Analysis of physical parameters identified very large-magnitude correlations between the variability of high-intensity running and sprint distance ($r = .75$, $P < .01$) and moderate correlations with high-intensity-running distance with and without ball possession ($r = .42$, $P < .01$). The CVs for the number of high-intensity activities displayed near-perfect correlations with recovery time between high-intensity activities ($r = .96$, $P < .01$) and large-magnitude correlations with high-intensity-running distance ($r = .66$, $P < .01$). Moderate- to large-magnitude correlations were observed for CVs between sprint distance and high-intensity distance WP ($r = .37$, $P < .01$), recovery time ($r = .41$, $P < .01$), and high-intensity-running distance ($r = .66$, $P < .01$). Analysis of technical parameters identified very large-magnitude correlations for CVs between possessions won and the number of interceptions ($r = .85$, $P < .01$) and moderate-magnitude correlations with the average number of touches per possession ($r = .34$, $P < .01$). Moderate-magnitude correlations were observed for CVs between the number of passes attempted with pass success and the number of passes received ($r = .30$–$.50$, $P < .01$).

## Discussion

The current study is the first to quantify the match-to-match variability of physical and technical parameters across both position and context. The data demonstrate that technical parameters varied more from match to match than physical parameters. Defensive players displayed higher CVs for offensive technical variables, while offensive players exhibited higher CVs for defensive technical variables. Physical and technical performances are variable regardless of context.

Currently, there is no exact measure of physical performance in elite soccer; the total distance covered and that performed at high intensity provide useful indicators of physical performance.[3,4] Both measures correlate with physical capacity, but high-intensity running to a higher degree than total distance covered.[17] This supports the existing contention that high-intensity running is a better indicator of match performance than total distance covered.[4,18] In the current study total distance covered did not vary from match to match (CV < 5%), which is in line with previous studies quantifying the match-to-match variability in elite soccer.[4–6] The current study found CVs for high-intensity-running distance ranging from 14% for wide midfielders to 20% for central defenders, which compare well with values reported for the same positions (13–19%)[5] and the average variability for all positions (14%).[6] The greater variability for central positions is probably indicative of the higher player density in central regions of the pitch in the modern game.[19,20] Previous research demonstrated that CVs for sprint distance were greater than high-intensity-running distance,[5] whereas these 2 parameters produced similar CVs in the current study. This is unsurprising due to the large-magnitude correlations between the CVs for the 2 variables. The high variability of these parameters has a direct impact on the assessment and evaluation of intervention strategies on match running performance; this is especially important as high-intensity-running and sprint bouts usually occur during significant moments in the game.[21]

This study is the first to quantify match-to-match variability of technical-performance parameters. We found that indicators such as possessions won, possessions lost, and average touches were higher, although nonsignificantly, for attackers than for all other positions. Attackers generally receive the ball in the offensive third of the pitch, often within sight of goal. Thus, attackers are required to take many touches to hold the ball up to retain possession in densely populated areas of the pitch.[22,23] Nevertheless, an attacker's ability to hold up play will be affected by the number and quality of possessions won along with the aptitude and tactics of the opposition defenders, thus affecting the variability in performance. The low match-to-match variability observed for the number of possessions won and lost indicates that teams in the EPL now adopt more possession-based strategies, maintaining possession to develop goal-scoring opportunities. Recent research has found that the number of short and medium passes performed during matches has increased from the 2006–07 season to 2012–13.[19] Although the current study did not measure the variability of passing distance, the previous findings combined with the current data demonstrating low match-to-match variability for possessions won and lost support the notion that teams now adopt possession-based playing styles rather than the direct playing styles previously used.[23]

The number of passes and percentage pass success for each position showed variability to be <40%. Passes made and pass success occur when the team is in possession. Although previously we have suggested there is low variability in the change of possession (possession won/lost), the variability in passing variables occurs due to the amount of possessions a team holds. High levels of ball possession provide greater opportunity to perform passes; in contrast, matches with low ball possession will reduce the time available to perform passes. Over the course of a season teams will encounter or adopt varying playing styles and tactics, which could potentially explain the variability in passing measures. In contrast, the number of tackles made and the number of times tackled demonstrated the highest CVs of the technical parameters (>50%). Attackers and wide midfielders had lower variability for the number of times they were tackled. Players in these positions gain the ball in attacking areas and are thus more likely to be tackled to reduce the attacking threat. In contrast, defenders (wide and central) experienced a more variable number of times they were tackled as they are less likely to pose a threat to the opposition goal; as a consequence, opposition strategy is more of an influence on these technical indicators. For example, some teams try to regain possession high up the pitch, applying pressure on players in defensive positions, while other teams will allow defenders to keep possession. As a result, depending on a team's strategy on regaining possession, the number of tackles completed between attackers and defenders will be affected and may explain the high CVs observed.

The relatively high CVs found for the number of tackles and times tackled may be due to the low frequency of occurrences in matches. As a result, small changes in the frequency of occurrences can have large impacts on the CVs observed.[2,7–9] In contrast, the numbers of passes attempted and successful passes made are more frequent and hence stable technical parameters. A 70% pass-success

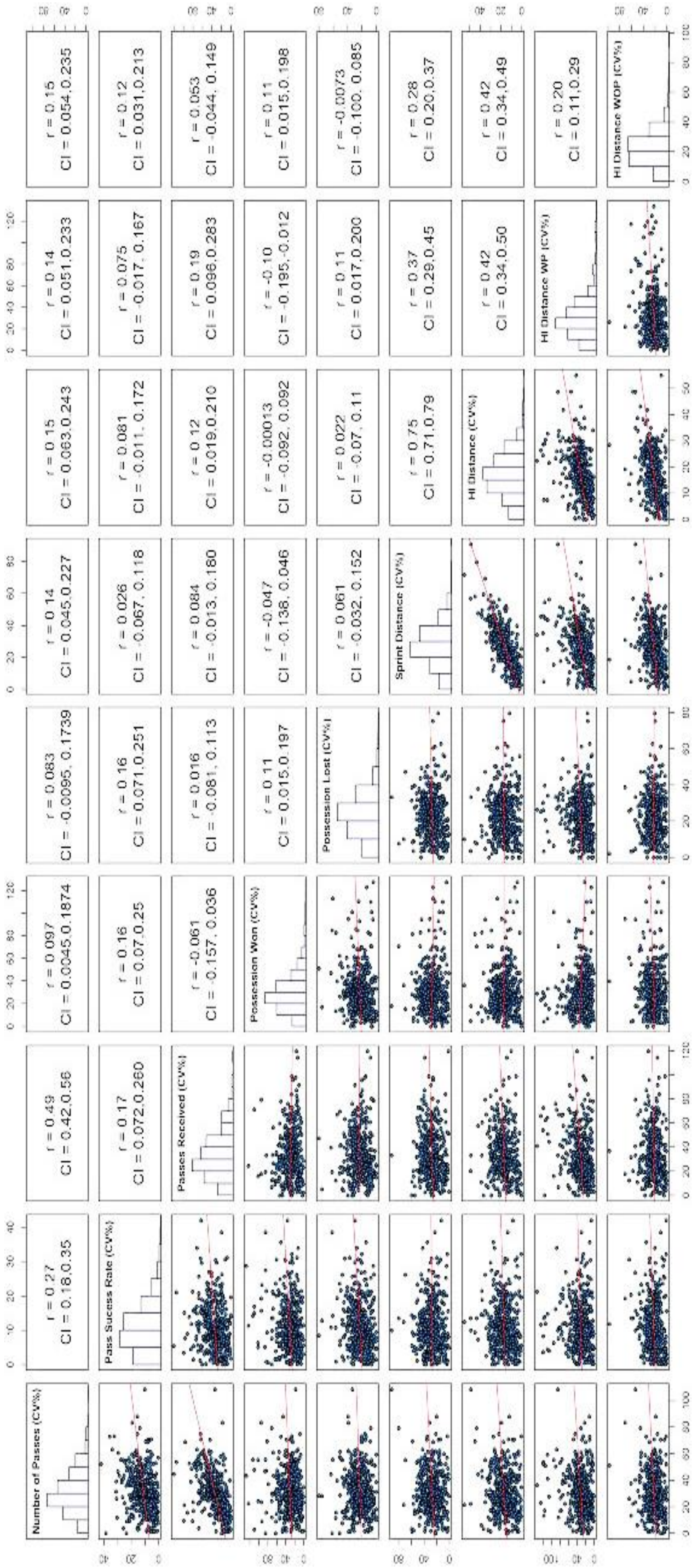


**Figure 3** — A correlation matrix between physical and technical coefficients of variation (CVs). Data are presented as Pearson correlations (*r* values) except for the panels running on a diagonal through the figure, which include histograms of distribution. Abbreviations: CI, 90% confidence intervals; HI, high-intensity; WP, with possession; WOP, without possession.

statistic is deemed a minimum requirement for elite soccer,[24] and thus the potential range of this measure is low, resulting in relatively low variability. The high variability observed in the majority of technical parameters highlights the difficulties in assessing the effectiveness of interventions or coaching adaptations on technical performance. Large subject numbers would be required to determine whether improvements in performance would be due to interventions or the inherent variability in performance. In addition, although researchers have previously analyzed the parameters that are important for success,[2,8,9,25] the high CVs observed for technical parameters in this study would suggest that success cannot be defined by a small list of elements but is instead a combination of factors. Success in one game could be as a result of a high turnover in possessions (high number of tackles, possessions won/lost), low pass-success rate, and high number of shots on/off target. In contrast, success in a different game may be a result of high numbers of passes made and pass-success rate and a low turnover of possessions but low number of shots on/off target.

One of the key findings of this study was the higher match-to-match variability observed for technical variables than for physical variables. The physical data trends found in the current study are similar to previous findings on EPL populations[5] suggesting that physical variability has remained relatively constant over recent seasons. Although there is inherent match-to-match variability in the physical performance of soccer players, the CVs observed may provide further evidence for the adoption of pacing strategies by players to ensure game completion.[12] For instance, sparing low-intensity activity such as walking and jogging in an attempt to preserve essential high-intensity running could the reason that total distance covered remains the same but high-intensity distance is highly variable.[26,27] In contrast, the variability of technical performance has not previously been analyzed. In the current study the contextual factors examined had minimal influence on the variability of players' physical or technical performance. Therefore, the results suggest that the changes in absolute technical performance previously identified[7–9,25] are a result of different contexts rather than the variability in performance. Technical performance in matches not only is affected by player ability or capacity but is highly dependent on team and opposition tactics, as well as contextual factors,[7–9,25] so external factors have greater influence on players' technical performance.

Rampinini et al[6] found that physical indicators were less variable during play against the same opposition, suggesting that playing styles, fitness, and tactics could influence variability in match play. It was surprising that match location, standard, and match result had little effect on overall match-to-match variability of physical and technical parameters in this study. Central defenders, fullbacks, and central midfielders displayed lower variability when playing at home than at away matches for high-intensity-running distance WP. Although previous research has highlighted differences in match indicators,[8,9,25,28] performance would be expected to vary a similar amount whether matches are at home or away, won or lost, or whether playing against a higher or lower standard of opposition. The limited influence of contextual factors on match-to-match CVs would suggest that the game is intrinsically variable, and that could be driven by tactics and playing strategies.

Although previous research has begun to analyze both technical- and physical-performance parameters within the same articles,[13,19,29,30] researchers have not analyzed the relationships between performance measures.[1] The correlation analysis performed in this study found small to moderate associations ($r$ = .22–.37, $P$ < .001) between CV values for the number of times tackled per match and the distance covered at high-intensity, high-intensity distance WP, sprint distance, and recovery time between high-intensity actions. All other correlations were less than trivial ($r$ < .2). The low correlations observed in this study would suggest that physical match-to-match variability is not related to technical variability, although tactical factors may warrant further study.

Despite the novel data presented and analyzed, there are some limitations in the current study. The range of observations for each player was high and could have influenced the variability observed. Furthermore, the study was restricted by the number of contextual variables available for analysis and the number of observations for each context. Therefore, future research could take into account more contextual variables such as the severity of match won/lost and the effect of tactical variables and formations. Future research could also investigate the interaction of the contextual variables on match-to-match variability—matches at home played against weaker opposition compared with matches played away against stronger opposition.

## Practical Applications

The findings of this study provide useful information on the variability of match play for practitioners in elite soccer. Specifically, the study extends previous research demonstrating that several important contextual factors (match location, standard of opposition, match result) do not influence match-to-match variability. It also presents data for the variability of important technical factors. This information could help with interpreting interventions and provide practitioners with an indication of the number of matches required to gain an accurate assessment of a player's physical and technical performance during match play.

## Conclusion

This is the first study to demonstrate the match-to-match variability of both technical- and physical-performance parameters in elite soccer. Positional analysis showed that attackers had high variability for defensive variables such as possessions lost and the number of tackles made per match. In contrast, defensive positions demonstrated higher CVs for attacking variables such as the number of times tackled per match and the number of passes received. Despite the considerable knowledge base linking technical performance and success, the findings from this study highlight the large variability in technical performance and therefore may suggest that a cautious approach must be taken when making these associations. In addition, match contexts (match location, match result, and opposition standard) had limited influence on match-to-match variability for either technical or physical parameters. The effect of match contexts on match performance as found in previous research is potentially a result of different playing strategies rather than the inherent variability between matches.

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## References

1. Mackenzie R, Cushion C. Performance analysis in football: a critical review and implications for future research. *J Sports Sci*. 2013;31(6):639–676. PubMed doi:10.1080/02640414.2012.746720

2. Castellano J, Casamichana D, Lago C. The use of match statistics that discriminate between successful and unsuccessful soccer teams. *J Hum Kinet*. 2012;31(March):139–147. PubMed
3. Bradley PS, Sheldon W, Wooster B, Olsen P, Boanas P, Krustrup P. High-intensity running in English FA Premier League soccer matches. *J Sports Sci*. 2009;27(2):159–168. PubMed doi:10.1080/02640410802512775
4. Mohr M, Krustrup P, Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci*. 2003;21(7):519–528. PubMed doi:10.1080/0264041031000071182
5. Gregson W, Drust B, Atkinson G, Di Salvo V. Match-to-match variability of high-speed activities in Premier League soccer. *Int J Sports Med*. 2010;31(4):237–242. PubMed doi:10.1055/s-0030-1247546
6. Rampinini E, Coutts AJ, Castagna C, Sassi R, Impellizzeri FM. Variation in top level soccer match performance. *Int J Sports Med*. 2007;28(12):1018–1024. PubMed doi:10.1055/s-2007-965158
7. Lago-Peñas C, Lago-Ballesteros J. Game location and team quality effects on performance profiles in professional soccer. *J Sports Sci Med*. 2011;10:465–471. PubMed
8. Lago C. The influence of match location, quality of opposition, and match status on possession strategies in professional association football. *J Sports Sci*. 2009;27(13):1463–1469. PubMed doi:10.1080/02640410903131681
9. Taylor JB, Mellalieu SD, James N, Shearer DA. The influence of match location, quality of opposition, and match status on technical performance in professional association football. *J Sports Sci*. 2008;26(9):885–895. PubMed doi:10.1080/02640410701836887
10. Bradley PS, O'Donoghue P, Wooster B, Tordoff P. The reliability of Prozone MatchViewer: a video-based technical performance analysis system. *Int J Perform Anal Sport*. 2007;7:117–129.
11. Di Salvo V, Collins A, McNeill B, Cardinale M. Validation of Prozone: a new video-based performance analysis system. *Int J Perform Anal Sport*. 2006;6:108–119.
12. Bradley PS, Noakes TD. Match running performance fluctuations in elite soccer: indicative of fatigue, pacing or situational influences? *J Sports Sci*. 2013;31(15):1627–1638. PubMed doi:10.1080/02640414.2013.796062
13. Bradley PS, Carling C, Archer D, et al. The effect of playing formation on high-intensity running and technical profiles in English FA Premier League soccer matches. *J Sports Sci*. 2011;29(8):821–830. PubMed doi:10.1080/02640414.2011.561868
14. Atkinson G, Nevill AM. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Med*. 1998;26(4):217–238. PubMed doi:10.2165/00007256-199826040-00002
15. Batterham AM, Hopkins WG. Making meaningful inferences about magnitudes. *Int J Sports Physiol Perform*. 2006;1(1):50–57. PubMed
16. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc*. 2009;41(1):3–13. PubMed doi:10.1249/MSS.0b013e31818cb278
17. Krustrup P, Mohr M, Amstrup T, et al. The Yo-Yo Intermittent Recovery Test: physiological response, reliability and validity. *Med Sci Sports Exerc*. 2003;35(4):697–705. PubMed doi:10.1249/01.MSS.0000058441.94520.32
18. Krustrup P, Mohr M, Ellingsgaard H, Bangsbo J. Physical demands during an elite female soccer game: importance of training status. *Med Sci Sports Exerc*. 2005;37(7):1242–1248. PubMed doi:10.1249/01.mss.0000170062.73981.94
19. Barnes C, Archer D, Hogg B, Bush M, Bradley PS. The evolution of physical and technical performance parameters in the English Premier League. *Int J Sports Med*. 2014;35(13):1095–1100. PubMed doi:10.1055/s-0034-1375695
20. Wallace JL, Norton KI. Evolution of World Cup soccer final games 1966–2010: game structure, speed and play patterns. *J Sci Med Sport*. 2014;17(2):223–228. PubMed doi:10.1016/j.jsams.2013.03.016
21. Faude O, Koch T, Meyer T. Straight sprinting is the most frequent action in goal situations in professional football. *J Sports Sci*. 2012;30(7):625–631 doi:10.1080/02640414.2012.665940. PubMed
22. Bangsbo J, Peitersen B. *Offensive Soccer Tactics: How to Control Possession and Score More Goals*. Champaign, IL: Human Kinetics; 2004.
23. Carling C, Williams M, Reilly T. *Handbook of Soccer Match Analysis*. Oxon, UK: Routledge; 2005. doi:10.4324/9780203448625
24. Dellal A, Chamari K, Wong DP, et al. Comparison of physical and technical performance in European soccer match-play: FA Premier League and La Liga. *Eur J Sport Sci*. 2011;11(1):51–59. doi:10.1080/17461391.2010.481334
25. Lago-Ballesteros J, Lago-Peñas C, Rey E. The effect of playing tactics and situational variables on achieving score-box possessions in a professional soccer team. *J Sports Sci*. 2012;30(14):1455–1461. PubMed
26. Drust B, Atkinson G, Reilly T. Future perspectives in the evaluation of the physiological demands of soccer. *Sports Med*. 2007;37(9):783–805. PubMed doi:10.2165/00007256-200737090-00003
27. Edwards AM, Noakes TD. Dehydration: cause of fatigue or sign of pacing in elite soccer? *Sports Med*. 2009;39(1):1–13. PubMed doi:10.2165/00007256-200939010-00001
28. Sánchez PA, García-Calvo T, Leo FM, Pollard R, Gómez M. An analysis of home advantage in the top two Spanish professional football leagues. *Percept Mot Skills*. 2009;108(3):789–797. PubMed doi:10.2466/pms.108.3.789-797
29. Bradley PS, Lago-Peñas C, Rey E, Diaz AG. The effect of high and low percentage ball possession on physical and technical profiles in English FA Premier League soccer matches. *J Sports Sci*. 2013;31(12):1261–1270. PubMed doi:10.1080/02640414.2013.786185
30. Bradley PS, Carling C, Diaz AG, et al. Match performance and physical capacity of players in the top three competitive standards of English professional soccer. *Hum Mov Sci*. 2013;32(4):808–821. PubMed doi:10.1016/j.humov.2013.06.002

**Appendix B: Copy of Study 3:**

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# Evolution of match performance parameters for various playing positions in the English Premier League

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ABSTRACT

This study aimed to investigate position-specific evolution of physical and technical performance parameters in the English Premier League (EPL). Match performance observations ($n = 14700$) were collected using a multiple-camera computerized tracking system across seven seasons (2006–07 to 2012–13). Data were analyzed relative to five playing positions: central defenders ($n = 3792$), full backs ($n = 3420$), central midfielders ($n = 3200$), wide midfielders ($n = 2136$) and attackers ($n = 2152$). High-intensity running distance increased in the final season versus the first season in all playing positions ($p < .05$, ES: 0.9–1.3) with full backs displaying the greatest increase (~36% higher in 2012–13). Similar trends were observed for sprint distance with full backs demonstrating the most pronounced increase across the seven seasons (36–63%, $p < .001$, ES: 0.8–1.3). Central players (central defenders and midfielders) illustrated the most pronounced increases in total passes and pass success rate ($p < .05$, ES: 0.7–0.9) whilst wide players (full backs and wide midfielders) demonstrated only small-moderate increases in total passes and pass success rate ($p < .05$, ES: 0.6–0.8). The data demonstrates that evolving tactics in the EPL have impacted on the physical demands of wide players and the

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technical requirements of central players. These findings could be used for talent identification or position-specific physical and technical training.



## 1. Introduction

Soccer match-play is characterized by its sporadic nature whereby multidirectional physical actions are integrated with an array of technical skills (Bradley et al., 2009; Wallace & Norton, 2014). Semi-automated computerized tracking systems have been used to identify the physical and technical requirements of elite soccer match-play and how these are influenced by positional, contextual and tactical factors (Bradley et al., 2011; Carling, Williams, & Reilly, 2005; Di Salvo et al., 2007; Lago, 2009; Lago, Casais, Dominguez, & Sampaio, 2010; Lago-Ballesteros, Lago-Peñas, & Rey, 2012). Relative to the overall distance covered by players, ~7–12% is covered at high-intensity and 1–4% whilst sprinting (Bradley et al., 2009; Di Salvo et al., 2010). Although team success is complex and multifactorial, technical indicators have been found to predict team success more accurately than physical indicators (Carling, 2013; Castellano, Casamichana, & Lago, 2012). More specifically, ball possession, number of shots, shots on target, number of passes and pass completion rates are all associated with team success (Castellano et al., 2012; Collet, 2013; Hughes & Franks, 2005; Lago-Ballesteros et al., 2012; Lago-Peñas & Lago-Ballesteros, 2011). Although physical performances are not associated with success, they impact technical proficiency (Rampinini et al., 2008), thus should not be disregarded as contributors to overall performance. Nevertheless, researchers often adopt a reductionist approach, analysing either physical or technical indicators in isolation across short time periods (Mackenzie & Cushion, 2013). Although physical and technical indicators can be seen as individual aspects of match-play, success is a culmination of suitable tactics completed with the appropriate level of physical and technical performance, analysing each in isolation restricts the context, understanding and application of the findings. Therefore, more research should adopt an integrated approach, analysing physical, technical and/or tactical indicators of various playing positions longitudinally in order to understand the overall development of soccer match-play.

Our research group identified high-intensity running and sprint distances have increased by 30–50% in the English Premier League (EPL), while the overall number of passes have increased by 40% across seven seasons (Barnes, Archer, Hogg, Bush, & Bradley, 2014). These longitudinal changes in the EPL mirrored those measured over a 44 year period in FIFA World Cup Final matches (Wallace & Norton, 2014). Nevertheless, previous studies failed to account for positional evolutionary trends (Bradley et al., 2009; Di Salvo et al., 2007, 2010; Gregson, Drust, Atkinson, & Di Salvo, 2010). Central midfielders have consistently been found to cover the greatest total distance whilst full backs, central midfielders and wide midfielders run greater distances at high-intensities (Barros et al., 2007; Bradley et al., 2009; Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009; Di Salvo et al., 2007). Various reasons have been proposed as to why these positional differences in locomotive patterns exist. Research demonstrates that positional differences in maximal oxygen uptake ($VO_{2max}$) are evident for soccer players, with central midfielders and full backs displaying the highest values (Reilly, Bangsbo, & Franks, 2000), whist others found no differences (Haugen, Tønnessen, Hem, Leirstein, & Seiler, 2014). Nevertheless, central midfielders and full backs consistently have the greatest physical capacities when assessed using intermittent running tests (Mohr, Krustrup, & Bangsbo, 2003; Reilly et al., 2000). Additionally, central midfielders and full backs perform and complete more passes compared to other positions (Redwood-Brown, Bussell, & Bharaj, 2012; Taylor, Mellalieu, & James, 2004). Given the evolutionary changes highlighted previously in elite soccer match-play (Barnes et al., 2014; Wallace & Norton, 2014), it would be of interest to track longitudinal positional changes to gain insight into physical and technical requirements of modern players. Thus, this study aimed to investigate the position-specific evolution of physical and technical parameters in the EPL using one of the largest controlled samples published to date.

## 2. Materials and methods

### 2.1. Match analysis and player data

Match performance data were collected from seven consecutive EPL seasons (2006–07 to 2012–13) using a computerized multiple-camera tracking system (Prozone Sports Ltd®, Leeds, UK). Players' movements were captured during matches by cameras positioned at roof level and analyzed using proprietary software to produce a dataset on each player's physical and technical performance. The validity and reliability of this tracking system has been quantified to verify the capture process and data accuracy (Bradley, O'Donoghue, Wooster, & Tordoff, 2007; Bradley et al., 2009; Di Salvo, Collins, McNeill, & Cardinale, 2006; Di Salvo et al., 2009). Ethical approval was obtained from the University of Sunderland with Prozone Sports Ltd® supplying the data and granting permission to publish.

Data were derived from Prozone's Trend Software and consisted of 1036 individual players across 22846 observations. Original data files were de-sensitized and included 33 different teams overall with all 20 teams evaluated in each season. Individual match data were only included for outfield players that had completed the entire 90 min, matches were excluded if a player dismissal occurred (Carling & Dupont, 2011). The total number of observations were substantially different across season (2006–07 to 2012–13), phase of season (Aug–Nov, Dec–Feb, Mar–May), position, location (Home and Away) and team standard based on final league ranking (A: 1st–4th, B: 5th–8th, C: 9th–14th, D: 15th–20th). The original data were re-sampled using a stratification algorithm in order to balance the number of samples in each of these factors thus minimizing errors when applying statistical tests. Re-sampling was achieved using the stratified function in the R package "devtools" (R Development Core Team) using the procedures of Wickham and Chang (2013), the complete breakdown of the sample is shown in Barnes et al. (2014). Positions were categorized as central defenders ($n = 3792$), full backs ($n = 3420$), central midfielders ($n = 3200$), wide midfielders ($n = 2136$) and attackers ($n = 2152$).

### 2.2. Match performance parameters

Activities were coded into: standing (0–0.6 km h$^{-1}$), walking (0.7–7.1 km h$^{-1}$), jogging (7.2–14.3 km h$^{-1}$), running (14.4–19.7 km h$^{-1}$), high-speed running (19.8–25.1 km h$^{-1}$) and sprinting (>25.1 km h$^{-1}$). Total distance represented the summation of distances in all categories. High-intensity running consisted of the combined distance in high-speed running and sprinting ($\geqslant$19.8 km h$^{-1}$) and was separated into three subsets based on the teams' possession status: with (WP) or without ball possession (WOP) and when the ball was out of play (BOP). Sprinting was divided into two subsets: explosive (entry into sprint category with no incursion into the high-speed category in the previous 0.5 s) and leading sprints (entry into sprint category immediately after an incursion into the high-speed category for 0.5 s or more; Di Salvo et al., 2010). Coding of technical events according to playing position was also conducted (Di Salvo et al., 2007). All positions included match events of passing variables (number of passes, passes received, pass distance and pass success) and possession won/lost. Pass distance referred to the overall length of pass, split into short (<10 m), medium (11–24 m) and long (>25 m).

### 2.3. Statistical analysis

One-way independent-measures analysis of variance tests were used to compare each season with Dunnet's *post hoc* tests used to verify localized differences. Statistical significance was set at $p < .05$. The effect size (ES) was calculated to determine the meaningfulness of the difference with magnitudes classified as trivial (<0.2), small (>0.2–0.6), moderate (>0.6–1.2) and large (>1.2–2.0), (Batterham & Hopkins, 2006). All analyzes were conducted using statistical software (R Development Core Team) and data visualization was carried out using the "ggplot2" package accessed via the Deducer Interface for the R statistical programming language.

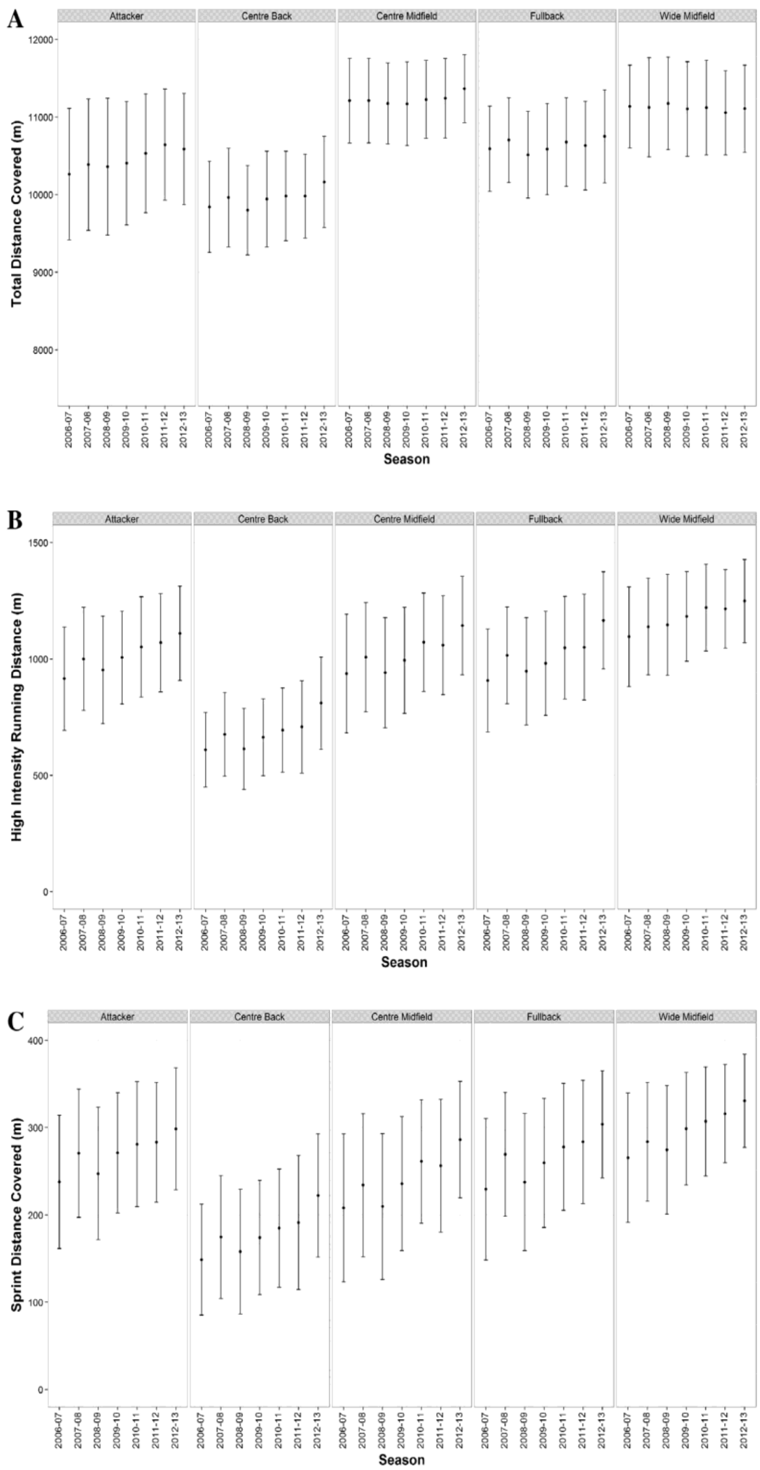


**Fig. 1.** Plots for distances covered in (A) total, (B) high-intensity running and (C) sprinting across seven seasons of the EPL. Each plot is split to represent each of the five positions analyzed. Data represent mean and standard deviations.

## 3. Results

### *3.1. Physical parameters*

Total distance covered during matches showed small changes between 2006–07 and 2012–13 seasons, increasing for central midfielders and defenders only (Fig. 1A; ~200–300 m, $p < .05$, ES: 0.3 and 0.5 respectively). Full backs showed the greatest change in high-intensity running distance (Fig. 1B; 35% increase, $p < .001$, ES: 1.3), nevertheless all positions demonstrated moderate increases in high-intensity running distance over the seven seasons (central defenders: 33%; wide midfielders: 27%; central midfielders: 30%; attackers: 24%, $p < .05$, ES: 1.1, 1.1, 1.0 and 0.9).

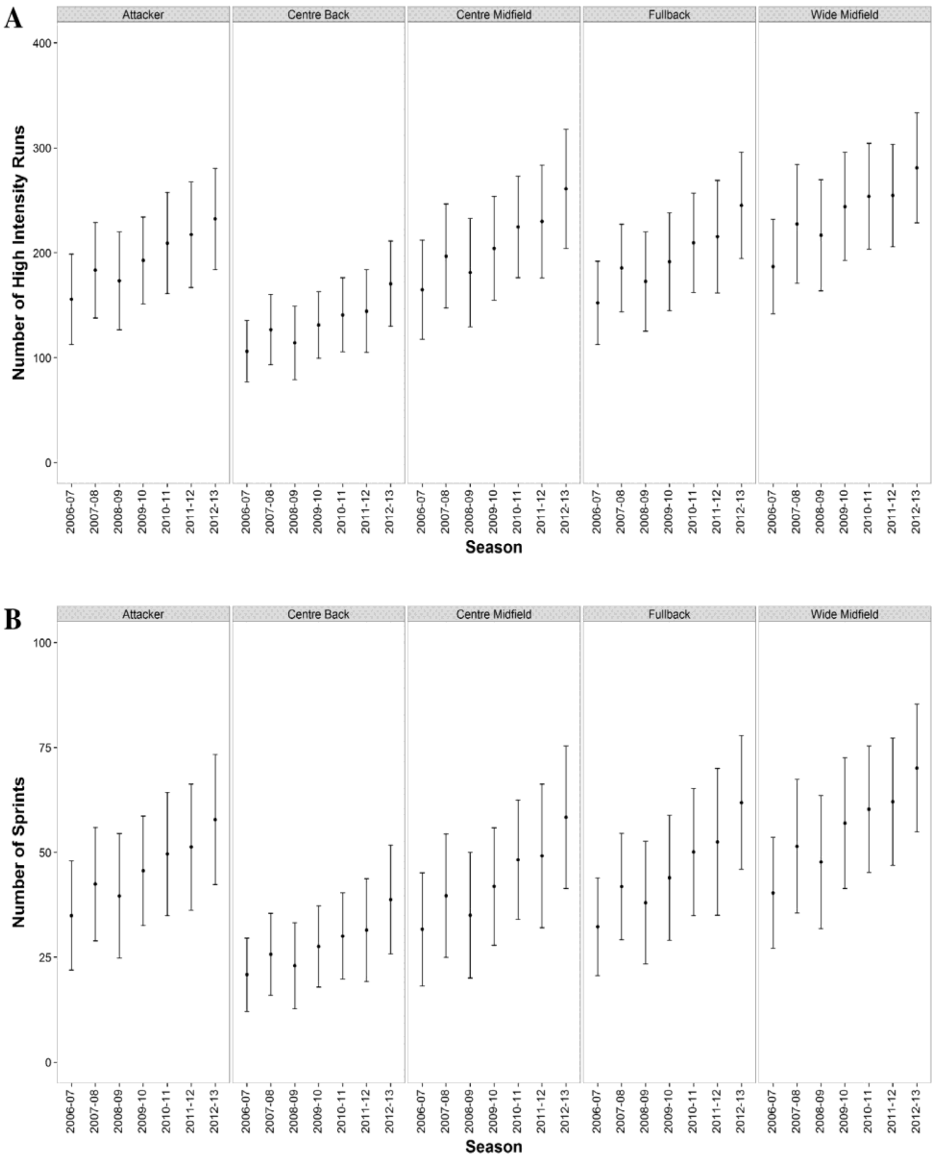


**Fig. 2.** Plots for number of (A) high-intensity actions, (B) sprints across seven seasons of the EPL. Each plot is split to represent each of the five positions analyzed. Data represent mean and standard deviations.

Central defenders, full backs and wide midfielders demonstrated moderate increases in high-intensity running distance covered WP (central defenders: 114 ± 61 vs. 193 ± 86 m, $p < .001$, ES: 1.1; full backs: 355 ± 159 vs. 503 ± 181 m, $p < .001$, ES: 0.9; wide midfielders: 591 ± 178 vs. 710 ± 171 m, $p < .01$, ES: 0.8). In contrast, central midfielders and attackers showed small increases ($p < .05$, ES: 0.5 and 0.6). All positions showed moderate increases in high-intensity distance covered WOP between 2006–07 and 2012–13 seasons, central defenders increased from 438 ± 120 to 533 ± 138 m ($p < .001$, ES: 0.7), full backs increased from 498 ± 133 to 657 ± 150 m ($p < .001$, ES: 1.1), central midfielders increased from 519 ± 166 to 697 ± 213 m ($p < .001$, ES: 0.9), wide midfielders increased from 480 ± 168 to 624 ± 200 m ($p < .001$, ES: 0.8) and attackers increased from 278 ± 124 to 386 ± 148 m ($p < .05$, ES: 0.8).

Sprint distances covered by full backs (62%, ES: 1.3) showed a greater increase compared to wide midfielders (53%, ES: 1.3), central positions (~53%, ES: 1.1) and attackers (Fig. 1C; 36%, ES: 0.8). The number of high-intensity runs and sprints performed increased for each position between 2006–07 and 2012–13 (Fig. 2A and B; ES: 0.8–1.3, 1.6–2.0, respectively). For both parameters, attackers exhibited the smallest increases whereas wide positions exhibited the greatest.

The number of explosive sprints increased by very large magnitudes ($p < .001$) for all positions (central defenders: 7 ± 5 vs. 19 ± 8, ES: 1.8; full backs: 11 ± 6 vs. 28 ± 10, ES: 2.1; central midfielders: 11 ± 7 vs. 29 ± 10, ES: 2.1; wide midfielders: 14 ± 7 vs. 33 ± 11, ES: 2.1; attackers: 12 ± 6 vs. 27 ± 9, ES: 2.0). Leading sprints showed moderate-large increases for all positions (central defenders: 13 ± 5 vs. 20 ± 7, full backs: 22 ± 8 vs. 35 ± 10, central midfielders: 20 ± 9 vs. 30 ± 10, wide midfielders: 27 ± 9 vs. 41 ± 11, $p < .001$), whereas attackers showed the smallest increase ($p < .01$) from 23 ± 9 to 32 ± 11 (ES: 1.2, 1.4, 1.1, 1.4 and 0.9, respectively).

### *3.2. Technical parameters*

Moderate-large magnitude increases were observed for central players (central defenders and midfielders) in the total number of passes performed between 2006–07 and 2012–13 compared to wide players (full backs and wide midfielders) and attackers who showed small increases (Fig. 3). Central

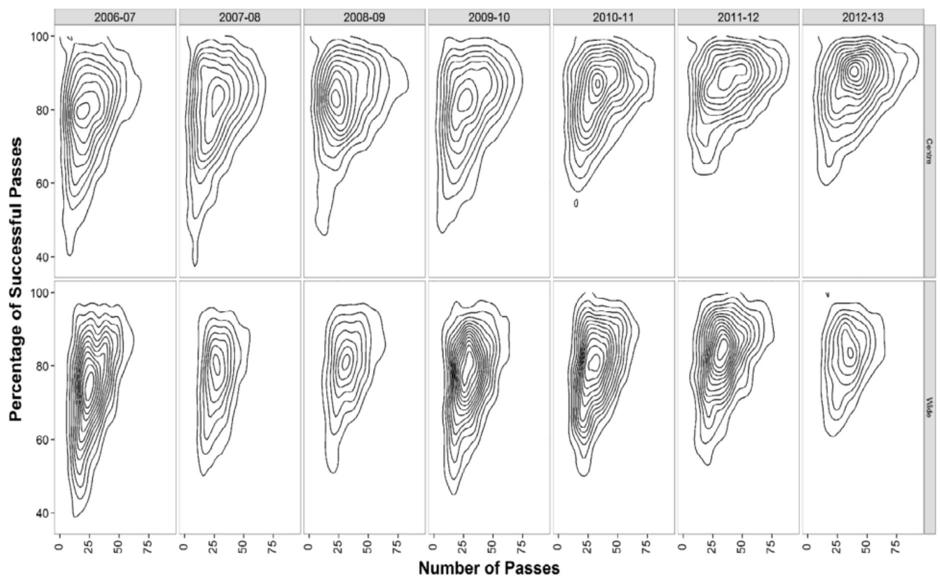


**Fig. 3.** Two-dimensional kernel density plots representing the number of passes and the pass success rate of central (central defenders and central midfielders) and wide players in the EPL (full backs and wide midfielders). The plot displays a similar number of passes performed by wide players, while central players increase the number of passes over the seven seasons (plot width). Nevertheless both wide and central players increased the success rate of passes (plot length).

defenders increased the number of passes by ~70%, central midfielders increased ~50% ($p < .001$, ES: 0.9). Full backs, wide midfielders and attackers showed similar increases (~25%) in the number of passes over the seven seasons ($p < .001$, ES: 0.5). Although wide players showed small increases in the number of passes over the seven seasons, similar increases in the pass success rate compared to central players were observed (all positions increased by ~7%, $p < .01$, ES: 0.7–0.9). No differences were identified for the pass success rate for attackers ($p > .05$, ES: 0.3).

Central midfielders and full backs performed 4 more short distance passes between 2006–07 and 2012–13 ($p < .001$, ES: 0.9). Central defenders and wide midfielders also showed small-moderate increases in the number of short distance passes (central defenders: 2.6 ± 2.5 vs. 4.5 ± 3.3; wide midfielders: 8.6 ± 4.5 vs. 12 ± 6.5, $p < .05$, ES: 0.6). Central midfielders performed 10 more medium distance passes in 2012–13 compared to 2006–07 ($p < .001$, ES: 0.9), whilst central defenders performed 8 more medium distance passes ($p < .001$, ES: 0.8) and full backs performed 5 more medium distance passes in 2012–13 ($p < .001$, ES: 0.6). Central defenders performed more long distance passes in 2012–13 ($p < .001$, ES: 0.6), whereas full backs and wide midfielders performed fewer long distance passes over the seven seasons ($p < .05$, ES: 0.4). Attackers showed trivial-small changes in the number of short, medium and long distance passes performed over the seven seasons ($p > .05$, ES: 0.6, 0.5 and 0.04, respectively).

All positions showed a decrease in the number of possessions lost between 2006–07 and 2012–13 (central defenders: 20 ± 6 vs. 16 ± 6, $p < .001$, ES: 0.6; full backs: 23 ± 7 vs. 20 ± 7, $p < .001$, ES: 0.4; central midfielders: 21 ± 6 vs. 19 ± 6, $p < .05$, ES: 0.4; wide midfielders: 26 ± 6 vs. 22 ± 6, $p < .05$, ES: 0.7; attackers: 23 ± 7 vs. 21 ± 6, $p < .05$, ES: 0.5). Small decreases in the number of final third entries were identified for full backs and wide midfielders between 2006–07 and 2012–13 (9 ± 5 vs. 7 ± 4, $p < .001$, ES: 0.5; 5 ± 3 vs. 4 ± 3, $p < .05$, ES: 0.3, respectively). No changes were evident for any position for the number of tackles or tackled events over the seven seasons.

## 4. Discussion

This study investigated the position-specific evolution of physical and technical parameters in the EPL. Previous large-scale studies have not controlled for seasonal, tactical and contextual factors (Di Salvo, Pigozzi, González-Haro, Laughlin, & De Witt, 2013; Gregson et al., 2010). These factors have been found to influence the physical and technical performances of elite players and thus should be accounted for in the study design (Bradley et al., 2009; Castellano et al., 2012; Di Salvo et al., 2009; Lago et al., 2010). This study is the first to re-sample data using a randomised stratification algorithm to account for these factors. Thus, this analytical approach will allow more appropriate generalisations to be made regarding the longitudinal performance characteristics of various playing positions.

Our research group recently reported that total distance covered in EPL matches had increased by ~2% across seven seasons (Barnes et al., 2014), although position-specific trends were not reported. The current study identified an increase in total distance covered for central players only (central defenders and midfielders), with wide players (full backs and wide midfielders) and attackers demonstrating negligible changes. These observed changes were, however, within the inherent match-to-match variability for total distance covered by all positions in the EPL (Gregson et al., 2010) and as such should be treated with care. It has been reported that the distance covered at high-intensity seems a superior, more sensitive indicator of performance than total distance covered as it correlates strongly with physical capacity (Bradley et al., 2011; Krustrup, Mohr, Ellingsgaard, & Bangsbo, 2005) and is a distinguishing variable between competitive standard and gender (Andersson, Randers, Heiner-Møller, Krustrup, & Mohr, 2010; Bradley et al., 2013; Mohr, Krustrup, Andersson, Kirkendal, & Bangsbo, 2008; Mohr et al., 2003). Our findings revealed pronounced increases for high-intensity running distance for all positions (24–36%), the magnitude of these changes were greater than the inherent match-to-match variability previously reported for this variable (Gregson et al., 2010). This could suggest that the elevation in high-intensity running over the seven seasons is due to evolving game patterns as opposed to natural variability.

The present findings suggest that the physical requirements of modern soccer match-play, particularly for high-intensity running, have evolved more for defenders (central defenders and full backs) and central midfielders (30–36%) than for attacking players (wide midfielders and attackers, 24–27%).

This trend in physical performance could potentially be attributed to improvements in the players' physical capacity through enhanced physical preparation, or via an influx of players into the EPL with innately higher levels of physical fitness. Evidence would suggest $VO_{2max}$ of elite players has stayed relatively stable over the last two decades (Tønnessen, Hem, Leirstein, Haugen, & Seiler, 2013) although this may not be the most appropriate measure of physical capacity in elite team sports, with intermittent exercise capacity identified as a more sensitive measure than $VO_{2max}$ (Iaia, Rampinini, & Bangsbo, 2009; Krustrup & Bangsbo, 2001). Data from our laboratory indicates that the average distance covered by elite soccer players during the Yo-Yo Intermittent Endurance Level 2 Test has increased minimally (Bradley et al., 2011, 2013) in contrast to the substantial increases in high-intensity running distances in EPL matches across a similar time period (Barnes et al., 2014). Thus, if the physical capacity of EPL players has remained stable across this time then these findings could be the result of players working at a higher proportion of their physical capacity in games. In support of this notion, Bradley et al. (2013) reported no differences in the intermittent exercise capacity of players in the top three tiers of the English game but found that lower tier players covered more distance at high-intensity in matches compared with top tier players.

Overall sprint distances increased by ~50% between 2006–07 and 2012–13, however when analyzed by position interesting differences were observed. The greatest increases in sprint distances were observed in full backs (63%), followed by central defenders, central midfielders and wide midfielders (all 54%) and attackers (36%). In 2012–13, players in wide (full backs and wide midfielders) and attacking positions covered a higher percentage of total distance by sprinting (3.5–4.2%) than central defenders or midfielders (2.3–2.9%). These findings have implications in terms of the physical preparation of players. This could be achieved through individual drills for each position or ideally during drills that simulate intense periods of match-play were all positions are working in tandem whereby tactical and technical aspects are merged with the unique physical demands of each position (e.g. full backs sprint whilst creating overlaps with wide midfielders followed by recovery runs).

The observed changes in the physical performance in the EPL may possibly be driven by changes in tactics and playing systems. For example, when in possession, modern tactics often require wide midfielders to play in more central positions attracting defenders inside and creating space for full backs to move into, thus introducing more players into attacking positions (Bangsbo & Peitersen, 2004; Tipping, 2007). When possession is lost, players must quickly recover from attacking positions into defensive areas, increasing the number of defensive players behind the ball and therefore reducing the space for attacking play (Bangsbo & Peitersen, 2002; Wallace & Norton, 2014). These tactical changes support the finding that full backs demonstrated the most pronounced increases in high-intensity running and sprinting across the seven seasons. This tactical change has arisen from changes in the traditional rigid playing systems (4-4-2, 4-3-3 and 4-5-1) to more dynamic contemporary systems (4-2-3-1, 4-1-4-1). Although is it difficult to discuss the impact of playing formations on physical performance as limited studies exist, the increasing popularity of the compact 4-2-3-1 system in the EPL could be one potential reason why full backs now cover more high-intensity and sprinting distances, but more research needs to be undertaken to verify this.

Previous research has reported that the absolute number of explosive and leading sprints is dependent on playing position (Di Salvo et al., 2009). Across the timeframe of this study, all positions in this study showed increases in the number of leading (39–59%) and explosive sprints (125–171%). For both types of sprints, attackers showed the smallest relative change whilst full backs and central defenders demonstrated the greatest. Although differences were observed in the absolute number of leading and explosive sprints completed, the proportions of explosive sprints are comparable amongst all positions (44–49%). The increase in the number and proportion of sprints in match-play has been proposed as one causative factor for increased injury rates, in particular groin and hamstring strains (Ekstrand, Hägglund, & Waldén, 2011). Research has highlighted an injury rate of 26 per 1000 h of match play in 2011–12, lower than the 30 injuries per 1000 h observed in 2006–07 (Ekstrand, Hägglund, Kristenson, Magnusson, & Waldén, 2013). Nevertheless these results were based on a small sample across European leagues, and not purely on the EPL, in order to understand the effects of sprint and high-intensity evolution on injury rates a contemporary injury analysis is required for the EPL. The aetiology of muscle injuries in soccer is complex, however there is currently widespread use of preventative programmes to reduce injury risk (Daly, 2013; Opar, Williams, & Shield, 2012). The absolute numbers of leading and explosive sprints as well as the distance covered at high-intensity and maximal speeds in 2012–13 were greater than previous studies conducted on players competing in the UEFA Champions League, Spanish La Liga and EPL (Bradley et al., 2009; Di Salvo et al., 2007; Lago et al., 2010), therefore supporting the general perception that the EPL has evolved into one of the most physically demanding leagues in soccer.

Soccer is based on a combination of physical, technical and tactical aspects of match play. Although the physical and tactical aspects are central to performance (Bradley et al., 2013; Lago-Ballesteros et al., 2012), a teams technical ability has been identified as the best indicator of success (Castellano et al., 2012; Collet, 2013; Rampinini, Impellizzeri, Castagna, Coutts, & Wisløff, 2009). The number of passes performed in World Cup final matches has been shown to have increased by ~40% over four decades (Wallace & Norton, 2014), a similar increase to that observed over a seven year period in the EPL (Barnes et al., 2014). When broken down by position, the present data set illustrates that the number of passes performed increased by a greater extent for central defenders (~66%) and central midfielders (44%), compared to full backs, wide midfielders and attackers (all ~25%). This increase in the number of passes is comprised primarily from increased short and medium distance passes (30–72%), whilst there was no increase in the number of long distance passes across all positions. Previous research has identified an increase in passing tempo across a longitudinal period (Wallace & Norton, 2014). Although this study did not directly analyze the number of passes per minute, the observed increase in passes over the course of a match, coupled with previous findings demonstrating increases in match stoppage time (Wallace & Norton, 2014) would suggest an increase in passing tempo. The greater relative increases in the number of passes by central players may be as a result of modifications to positional duties. Previously, central defenders were used purely in a defensive role, and although this primary duty is unchanged (no differences in the number of tackles and interceptions), their offensive contribution has evolved. The increase in the number of passes could indicate an evolution of positional tactics, with many teams now focussing on possession based strategies (notion supported by the reduction in the number of possessions won and lost over the seven seasons), awaiting opportunities to exploit gaps in the oppositions defence. Teams use short to medium distance passes to increase the likelihood of pass success, essential for maintaining possession in areas of increased player density whilst still attempting to find weakness in the opposition defence (Bangsbo & Peitersen, 2004; Tipping, 2007). As a consequence, central defenders, provide extra passing options when in possession (Bangsbo & Peitersen, 2004; Tipping, 2007). This is further supported by recent findings by Prozone (2014) who noted an increase in the number of passes per shot since 2006–07, suggesting more patient build up play by teams, probing the opposition defence before finding weaknesses which may lead to a shot on goal. Further evidence can be seen in the number of passes received with central defenders (109%) and central midfielders (70%) showing greater increases than other positions. The technical findings of this study have implications for player recruitment, it is now important to identify players who are able to fit the system and style of play of the recruiting club. Thus, possession based teams need to search for central defenders who are not only accomplished defenders but also comfortable on the ball with excellent passing ability.

## 5. Conclusions

This study demonstrates that players in wide and attacking positions have increased the distance covered at high-intensity and sprinting to a greater extent than central defenders and central midfielders between 2006–07 and 2012–13. In contrast, central players were found to have increased the number of passes and pass completion rates over the same period. These evolutionary trends could be attributed to tactical modifications. These findings provide benchmark requirements of modern EPL players in each position and can therefore assist in player recruitment and development of position-specific training.

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## References


Andersson, H., Randers, M. B., Heiner-Møller, A., Krustrup, P., & Mohr, M. (2010). Elite female soccer players perform more high-intensity running when playing in international games compared with domestic league games. *Journal of Strength and Conditioning Research, 24*, 912–919.

Bangsbo, J., & Peitersen, B. (2002). *Defensive soccer tactics: How to stop players and teams from scoring*. Champaign, IL: Human Kinetics.

Bangsbo, J., & Peitersen, B. (2004). *Offensive soccer tactics: How to control possession and score more goals*. Champaign, IL: Human Kinetics.

Barnes, C., Archer, D., Hogg, B., Bush, M., & Bradley, P. S. (2014). The evolution of physical and technical performance parameters in the English premier league. *International Journal of Sports Medicine* (Epub ahead).

Barros, R. M. L., Misuta, M., Menezes, R., Figueroa, P., Moura, F., Cunha, S., et al (2007). Analysis of the distances covered by first division Brazilian soccer players obtained with an automatic tracking method. *Journal of Sports Science and Medicine, 6*, 233–242.

Batterham, A. M., & Hopkins, W. G. (2006). Making meaningful inferences about magnitudes. *International Journal of Sports Physiology and Performance, 1*, 50–57.

Bradley, P. S., Carling, C., Archer, D., Roberts, J., Dodds, A., Di Mascio, M., et al (2011). The effect of playing formation on high-intensity running and technical profiles in English FA premier league soccer matches. *Journal of Sports Sciences, 29*, 821–830.

Bradley, P. S., Carling, C., Diaz, A. G., Hood, P., Barnes, C., Ade, J., et al (2013). Match performance and physical capacity of players in the top three competitive standards of English professional soccer. *Human Movement Science, 32*, 808–821.

Bradley, P. S., O'Donoghue, P., Wooster, B., & Tordoff, P. (2007). The reliability of Prozone matchviewer: A video-based technical performance analysis system. *International Journal of Performance Analysis in Sport, 7*, 117–129.

Bradley, P. S., Sheldon, W., Wooster, B., Olsen, P., Boanas, P., & Krustrup, P. (2009). High-intensity running in English FA premier league soccer matches. *Journal of Sports Sciences, 27*, 159–168.

Carling, C. (2013). Interpreting physical performance in professional soccer match-play: Should we be more pragmatic in our approach? *Sports Medicine, 43*, 655–663.

Carling, C., & Dupont, G. (2011). Are declines in physical performance associated with a reduction in skill-related performance during professional soccer match-play? *Journal of Sports Sciences, 29*, 63–71.

Carling, C., Williams, M., & Reilly, T. (2005). *Handbook of soccer match analysis*. Oxon, UK: Routledge.

Castellano, J., Casamichana, D., & Lago, C. (2012). The use of match statistics that discriminate between successful and unsuccessful soccer teams. *Journal of Human Kinetics, 31*, 139–147.

Collet, C. (2013). The possession game? A comparative analysis of ball retention and team success in European and international football, 2007–2010. *Journal of Sports Sciences, 31*, 123–136.

Daly, B. Y. C. (2013). Sprint-related hamstring injuries the current state of play. *sportEX Medicine, 58*, 20–27.

Di Salvo, V., Baron, R., González-Haro, C., Gormasz, C., Pigozzi, F., & Bachl, N. (2010). Sprinting analysis of elite soccer players during European Champions League and UEFA Cup matches. *Journal of Sports Sciences, 28*, 1489–1494.

Di Salvo, V., Baron, R., Tschan, H., Calderon Montero, F. J., Bachl, N., & Pigozzi, F. (2007). Performance characteristics according to playing position in elite soccer. *International Journal of Sports Medicine, 28*, 222–227.

Di Salvo, V., Collins, A., McNeill, B., & Cardinale, M. (2006). Validation of Prozone: A new video-based performance analysis system. *International Journal of Performance Analysis in Sport, 6*, 108–119.

Di Salvo, V., Gregson, W., Atkinson, G., Tordoff, P., & Drust, B. (2009). Analysis of high intensity activity in premier league soccer. *International Journal of Sports Medicine, 30*, 205–212.

Di Salvo, V., Pigozzi, F., González-Haro, C., Laughlin, M., & De Witt, K. (2013). Match performance comparison in top English soccer leagues. *International Journal of Sports Medicine, 34*, 526–532.

Ekstrand, J., Hägglund, M., Kristenson, K., Magnusson, H., & Waldén, M. (2013). Fewer ligament injuries but no preventive effect on muscle injuries and severe injuries: An 11-year follow-up of the UEFA Champions league injury study. *British Journal of Sports Medicine, 47*, 732–737.

Ekstrand, J., Hägglund, M., & Waldén, M. (2011). Injury incidence and injury patterns in professional football: The UEFA injury study. *British Journal of Sports Medicine, 45*, 553–558.

Gregson, W., Drust, B., Atkinson, G., & Di Salvo, V. (2010). Match-to-match variability of high-speed activities in premier league soccer. *International Journal of Sports Medicine, 31*, 237–242.

Haugen, T. A., Tønnessen, E., Hem, E., Leirstein, S., & Seiler, S. (2014). VO2max characteristics of elite female soccer players, 1989–2007. *International Journal of Sports Physiology and Performance, 9*, 515–521.

Hughes, M., & Franks, I. (2005). Analysis of passing sequences, shots and goals in soccer. *Journal of Sports Sciences, 23*, 509–514.

Iaia, F. M., Rampinini, E., & Bangsbo, J. (2009). High-intensity training in football. *International Journal of Sports Physiology and Performance, 4*, 291–306.

Krustrup, P., & Bangsbo, J. (2001). Physiological demands of top-class soccer refereeing in relation to physical capacity: Effect of intense intermittent exercise training. *Journal of Sports Sciences, 19*, 881–891.

Krustrup, P., Mohr, M., Ellingsgaard, H., & Bangsbo, J. (2005). Physical demands during an elite female soccer game: Importance of training status. *Medicine and Science in Sports and Exercise, 37*, 1242–1248.

Lago, C. (2009). The influence of match location, quality of opposition, and match status on possession strategies in professional association football. *Journal of Sports Sciences, 27*, 1463–1469.

Lago, C., Casais, L., Dominguez, E., & Sampaio, J. (2010). The effects of situational variables on distance covered at various speeds in elite soccer. *European Journal of Sport Science, 10*, 103–109.

Lago-Ballesteros, J., Lago-Peñas, C., & Rey, E. (2012). The effect of playing tactics and situational variables on achieving score-box possessions in a professional soccer team. *Journal of Science and Medicine in Sport, 30*, 37–41.

Lago-Peñas, C., & Lago-Ballesteros, J. (2011). Game location and team quality effects on performance profiles in professional soccer. *Journal of Sports Science and Medicine, 10*, 465–471.

Mackenzie, R., & Cushion, C. (2013). Performance analysis in football: A critical review and implications for future research. *Journal of Sports Sciences, 31*, 639–676.

Mohr, M., Krustrup, P., Andersson, H., Kirkendal, D., & Bangsbo, J. (2008). Match activities of elite women soccer players at different performance levels. *Journal of Strength and Conditioning Research, 22*, 341–349.

Mohr, M., Krustrup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Sciences, 21*, 519–528.

Opar, D., Williams, M. D., & Shield, A. J. (2012). Hamstring strain injuries: Factors that lead to injury and re-injury. *Sports Medicine, 42*, 209–226.

Prozone. (2014). *Style and substance the evolution of the premier league – Prozone sports*. <http://www.prozonesports.com/style-and-substance-the-evolution-of-the-premier-league/> Retrieved from 22.07.14.

Rampinini, E., Impellizzeri, F., Castagna, C., Coutts, A., & Wisløff, U. (2009). Technical performance during soccer matches of the Italian serie A league: Effect of fatigue and competitive level. *Journal of Science and Medicine in Sport, 12*, 227–233.

Rampinini, E., Impellizzeri, F. M., Castagna, C., Azzalin, A., Ferrari Bravo, D., & Wisløff, U. (2008). Effect of match-related fatigue on short-passing ability in young soccer players. *Medicine and Science in Sports and Exercise, 40*, 934–942.

Redwood-Brown, A., Bussell, C., & Bharaj, H. S. (2012). The impact of different standards of opponents on observed player performance in the English premier league. *Journal of Human Sport and Exercise, 7*, 341–355.

Reilly, T., Bangsbo, J., & Franks, A. (2000). Anthropometric and physiological predispositions for elite soccer. *Journal of Sports Sciences, 18*, 669–683.

Taylor, J. B., Mellalieu, S. D., & James, N. (2004). Behavioural comparisons or positional demands in professional soccer. *International Journal of Performance Analysis in Sport, 4*, 81–97.

Tipping, J. (2007). The 1-4-5-1 System. *Soccer Journal* (April), 40–45.

Tønnessen, E., Hem, E., Leirstein, S., Haugen, T., & Seiler, S. (2013). Maximal aerobic power characteristics of male professional soccer players, 1989–2012. *International Journal of Sports Physiology and Performance, 8*, 323–329.

Wallace, J. L., & Norton, K. I. (2014). Evolution of World Cup soccer final games 1966–2010: Game structure, speed and play patterns. *Journal of Science and Medicine in Sport, 17*, 223–228.

Wickham, H., & Chang, W. (2013). *Tools to make developing R code easier*.

**Appendix C: Copy of Study 4:**

Bush, M., Archer, D.T., Barnes, C., Hogg, B. and Bradley, P.S. (2016). Longitudinal Match Performance Characteristics of UK and Non-UK Players in the English Premier League. *Science and Medicine in Football, In Press*

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# Longitudinal match performance characteristics of UK and non-UK players in the English Premier League

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**ABSTRACT**

This study investigated the longitudinal match performance characteristics in the English Premier League (EPL), with special reference to player nationality (UK vs. non-UK). Match observations ($n$ = 14700) were collected using a multi-camera computerised tracking system across 7 consecutive EPL seasons (2006–2007 to 2012–2013). Player nationality referred to their birthplace, with players born in England, Scotland, Wales or Northern Ireland classified as the UK players and other nationalities considered non-UK. The non-UK players demonstrated the most pronounced increases in high-intensity running distance across the 7 seasons compared with UK players ($P < 0.001$, ES: 0.91 vs. 0.73). The UK players covered more high-intensity running distance in 2006–2007 ($P < 0.001$, ES: 0.24 [CI 0.17–0.31]), however by 2012–2013 both populations covered similar distances ($P > 0.05$, ES: 0.08 [CI 0.01–0.15]). In contrast, the non-UK players performed more passes in 2006–2007 compared with the UK players ($P < 0.001$, ES: 0.23 [CI 0.16–0.3]), however by 2012–2013, passing performance between the UK and non-UK players was equal ($P > 0.05$, ES: 0.05 [CI −0.01–0.13]). The data demonstrates that the longitudinal match performance characteristics in the EPL are similar between the UK and non-UK populations.

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## Introduction

Soccer is a complex sport with players randomly transitioning between maximal, or near-maximal, multidirectional high-intensity efforts and longer periods of low-intensity activity (Bangsbo, Mohr, & Krustrup, 2006). Players typically cover 9–14 km in total during a match with high-intensity running accounting for ~10% of that distance (Di Mascio & Bradley, 2013; Mohr, Krustrup, & Bangsbo, 2003). The physical demands of match play have been quantified in the English Premier League (EPL) (Bradley et al., 2009; Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009), Italian Serie A (Mohr et al., 2003; Vigne, Gaudino, Rogowski, Alloatti, & Hautier, 2010), Spanish La Liga (Castellano, Blanco-Villaseñor, & Alvarez, 2011), French Ligue 1 (Carling, 2010), German Bundesliga (Hoppe, Slomka, Baumgart, Weber, & Freiwald, 2015) in addition to the UEFA European Champions League (Bradley, Dellal, Mohr, Castellano, & Wilkie, 2014; Di Salvo et al., 2010). The research results suggest that the EPL is one of the most physically intense Leagues in Europe (Bradley et al., 2009; Dellal et al., 2011; Di Salvo et al., 2009). Despite the physicality of modern match play, players are still expected to be proficient in an array of technical skills, more particularly passing performance, and have exceptional tactical awareness in order to be successful, which is more closely related with game outcome (Barnes, Archer, Hogg, Bush, & Bradley, 2014; Bradley et al., 2013; Carmichael, Thomas, & Ward, 2001; Dellal et al., 2011; Lago & Martín, 2007; Rampinini, Impellizzeri, Castagna, Coutts, & Wisløff, 2009). More limited information is available on the technical variables in different leagues. Nevertheless the information available suggests passing performance is lower in the EPL compared with the main European Leagues. Players in the EPL perform both fewer passes in total and fewer successful passes compared to players in the Italian Serie A (Rampinini et al., 2009). In addition, more long passes are observed in the EPL compared with the Italian and Spanish Leagues (Barnes et al., 2014; Dellal et al., 2011; Rampinini et al., 2009). It may be speculated, but unproven, that the greater technical performance observed by players in other leagues would be transferred when players transfer between leagues. Although technical match parameters are strongly influenced by playing styles, formations and location on the pitch (Bradley et al., 2011) which must be factored into the interpretation of data.

The EPL has undergone substantial change over the last decade with the distances covered at high intensity and sprinting increasing by 30–50% and the number of passes rising by 40% (Barnes et al., 2014), with subsequent research identifying these evolutionary trends to be position and tier specific (Bush, Barnes, Archer, Hogg, & Bradley, 2015; Bradley et al., 2015). Despite a lack of supporting evidence, a commonly held belief within the game is that the increased migration of the non-UK players into the EPL could account for these recent alterations in technical performances (Richardson, Littlewood, Nesti, & Benstead, 2012), although its unclear why such pronounced increases have been observed in physical performances. The increased proportion of the non-UK players in the EPL is related to the Bosman ruling which abolished foreign player quotas for clubs,

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allowing teams to buy the non-UK players without restriction (Binder & Findlay, 2012; Littlewood, Mullen, & Richardson, 2011; Richardson et al., 2012). Nevertheless, previous studies have not accounted for the influence of the non-UK players on longitudinal match performance and thus the present study investigated the longitudinal impact of the UK and non-UK players on match performance characteristics in the EPL.

## Methods

### *Match analysis and player data*

Match performance data were collected from 7 consecutive EPL seasons (2006–2007 to 2012–2013) using a computerised multiple-camera tracking system (Prozone Sports Ltd.®, Leeds, UK). Players' movements were captured during matches by cameras positioned at roof level and analysed using proprietary software to produce a data set on each player's physical and technical performance. The validity and reliability of this tracking system has been quantified to verify the capture process and data accuracy (Di Salvo, Collins, McNeill, & Cardinale, 2006; Di Salvo et al., 2009). Ethical approval was obtained from the appropriate institutional ethics committee with Prozone Sports Ltd.® supplying the data and granting permission to publish.

Data were derived from Prozone's Trend Software and consisted of 1036 individual players across 22,846 player observations. Original data files were desensitised but included 33 different teams overall with 20 teams evaluated in each season. Individual match data were only included for outfield players that had completed the entire 90 min (Carling & Dupont, 2011). Matches were excluded if a player dismissal occurred. The total number of observations was substantially different across season (2006–2007 to 2012–2013 [range = 2604–4794]), phase of season (August–November, December–February, March–May [range = 6828–8214]), position (attackers, central defenders, central midfielders, full backs, wide midfielders [range = 3405–5755]), location (Home and Away [range-11399–11447]) and team standard based on final league ranking. The original data was subjected to a number of resampling processes in order to balance the number of observations in each of these categories thus minimising errors when applying statistical tests. Table 1 shows a detailed breakdown of the resampled data. The resampling was achieved using the stratified function in the R package "devtools" (R Development Core Team) using the procedures of Wickham and Chang (2013) with 14,700 player observations included for further analysis.

### *Classification of player nationality*

Classifying a players' nationality is a complex process, thus a systematic approach was taken to enable the longitudinal match performance trends of players with different nationalities to be explored. The national team a player was eligible to play for dictated the nationality selected for that individual. Players with an English, Scottish, Welsh or Northern Irish nationality were considered the UK players, with all other nationalities considered non-UK, including players of Republic of Ireland nationalities due to historical political and social issues (McGovern, 2002). Table 2 shows a detailed breakdown of the UK and non-UK observations.

### *Match performance parameters*

Activities were coded into the following: standing (0–0.6 $km \cdot h^{-1}$), walking (0.7–7.1 $km \cdot h^{-1}$), jogging (7.2–14.3 $km \cdot h^{-1}$), running (14.4–19.7 $km \cdot h^{-1}$), high-speed running (19.8–25.1 $km \cdot h^{-1}$) and sprinting (>25.1 $km \cdot h^{-1}$) (Bradley et al., 2009). High-intensity running consisted of the combined distance in high-speed running and sprinting (≥19.8 $km \cdot h^{-1}$) and was separated into 3 subsets based on the teams' possession status: with or without ball possession and when the ball was out of play (WP, WOP and BOP, respectively). An explosive sprint is where a player enters a sprint immediately after a low-to-moderate speed activity (<19.8 $km \cdot h^{-1}$) in the previous 0.5 s period, without entering a high-speed run. A leading sprint is where a player enters a sprint from a high-speed run in the previous 0.5 s period (Di Salvo et al., 2010). Match analysis included the coding of technical parameters according to playing position based on the criteria defined by

**Table 1.** Detailed breakdown of the sample data following the re-sampling process.

| Season | 2006–2007 | 2007–2008 | 2008–2009 | 2009–2010 | 2010–2011 | 2011–2012 | 2012–2013 | Total |
|---|---|---|---|---|---|---|---|---|
| **Month** | | | | | | | | |
| August–November | 700 (33) | 700 (33) | 700 (33) | 700 (33) | 700 (33) | 700 (33) | 700 (33) | **4900 (33)** |
| December–February | 700 (33) | 700 (33) | 700 (33) | 700 (33) | 700 (33) | 700 (33) | 700 (33) | **4900 (33)** |
| March–May | 700 (33) | 700 (33) | 700 (33) | 700 (33) | 700 (33) | 700 (33) | 700 (33) | **4900 (33)** |
| **Location** | | | | | | | | |
| Home | 1083 (52) | 1078 (51) | 1050 (50) | 1069 (51) | 1051 (50) | 1049 (50) | 1019 (49) | **7399 (50)** |
| Away | 1017 (48) | 1022 (49) | 1050 (50) | 1031 (49) | 1049 (50) | 1051 (50) | 1081 (51) | **7301 (50)** |
| **Position** | | | | | | | | |
| AT | 315 (15) | 310 (15) | 309 (15) | 308 (15) | 306 (15) | 306 (15) | 298 (14) | **2152 (15)** |
| CB | 534 (25) | 527 (25) | 523 (25) | 539 (26) | 554 (26) | 546 (26) | 569 (27) | **3792 (26)** |
| CM | 459 (22) | 463 (22) | 465 (22) | 464 (22) | 454 (22) | 452 (22) | 443 (21) | **3200 (22)** |
| FB | 475 (23) | 489 (23) | 493 (23) | 487 (23) | 491 (23) | 487 (23) | 498 (24) | **3420 (23)** |
| WM | 317 (15) | 311 (15) | 310 (15) | 302 (14) | 295 (14) | 309 (15) | 292 (14) | **2136 (15)** |
| **Standard** | | | | | | | | |
| A (1st–4th) | 319 (15) | 245 (12) | 339 (16) | 360 (17) | 424 (20) | 446 (21) | 386 (18) | **2519 (17)** |
| B (5th–8th) | 509 (24) | 436 (21) | 407 (19) | 385 (18) | 459 (22) | 347 (17) | 422 (20) | **2965 (20)** |
| C (9th–14th) | 486 (23) | 719 (34) | 656 (31) | 713 (34) | 587 (28) | 636 (30) | 651 (31) | **4448 (30)** |
| D (15th–20th) | 786 (37) | 700 (33) | 698 (33) | 642 (31) | 630 (30) | 671 (32) | 641 (31) | **4768 (32)** |
| **Nationality** | | | | | | | | |
| UK | 968 (46) | 979 (47) | 972 (46) | 1006 (48) | 975 (46) | 1049 (50) | 931 (44) | **6880 (47)** |
| Non-UK | 1132 (54) | 1121 (53) | 1128 (54) | 1094 (52) | 1125 (54) | 1051 (50) | 1169 (56) | **7820 (53)** |
| **Overall** | **2100** | **2100** | **2100** | **2100** | **2100** | **2100** | **2100** | **14700** |

Table 2. The number of the UK and non-UK observations per season following resampling. The observations are broken down into the 5 main outfield playing positions; Centre Backs (CB), Full Backs (FB), Centre Midfielders (CM), Wide Midfielders (WM) and Attackers (AT).

| Season | | 2006–2007 | 2007–2008 | 2008–2009 | 2009–2010 | 2010–2011 | 2011–2012 | 2012–2013 | Total |
|---|---|---|---|---|---|---|---|---|---|
| CB | UK | 218 | 222 | 233 | 307 | 274 | 301 | 237 | 1792 |
| | Non-UK | 316 | 305 | 290 | 232 | 280 | 245 | 332 | 2000 |
| **CM** | **UK** | 211 | 241 | 250 | 231 | 241 | 253 | 195 | 1622 |
| | Non-UK | 248 | 222 | 215 | 233 | 213 | 199 | 248 | 1578 |
| **FB** | **UK** | 244 | 239 | 236 | 208 | 233 | 239 | 250 | 1649 |
| | Non-UK | 231 | 250 | 257 | 279 | 258 | 248 | 248 | 1771 |
| **WM** | **UK** | 166 | 146 | 135 | 121 | 126 | 155 | 141 | 990 |
| | Non-UK | 151 | 165 | 175 | 181 | 169 | 154 | 151 | 1146 |
| **AT** | **UK** | 129 | 131 | 118 | 139 | 101 | 101 | 108 | 827 |
| | Non-UK | 186 | 179 | 191 | 169 | 205 | 205 | 190 | 1325 |
| **Overall** | | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 14700 |

Prozone and included the number of passes, received passes and successful passes (Barnes et al., 2014). Pass distance referred to the overall length of the pass and was split into short (≤10 m), medium (11–24 m) and long (≥25 m). Technical performance was limited to passing variables due to the high variability of other technical parameters (Bush, Archer, Hogg, & Bradley, 2015), making meaningful differences between categories more difficult to identify.

### *Statistical analysis*

Factorial analysis of variance (ANOVA) tests with sphericity assumed were used to compare the UK and non-UK populations from each season. Dunnet's *post hoc* tests used to verify localised differences relative to 2006–2007 for each subsequent season with significance set at $P < 0.05$. Normality was assessed visually, since even minor deviations from normality can result in data being classified as not normally distributed with such a large data set. The effect size (ES) was calculated to determine the meaningfulness of the difference, corrected for bias using Hedges formula and presented with 90% confidence intervals (CI). Calculations of absolute change per season for selected indicators were assessed based on the 90% CI of the coefficient of the slope (linear regression). The ES magnitudes were classified as trivial (<0.2), small (>0.2–0.6), moderate (>0.6–1.2) and large (>1.2; Batterham & Hopkins, 2006). All analyses were conducted using statistical software (R Development Core Team) and data visualisation was carried out using the ggplot2 package accessed via the Deducer Interface for the R statistical programming language.

## Results

### *Physical parameters*

The UK players covered greater distances at high-intensities compared with the non-UK players $F$ (1,6) = 19.433, $P < 0.001$. Further analysis identified these results to be different in 2006–2007 (929 ± 310 vs. 858 ± 286 m, $P < 0.01$, ES: 0.24 [CI 0.17–0.31]). However, the non-UK players recorded greater increases over the 7 seasons ($P < 0.001$, ES: 0.91 [CI 0.83–0.97] vs. 0.73 [CI 0.65–0.80]), resulting in comparable high-intensity running distance being covered by 2012–2013 (UK: 1167 ± 344 vs. non-UK: 1139 ± 331 m, ES: 0.08 [CI 0.01–0.15]). These increases were equivalent to 31 (CI 27–34) and 40 (CI 37–43) $m \cdot match^{-1} \cdot season^{-1}$ for the UK and non-UK players, respectively (Figure 1(a)). In contrast, only trivial differences were observed in high-intensity running distance WP, $F$ (1,6) = 4.057, $P < 0.05$. Subsequent analysis identified these trivial differences to be present in both 2006–2007 (UK: 391 ± 240 vs. non-UK: 358 ± 235 m, $P < 0.05$, ES: 0.14 [CI 0.07–0.21]), and 2012–2013 (UK: 478 ± 260 vs. non-UK: 478 ± 261 m, ES: 0.0 [CI −0.07–0.07]). Though the increase was equivalent to 9 (CI 7–12) and 19 (CI 17–21) $m \cdot match^{-1} \cdot season^{-1}$ for the UK and non-UK players, respectively. Differences were observed between the UK and non-UK players for high-intensity running distance WOP, $F$ (1,6) = 76.112, $P < 0.001$. These trivial differences were detected in 2006–2007 (UK: 468 ± 164 vs. non-UK: 437 ± 159 m, $P < 0.001$. ES: 0.19 [CI 0.12–0.26]) and 2012–2013, although non-significant in the latter, (UK: 599 ± 192 vs. non-UK: 581 ± 202 m, $P > 0.05$, ES: 0.09 [CI 0.02–0.16]), being equivalent to 18 (CI 17–20) and 19 (CI 17–20) $m \cdot match^{-1} \cdot season^{-1}$ for the UK and non-UK players, respectively.

The UK players covered significantly different sprint distances compared with the non-UK players $F$ (1,6) = 6.807, $P < 0.01$. Further analysis highlighted these trivial differences in 2006–2007 (243 ± 117 vs. 222 ± 110 m, $P < 0.001$, ES: 0.19 [CI 0.11–0.26]), and 2012–2013 (UK: 355 ± 147 vs. non-UK: 346 ± 133 m, ES: 0.06 [CI −0.01–0.14]). Sprint distance increased by 15 (CI 14–17) and 18 (CI 17–19) $m \cdot match^{-1} \cdot season^{-1}$ for the UK and non-UK players, respectively (Figure 1(b)). No differences were observed between the UK and non-UK players, respectively, for both the number of sprints performed (2006–2007: 32 ± 15 vs. 30 ± 14; 2012–2013: 57 ± 21 vs. 56 ± 20, $P > 0.05$, ES: <0.15 [CI −0.02–0.21]) and the average distance per sprint (2006–2007: 6.9 ± 1.3 vs. 6.9 ± 1.4 m; 2012–2013: 5.9 ± 0.9 vs. 5.9 ± 0.8 m, $P > 0.05$, ES: 0.0 [CI −0.07–0.07]), with similar changes across the seasons. The number of sprints performed increased by 3.5 (CI 3.4–3.7) and 4.0 (CI 3.8–4.1) $match^{-1} \cdot season^{-1}$ in the UK and non-UK players, respectively, whereas the average distance covered per sprint decreased annually by 0.2 (CI 0.1–0.2) $m \cdot match^{-1} \cdot season^{-1}$ in both groups. In addition, the number of leading (2006–2007: 21 ± 10 vs. 20 ± 9, $P > 0.05$, ES: 0.11 [CI 0.03–0.18]; 2012–2013: 31 ± 13 vs. 30 ± 12, $P > 0.05$, ES: 0.08 [CI 0.01–0.15]) and explosive sprints (2006–2007: 11 ± 7 vs. 10 ± 6, $P > 0.05$, ES: 0.15 [CI 0.08–0.23]; 2012–2013: 27 ± 11 vs. 26 ± 10, $P > 0.05$, ES: 0.1 [CI 0.02–0.17]) did not differ between the UK and non-UK in both seasons, these having increased annually per match by a similar magnitude for leading (1.2 [CI 1.1–1.4] and 1.5 [CI 1.4–1.6]) and explosive sprints (2.3 [CI 2.2–2.4] and 2.5 [CI 2.4–2.5]), respectively.

### *Technical parameters*

Technical data revealed trivial to small differences between the UK and non-UK players. The number of passes performed highlighted differences between the UK and non-UK players $F$ (1,6) = 52.784, $P < 0.001$. Subsequent analysis identified the non-UK players performed 3 more passes per match in 2006–2007 (27 ± 14) compared with the UK players (24 ± 12, ES: 0.23 [CI 0.16–0.3]), however, by 2012–2013, this difference was trivial (non-UK 36 ± 17 vs. UK: 35 ± 17, $P > 0.05$, ES: 0.05 [CI −0.01–0.13]). This was equivalent to an increase of 1.8 (CI 1.6–1.9) and 1.7 (CI 1.6–1.9) $passes \cdot season^{-1}$ made by the UK and

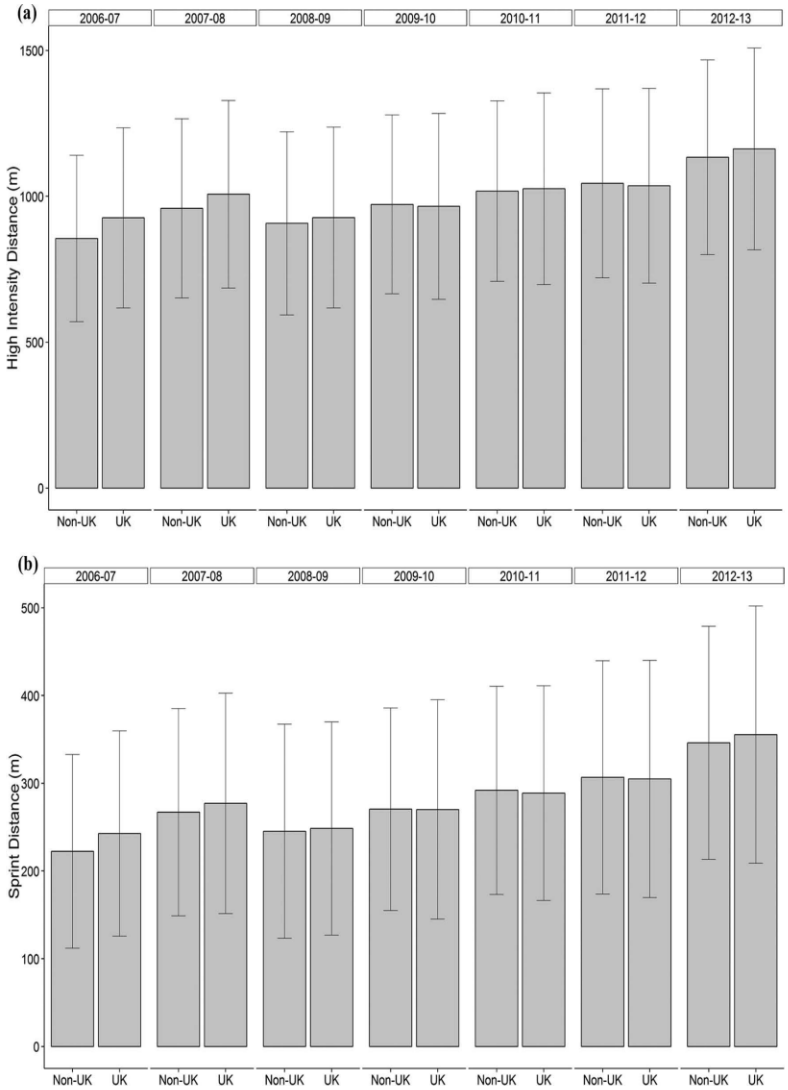


Figure 1. (a) High-intensity running and (b) sprinting distances covered by the UK and non-UK players across the 7 seasons of the EPL. Data represents means and standard deviations.

Table 3. Changes in the number of passes and passing distance between the UK and non-UK players.

| | Short pass | | Medium pass | | Long pass | | Total pass | | Pass completion (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | UK | Non-UK | UK | Non-UK | UK | Non-UK | UK | Non-UK | UK | Non-UK |
| **2006–2007** | 5.7 ± 3.9 | 6.6 ± 4.5 | 12.3 ± 7.9 | 14.3 ± 9.3 | 5.9 ± 4.0 | 5.6 ± 4.0 | 23.8 ± 12.4 | 26.5 ± 14.2 | 75.3 ± 13.4 | 77.2 ± 12.1 |
| **2007–2008** | 6.7 ± 4.4 | 7.3 ± 5.0 | 13.8 ± 8.3 | 14.7 ± 9.2 | 6.1 ± 4.1 | 5.4 ± 3.8 | 26.6 ± 13.1 | 27.4 ± 14.2 | 77.0 ± 12.3 | 78.9 ± 11.9 |
| **2008–2009** | 7.2 ± 4.8 | 8.5 ± 5.7 | 15.9 ± 9.7 | 17.5 ± 10.8 | 6.6 ± 4.5 | 5.9 ± 4.5 | 29.7 ± 15.0 | 31.8 ± 16.8 | 79.8 ± 11.4 | 81.4 ± 10.5 |
| **2009–2010** | 7.0 ± 4.8 | 8.1 ± 5.4 | 14.7 ± 9.3 | 16.3 ± 9.4 | 6.2 ± 4.5 | 5.7 ± 4.0 | 27.9 ± 14.7 | 30.0 ± 14.4 | 77.1 ± 12.5 | 79.2 ± 11.2 |
| **2010–2011** | 7.6 ± 4.8 | 8.8 ± 5.4 | 17.3 ± 10.2 | 18.0 ± 9.9 | 6.8 ± 4.4 | 5.7 ± 4.0 | 31.7 ± 15.7 | 32.5 ± 14.6 | 80.4 ± 11.0 | 81.8 ± 9.9 |
| **2011–2012** | 8.8 ± 5.9 | 10.3 ± 6.8 | 18.8 ± 12.0 | 20.6 ± 11.6 | 6.3 ± 4.5 | 6.2 ± 4.7 | 33.9 ± 18.2 | 37.1 ± 18.1 | 83.6 ± 9.9 | 84.5 ± 9.3 |
| **2012–2013** | 9.1 ± 5.7 | 9.6 ± 6.2 | 19.3 ± 11.1 | 20.2 ± 11.5 | 6.2 ± 4.6 | 6.2 ± 4.4 | 34.7 ± 16.8 | 36.9 ± 17.3 | 83.0 ± 10.0 | 83.5 ± 10.2 |

non-UK players, respectively (Table 3). When broken down, the number of short passes increased from 6 ± 4 in 2006–2007 to 9 ± 5 (ES: 0.61 [CI 0.53–0.68]) for the UK players and from 7 ± 5 to 10 ± 6 (ES: 0.54 [CI 0.47–0.61]) for the non-UK players, annual changes of 0.5 (CI 0.5–0.6) passes · match$^{-1}$ · season$^{-1}$. Over the same time period, there was an increase in the number of medium passes made $\boldsymbol{F}$ (1,6) = 65.302, $P < 0.001$. Further tests revealed this to be for both the UK (12 ± 8 to 19 ± 11, ES: 0.73 [CI 0.65–0.80]) and non-UK players (14 ± 9 to 20 ± 12, ES: 0.56 [CI 0.49–0.63]), increasing annually to a similar

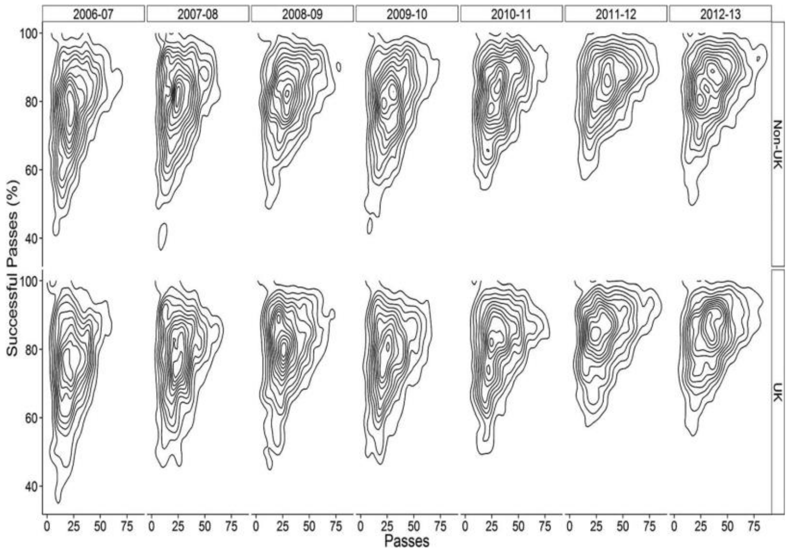


**Figure 2.** Two-dimensional kernel density plots representing the number of passes and the pass success rate of the UK and non-UK players across 7 seasons. The plot displays an increasing number of passes for both the UK and non-UK (plot width), while the UK players show a greater change in pass completion rate over the 7 seasons (plot length).

degree (1.1 [CI 1.0–1.2] passes · match$^{-1}$ · season$^{-1}$). Pass success rate recorded different results across the seasons between the UK and non-UK players $F$ (1,6) = 63.308, $P$ < 0.001. Non-UK players recorded a trivially different pass success rate in 2006–2007 (UK: 75 ± 13 vs. non-UK: 77 ± 12%, ES: 0.16 [CI 0.09–0.23 and 2012–2013 (UK: 83 ± 10 vs. non-UK: 84 ± 10%, ES: 0.10 [CI 0.03–0.17]). Pass success rate increased by 1.3 (CI 1.2–1.4) and 1.1% (CI 1.0–1.2) match$^{-1}$ · season$^{-1}$ for the UK and non-UK players, respectively (Figure 2). The percentage of occurrences of the UK players with a passing success rate of <70% decreased from 29% in 2006–2007 to 9% in 2012–2013, whereas it decreased from 24% to 10% for the non-UK players over the same time period. The number of passes received differed between the UK and non-UK players $F$ (1,6) = 60.639, $P$ < 0.001. These differences were identified to be of trivial magnitudes for the non-UK compared with the UK players in both 2006–2007 (20 ± 13 vs. 18 ± 11, ES: 0.17 [CI 0.09–0.24]) and 2012–2013 (UK: 29 ± 15 vs. non-UK: 30 ± 15, ES: 0.07 [CI −0.01–0.14]), increasing by 1.8 (CI 1.7–1.9) passes · match$^{-1}$ · season$^{-1}$.

## Discussion

The aim of this study was to investigate the longitudinal match performance characteristics of the UK and non-UK players in the EPL. Research to date on the involvement of the UK and non-UK players in the EPL has focussed on migration patterns (Maguire & Pearton, 2000; Richardson et al., 2012), the legal aspects of player movement (Gardiner & Welch, 2011) and the impact of migration on national teams (Binder & Findlay, 2012; Maguire & Pearton, 2000). To our knowledge, although some research has analysed the differences between different leagues (Dellal et al., 2011; James, Mellalieu, & Hollely, 2002), no research has examined the longitudinal effect of player nationality on match performance.

The results from the present study suggest that the UK players performed more physical workloads during matches compared with the non-UK players in 2006–2007, while the opposite was observed for technical variables, with the non-UK players performing more passes compared with the UK players. Interestingly, the non-UK players recorded a marginally higher number of passes received than the UK players which could suggest, they were more confident ball-playing footballers compared with the UK players. Nevertheless, by the 2012–2013 seasons, there was little difference between the UK and non-UK players' physical and technical performances. The non-UK players demonstrated greater relative increases for physical parameters in this study compared with the UK players (sprint distance: 55% vs. 47%; high-intensity distance: 33% vs. 27%; high-intensity distance WOP: 35% vs. 27%; leading sprints: 52% vs. 46%). Nevertheless, it is important to point out that the ES for these UK and non-UK comparisons were of trivial to small magnitudes and thus these differences may not be practically meaningful. Although unlikely to have a major impact on findings, it is worthy of note that the resampling process had minor effect on the number of observations for the UK and non-UK players and the proportions of players in the EPL differs marginally from the resampled data (Table 2). It is possible that the UK players were more accustomed to working at higher intensities compared with the non-UK players. Players' intermittent exercise test performances have been shown to correlate with physical match performance (Bradley, Bendiksen et al., 2014; Krustrup et al., 2003). There are limited physical capacity differences in Middle Eastern, Asian and African players in comparison with the UK players (Chaouachi et al., 2010; Kulkarni, Levin, Peñailillo, Singh, & Singh, 2013; Ueda et al., 2011). Although players are performing lower physical workloads during matches in different national leagues (Barros et al., 2007), this is probably due to the requirements of the respective leagues rather than the players' individual capacities. In support of this, researchers have observed changes in physical performance when performing at different playing levels without changes in the physiological profile of players (Andersson, Randers, Heiner-Møller, Krustrup, & Mohr, 2010; Bradley et al., 2013). This suggests that player work rates are dictated by the situational and tactical factors, independent of their physical capacities. Alternatively, and more probable, are improvements in the recruitment process permitting clubs to employ the non-UK players with greater capacity to work at higher intensities.

There is limited research assessing the technical performance from different world leagues, though it would suggest limited differences exist within European countries (James et al., 2002; Janković, Leontijević, Jelušić, & Pašić, 2011; Tenga, Ronglan, & Bahr, 2010). In the present study, the UK players demonstrated greater percentage increases for passing variables compared with the non-UK players (passes: 48% vs. 34%; passes received: 63% vs. 50%; short passes: 67% vs. 47%; medium passes: 56% vs. 38%). In support of this, the percentage of player occurrences with a passing success rate of <70%, identified as a minimum requirement in elite soccer (Dellal et al., 2011), was lower in the UK players compared with the non-UK players in 2006–2007 (29% vs. 24%), whereas by 2012–2013, no differences were present (UK: 9% vs. non-UK: 10%). Overall, these data could suggest that the non-UK players were initially accustomed to more technically based playing styles before employment in the UK and may therefore have contributed to the development of possession-based playing strategies in the EPL. Alternatively, these changes in technical performance in both the UK and non-UK players could be due to the influx of foreign managers employing this style of play within their coaching philosophy and recruiting players that can integrate into the playing style (Barnes et al., 2014; Bush, Barnes et al., 2015).

The physical demands (both the total distance and distances at high intensity and sprinting) in the EPL across the 7 seasons analysed in this study are consistently higher than those measured in other leagues in both Europe and worldwide (Barros et al., 2007; Dellal et al., 2011). As a result, the non-UK players transitioning into the EPL may be required to perform greater physical workloads during matches, while replicating the technical ability they were recruited for. The present study accounted for player nationality, and while the results displayed fewer obvious trends, a convergence over time was evident for both physical and technical performance between the UK and non-UK players. It is possible that the UK players have encouraged the evolution in the non-UK players' physical performance, while the non-UK players' technical performance has aided the UK players' technical performance. Due to the number of the non-UK players in the EPL, as well as the growing arguments associated with the reducing numbers of the UK players and the wider effects on the UK national teams, the FA has proposed to increase the minimum number of "home-grown" (affiliated to a the UK-based football association for 3 years before the age of 21) players in the EPL from 8 to 12 per squad (The FA, 2015), with a short-term view of increasing the playing opportunities for the UK players and a long-term view of improving the success of the national teams. Nevertheless, it is important to note that these are currently proposals and have not been implemented.

The results of the present study are presented over a limited number of seasons. Thus, in order to gain a greater understanding of the influx of the non-UK players and their effects on the EPL, a more historic comparison would be required. Nevertheless, this would be challenging, as this would predate the introduction of semi-automated tracking systems. In addition, some of the physical and technical developments may be driven by altered tactics or playing styles, for example, playing formation can influence some physical and technical performance metrics during a match (Bradley et al., 2011). Due to the nature of the data set and the fluidity of these factors, it was not factored into the analysis. Moreover, due to the nature of the desensitised data, it was impossible to discriminate between the non-UK players who had played in the EPL for consecutive seasons and those in their first season (repeated measures design needed); with this information, it could be assessed whether the non-UK players bring greater performance to the EPL or whether the non-UK players adapt after playing a number of seasons in the EPL. It must also be noted that player nationality was classified by the players eligibility for a national side, however, this does not acknowledge the fact that a player can be eligible for a national side but can play their entire domestic career in a different country, nor does this acknowledge a player's true place of birth, as players can play for a national side dependent upon their relatives registered birth country.

In conclusion, small differences were observed in the physical and technical performance of a large sample of the UK and non-UK players in 2006–2007, namely the UK players covering greater high-intensity distances but with lower numbers of passes being made when compared with the non-UK players. However, by the 2012–2013 seasons, these small differences are no longer present. It can be speculated that the non-UK players have increased their physical performance to match their UK counterparts over the seasons in question, either through individual adaptation or altered player recruitment policies. The UK players' relative improvements in technical performance may also have been due to similar factors, but these changes may also be partly explained due to altered playing styles or tactics adopted by EPL teams over this period.

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## References

Andersson, H., Randers, M. B., Heiner-Møller, A., Krustrup, P., & Mohr, M. (2010). Elite female soccer players perform more high-intensity running when playing in international games compared with domestic league games. *Journal of Strength and Conditioning Research*, *24*(4), 912–919. doi:10.1519/JSC.0b013e3181d09f21

Bangsbo, J., Mohr, M., & Krustrup, P. (2006). Physical and metabolic demands of training and match-play in the elite football player. *Journal of Sports Sciences*, *24*(7), 665–674. doi:10.1080/02640410500482529

Barnes, C., Archer, D., Hogg, B., Bush, M., & Bradley, P. S. (2014). The evolution of physical and technical performance parameters in the English premier league. *International Journal of Sports Medicine*, *35* (13), 1095–1100. doi:10.1055/s-00000028

Barros, R., Misuta, M., Menezes, R., Figueroa, P., Moura, F., Cunha, S., … Leite, N. (2007). Analysis of the distances covered by first division Brazilian soccer players obtained with an automatic tracking method. *Journal of Sports Science and Medicine*, *6*, 233–242.

Batterham, A. M., & Hopkins, W. G. (2006). Making meaningful inferences about magnitudes. *International Journal of Sports Physiology and Performance*, *1*(1), 50–57. doi:10.1123/ijspp.1.1.50

Binder, J., & Findlay, M. (2012). the effects of the bosman ruling on national and club teams in Europe. *Journal of Sports Economics*, *13*(2), 107–129. doi:10.1177/1527002511400278

Bradley, P. S., Archer, D. T., Hogg, B., Schuth, G., Bush, M., Carling, C., & Barnes, C. (2015). Tier-specific evolution of match performance characteristics in the English premier league: It's getting tougher at the top. *Journal of Sports Sciences*, *0414*, 1–8.

Bradley, P. S., Bendiksen, M., Dellal, A., Mohr, M., Wilkie, A., Datson, N., … Krustrup, P. (2014). The application of the Yo-Yo intermittent endurance level 2 test to elite female soccer populations. *Scandinavian Journal of Medicine & Science in Sports*, *24*(1), 43–54. doi:10.1111/sms.2014.24.issue-1

Bradley, P. S., Carling, C., Archer, D., Roberts, J., Dodds, A., Di Mascio, M., … Krustrup, P. (2011). The effect of playing formation on high-intensity running and technical profiles in English FA premier league soccer matches. *Journal of Sports Sciences*, *29*(8), 821–830. doi:10.1080/02640414.2011.561868

Bradley, P. S., Carling, C., Diaz, A. G., Hood, P., Barnes, C., Ade, J., … Mohr, M. (2013). Match performance and physical capacity of players in the top three competitive standards of English professional soccer. *Human Movement Science*, *32*(4), 808–821. doi:10.1016/j.humov.2013.06.002

Bradley, P. S., Dellal, A., Mohr, M., Castellano, J., & Wilkie, A. (2014). Gender differences in match performance characteristics of soccer players competing in the UEFA champions league. *Human Movement Science*, *33*, 159–171. doi:10.1016/j.humov.2013.07.024

Bradley, P. S., Sheldon, W., Wooster, B., Olsen, P., Boanas, P., & Krustrup, P. (2009). High-intensity running in English FA premier league soccer matches. *Journal of Sports Sciences*, *27*(2), 159–168. doi:10.1080/02640410802512775

Bush, M., Archer, D., Hogg, R., & Bradley, P. S. (2015). Factors influencing physical and technical variability in the English premier league. *International Journal of Sports Physiology and Performance*, *10*, 865–872. doi:10.1123/ijspp.2014-0484

Bush, M., Barnes, C., Archer, D., Hogg, B., & Bradley, P. S. (2015). Evolution of match performance parameters for various playing positions in the English premier league. *Human Movement Science*, *39*, 1–11. doi:10.1016/j.humov.2014.10.003

Carling, C. (2010). Analysis of physical activity profiles when running with the ball in a professional soccer team. *Journal of Sports Sciences*, *28*(3), 319–326. doi:10.1080/02640410903473851

Carling, C., & Dupont, G. (2011). Are declines in physical performance associated with a reduction in skill-related performance during professional soccer match-play? *Journal of Sports Sciences*, *29*(1), 63–71. doi:10.1080/02640414.2010.521945

Carmichael, F., Thomas, D., & Ward, R. (2001). Production and efficiency in association football. *Journal of Sports Economics*, *2*(3), 228–243. doi:10.1177/152700250100200303

Castellano, J., Blanco-Villaseñor, A., & Alvarez, D. (2011). Contextual variables and time-motion analysis in soccer. *International Journal of Sports Medicine*, *32*(6), 415–421. doi:10.1055/s-0031-1271771

Chaouachi, A., Manzi, V., Wong, D. P., Chaalali, A., Laurencelle, L., Chamari, K., & Castagna, C. (2010). Intermittent endurance and repeated sprint ability in soccer players. *Journal of Strength and Conditioning Research*, *24*(10), 2663–2669. doi:10.1519/JSC.0b013e3181e347f4

Dellal, A., Chamari, K., Wong, D. P., Ahmaidi, S., Keller, D., Barros, R., … Carling, C. (2011). Comparison of physical and technical performance in European soccer match-play: FA premier league and La Liga. *European Journal of Sport Science*, *11*(1), 51–59. doi:10.1080/17461391.2010.481334

Di Mascio, M., & Bradley, P. S. (2013). Evaluation of the most intense high-intensity running period in English FA premier league soccer matches. *Journal of Strength and Conditioning Research*, *27*(4), 909–915. doi:10.1519/JSC.0b013e31825ff099

Di Salvo, V., Baron, R., González-Haro, C., Gormasz, C., Pigozzi, F., & Bachl, N. (2010). Sprinting analysis of elite soccer players during European champions league and UEFA cup matches. *Journal of Sports Sciences*, *28* (14), 1489–1494. doi:10.1080/02640414.2010.521166

Di Salvo, V., Collins, A., McNeill, B., & Cardinale, M. (2006). Validation of prozone: A new video-based performance analysis system. *International Journal of Performance Analysis in Sport*, *6*, 108–119.

Di Salvo, V., Gregson, W., Atkinson, G., Tordoff, P., & Drust, B. (2009). Analysis of high intensity activity in premier league soccer. *International Journal of Sports Medicine*, *30*(3), 205–212. doi:10.1055/s-0028-1105950

Gardiner, S., & Welch, R. (2011). Nationality and protectionism in football: Why are FIFA's '6+5 rule' and UEFA's 'home-grown player rule' on the agenda? *Soccer & Society*, *12*(6), 774–787. doi:10.1080/14660970.2011.609679

Hoppe, M. W., Slomka, M., Baumgart, C., Weber, H., & Freiwald, J. (2015). Match running performance and success across a season in German Bundesliga soccer teams. *International Journal of Sports Medicine*, *36*(7), 563–566. doi:10.1055/s-00000028

James, N., Mellalieu, S. D., & Hollely, C. (2002). Analysis of strategies in soccer as a function of European and domestic competition. *International Journal of Performance Analysis in Sport*, *2*(1), 85–103.

Janković, A., Leontijević, B., Jelušić, V., & Pašić, M. (2011). Analysis of passes of Serbian football (soccer) team in qualifying for the World Cup 2010. *Anthropological Aspects of Sports, Physical Education and Recreation*, *2* (1), 235–244. doi:10.5550/SP.2.2010.29

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., … Bangsbo, J. (2003). The yo-yo intermittent recovery test: Physiological response, reliability and validity. *Medicine & Science in Sports & Exercise*, *35*(4), 697–705. doi:10.1249/01.MSS.0000058441.94520.32

Kulkarni, K., Levin, G., Peñailillo, L., Singh, A., & Singh, S. J. (2013). Physical and physiological characteristics of elite Indian national football players. *Journal of Athletic Enhancement*, *2*, 6.

Lago, C., & Martín, R. (2007). Determinants of possession of the ball in soccer. *Journal of Sports Sciences*, *25*(9), 969–974. doi:10.1080/02640410600944626

Littlewood, M., Mullen, C., & Richardson, D. (2011). Football labour migration: An examination of the player recruitment strategies of the 'big five' European football leagues 2004–5 to 2008–9. *Soccer & Society*, *12* (6), 788–805. doi:10.1080/14660970.2011.609680

Maguire, J., & Pearton, R. (2000). The impact of elite labour migration on the identification, selection and development of European soccer players. *Journal of Sports Sciences*, *18*(9), 759–769. doi:10.1080/02640410050120131

McGovern, P. (2002). Globalization or internationalization? Foreign footballers in the English league, 1946-95. *Sociology*, *36*(1), 23–42. doi:10.1177/0038038502036001002

Mohr, M., Krustrup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Sciences*, *21*(7), 519–528. doi:10.1080/0264041031000071182

Rampinini, E., Impellizzeri, F., Castagna, C., Coutts, A., & Wisløff, U. (2009). Technical performance during soccer matches of the Italian Serie A league: Effect of fatigue and competitive level. *Journal of Science and Medicine in Sport*, *12*(1), 227–233. doi:10.1016/j.jsams.2007.10.002

Richardson, D., Littlewood, M., Nesti, M., & Benstead, L. (2012). An examination of the migratory transition of elite young European soccer players to the English premier league an examination of the migratory transition of elite young European soccer players to the English premier league. *Journal of Sports Sciences*, *30*(15), 1605–1618. doi:10.1080/02640414.2012.733017

Tenga, A., Ronglan, L. T., & Bahr, R. (2010). Measuring the effectiveness of offensive match-play in professional soccer. *European Journal of Sport Science*, *10*(4), 269–277. doi:10.1080/17461390903515170

The FA. (2015). FA Chairman's update on England Commission. Retrieved May 10, 2015, from http://www.thefa.com/news/thefa/2015/mar/greg-dyke-england-commission-homegrown-players-work-permits-march-2015

Ueda, S., Yamanaka, A., Yoshikawa, T., Katsura, Y., Usui, T., Orita, K., & Fujimoto, S. (2011). Differences in physiological characterization between Yo-Yo intermittent recovery test level 1 and level 2 in Japanese College soccer players. *International Journal of Sport and Health Science*, *9*, 33–38. doi:10.5432/ijshs.20100032

Vigne, G., Gaudino, C., Rogowski, I., Alloatti, G., & Hautier, C. (2010). Activity profile in elite Italian soccer team. *International Journal of Sports Medicine*, *31*(5), 304–310. doi:10.1055/s-0030-1248320

Wickham, H., & Chang, W. (2013). *Tools to make developing R code easier*. Retrieved from https://cran.r-project.org/web/packages/devtools/index.html

## Appendix D: Provisional Copy of the Questionnaire to be sent to coaches and analysts.

Q1: What age bracket do you fit into?

☐ 18-25
☐ 26-35
☐ 36-45
☐ 46-55
☐ 55+

Q2: What is the highest level of educational qualification do you currently hold?

☐ Postgraduate degree
☐ Undergraduate degree/HND
☐ A-levels (or equivalent)
☐ GCSE/O-levels/BTEC

Q3: What is your current coaching qualification?

☐ Pro-license
☐ A-license
☐ B-license

Q4: What was the highest playing level you achieved?

☐ International
☐ Professional
☐ Semi-Professional
☐ Amateur
☐ None

Q5: How important is data in your coaching role?

☐ Very important
☐ Important in some circumstances
☐ Occasionally important
☐ Of little importance
☐ Rarely useful
☐ Not at all important

Q6: What experience do you have using data provided by sports analysis systems?

☐ I have heard of and have frequent access to performance data from systems like Prozone
☐ I have heard of systems like Prozone but have limited access to the data they provide
☐ I have heard of systems like Prozone but they are not available in my current position
☐ I have not heard of or have access to systems like Prozone (Please move on to Q8)

Q7: How do you use the data you have access to?

☐ I provide players with some/all of the data
☐ I use the data to influence my coaching session
☐ I use the data to gain a better understanding of the previous performance
☐ I use the data to monitor performance over a period of time
☐ I do not use the data

Q8: Where do coaches go to source information and performance data from? (Please tick all that apply)

☐ Analysts at the club
☐ Social media
☐ Academic research
☐ Coaching clinics
☐ Coaching courses

Below are a number of examples of data representation and visualisation. Please take time to examine the examples before answering the questions below.

Q9: In your own words, describe what the data in the examples above represent.

Q10: How important is the visualisation format in helping to understand the data?

☐ Very important
☐ A little important
☐ Neither important or unimportant
☐ Not very important
☐ Not at all important

Q11: Rank the visualisation formats in order of effectiveness and ease of understanding. (1-most effective, 3-least effective).