To assess the relationships between physical and performance characteristics with the external demands of match play in professional u18 soccer players.

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by

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List of Abbreviations and Acronyms

ARB – Arbitrary speed zones
IND – Individualised techniques
   – Maximal Oxygen consumption
   – First ventilator threshold
RCT/ – Second ventilator threshold
ASR – Anaerobic speed reserve
HSR – High speed running
THSR – Total high speed running
TVHSR – Total very high speed running
%HSR – Relative high speed running
%VHSR – Relative very high speed running
%THSR – Relative total high speed running
%TVHSR – Relative total very high speed running
MSS – Maximum sprint speed
MAS – Maximum aerobic speed
MMS –
RSS – Repeated sprint sequences
SP – Sprint distance
THSR – Total high speed running
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Abstract

The aim of the study was to examine the change of intensity distribution when applying arbitrary (ARB) and 4 different individualised (IND) techniques to soccer match time motion data.

53 match observations (5Hz GPS) from 12 full time u18 elite soccer players were recorded within 6 weeks of routine laboratory and field assessments of various fitness characteristics. High speed running (HSR), very high speed running (VHSR) and sprint (SP) distance were reported both absolute (m) and relative (%) for all 5 analysis methods.

Individualised time motion data according to maximum sprint speed (MSS) underestimated distance covered at both HSR and SP when compared to the use of respiratory compensation threshold (RCT) (-2.53; CI: -4.64 to -4.3; ES:06 and -1.3: CI: -1.57 to -1.06; ES:1.2) and maximum aerobic speed (MAS) (-1.70; CI: -2.19 to -1.20; ES: 0.6 and 1.03; CI: 0.81 to 1.25; ES: 1.2). Using speed at ( ) has no significant benefit over using MAS in the determination of VHSR, with the difference deemed negligible when the added stress of exhaustive testing for both the practitioner and participant is taken into account.

Interpretation of match intensity distribution changes when player dependant as oppose to independent speed zones are applied. The determination of a player’s phenotype would allow a better choice of which individualised technique best suits an individual, accounting for metabolic differences within the team as oppose to using one technique for all players within a team.
Introduction:

Participating in soccer at the elite level requires the performer to excel in a multi faceted sport in which physical, psychological and technical components all have an impact on successful performance. To develop a player’s performance capacity, coaches need to gain an insight and understanding into the demands of the sport on a day-to-day basis. Time-motion analysis allows coaches to gain an understanding on the physical demands placed upon a player during training and matches (Di Salvo, Collins, McNill & Cardinale, 2006). One of the recent advances in this field is the development of the Global Positioning Systems (GPS) and its use within a sports domain. Research during the late 90s was published attempting to validate the use of GPS systems to measure human locomotion (Schutz & Chambaz, 1997). Since then, a large volume of research into the use of GPS technology and its application in sports has been published (Aughey, 2011; Bucheit, Mendez-Villanueva, Simpson & Bourdon, 2010; Larsson, 2003; Bucheit, Mendez-Villanueva, Simpson & Bourdon, 2010b; Varley, Aughey & Pedrana, 2011). As a result, 11 Premier League teams used the Catapult GPS systems during the 2011-2012 seasons with a number of other teams using rival manufacturers such as GPSports, collectively showing its growth and importance in professional soccer. It is also now possible for coaches to gain instantaneous feedback on external load parameters such as distance and intensity using the software in ‘real-time’ or ‘streaming mode’ (Aughey & Fallon, 2009; MacLeod, Morris, Nevill & Sunderland, 2009), with the advantage of being able to change variables such as distance covered at high speed to meet the aims of the training session as it happens.
It is reported that elite male soccer players cover approximately 9-12 km.hr\(^{-1}\) during a competitive 90-minute game (Bangsbo, Mohr & Krustup, 2006; Mohr, Krustup & Bangsbo, 2011; Rampinini, Impellizzeri, Castanga, Coutts & Wisloff, 2009), with an estimated energy expenditure of 5700KJ for a player with a 75kg body mass (Reilly, Bangsbo & Franks, 2000). There are many external factors that can affect total distance covered in a game including playing position (Bucheit, Mendez-Villanueva, Simpson & Bourdon, 2010) tactics (Bradley et al., 2011), experience and age (Gastin, Fahrner, Meyer, Robinson & Cook, 2013). Early research focused heavily on the distance a player covered as a performance indicator, however more recently, this has been suggested to be a poor indicator of performance (Bangsbo et al., 1991; Bradley, Sheldon Wooster, Olsen, Boanas & Krustup, 2009; Mohr, Krustup & Bangsbo, 2003). Krustup, Mohr and Bangsbo (2003), explained that exercise performed during a match is of intermittent nature, were low intensity activities make up 75% of total match play. These low intensity actions require little energy production, whereas the high intensity actions require a high anaerobic energy turnover (Boone, Vaeyens, Stayaert, Vandeon-Bossche & Bourgois, 2012). These actions at high intensity can differentiate playing standard with the more elite players performing more high intensity actions (elite European player vs. a top Danish League player) and separate top class players from a player of lesser ability (Mohr et al., 2003). In support, Reilly, Bangsbo and Franks (2000) remarked that an elite player may not have to cover as much distance during a game if they have a well developed tactical sense as well as a high technical standard which together allow elite players to have a marked impact during an intensely contested match without
covering as much distance. As a result, it could be hypothesized that the aerobic system contributes significantly to a game stimulus, but the most important actions are carried out by the anaerobic energy system and are of high intensity including actions such as sprints, accelerations, jumps and tackles.

The importance of high-speed running (HSR) distance was first introduced during the early 70s. It was reported that players who could sustain a high work rate throughout a game (superior aerobic endurance) had an advantage over equal ability counterparts whose glycogen stores were depleted earlier (anaerobic based players), prohibiting them to work at higher intensities during key periods of the game (Saltin, 1973). As a result, researchers have focused on the incidence of HSR and its strength as being a key performance indicator (KPI) (Bradley et al., 2009; Mohr, Krstrup & Bangsbo, 2003; Sirotic, Coutts, Knowles & Catterick, 2009). Mohr et al. (2003) found that the amount of HSR running a player performed successfully discriminates a top class player (defined as a player representing their national team ranked 1-10 in the FIFA rankings) from a moderate standard player (defined as a player playing for their National team ranked higher than 20 on the official FIFA list). There was found to be only a 5% increase in total distance covered from top class players to the moderate class players. However, the moderate standard players were found to perform 28% less HSR running and 58% less sprinting distance than their more elite counterparts. This suggests that players of lesser ability can cover as much distance as an elite player, however a greater amount of this distance is spent at lower speeds, covering less distance during the important bouts of anaerobic work. Although research has
suggested HSR is a good indicator of physical performance, Gregson, Drust, Atkinson and Di Salvo (2010) found match – to – match variation in this parameter to be high (16-30%). This would indicate that high speed running performed during a game might not provide an accurate indication of a player’s physical performance with the standard of opposition and score of the match having an influence. Although a large volume of past research favors the use of HSR as a predictor of performance, Di Salvo et al. (2009) reported less HSR performed by the top 4 teams compared to their lower ranked teams in the same league. This could be as a result of the more elite players having a better-developed technical sense, which in turn may reduce the physical outputs they have to achieve to be successful. Nevertheless, within research and applied practice HSR is accepted as an indicator of physical performance hence it should be measured accurately.

**Arbitrary Thresholds**

Time-motion studies have largely used arbitrary speed thresholds, which were originally adopted by Bangsbo, Norregaard and Thorso (1991). The speed thresholds used by Bangsbo and colleagues were originally employed to categorise various locomotor activities such as standing (0-6 km.hr⁻¹) and walking (6-8km.hr⁻¹). However since then, they are routinely used by researchers and professionals to define boundaries between intensity of activity classifications when quantifying external physical loads (Vescovi, 2012). Without scientific justification to support the use of these thresholds, it could be suggested that they were used in accordance with Bangsbo’s work
and reflect the locomotor characteristics developed in early research. A variety of speed thresholds have been used in past research to determine HSR, ranging from 13 km.hr\(^{-1}\) (Rebelo et al., 2012) to 19.8 km.hr\(^{-1}\) (Carling, Le Gall & Dupnot, 2012). This equates to a 20% difference when comparing the lowest to the highest defined zone and therefore accounts for a significant amount of an elite players speed range. Moreover, past research has used the 19.8 km.hr\(^{-1}\) speed threshold interchangeably to represent different speed thresholds; HSR (Bradley et al., 2011; Carling, Le Gall & Dupont, 2012) and very high speed running (VHSR) (Bradley et al., 2010; Faude, Koch & Meyer, 2012).

With analysis software Amisco and ProZone favouring 19.8 km.hr\(^{-1}\), and many researchers using ~18 km.hr\(^{-1}\) to represent HSR (Di Salvo et al., 2007; Mohr, Krustrup & Bangsbo, 2011; Mohr et al., 2003), the closest viable physiological phenomena in the exercise intensity continuum to represent this is a player’s maximal aerobic speed (MAS) - produced during an incremental treadmill test to exhaustion. This was demonstrated by Lovell and Abt (2013), in which a player’s maximal aerobic speed ranged from 17-21km.hr\(^{-1}\).

Using the same thresholds as past research has the obvious advantage of between study contrasts (Bradley et al., 2009; Di Salvo et al., 2009; Rampinini et al., 2007) and also allows practitioners to compare independent populations such as age (Mendez-Villanueva et al., 2011), gender (Mohr, Krustrup, Andersson, Kirkendal & Bangsbo, 2008), playing level (Mohr et al., 2003) and international differences (Andersson, Raders, Heiner-Moller, Krustrup & Mohr, 2010). It is also important to relate the activities to the nature of the game.
Recently, research has employed individualized speed zones, which have been based around one, or a multitude of physical performance characteristics e.g. maximum speed. A soccer game at any level is absolute in nature, and although individualized thresholds give a practitioner a representation of a player’s physical performance, it may distract away from the player v player nature of a game where players physiological qualities are tested against an opponent in a competitive environment.

The construct validity of using arbitrary thresholds has been discussed. Vescovi (2012) remarked that the quantification of external loads placed upon a player requires constant evaluation and implementation of thresholds, which accurately reflect the physical capabilities and training status of that individual player. Also, as the exercise intensity continuum is individual in nature (Whaley, 2006), determination of match activities based on player independent thresholds could be erroneous. In accordance, using individualized player thresholds would present data, which is more accurate for a player on an individual, isolated basis. Without an individualized approach to match activities the true demands of soccer match play and also training loads is unknown and therefore designing player bespoke training programs and prescription would be difficult.

Individualized Thresholds

Despite attempts (Green & Dawson, 1993; Medbo et al., 1988) there is still a lack of a gold standard measure which successfully discriminates the distance covered at high speed compared to moderate speed activities.
A recent study by Buchheit, Mendez-Villanueva, Simpson & Bourdon (2010), highlighted the differences between using individualised and arbitrary thresholds using peak speed in the form of repeated sprint sequences (RSS) in elite youth soccer players of differing ages (U13 – U18). Results showed that when using arbitrary thresholds, the older players presented more RSS than the younger age groups, whilst interestingly, when employing individualised zones (based on peak speed estimates), the younger age groups performed more RSS than their older counterparts. This may suggest that younger athletes are able to perform at a higher percentage of their peak speed due to a well-developed aerobic system. In support, if the same speed thresholds were used for the youth players as the senior players, distances covered at HSR and sprinting would be underestimated for youth players because absolute sprint speed increases with the age of the player (Mujika et al., 2009; Papaiakovou et al., 2009). It also shows that employing individualised thresholds changes the interpretation of player’s work load and intensity.

Similar work by Harley and colleagues (Harley et al., 2010) uses age-related group mean speed alone to individualise speed thresholds. Harley and colleagues identified unique trends in match data when employing age related speed zones, which changed the perceived physical demands of an age group when compared to the same data set, analysed using set thresholds. Although using peak speed to base the definition of speed zones offers an individualised approach, employing only one method for all players in a team does not account for the underlying physiological differences seen in athletes. This may bias players that are naturally slower than teammates (if peak speed
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alone is used), essentially not accounting for aerobic/ anaerobic, power and mechanical differences between players. Mendez – Villanueva and colleagues (Mendez-Villanueva, Buncheit, Simpson & Pelota, 2010) suggested players who attain higher maximum speeds during sprint tests have no physical performance advantage due to tactical constraints imposed during a game situation which limit the opportunity to execute at this speed. This adds weight to the argument that using peak speed alone to individualise could underestimate/ overestimate HSR for a more anaerobic/ aerobic athlete respectively.

The qualitative relationship between endurance performance in sports and an athlete’s maximal aerobic speed (MAS) has been established for over 2 decades (Daniels & Daniels, 1992). The maximum speed in which oxygen is consumed and utilised in isolation by the aerobic energy system gives us an objective marker for the turn point of aerobic, to anaerobic energy production. Bundle, Huyt and Weyand (2003) reported the potential of MAS as a justified marker which represents the shift from speeds in which a player can maintain for several hours, to speeds which can be maintained for several seconds only. The results from the same study offers a viable justification showing the anaerobic energy release which fuels brief maximal bursts of high intensity activity to decline rapidly as the duration of work increases. This contrasts with aerobic energy release which remains consistent with event duration.

The measurement of MAS is commonly attained during a test under laboratory conditions (Abt & Lovell, 2009). However, some researchers and practitioners use field tests which acquire less expertise and resources such
as a 20m progressive track (Chtara et al., 2005). Using data from Bundle, Huyt and Weyand (2003) anaerobic energy release which fuel maximal burst of high intensity activity declines as the duration of the trial increases. In contrast, peak rates of aerobic energy release during prolonged efforts vary relatively little with event duration. It is the speed at this turn point which is vital to discriminate moderate and high speed activities. In 2003, the same authors (Bundle, Huyt & Weyand, 2003) reported speeds associated with a players MAS can successfully determine high speed running with high speed running attributed to distances covered above this speed (> MAS).

Abt and Lovell (2009) presented individualised time motion data based on the speed associated with players’ respiratory compensation threshold (\(R_c\)) as opposed to using arbitrary zones. One player’s rank within the team (total high speed running performed in a game) changed 4 ranks out of a possible 10, which is significant when assessing the physical demands placed upon that player during games and training. Speed at \(R_c\) has also been used in previous studies to delimit moderate intensity activities (<) and high intensity activities (>) in sub elite endurance runners (Esteve – Lanao et al., 2005). Abt and Lovell (2009) demonstrated that using speed at \(R_c\) to represent HSR presented a 24% decrease from the default threshold of 19.8 km.hr\(^{-1}\). Using these findings, past research applying thresholds over 15.3 km.hr\(^{-1}\) may have significantly underestimated the true distance player’s cover at high intensity (167%). In 2013, the same authors reported similar findings when contrasting distance covered at HSR for two central midfield (CM) players when individualised (>) as opposed to arbitrary zones were employed (Abt & Lovell, 2013). A 41% difference in HSR distance between the two players was noted.
when using individualized zones compared to 5% difference when using arbitrary zones, which was deemed negligible. The large increase (when using speed at a as opposed to arbitrary zones) in HSR distance (167% and 41% respectively) could highlight that speed at a isn’t a suitable physiological measure for all players in a team, with this being dependent on their physiological strengths.

A recent study by Mendez – Villanueva, Bucheit, Simpson and Bourdon (2012) introduces using maximum aerobic speed (MAS), maximum sprint speed (MSS) and the calculation of the players anaerobic speed reserve (ASR) to define activities at high speed (30% ASR-MSS) and activities at low speed (<MAS). MAS and MSS provide markers of performance capacity, which represent the functional limit of aerobic endurance and anaerobic sprint work respectively (Bundle, Huyt & Weyand, 2003). ASR therefore could represent the transition between these two physiological measures and more importantly provide a means to categorise the end point of activities at high speed and the start of distance covered at VHSR and sprinting (SP). Blondel, Berthoin, Billat and Hensel (2001) found that when the intensity of an activity is over velocity at a, it is calculated best by expressing the velocity as a percentage of the athletes ASR. This could suggest that ASR, and percentages of it provides a sensitive physiological measure to define activities occurring at speeds over a. Although research into this phenomenon is limited, Mendez-Villanueva, Bucheit, Simpson and Bourdon (2012) used the player’s speed at 30% of their ASR to define the start of sprinting occurrence.
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Previous research typically uses 5-6 speed zones when determining match activities (Bradley et al., 2011; Mohr, Krustrup & Bangsbo, 2011), with only two of these representing distance ≥ HSR. With the reported importance of distance-covered ≥ HSR, two thresholds may not offer sensitivity to differentiate between actions at high intensity, which may differ considerably in action and speed of execution. Using the default speed of 19.8km.hr⁻¹, and an assumed peak speed of 35 km.hr⁻¹, a total speed difference of 15.2 km.hr⁻¹ is defined by just two thresholds, equating to 31% of a player’s total speed capability. When looking at the lower speed thresholds in research (Mallo, Navarro, Aranda & Helsen, 2009; Mohr et al., 2003) increments are a lot smaller, making the thresholds at lower speed (< HSR) more sensitive. If an additional threshold between HSR and SP were to be introduced, it would be important that a physiological measure is used which successfully represents the transition between actions performed at high speed and actions performed sprinting (aerobic to solely anaerobic metabolism).

This study will examine the advantages of using player dependant as opposed to player independent thresholds when defining match activities, and the differences of using player dependant thresholds when quantifying external work load for a player’s training and match play data.

The various methods used for individualisation discussed in the introduction, will also be critiqued, with a new method presented for future use combining one or more of the aforementioned techniques.
Below summarises the main focuses of the thesis:

- Assess the relationships between physiological and performance characteristics with the external demands of match play.

- Describe the relative external exercise intensity distribution during match play in youth soccer.

- Contrast methods of individualising time-motion data used in previous literature.

- Present an approach incorporating all aspects of the individual’s performance characteristics.
Literature Review:

When a soccer player progresses through a player development pathway from a part time academy player to a full time professional, additional loads and stresses are placed upon their bodies due to increased contact time with coaches and sport practitioners. It is important that both sport practitioners and coaches have a clear understanding of these extra stresses and the load imposed upon the athlete, in order to correctly assist performance and reduce the likelihood of injury, which becomes more prevalent with increasing age (Le Gall, Carling & Reilly, 2007; Moore, Cloke, Avery, Beasley & Deehan, 2011). In England, the existence of soccer academies at professional clubs started in 1998 resulting in players being recruited from a younger age, being exposed to more frequent training during the foundation and youth development stages (ages 9-16). As a result, academy coaches are seeking to optimize early detection of physical potential and subsequent development of young players. Academies now invest heavily in monitoring tools and processes which objectively and subjectively track intensity of any training/ match modality in which the players are exposed to physical load.

In the early century, the use of rates of perceived exertion (RPE) was introduced in an attempt to subjectively quantify the intensity of training (Foster et al., 2001) with the obvious attraction of it being easy to measure. Later research validated the use of RPEs as a measure of internal load during aerobic (Impellizzeri, Rampinini, Coutts, Sassi & Marcora, 2004) and anaerobic (Day, McGuigan, Brice & Foster, 2004) exercise respectively. Although this method helped coaches gain an understanding of the physical
demands of their training session, it had some obvious drawbacks. As with any subjective feedback, it can be affected by external factors which cannot be controlled for. An individual may rate the session differently depending on factors such as mood, successfulness of training and peer pressure. Also, as soccer is a multifaceted sport, there are various reasons sessions could be perceived as hard. The technical demand of the session could be very high or the physical demand of the session could be high. This disparity may lead to misleading feedback. Weston (2013) suggested the use of a differential scale for technical and physical performance separately to overcome this issue. This would provide more accurate feedback on the main stress of the session. However, the subjectivity of the method cannot banish the bias of psychological and social impacts and their effect upon a player’s RPE score. A monitoring tool which is more sensitive to changes in fitness levels would be desired within a professional sport domain (Akubat, Patel, Barrett & Abt, 2012).

Following this, the use of heart rate (HR) monitors were introduced to try and gain an objective understanding of the internal load placed upon soccer players during training (Bangsbo, 1994) and match play (Ali & Farrally, 1991). HR monitors have allowed practitioners and coaches to gain an objective measure of internal load during intermittent exercise. HR max has routinely being used to assess the response of the Heart and CV system to exercise (Ashley, Myers & Froelicher, 2000). Initially, practitioners and researchers used a HR max estimation based around a standard calculation of 220-athletes age. However, research since 1971 has criticised this method with
the estimation being based on a superficial observation and it lacking subjectivity between athletes (Robergs & Landwehr, 2002), thus questioning its construct validity.

An accurate measure of internal load is particularly important in team sports were individuals cardiac output response can vary significantly to the same exercise stimulus (Manzi et al., 2010). As a result, it is important that an athlete’s true HR max is measured and used for subsequent analysis.

Further, HR response to exercise is regularly used to assess the internal load of soccer practice; however it lacks sensitivity when related to measures of external load. In light of this, it seems the measure of external load is of equal importance as an athlete’s internal response may differ dependant on the type of external load i.e. intensive vs. extensive practice (Kelly & Drust, 2009).

Quantifying the external load demands of training also allows coaches to better understand the day to day distribution of training stress with the aim of maximising adaptations, whilst minimizing the risk of negative outcomes such as fatigue, injury or stagnation. This allows feedback regarding the periodization of any micro-, macro- or meso cycle as well as peaking for competition. More recently, the development of Global Positioning Systems (GPS) has allowed coaches and practitioners a more comprehensive and accurate breakdown of a player’s movement pattern in team sports (Jennings et al., 2010). Within the past 4 years, research examining the use of GPS for analysis of player and team performance has grown (Aughey & Faloon, 2009; Barbero-Alvarez, Coutts, Granada, Barbero-Alvarez & Castanga, 2010; Coutts, Quinn, Hocking, Castanga & Rampinini, 2010; Petersen, Pyne, Portus & Dawson, 2009).
The use of GPS to quantify the external load of team sport players is now commonplace in professional clubs due to its integration into the FA Academy framework and with FA necessitating its use with u16 age groups and above at Category One status academies (thefa.com). Increased awareness and use of GPS within soccer was seen during the late 90s (1997) after a paper was published by Schutz and Chambaz trying to validate its use within a sporting setting. Since then a large volume of research has been published reporting the validity of using the GPS and its performance measures. GPS is commonly used to measure distances players travel in both training and game settings. Further to this, GPS can delimit the different speeds these distances are covered at by using thresholds which are set within the software. The reliability of GPS units is commonly discussed in literature (Coutts and Duffield, 2010; Macleod et al, 2009). Coutts and Duffield (2010) and Macleod et al. (2009) both reported similar findings showing GPS units sampling at a frequency of 5Hz overestimate and underestimate distances covered during multi directional courses by 1 & -3% respectively. However, the average speed reported in both studies was < 14.4km.hr⁻¹ which is classified as ‘moderate speed running’ (Mohr et al., 2003) and therefore a less important speed of movement compared to distance at a speed of ≥ 19.8 km.hr⁻¹ (Bradley, Sheldon, Wooster, Olsen, Boanas & Krstrup, 2008; Di Salvo et al., 2007). A more recent study by Gray, Jenkins, Andrews, Taaffe and Glover (2011) reported an underestimation of 1-10%, with the higher values attributed to higher speeds. The average speed reported in this study was 24.1 km.hr⁻¹ which more closely relates to the speed of soccer match play movement and is defined in the same Mohr study as ‘high speed running’
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(Mohr et al., 2003). Findings from Portas et al. (2007) and Townsend et al. (2008) further extend these findings. It is therefore widely accepted that GPS is a valid and reliable modality of monitoring distances covered over long periods, however it becomes less sensitive when the effort is shorter (<15m) were acceleration/ deceleration and the position of the athlete changes quickly (Barbero – Alvarez et al., 2010; Varley, Fairweather and Aughey, 2012). Despite the underestimation of distances at increasing speeds, it is tempting to say the use of GPS in soccer has been accepted without the presence of a gold standard measuring tool (Aughey, 2010; Coutts, Qinn, Hocking, Castanga & Rampinini, 2010; Randers et al., 2010).

Distances Covered in Soccer

Association football (soccer) is 90 minutes in duration, which is made up of two 45-minute periods, interjected by a 15-minute period termed ‘half time’. Some games (mostly in a cup competition) necessitate 30 minutes extra time, with penalties preceding this, where needed to determine a finite result. Strudwick and Reilly (2001) reported that total distance covered increased during, and after the 1992 season which saw the inauguration of the ‘Premier League’. A myriad of factors affect total distance covered in a game including: playing standard (Mohr et al., 2003; 2008), playing position (Di Salvo et al., 2007; Mohr et al., 2003), players’ physical capacity (Bangsbo, 1994) and the style of play adopted by the team (Bradley et al., 2011). The effect of playing standard on total distance covered has shown conflicting results. A study by Mohr et al. (2003) contrasted distances covered by top class European players (playing for an Elite European team) and moderate class professional
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players (signed for a Danish team in the top league). This study reported similar distances between both standard of players, with the elite players covering 5% more during a game compared to the lesser elite players (10.3 km\(^{-1}\) vs 10.8 km\(^{-1}\)). This distance could be seen as negligible suggesting that total distance covered does not change significantly between playing standard. However, more recent research (Reilly et al., 2008) reported distance covered during a competitive match is greater in the higher divisions due to the increased tempo the games are played at. Dellal et al. (2010a) tried to add weight to this argument comparing distances covered in the Spanish La Liga and Champions League games, with games in the French Ligue 1. This research showed a 2% increase in favour of the elite players (Spanish La Liga & Champions League Teams). However comparing distances covered in a cup competition such as the Champions League, with French League games may be erroneous due to an increased necessity to win cup games in a ‘knockout’ style competition. Table 1 illustrates the disparity in distances covered between different research papers.
Table 1 – Average distance covered (m) reported for players of differing age and standard in published research.

<table>
<thead>
<tr>
<th>Players</th>
<th>Average Distance Covered</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top class European players</td>
<td>10.9</td>
<td>Mohr et al. (2003)</td>
</tr>
<tr>
<td>Moderate class Danish players</td>
<td>10.3</td>
<td>Mohr et al. (2003)</td>
</tr>
<tr>
<td>First Division Brazilian players</td>
<td>10.0</td>
<td>Barros, Misuta, Menezes, Figueroa, Moura, Cunha, Anido and Leite (2007)</td>
</tr>
<tr>
<td>18 English professional players</td>
<td>10.7</td>
<td>Rampinini et al. (2007)</td>
</tr>
<tr>
<td>17 South American professionals</td>
<td>8.6</td>
<td>Rienzi et al. (2000)</td>
</tr>
<tr>
<td>Elite Premier League players</td>
<td>10.7</td>
<td>Bradley, Sheldon, Wooster, Olsen, Boanas and Krustrup (2009)</td>
</tr>
<tr>
<td>U16 elite male players</td>
<td>7.7</td>
<td>Harley, Barnes, Portas, Lovell, Barrett, Paul and Weston (2010)</td>
</tr>
<tr>
<td>3540 elite French first League players</td>
<td>10.4</td>
<td>Dellal, Wong, Moalla and Chamari, (2010a)</td>
</tr>
</tbody>
</table>

Performance within a soccer game has been characterised as intermittent in nature, with distance at low intensity making up 75% of total match play. With this in mind, and the weak correlation total distance covered has on playing standard, distance covered at high speed has become a heavily researched topic. Low intensity activities require little energy turnover, whereas the actions at high intensity require a high anaerobic turnover (Boone et al., 2012). Mohr et al. (2003) was one of the first papers published suggesting that the amount of high intensity work performed by a player was a successful determinant of performance level. Since this, a large volume of recent research has centred on the use of high intensity distance/ actions in soccer.
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(Andersson et al., 2010; Bradley et al., 2009; Carling, Le Gall & Dupnot, 2012; Di Mascio & Bradley, 2012; Di Salvo, Gregson, Atkinson, Tordoff & Drust., 2009).

Players who can sustain a higher work rate throughout a match have an advantage over equal ability counterparts, whose glycogen stores are depleted earlier in the game or training session prohibiting them to work during key periods of the game, namely the 75-90 minute stage, were players are at their greatest risk of being affected by fatigue. Mohr et al. (2003) showed the increased sensitivity high speed running (HSR) has as oppose to total distance covered when discriminating between elite and less elite players. Results showed a 5% difference in total distance covered, however a more substantial 28% difference in distance at high speed (> 18km.hr⁻¹) and 58% sprint distance (> 30km.hr⁻¹). A later study by Mohr et al. (2008) looked at the incidence of distance at high speed as a performance predictor in elite (19 National Team Players) and sub-elite (15 professional Danish and Swedish players) women soccer players; similar results were reported. There was a 28% increase in high speed running performed by the elite players with distance covered sprinting (SP) also greater for the elite players (24%). Both papers by Mohr indicate that with increasing standards of play, the higher the intensity of running during the game, with overall total distance covered changing insignificantly (~5%). Although these findings strongly support the use of HSR as a performance indicator, results from Bucheit, Mendez-Villanueva, Simpson and Bourdon (2010) and Bradley et al (2013a) would suggest HSR cannot discriminate between successfulness of teams competing at the same playing standard. Soccer at an elite level has a high
technical and tactical focus. As a result, a player’s physical behaviour is constrained and the ability to work at their maximal capacity is reduced. Mendez-Villanueva, Bucheit, Simpson, Peltola and Bourdon (2011) explained this modulates the relationship between ‘potential’ maximal performance and ‘actual’ performance. This is echoed in a study by Mujika, Santisteban, Impellizzerri and Castanga (2009) which found no difference in high intensity activity between elite players who were successful and unsuccessful players progressing to professional levels.

Despite these contradictory findings, HSR has been proven to be a performance indicator by a large volume of studies (Bangsbo et al., 1991; Commetti, Maffiuletti, Pousson, Chatard & Maffulli, 2001; Krstrup et al., 2003; 2005; Mohr et al., 2003; 2008; Ingebrigtsen et al, 2012) and is being continually used in research and applied settings alike.

Arbitrary Zones

The majority of the studies referenced have used arbitrary speed zones to attribute HSR and SP distance during a match. A number of these studies have referenced the work of Bangsbo et al. (1991) as support for choosing their speed zone boundaries. The speed thresholds used in the mentioned study by Bangsbo were originally developed as a means for categorising various locomotor activities i.e. standing (0-6 km.hr⁻¹) and walking (6-8 km.hr⁻¹), but since have been used by researchers to represent boundaries of intensity classification (Vescovi, 2012). This could have led to misleading conclusions with the thresholds not being a true representation of the speed
intensity, with it instead reflecting the intensity of an activity. With past research using a wide range of speed thresholds to categorise the same movement intensity, it is tempting to suggest that there is still no agreement as to what arbitrary speed best attributes different locomotor classifications. Table 2 shows the difference in speeds used to represent the same movement intensity in past research. Within current research there is a 20% difference between the lowest and highest speed associated with HSR (Rebelo et al., 2012; Carling, Le Gall & Dupnot, 2012) which accounts for a large percentage of an elite player’s speed range. This difference could have an impact on the interpretation of results between research with differences in distances reported in these studies being large due to the difference in the speeds used to anchor key thresholds. Using arbitrary speed zones has the obvious advantage of between study contrasts (Bradley et al., 2009; Di Salvo et al., 2009; Rampinini, Coutts, Castanga, Sassi & Impellizzeri, 2007) and also allows practitioners to compare independent populations such as age (Mendez-Villanueva et al., 2011), gender (Mohr et al., 2008), playing level (Mohr et al., 2003) and international differences (Andersson et al., 2010). However, if the arbitrary speed zones vary between studies, this may make comparisons very difficult.
Table 2 – Speed zones used in research over the past 10 years which represent the same movement intensity.

<table>
<thead>
<tr>
<th>Speeds used to define HSR and SP thresholds (km.hr(^{-1}))</th>
<th>HSR</th>
<th>SP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rebelo et al. (2012)</td>
<td>13.0</td>
<td>&gt;25.1</td>
</tr>
<tr>
<td>Carling, Le Gall and Dupnot (2012)</td>
<td>19.8</td>
<td>&gt;25.1</td>
</tr>
<tr>
<td>Di Salvo et al. (2010)</td>
<td>-</td>
<td>&gt;19.0</td>
</tr>
<tr>
<td>Mohr et al. (2003)</td>
<td>18.0</td>
<td>&gt;30</td>
</tr>
<tr>
<td>Randers et al. (2010)</td>
<td>-</td>
<td>&gt;19.0</td>
</tr>
<tr>
<td>Di Salvo et al. (2007)</td>
<td>19.1</td>
<td>&gt;23.0</td>
</tr>
<tr>
<td>Barros et al. (2007)</td>
<td>19.0</td>
<td>&gt;23.0</td>
</tr>
<tr>
<td>Bradley et al. (2011)</td>
<td>19.8</td>
<td>&gt;25.1</td>
</tr>
<tr>
<td>Weston et al. (2011)</td>
<td>19.8</td>
<td>&gt;25.2</td>
</tr>
</tbody>
</table>

Recently, the construct validity of using arbitrary thresholds has been questioned. Vescovi (2012) remarked that the quantification of external loads placed upon a player requires constant evaluation and implementation of thresholds, which accurately reflect the physical capabilities and training status of that individual player. This may suggest that using player dependent speed zones offers coaches and practitioners more accurate information on the physical performance capabilities of the athlete. This may help the tracking of a player’s physical development throughout the season and may provide coaches with valuable information in which player bespoke training programs can be designed. It may be logical to suggest that a player’s performance capabilities improve as the season progresses due to increased game and training stimulus which in turn improves a player’s endurance fitness characteristics (Krustrup et al, 2003, Rampinini, Coutts, Castanga, Sassi & Impellizzerri, 2007), repeated sprint ability (Castanga, Bishop, Ferrari Bravo, Tibaudi & Wisloff, 2008) and maximal speed (Caldwell & Peters, 2009). This was echoed in literature by Silva et al. (2013) reporting a significant correlation with time point in the season and physical match.
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performance (increased distance and high intensity actions in a game) especially in the last quarter of the season when compared to the , and quarters. Taking this into account, using set thresholds would see the player’s performance outputs increase naturally as the season progressed due to fitness based improvements rather than changes in tactics/individual player intensity improvements. Further, a player’s speed at which they start running at high speed and sprinting could be faster or slower than the absolute speeds used to ascertain distances covered during games, depending not only on their fitness characteristics, but also player phenotype and metabolic favoring. In support, Castanga, Impellizzeri, Cecchini, Rampinini and Alvarez (2009) reported a significant relationship between game related physical performance and the player’s physical capacity determined by means of laboratory or field tests such as VO2 max testing and/or YoYo IR2 maximal tests. The exercise intensity continuum is player dependent so it may be logical to suggest that time motion metrics mirror this with speed criteria’s anchored according to recognised physiological markers.

It could be fair to summarise that arbitrary speed zones allow for important feedback regarding the performance capacity of players and has some use with between study contrasts; however they are unable to account for individual physiological differences which may change the external load demands of soccer match play, ‘actual’ distance covered within different locomotor categories, and in turn the recovery/regeneration protocols for a player whose ‘actual’ physical stress is disguised by poorly chosen speed thresholds, collectively making the use of arbitrary speed zones problematic.
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Individualised Zones

In light of the problems associated with player independent speed zones, it seems a more individualised approach may be needed. It is important that speed zone boundaries are clearly anchored by underlying physiological events which can be continually monitored throughout the season and represent the current physical state of a player (Esteve-Lanao et al., 2005). As a result, current research has introduced the use of individualised speed thresholds and applied their use to soccer match play (Abt & Lovell, 2009; 2013; Bucheit, Mendez-Villanueva, Simpson & Bourdon, 2010; Mendez-Villanueva et al., 2010; Vescovi, 2012). Rampinini et al. (2007) and Silva, Magalhaes, Ascensao, Seabra and Rebelo (2013) reported alterations in players’ game physical parameters during the in-season period with the players training status linked with their ability to maintain high intensity performance variables during a game. Increases in match related physical parameters are a result of an increased physical capacity (Rampinini, Coutts, Castanga, Sassi & Impellizerri, 2007). The importance of using individualised speed zones was further explained by Bucheit et al. (2010) who remarked it was of no surprise that older players more easily achieved distance at high speed due to peak velocity increasing concurrently with age (u14-u18). This would make distance at high speed more easily attainable due to the maturation of the player as opposed to their superior/ improved physiological capacity. As a result, it is important that individualised zones reflect the current and ever changing physical status of a player who works in an environment which encourages changes with regular training and match stimuli.
Use of Maximum Sprint Speed

Due to limited time, expertise and most importantly resources at a professional soccer club, it is important that methods measuring physiological parameters can be implemented easily and without disruption of the players’ typical workloads and work types. One method used by practitioners is the use of a players maximum sprint speed (MSS), determined by a 30-40m maximal linear sprint test during their regular training routine (Harley et al., 2010 and Bucheit et al., 2010). Bucheit and colleagues, (2010) highlighted the importance of individualising speed zones when quantifying the load of training/ match relative to the player’s physical capacities. The research contrasts match activities based around absolute speed thresholds (distance covered at a speed > 19km.hr⁻¹), with individualised speed zones (distance covered above 61% of a player’s MSS). This study reported that when speed zones were normalised according to peak speed (>61%), it was the younger age groups (u13-16) whom presented a higher amount of repeated sprint sequences (RSS) and also the average sprint duration was higher when compared with their older counterparts (u17-18). Furthermore, the normalised data showed it was in fact the youngest players (u13) who presented more RSS, this compared with the u18 age group recording the greatest amount of RSS when absolute speed zones were applied. This is in line with work from Castellano, Blanco-Villasenor and Alvarez, (2011) who stated that the ability to work at the end functionality limit of a players speed zone was limited due to increased technical and tactical constraints, which is more prevalent with increasing age of the player, as their tactical game understanding grows.
Harley et al. (2010) presented results from a novel approach of individualising speed zones using normalised group derived MSS characteristics. When applying these zones to match play data, it was found that the intensity of a soccer game was very similar between younger and older age groups (u12-u16). When contrasting results from this study to Castanga, D’Ottavio and Abt (2003), there was a significant 1.8% increase in the amount of high speed running when age adjusted velocity thresholds were used. Castanga (2003) used an arbitrary value of 13km.hr⁻¹ to denote HSR for a group of u12 players, whereas Harley et al. (2010) employed a lower speed of 10.94km.hr⁻¹ (based on MSS estimates) which more accurately represents the speed capabilities of players within this age group, this is consistent with the work of Mendez-Villanueva et al (2011) who found sprint speed to increase from u14 through to u18 players. Although using group averages gives a better indication of age specific match activities, it still lacks a level of individualisation on a player v player basis which a within age group average may disguise, were players with an extreme aerobic/ anaerobic metabolism disposition are unfairly biased.

Although using peak speed to individualise zones helps to quantify a players' external load relative to their performance capabilities, it may not be suitable to use this as a stand-alone method for a squad of players, with it favouring players possessing ‘aerobic endurance’ characteristics in the team. In accordance, peak rates of anaerobic energy release, which are used for high intensity actions during a match, have been found to decline rapidly as the duration of the action increases (Saltin, 1990). This could impact upon a players match activities with distances covered at their highest speeds.
decreasing, as the ability to sustain the speed declines with the distance of the sprint. In contrast, a player with a well-trained aerobic endurance system can maintain efforts in excess of 80% of the aerobic power for events lasting anywhere between 10-120 minutes (Daniels & Daniels, 1992), thus suggesting aerobic based players can work at a greater percentage of their maximum speed during games without development of fatigue and consequential drop offs. Mendez-Villanueva and colleagues (Mendez-Villanueva, Bucheit, Simpson, Peltola & Bourdon, 2010) argued that the players who attain higher maximum speeds in sprint tests have no physical performance advantage in a game over players performing at the same standard, due to tactical constraints imposed i.e. style of play, which limit the chance to execute at this speed during a game. When looking at two central defenders (one of whom possessed more endurance characteristics, with the second possessing a higher absolute MSS) the endurance based player compensated by performing at a higher percentage of their maximum speed (84% vs 89%) throughout the match. Again this supports the hypothesis that using peak speed alone could underestimate HSR distance for a player with a high peak speed (especially with the tactical constraints limiting the chance to execute at this speed during a match), and overestimate the same distance for a player with more of an endurance phenotype. Work by Bucheit, Simpson and Mendez-Villanueva (2013) further supported this showing no significant correlation between match running performance and physical capacity of centre backs were their chance to perform at the end range of speed zone is severely limited. All of the aforementioned points highlight and reinforce the
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potential drawbacks with using linear sprint speed as it lacks a true representation of match related activity.

A novel way of individualising player speed zones according to peak speed is demonstrated by Gastin et al (2013) who used a range of 10 – 110% of a players speed range to ascertain movement classifications. HSR was characterised by any action performed at a speed between 80-95% MSS, with sprinting defined by a 95 – 100% MSS boundary. This would mean that a player with a MSS of 32.4 km.hr⁻¹ would only register as covering distance above high speed when he or she hits 25.9 km.hr⁻¹ which has been routinely used to represent sprint distance in earlier studies (Mohr et al, 2008; Mohr et al, 2003; Krustrup et al, 2006). This disparity may lead to an underestimation of work intensity with between study comparisons again proving difficult.

Use of MAS

Another method used for individualising speed thresholds is the use of maximal aerobic speed (MAS). MAS; the maximum speed reached during an incremental test to exhaustion, representing the body’s functional limit for aerobic performance (Carter & Dekerle, 2013; Fukda, Smith, Kendall, Cramer & Stout, 2012). It differs from speed at ( ) which is commonly reported in research and represents the speed reached at the lowest attainment of (Da Silva et al., 2011). This difference means MAS gives the speed were the athlete is at a true endpoint of aerobic endurance as opposed to a speed which concurs with the onset of an objective marker such as respiratory exchange ratio ≥ 1.10 (Clarke, Presland, Rattray & Pyne 2013), or volitional exhaustion. has been shown as a good representation of performance levels
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in elite soccer players (Daniels & Daniels, 1992) and elite level referees (Castanga, Abt & D’Ottavio, 2002). The importance of a high in soccer is valuable also for its support in the recovery process from bouts of high intensity intermittent exercise. MacMillan, Helgerud, Grant, Newell, Wilson, Macdonald and Hoff, (2005) commented on the ability of a high aerobic endurance performance and its potential to enhance recovery and as a result optimise performance in a game were the aerobic system contributes 90% of total energy cost of match play (Bangsbo, 1994; Helgerud et al., 2001). Contrasting this is the theory that it is the 10% that the aerobic energy system doesn’t contribute that is the most important actions in determining soccer performance. These actions are usually short in duration and high in intensity and the ability to repeatedly perform this during a highly contested sport is vital to successful performance (Krustrup, Mohr, Ellingsgaard & Bangsbo, 2005). These actions would start at the upper limit of aerobic performance and the lowest limit of the athletes anaerobic speed reserve (ASR) which represents the speed range between MAS and MSS. Rampinini et al. (2007) presented results which would support the use of MAS in speed zone classification, showing a positive correlation between MAS values, anaerobic performance and as a result distance covered ≥ very high speed running (VHSR).

Previous literature confirms that performance within a soccer domain is characterised by short bouts of high intensity work interspersed by longer periods of lower intensity activity. The maximum speed in which energy is produced solely by the aerobic system gives an indication of the speeds at the turn point of aerobic to anaerobic energy production. Bundle, Hoyt and
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Weyand (2003) report that the use of MAS as a performance indicator discriminates speeds which humans can maintain for several hours to speeds which can be maintained for a couple of seconds to a minute only. This discrimination helps to predict the successfulness of performance, but also the ability to profile the movement and speed classification of players at different performance levels and positions amongst other variables. Data from Bundle, Huyt and Weyand (2003) suggests that anaerobic energy release which is vital for anaerobic high intensity bursts declines steeply as the duration of the trial increases, it is at this point that aerobic metabolism is utilised alongside to help maintain performance. In contrast, peak rates of aerobic energy release during prolonged efforts vary relatively little with event duration. It is the speed at this turn point which is vital to discriminate moderate and high speed activities. The same paper uses >MAS to represent activities >HSR however it doesn’t give an indication as to the limits of other thresholds important to soccer i.e. moderate speed running and sprinting (Andrzejewski, Chmura, Pluta, Strzelczyk & Kasprzak, 2013). Scrimgeour et al. (1986) presented results confirming MAS to be a predictor of successful running performance. Participants who presented the highest MAS were also the most economical. This correlation was the strongest ($r = -0.94$) over the 10km distance which is comparable to the total volume of an elite soccer game (Mohr, Krustrup & Bangsbo, 2011; Rampinini et al., 2009). Although the correlation score presented by Scrimgeour and colleagues is high, it must be viewed with caution when applying it to a soccer domain. HSR bouts are interspersed not only with periods of low intensity activity but also with periods of high acceleration/ deceleration load (Osognach, Posner, Bernardini, Rinaldo
& Di Prampero 2010). Most of these accelerations and decelerations fail to reach the speeds associated with ≥ HSR, but are as metabolically taxing to the athlete (Osgnach et al., 2010). As a result, the successfulness of MAS as a predictor of performance in soccer may be weaker in an elite environment where tactical constraints impacts heavily upon match running performance which is often compensated by superior acceleration/ deceleration and lateral movement profiles (Bucheit et al., 2012). This paper will try and associate and validate these activity classifications as percentiles of an athlete’s MAS.

Use of , and

Castanga, Abt and D’Ottavio (2002) explained that successful endurance performance is based upon two important physiological parameters; and the highest sustainable work rate commonly referred to as second ventilatory threshold (\(V\)). Bangsbo et al. (1994) reported the intensity of work during a soccer match is ~75% of a player's \(V\), with this value typically representing values around the second ventilatory threshold (\(V\)). Edwards, Clark and MacFadyen (2003) reported the differences in lab measured and between off-, and on- season periods. There was found to be a 4% improvement in \(2.02 \text{ ml.kg.min}\) and a 4% increase in \(1.86 \text{ ml.kg.min}\) with no significant change in \(V\). Due to the highly trained state of a soccer player, it could be suggested that their \(V\) reaches a level in which further improvement is limited and as a result doesn't provide practitioners with a sensitive objective marker for the aerobic fitness and improvements of elite sportspeople. Interestingly, Edwards et al. (2003) reported a significant increase in the duration of exercise tolerance at \(11\%) which shows a positive effect of the in season
period on a players capacity to work for longer at their . Thus gives an accurate indication of aerobic fitness, but and act as more sensitive markers to changes in fitness due to increased training load throughout a season, with Bishop et al. (1998) remarking on the importance of this in soccer where aerobic metabolism is heavily stressed. Physiological support is shown with being associated with peripheral aerobic responses (such as increased capillary density) this is in opposition to improvements in which is limited to more central factors (Denadi, 1999; Bassett & Howley, 2000). In relation to performance within a soccer game, a player with a higher is likely to be able to cover more distance at a higher intensity (> VHSR) without the accumulation of lactate and its inhibiting effects (Pedro et al., 2013; Ziogas et al., 2011).

The transition between exercise at low speed (LSR), moderate speed (MSR) and HSR needs to be anchored by underlying objective measures with Kindermann et al. (1979) introducing the aerobic – anaerobic transition in early research. Kindermann et al. (1979) remarked that the transition between the aerobic and anaerobic metabolism should resemble the first increase in blood lactate with the anaerobic threshold corresponding to the maximal lactate steady state. Lucia et al. (1998; 1999) extended Kindermann’s work identifying two aforementioned ventilatory changes which accurately represent the differing intensity aerobic exercise termed and respectively. Research since this has used player’s and to delimit locomotor thresholds applied within a soccer domain and represent low speed, and high speed running respectively. Abt and Lovell (2009) were first to report this with their research reporting distance > speed at (determined by an incremental
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treadmill test) to represent HSR in professional soccer payers, with distance < representing LSR, Esteve-Lanao et al. (2005) used the same objective markers to represent HSR in elite endurance runners. The mean  reported by Abt and Lovell was 15.3km.hr⁻¹ resulting in a -4.5km.hr⁻¹ difference from the default HSR threshold of 19.8km.hr⁻¹ (default threshold used by ProZone). This 24% reduction in speed used to define HSR results in a large discrepancy in a players match activities. As a result, Abt and Lovell (2009) reported that the ranking of player’s changes when  is applied compared to the default threshold, with one players rank changing four places. This could have large implications not only on individualising players training load, but also prescribing a player’s recovery programme post matches, which has been reported to be an important component for injury and illness prevention with a need for this to be individualised according to a players match and training intensity load (Brink, Visscher, Arends, Zwerver, Post & Lemmink, 2010). With the large increase in HSR (167%) when applying as a criterion measure of HSR, it could be suggested that using one individualised method for all players within a team may not be suitable on a ‘one method suits all’ basis as players possess differing phenotypes. It may be more accurate to subscribe an individualised method based on a player’s phenotype by a category as simple as playing position (with an obvious presumption that a players playing position can predispose them to a certain metabolic favouring).

Although Abt and Lovell (2009), and studies preceding it use an objective physiological measure to define HSR, it does not offer advice as to where a player’s HSR ends and they begin to cover distance SP. For ease and
practicality, it would be advantageous if an objective measure could be gained from the same physiological/ performance test, which correctly represents the transition from aerobic metabolism to solely anaerobic metabolism, therefore correctly identifying distance covered at the top end of a player’s speed range. Previous research has highlighted possible objective markers to represent LSR and HSR, however to our knowledge literature offering advice as to markers for distance above high speed is limited. Dupnot, Akakpo and Berthoin (2004) found an 8.1% increase in \( \text{after two, 10 week high intensity interval training programmes which would suggest that speed reached at the onset of } \) is a sensitive objective marker of training based adaptations. As a result, may give practitioners and researchers an option to individualise distance above high speed, classified as very high speed running (VHSR; Scott et al. 2013; Bradley et al., 2009; Rampinini et al., 2009) from the same incremental treadmill test used to determine and (Mendez-Villanueva et al., 2010). In contrast to these findings, Barbero-Alvarez et al. (2008) reported running speeds at to be similar independent of playing standard. Looking more closely at the latter study, Barbero-Alvarez and colleagues failed to acknowledge the effect that the difference in body mass between the semi- and professional players; 69.8 vs. 75.3kg (5.5kg discrepancy), may have had on results (Pedro et al., 2013). Edwards, Clark and MacFadyen (2003) advised to be an insensitive measure in detecting a cute changes in fitness characteristics (off- vs. on- season tests). What Edwards and colleagues failed to acknowledge was although absolute didn’t show a correlation with changes in fitness, the speed at the onset of was probably higher pre to post-test if it is assumed results from Dupont and authors are correct. In light
of this, it could be hypothesized that higher speeds attained at would be a beneficial indicator of performance level with the player being able to operate at a quicker speed at the same physiological end point of aerobic metabolism. Despite this conflict in beliefs, the ability of in identifying the transition from aerobic to anaerobic metabolism cannot be forgotten. This may prove vital in discriminating high speed from moderate speed running and similarly high speed from sprint distance (Bundle, Huyt & Weyand 2003). Helgerud, Engen, Wisloff and Hoff (2001) supported this with findings that a higher increased physical and technical performance in a game (total distance covered and number of sprints). Due to the lack of research based around individualising match activities above high speed, it is unknown whether is in fact a valid measure to represent the start of VHSR with it being described as the ‘lowest’ speed to elicit (Billat, Blondel & Berthoin, 1999; Da Silva, Dittrich & Guglielmo, 2011). As a result, in soccer players has recently been reported to be as low 16.0km.hr⁻¹ (Akubat & Abt, 2011). This would represent a 19.2% decrease from arbitrary speeds routinely used in VHSR calculations in previous studies (Scott et al., 2013; Bradley et al., 2009). It may be tempting to suggest that MAS (speed which is attained during the same treadmill test to exhaustion) may offer a more accurate measure to resemble the change of speeds from high load end limit aerobic to anaerobic metabolism. MAS has being described as the ‘highest’ speed attained during an incremental treadmill test to exhaustion and has been reported to be 9.8% (1.5km.hr⁻¹) higher than speed at (Chamari et al., 2005).

In support, Denadai (1999) explained that represents the most upper limit of energy transfer responsible via aerobic metabolism and is considered to be
the main physiological indicator of maximal aerobic power; this would suggest that MAS more accurately represents the acute turn point from aerobic to anaerobic energy production and therefore HSR to VHSR.

With MAS identified as possible valid markers for distance covered at very high speed, it is necessary to find an equally valid measure which represents distance covered at the upper limit of a player’s anaerobic speed range (SP distance). Bundle, Huyt and Weyand (2003) approached this problem by predicting high speed efforts may conform to the same general relationship as those for endurance performance (>MAS, >endurance performance). It was postulated that the exponential decrements in all out speed, in relation to trial duration would conform to a general relationship based on the individual’s anaerobic speed reserve (ASR). ASR represents the functional limit of aerobic performance represented by MAS (Mendez-Villanueva, Bucheit, Simpson & Bourdon, 2012) or (Blondel, Bertoin, Billat & Hensel, 2001) and anaerobic sprint work (MSS) to predict high speed performance. This relationship allows high speed performance to be predicted from two variables which are easily attained (MAS & MSS), based on logic that as all out trial duration effort increases, the energy production has a more aerobic bias. Although a player’s ASR gives us an insight into their top speed range, it is still unknown as to where the metabolism changes to solely anaerobic and therefore represents activities in the athlete’s highest speed zone, correctly identifying the shift from VHSR to SP distance. Examining data points from an incremental max test may allow for experts to identify an obvious detection of this turn point, which would allow for an individualized approach to a player sprint distance (percentile of ASR).
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Speed at \( \max \), maximal aerobic speed and maximal sprint speed offer three viable methods to base individualized speed thresholds around; however the differences and advantages/disadvantages of these methods have not been discussed and critiqued in a research article thus far. It is hoped that this research will further extend current work and inform practitioners of best practice when analyzing time motion data from training and match play alike.

Methods:

*Experimental Approach to the Problem:*

In order to examine the difference between using individualised thresholds as opposed to arbitrary zones, competitive match data from two consecutive U18 seasons were collected and analysed. During each fixture, outfield players
wore a Global Positioning System (GPS) harnessed between the player’s shoulder blades using a custom fit undergarment, which measures distances covered at set locomotor speeds performed by each player throughout the match. Players completed laboratory and fitness based assessments at 4 different time points during the in season period. Each assessment was arranged according to strict criteria in which players had to be fully recovered from any exhaustive exercise and as a result (15 hours), took place at least 48 hours post match play, with assessments conducted at the same time of day over a 2 day ‘testing’ period. The laboratory assessment took the form of a maximal treadmill test to exhaustion. During the test, standard cardio-respiratory measurements were taken and used to represent the different locomotor categories for 3 individualised threshold methods. These were then used to anchor the commencement of LSR, HSR, VHSR and SP speed thresholds for the 3 different individualised analysis methods used in this research. The players maximal sprint speed (MSS) was assumed during a 40m sprint test which took place at the player’s training facility the day directly following their laboratory assessment. Data collected from assessments were used to create player dependant speed zones and were applied to matches that were played within a ± 8 week period of the assessment date. This was to account for in season variation in fitness characteristics as a result of regular training and match play stimulus or conversely the negative effect of injury or reduced training load. Two of the individualised methods used MAS ( ) and MSS ( ) to anchor low speed, high speed and sprint distance with the two other methods using a combination of the respiratory compensation threshold (RCT) and ASR ( ), and a combination of MAS and MSS ( &MSS). Table 5
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details all 4 individualised methods and criteria used to represent the different locomotor classifications more closely.

Participants

The participants in this study were 21 full-time soccer players aged 16-18 years from an Npower Championship Football Club competing in the Northern Section of the Youth Alliance League. For all scheduled laboratory tests and matches analysed during the testing period, the Club Physiotherapist reported no injuries prior to the event. All matches were sectioned into a ‘match cluster’ (4 match clusters in total; A, B, C & D) according to the ± 8 week period in which the matches resided with respect to the physical assessment. Each match cluster corresponded directly to a testing period i.e. match cluster ‘A’ would use data obtained from the lab and field assessment ‘1’ to apply to games that lie within that match cluster. Table 3 shows the amount of games that took place within each match cluster. When an injury was sustained during a match or match cluster, all of the players data for that match was excluded from analysis. Furthermore, data was only analysed if the player had completed at least 90% of the training sessions during the given ± 8 week period. All players generally took part in 7 hours soccer training, 3 hours strength and conditioning training, and one competitive match per week, all of which players were accustomed too.

All participants completed an informed consent (see Appendix 2) and pre testing medical questionnaire (see Appendix 4) in accordance with the requirements of the SHES ethics committee at the University of Hull. Before
testing, all participants were fully explained as to the aim of the test, protocols and justification for the tests (see Appendix 1 for participant information sheet).

**Match Configuration**

All games were competitive League fixtures, which were played in accordance with the rules presented by the Football Association. Games were played on a full size grass pitch meeting FIFA requirements (90-120m x 45-90m). All matches were 90 minutes in duration, with the additional time added at the discretion of the match officials. To account for differences in playing times between players, and between matches, data collected during the 90-minute regulation time only was used, with any data from additional time disregarded. Only players who had completed all 90 minutes of the game were used, with any players substituted also disregarded. Tactically, the team played in a 4-4-2 formation throughout the data collection period. Physically, playing a 4-4-2 or 4-3-3 formation is more demanding than playing in a 4-5-1 formation (greater distance covered jogging), therefore showing the importance of the tactical formation being consistent throughout data collection (Bradley et al., 2011).

**Match Data**

A Global Positioning System (GPS) sampling at 5Hz was used for match data collection. A 5Hz GPS unit (MinimaxX, Catapult Innovations, Canberra; firmware 6.75) was used due to its reported increased accuracy when
analysing distances at higher velocities, compared to using a sampling frequency of 1Hz (Coutts & Duffield, 2010; Duffield, Reid, Baker & Spratford, 2009). The players wore a custom fit vest, which allowed the GPS unit to fit into a pocket, which sat between the shoulder blades of the player. The vests were fitted tight to try and reduce any movement artefact. GPS units were powered on 20 minutes before scheduled kick off to allow suitable time for the GPS to pick up and lock on to at least 6 orbiting signals. The GPS were kept in clear view of the sky and were fitted into the vests moments before kick off.

All match data was collected from the 2010-2011 and 2011-2012 competitive seasons. Using similar standard opposition (using only competitive league games), was likely to reduce the effect of match-by-match performance variability (Rampinini et al., 2007b). The players were categorised dependant upon playing position with the following positions chosen in accordance with Di Salvo et al., (2007); centre backs (n=4), full backs (n=3), centre midfield (n=5), wide midfield (n=5) and strikers (n=4). Originally, 22 games over the two seasons were analysed with a total of 220 match files. The players’ match-play data was only included in the analysis if the match was within a set time frame (±8 weeks) from the testing period. It was assumed that for players who participated in 90% of training sessions during this within-season period, there would be little change in the players’ fitness characteristics (MacMillan et al., 2005). Matches were sectioned into 4 clusters (A, B, C & D) which directly corresponded with one of the 4 testing periods, i.e. match cluster ‘A’ would be matches which lay within ± 8 weeks of testing period ‘1’. Matches within the clusters were only used for analysis if physiological/ performance and match data had been collected within the 8 week period (± 8
weeks). This resulted in a total of 20 games being used for analysis with Table 3 showing the distribution of these games according to each cluster.

Table 3 – The distribution of matches used for analysis between the 4 match clusters.

<table>
<thead>
<tr>
<th>Match Cluster</th>
<th>Number of Matches Analysed</th>
<th>Match Observations Per Cluster</th>
<th>Eligible Players Per Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6</td>
<td>19</td>
<td>5</td>
</tr>
<tr>
<td>B</td>
<td>4</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>C</td>
<td>6</td>
<td>19</td>
<td>7</td>
</tr>
<tr>
<td>D</td>
<td>4</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>20</strong></td>
<td><strong>53</strong></td>
<td><strong>19</strong></td>
</tr>
</tbody>
</table>

All games were played at the same time of day (11am kick off); to avoid any influence circadian variation would have on performance (Reilly and Brooks, 1986). The distribution of home and away games was also somewhat equal, with a total of 13 being played at home and 9 played away. Only players who completed the full game, and where signals from 6 or more earth orbiting satellites and/or the horizontal displacement of the positioning was less than 1.5 were used for data analysis, all other data sets were disregarded (as per the manufacturers handbook). Thus based on these stringent game inclusion criteria, only 20 games were used, resulting in 53 cases used for analysis (from a possible 200 cases). Table 4 quantifies how many player cases were lost based on each exclusion criteria. Technical error represents data that was unavailable due to one of the following reasons: insufficient satellite coverage (9 cases); loss of unit power (25 cases); and inability to retrieve data from the unit (11 cases).
This allowed the performance of 12 players in 5 different playing positions to be examined in this study. Match performance was analysed for a total of 3 centre backs (14 cases), 3 full backs (11 cases), 3 centre midfielders (16 cases), 1 wide midfielder (7 cases) and 2 strikers (4 cases). Data from 9 players were disregarded due to the reasons outlined in Table 4.

Table 4 – Categorises numbers of lost match files due to each exclusion criteria.

<table>
<thead>
<tr>
<th>Exclusion Criteria</th>
<th>Number of disregarded cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unavailable Laboratory Data</td>
<td>44</td>
</tr>
<tr>
<td>Missing Peak Speed Data</td>
<td>8</td>
</tr>
<tr>
<td>Technical Error</td>
<td>45</td>
</tr>
<tr>
<td>Less than 90 minutes played</td>
<td>49</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>148</strong></td>
</tr>
</tbody>
</table>

**Incremental Treadmill Test**

An incremental treadmill test (Woodway ELG, Woodway Weil an Rhein, Germany) was used to determine the running speeds associated with respiratory compensation threshold (RCT) and maximal aerobic consumption ( ). All testing took place at the University of Hull site in the Physiology Testing Laboratories. Tests took place in the morning (9am-12pm), at least 15 hours after any physical exertion, with players completing the test at similar
times between repeated assessments (± 1 hour) to increase test-retest reliability. The assessments were conducted at the start of both the 2010-2011 (battery 1) and 2011-2012 (battery 3) in season periods (second week of the competitive season) and at an approximate mid-point of each season; test battery 2 was scheduled 7 weeks after battery 1, and test battery 4 was undertaken 22 weeks after test battery 3. Players were asked to refrain from drinking caffeinated products 12 hours before testing, consuming food 3 hours prior to testing and to consume their normal diet. Players were also instructed to keep fully hydrated up to the commencement of the test. For Health and Safety reasons, participants were harnessed into the treadmill to prevent injury due to slipping, tripping or feinting (see Appendix 6). Participants were verbally encouraged throughout the test to give maximal effort to exhaustion. All players wore their standard lightweight training top and shorts with running trainers. Players were asked to warm up on a cycle ergometer (Monark 874E, Monark Exercise AB, Varberg, Sweden) at a self-selected pace for the 5 minutes immediately prior to test commencement. Treadmill speed started at 7.0 km.hr⁻¹ for the first 3 minutes of the test and increased in a ramped fashion by 0.2 km.hr⁻¹ every 12 seconds thereafter. The treadmill was set at a 2% gradient to represent the additional energetic cost of exercising in typical match-play conditions with air resistance and altered terrain.

Expired air (Oxycon Pro, Jaeger, Hochberg, Germany) and Heart Rate (Polar FS1, Polar Electro, OY, Finland) were measured continuously during the test using a breath-by-breath gas analysis system (Quark, Cosmed, Rome, Italy). Before and after every test, the breath-by-breath collection system was re calibrated in line with the manufacturers requirements.
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For the purpose of this study, was taken as the peak oxygen consumption taken from 15 second averaged data, where the respiratory exchange ratio exceeded 1.10 and the players corresponding heart rate resided within ± 10 beats per minute of their age predicted maximum.

Determination of RCT and

From the incremental treadmill test, the speeds corresponding to RCT and were attained. The means of determination was visual inspection by an expert trained practitioner. RCT was determined as a clear increase in the ventilatory equivalent for oxygen () and carbon dioxide () coupled with a decrease in end tidal pressure of . This method has been used previously by Foster et al. (2005); Lucia et al. (2000), and more recently by Abt and Lovell (2009). was taken as the running speed at which the oxygen consumption was ≥ 95% of the measured maximum. These methods have been used recently by Madden, Hunter and Lovell (2013). was used to delimit very high speed and sprinting speed zones as part of the analysis (see Table 5).

Determination of MAS

Maximum aerobic speed was classified as the maximal running speed attained during the incremental treadmill test to exhaustion. This followed procedures used by Da Silva, Monteiro, Cunha, Myers and Farinatti (2012). MAS was used to anchor key speed thresholds during analysis for the and &MSS methods. Whilst MAS is strongly correlated with (r= 0.9; Leger &
Boucher, 1980), and can be easily measured in field-based settings, it typically overestimates by 5-10% and is influenced by the individuals ASR (Bucheit & Laursen, 2013). In this study MAS was determined in addition to examine whether the application of these speeds had any noticeable change on interpretation of match running performance.

**Determination of Maximum Sprint Speed (MSS)**

Sprint tests were completed on grass, at the player’s regular training ground facility. All tests were carried out on a day were players were fully recovered from any exhaustive physical exercise (at least 48 hours post) and weren’t in any state of fatigue (± 2 days from any competitive game). The tests only went ahead if the ground was firm, with no excessive wind or weather conditions hindering the players’ performance in the test. It has been reported that keeping the ground type consistent during testing is vital for validity purposes with artificial 3G turf being seen as the ‘gold standard’ (Vescovi, 2012). Without access to a 3G facility, the player’s regular training surface was used with the conditions kept as similar as possible during all tests reflecting good practice outlined by Da Silva, Gugliemo, Carminatti, De Oliveira, Dittrich and Paton (2011) and Hughes et al. (2013). The format of the tests was mirrored for all sprint tests and the time they were carried out was also replicated (10am-11am). Sprint tests were carried out at least 24 hours after completion of the test.

SmartSpeed timing gates (SmartSpeed, Fusion Sport, HaB International LTD, Warwickshire, UK) were used and were positioned at 10, 20, 30 and 40m.
The test track started with a 0.5m rolling start with participants starting when they were ready thus eliminating any effect of reaction time. Participants were told to sprint maximally, 5m past the last timing gate to ensure a max speed was recorded, preventing participants from decelerating before the end of the test trial (Buchheit, Mendez-Villanueva, Simpson & Bourdon, 2010).

Players completed their generic pre match warm up before testing. The warm up consisted of 5 min speed agility and quickness work including dynamic stretching, 10 minute ball mastery and movement session, and finally 10 minute small sided game/ possession practice. Although this is a longer warm up compared to previous research (Hughes et al. 2013), it was selected to replicate the players regular pre match warm up (Towlson, Midgley & Lovell, 2013) offering some routine to testing procedures and was a similar duration to that used by Mendez-Villanueva et al., (2011). Also, the players were engaging in a football session directly after completion of the field tests which necessitated players to be suitably prepared both physically and psychologically. Each participant completed 3 trials (with at least a 3 minute rest in between trials), with their speeds at 10m, 20m, 30m and 40m recorded to the nearest 0.01s. The fastest speed over a 10m sector measured during any of the trials was assumed to determine peak speed in accordance with recent practice (Bucheit et al., 2010; Mendez-Villanueva et al., 2013).

**Anaerobic Speed Reserve (ASR)**

and MSS was used in this study as the lower, and upper boundary respectively of the anaerobic speed reserve (ASR) which represents the
functionality limits of a players anaerobic speed capacity (Bundle, Hoyt & Weyand, 2003). Once the ASR was determined, 30% of the players ASR was calculated and used to delimit the very high speed running and sprinting zones as part of the analysis methods. As part of the &MSS, MAS and MSS were used to calculate ASR to determine whether the use of MAS changed the interpretation of match running performance.

Methods used to profile match performance

This study compares the differences between using 4 different methods to determine match activities, one method adopted arbitrary thresholds, and 4 different ways to individulaise match data were also employed resulting in 5 methods used for analysis.

The first player dependant analysis method used focused on RCT as its main anchor, with and MSS also used to represent aerobic to anaerobic functional limits ( ), respectively. The second method used percentages of the players’ MAS ( ) in isolation to categorise the running distances. The third method used percentages of a players’ MSS ( ) alone, and the fourth method used a combination of both MAS and MSS ( &MSS). Table 5 shows the speed boundaries used to define each locomotor activity in more detail.

<table>
<thead>
<tr>
<th>Analysis Method</th>
<th>Locomotor Classification</th>
<th>ARB(km.h⁻¹)</th>
<th>&amp;MSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Speed Running (LSR)</td>
<td>&lt;14.99</td>
<td>&lt;RCT</td>
<td>&lt;79% MAS</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Activity</th>
<th>RCT -</th>
<th>%THSR</th>
<th>%TVHSR</th>
<th>%SP</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Speed Running (HSR)</td>
<td></td>
<td>15.0 – 17.99</td>
<td>80 - 99% MAS</td>
<td>50 - 59% MSS</td>
</tr>
<tr>
<td>Very High Speed Running (VHSR)</td>
<td></td>
<td>18.0 – 24.99</td>
<td>100 - 139% MAS</td>
<td>60 - 79% MSS</td>
</tr>
<tr>
<td>Sprinting (SP)</td>
<td></td>
<td>25.0 – 35.0</td>
<td>140% MAS – 35km/h</td>
<td>79 - 100% MSS</td>
</tr>
</tbody>
</table>

RCT: speed corresponding to a players respiratory compensation threshold; : Speed corresponding to the players velocity at attaining 95% maximal oxygen consumption; ASR: anaerobic speed reserve; MAS: maximal aerobic speed; MSS: maximum sprint speed.

A case study approach was taken to compare individual’s match intensity distribution when employing the 5 different analysis methods, and shows the effect of using individualised threshold on individuals as opposed to group based means, suggesting a more ‘pragmatic’ approach (Carling, 2013). This helped explore more deeply the possible effects of bias, the impact of outliers and to better inform practitioners working in the domain. With group based mean data giving a general overview, it may mask differences in relative time motion data where their physiological profile is different in bias.

**Case Study 1**

The first case study focused on player #17 and player #21 who achieved the lowest and highest MSS during the testing period. The effect of this metabolic favouring (aerobic vs. anaerobic), and the change of intensity distribution when the 5 different analysis methods were employed will be discussed.

**Case Study 2**

Case study number two used player #8 and player #16 who showed very similar aerobic based fitness characteristics, however differed markedly in their anaerobic profile (MSS). The effect of this on the ASR and subsequent relative distance at %THSR, %TVHSR and %SP were investigated.
Case Study 3

Case study 3 highlights the interpretation differences in player's game intensity and their subsequent change in rank within the team when the 5 different analytical approaches were applied.

Case Study 4

The final case study centres around the sensitivity of the analytical approaches using both aerobic and anaerobic measures of fitness (and MSS) in detecting changes in fitness within a season.

Statistical Analysis

The distance covered in each speed zone was expressed as a percentage of the total distance covered (TDC), with data presented as mean ± SD unless otherwise stated. Group based differences between the individualisation methods were assessed using magnitude-based inferences with a within subjects model. A priori we determined the minimum practically important difference as 0.6 between-subjects SD, with any difference at 1.2 also reported. Whilst a conservative threshold, this was considered necessary to avoid both type I and family-wise error, particularly given the high-degree of between-match variability of high-speed running parameters (Gregson et al., 2010). Using a customized spread sheet (Hopkins, 2006), the magnitude of
the effect statistic was classified as moderate or large via standardised thresholds (0.6 and 1.2, respectively) established from the between-subject standard deviation. Mechanistic inferences were determined from the disposition of the 90% confidence interval for the mean difference to these standardized thresholds. Where the difference in percentage distance covered was ≥ 5% in both a substantially positive and negative sense, the true effect was classified as unclear. In the event that a clear interpretation was possible, the following probabilistic terms were adopted: < 0.5 %, most unlikely; 0.5–5 %, very unlikely; 5–25 %, unlikely; 25–75 %, possibly; 75–95 %, likely; 95–99.5 %, very likely; > 99.5: most likely.

Results
The players mean TDC during analysed matches was 10,296 (± 683m) coefficient of variance (CV) 8.5% of which 9.0 (2.2%) CV 24.5% was covered at high speed according to ARB thresholds. This percentage increased to 11.3 (5.2%) CV 46.6%, 10.1 (2.6%) CV 25.3% and 10.1 (2.6%) CV 25.3 % when employing , and MSS thresholds respectively. Conversely, when applying thresholds to the match data high speed running decreased to 8.3 (2.2%) CV 26.0%. Table 6 shows the squad mean physical and performance characteristics.

Table 6 – Squad mean (SD) results from the laboratory and field assessments.

<table>
<thead>
<tr>
<th>RCT (km.h⁻¹)</th>
<th>(ml.kg⁻¹.min⁻¹)</th>
<th>(km.h⁻¹)</th>
<th>MAS (km.h⁻¹)</th>
<th>30% ASR (km.h⁻¹)</th>
<th>MSS (km.h⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.296</td>
<td>30% ASR</td>
<td>30% ASR</td>
<td>30% ASR</td>
<td>30% ASR</td>
<td>30% ASR</td>
</tr>
</tbody>
</table>

Table 6 – Squad mean (SD) results from the laboratory and field assessments.
Intensity distribution determination methods in soccer.

<table>
<thead>
<tr>
<th>Locomotor Classification</th>
<th>ARB</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Speed Running (LSR)</td>
<td>&lt;15</td>
<td>&lt; 14.94</td>
<td>&lt;14.44</td>
<td>&lt;15.66</td>
</tr>
<tr>
<td>High Speed Running (HSR)</td>
<td>15</td>
<td>14.94</td>
<td>14.44</td>
<td>15.66</td>
</tr>
<tr>
<td>Very High Speed Running (VHSR)</td>
<td>18</td>
<td>18.61</td>
<td>18.87</td>
<td>18.79</td>
</tr>
<tr>
<td>Sprinting (SP)</td>
<td>25</td>
<td>22.64</td>
<td>26.40</td>
<td>25.09</td>
</tr>
<tr>
<td>Maximum</td>
<td>35</td>
<td>31.36</td>
<td>35.0</td>
<td>31.36</td>
</tr>
</tbody>
</table>

Table 7 – Speeds (km.hr⁻¹) associated with different locomotor classifications for all 5 analysis methods.

When applying ARB speed thresholds, VHSR represented 7.6 (2.4%) CV 31.5% of TDC. This decreased to 4.4 (1.6%) CV 37.2%, 5.8 (2.0%) CV 34.7%, 5.8 (2.0%) CV 33.6% and 4.4 (1.5%) CV 36.1%, when applying , , and &MSS, respectively.

Similar trends were found with distance covered sprinting (relative to total distance covered). According to ARB speed zones, 0.9 (0.5%) CV 57.0% TDC was attributed to sprint distance with this increasing to 2.3 (1.0%) CV 42.3% and 2.0% (0.9%) CV 44.4% when applying and &MSS thresholds, decreasing to 0.43 (0.3%) CV 72.7% and 0.9 (0.5%) CV 51.6%, for and respectively.

Distance covered for all locomotor classifications for all 5 analysis methods are detailed in absolute values in Table 8. Group mean speeds associated with different locomotor classifications for all 5 analysis methods are detailed in Table 7, with Figure 1 showing the same data but for each individual.
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maximum aerobic speed method; : running speeds corresponding to the individualised peak speed method; &MSS: running speeds corresponding to the individualised maximum aerobic speed and max sprint speed method.

![Figure 1 – Running speeds corresponding to the different speed zones as outlined in Table 7 for all 12 participants.](image)

underestimated %HSR compared to ARB (mean difference: -0.73%; confidence intervals (CI): -1.08 to -0.38%; effect size (ES): 0.6), (-2.5; CI: -4.64 to -0.43; ES: 0.6), (-2.53; CI: -4.64 to -0.43; ES: 0.6); (-1.70; CI: -2.19 to -1.20; ES: 0.6) and &MSS methods (-1.70; CI: -2.19 to -1.20; ES: 0.6). also underestimated SP distance when compared to (-1.3; CI: -1.57 to -1.06; ES: 1.2) and &MSS (1.03; CI: 0.81 to 1.25; ES:1.2). As a result, %VHSR distance was overestimated when compared to the same two methods; (1.1; CI: 0.54 to 1.67; ES 0.6) and &MSS (-1.8; CI: -2.4 to -1.22; ES:1.2) respectively.
overestimated %HSR distance (1.81; CI: 0.13 to 3.74; ES: 0.6) when compared to ARB method.

Table 8 – Mean distance covered (SD) within each locomotor classification for all 5 analysis methods.

<table>
<thead>
<tr>
<th>Locomotor Classification</th>
<th>ARB</th>
<th>&amp;MSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Speed Running (LSR)</td>
<td>8425 (585)</td>
<td>8541 (621)</td>
</tr>
<tr>
<td></td>
<td>8329 (766)</td>
<td>8654 (669)</td>
</tr>
<tr>
<td>High Speed Running (HSR)</td>
<td>922 (226)</td>
<td>1036 (262)</td>
</tr>
<tr>
<td></td>
<td>1151 (536)</td>
<td>850 (221)</td>
</tr>
<tr>
<td>Very High Speed Running (VHSR)</td>
<td>781 (246)</td>
<td>619 (208)</td>
</tr>
<tr>
<td></td>
<td>449 (167)</td>
<td>427 (154)</td>
</tr>
<tr>
<td>Sprinting (SP)</td>
<td>93 (53)</td>
<td>91 (47)</td>
</tr>
<tr>
<td></td>
<td>234 (99)</td>
<td>205 (91)</td>
</tr>
</tbody>
</table>

&MSS underestimated %HSR (0.86; CI: 0.50 to 1.22; ES: 0.6) with a concomitant decrease in %VHSR (-0.70; CI: -0.97 to -0.43; ES 0.6) and SP distance (-1.75; CI: -2.06 to -1.44; ES:1.2) versus analysis.

underestimated SP distance versus both (-1.74: CI: -2.06 to -1.44; ES: 1.2) and ARB methods (-0.48: CI: -0.6 to -0.35; ES: 1.2).

Unsurprisingly all individualised analysis methods underestimated distance covered %VHSR versus ARB method; (-2.61; CI: -31.2 to -2.10; ES: 0.6); (-1.75; CI: -2.13 to -1.38; ES: 0.6); (-1.51; CI: -1.95 to -1/07; ES: 1.2) and &MSS (-3.31; CI: -3.75 to -2.88; ES: 1.2).

Relative total high speed running (%THSR) was underestimated when thresholds were applied to the time motion data compared to ARB (-2.28; CI: -3.17 to -1.38; ES: 0.6) and (-2.74; CI: -5.11 to -0.38; ES: 0.6). &MSS also
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underestimated distance ≥%THSR (-1.41; CI: -2.29 to -0.53; ES: 0.6) versus ARB method. When looking at relative distance covered very high speed running (%TVHSR), and &MSS both underestimated distance versus ARB (-2.23; CI: -2.68 to -1.77; ES: 1.2 and -2.32; CI: -2.76 to -1.88; ES: 1.2 respectively). %TVHSR was also underestimated when thresholds were compared to definitions (-0.89, CI: -1.24 to 0.54; ES*: 0.2).

Case Study #1 – The effect of a low, vs. a high MSS on intensity distribution.

Player 17 and Player 21 presented the highest and lowest MSS during the testing period respectively. Table 9 shows the difference this makes to THSR distance and SP distance according to the 4 IND analysis methods. These players were chosen to highlight this effect in more depth rather than using squad based means which can sometimes mask intra-individual differences.

<table>
<thead>
<tr>
<th>Analysis Method</th>
<th>Player 17 vs. Player 21</th>
<th>THSR (m)</th>
<th>SP (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VT</td>
<td>673 vs. 1593</td>
<td>667 vs. 2086</td>
<td>74 vs. 262</td>
</tr>
<tr>
<td>MAS</td>
<td>667 vs. 2086</td>
<td>51 vs. 118</td>
<td></td>
</tr>
<tr>
<td>MSS</td>
<td>974 vs. 2085</td>
<td>0 vs. 35</td>
<td></td>
</tr>
<tr>
<td>MAS&amp;MSS</td>
<td>667 vs. 2047</td>
<td>74 vs. 216</td>
<td></td>
</tr>
</tbody>
</table>

Case Study #2 – Anaerobic Speed Reserve: Impact of using multiple fitness characteristics encompassing aerobic and anaerobic markers.
Players #8 and player #16 were chosen for this analysis as a result of their similar (18.8 vs. 19.0 km.hr\(^{-1}\)) and their similar MAS (19.2 vs. 19.0 km.hr\(^{-1}\)), this combined with their markedly different MSS (30.3 vs. 32.5 km.hr\(^{-1}\)) meant they were useful to investigate the impact of using ASR within match intensity determination methods. Both players recorded similar match volume distance (TDC; 10 927 ± 521, vs. 10 037 ± 746m), with their relative intensity distribution being similar according to ARB analysis method (see Table 10). When applying MSS to the match data, %TVHSR of player #16 (higher MSS) were underestimated in comparison to player #8. Contrastingly, when and &MSS analysis methods were used, which were derived from measures of both aerobic and anaerobic phenotypes, the underestimation shown using MSS methods was not apparent.

Table 10 – Match play intensity distribution according to: ARB, and &MSS using two players with similar aerobic qualities but differing MSS.

<table>
<thead>
<tr>
<th>Locomotor Category</th>
<th>Analysis Method</th>
<th>Player #</th>
<th>%LSR (SD)</th>
<th>%THSR (SD)</th>
<th>%TVHSR (SD)</th>
<th>%SP (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ARB</td>
<td>8</td>
<td>81.3 (1.6)</td>
<td>18.7 (1.6)</td>
<td>9.7 (1.4)</td>
<td>1.1 (0.6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td>80.5 (3.0)</td>
<td>19.5 (3.0)</td>
<td>9.7 (3.5)</td>
<td>1.4 (0.9)</td>
</tr>
<tr>
<td></td>
<td>MSS</td>
<td>8</td>
<td>81.8 (1.7)</td>
<td>18.1 (1.7)*</td>
<td>9.1 (1.2)*</td>
<td>1.3 (0.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td>85.1 (3.2)*</td>
<td>14.8 (3.2)</td>
<td>6.6 (2.5)</td>
<td>0.9 (0.6)</td>
</tr>
<tr>
<td></td>
<td>&amp;MSS</td>
<td>8</td>
<td>82.6 (1.9)</td>
<td>17.3 (1.8)</td>
<td>7.1 (1.2)</td>
<td>2.7 (0.6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td>81.3 (3.0)</td>
<td>18.6 (3.1)</td>
<td>7.5 (2.7)</td>
<td>2.5 (1.4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
<td>80.6 (1.6)*</td>
<td>19.3 (1.6)</td>
<td>7.9 (0.6)</td>
<td>3.0 (1.2)*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td>74.4 (2.9)</td>
<td>25.6 (3.0)*</td>
<td>7.5 (1.4)</td>
<td>2.4 (2.7)</td>
</tr>
</tbody>
</table>

*denotes practically meaningful difference (>0.6 between subjects SD) between match clusters.

Case Study #3 – Change in rank of players match intensity demands: The interpretation change when applying .
Table 11 shows player’s HSR distance can change according to which method is employed. For this analysis, game 11 was used as it had the highest amount of players involved within final analysis (n=4). Player A was ranked highest for distance covered at high speed according to ARB threshold, however when speed zones were applied their HSR distance was ranked 3 out of 4. Conversely, player C was ranked second for all analysis methods, however when was applied his rank changed +1. It seems that when applying speed zones, it is clear that the interpretation of a players speed intensity and their subsequent rank within the team changed significantly.

Player A had a higher speed at RCT (16.2km.hr⁻¹) compared to player C (13.8km.hr⁻¹) and shows how using speeds at different physiological events changes distances covered at locomotor speeds.

Table 11 – Players rank within the squad based on high speed running (1 = highest distance covered, 4 = lowest distance covered) when defined using the 5 different methods (using data from game 11).

<table>
<thead>
<tr>
<th>Player</th>
<th>ARB</th>
<th>&amp;MSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>C</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>D</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

Case Study #4 - Impact of seasonal variation in fitness upon intensity distribution: sensitivity of analysis techniques.

Case study 4 was used to investigate the sensitivity of the different analytical techniques on detecting acute changes in fitness characteristics. Match clusters 5 and 6 were chosen which represented mid-season and end-season
games respectively. The overall match volume distance didn’t change significantly between games within the two match clusters which were played within a few weeks of fitness assessments (9589 ± 402 vs. 9588 ± 530m). The player used for this case study saw a decline in RCT (15.6 vs. 14.0 km.hr⁻¹), (19.2 vs. 18.4 km.hr⁻¹) while interestingly his MAS remained unchanged (22.2 vs. 22.0 km.hr⁻¹). Table 12 shows how the relative distance within various locomotor categories changed depending on fitness characteristic used within the analysis method. Although we witnessed a reduced level of fitness as the season progressed, %TVHSR was increased slightly upon the application of ARB method, however when &MSS and &MSS were applied to match data the intensity distribution was increased in match cluster 6 for %THSR, %TVHSR and %SP locomotor categories.

Table 12 – Comparison of match play distribution data from match cluster 5 and 6 using different analytical approaches.

<table>
<thead>
<tr>
<th>Locomotor Category</th>
<th>Analysis Method</th>
<th>Match Cluster</th>
<th>%LSR</th>
<th>%THSR</th>
<th>%TVHSR</th>
<th>%SP</th>
</tr>
</thead>
<tbody>
<tr>
<td>%LSR</td>
<td>ARB</td>
<td>5</td>
<td>84.4 (2.1)</td>
<td>15.6 (2.1)</td>
<td>7.2 (1.3)</td>
<td>0.5 (0.4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>82.6 (2.5)</td>
<td>17.4 (2.5)</td>
<td>8.9 (1.4)*</td>
<td>0.6 (0.2)</td>
</tr>
<tr>
<td>%THSR</td>
<td>ARB</td>
<td>5</td>
<td>87.7 (1.8)*</td>
<td>12.2 (1.8)</td>
<td>3.9 (1.2)</td>
<td>1.4 (0.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>83.4 (2.5)</td>
<td>16.6 (2.5)*</td>
<td>6.0 (1.0)*</td>
<td>2.1 (0.5)*</td>
</tr>
<tr>
<td>%TVHSR</td>
<td>ARB</td>
<td>5</td>
<td>86.4 (2.0)*</td>
<td>13.6 (2.0)</td>
<td>4.9 (1.3)</td>
<td>1.8 (0.8)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>78.8 (3.1)</td>
<td>21.2 (3.1)*</td>
<td>7.8 (1.2)*</td>
<td>2.5 (0.6)*</td>
</tr>
</tbody>
</table>

* denotes practically meaningful difference (> 0.6 between-subjects SD) between match-clusters
Discussion:
This study sought to describe the intensity distribution during match play based on individualised approaches, and demonstrate the differences in time motion data associated when applying both arbitrary and a range of individualised analysis techniques to time motion data for locomotor categorisation.

Although originally empirical analysis was applied on a cohort-basis to determine general team based differences between analytical approaches, the effect of using different individualised techniques on the interpretation of external match intensity demands on an individual, player v player basis was also applied using a case study approach.

The main findings of the study were:

- U18 elite youth soccer players cover on average 10,221m per game with 24.5% covered at HSR, 7.6% VHSR and 0.9% SP according to ARB speed thresholds.
- It was ARB thresholds which produced the highest distance %VHSR when compared to all 4 individualised methods.
- The use of MSS to individualise player game data resulted in erroneous interpretation of %HSR and %VHSR data.
• MAS determination was unable to detect the transition in speed to a high intensity domain, and resulted in an underestimation of distance covered at %TVHSR and %SP locomotor categories.

• If the commonly used speed of 19.8km.hr\(^{-1}\) was used to represent HSR, it would grossly underestimate distance ≥HSR distance (compared to the arbitrary speed of 15.0km.hr\(^{-1}\)) by 340%, and by 321% when compared to the average speed employed by all 4 IND methods in this study.

• Employing speed zones resulted in the greatest change in the interpretation of players speed intensity during a match stimulus and subsequent rank within the team (see Table 11 and Case Study #3).

• MAS differences resulted in a 7.5% change in intensity distribution (TVHSR) meterage which was deemed in significant due to the reported 5-10% inaccuracy of distance covered >HSR when using 5Hz GPS units within a soccer setting (Gray et al., 2011).

• Time motion data and the subsequent interpretation is likely to change when comparing cases on an individual basis (case study approach) as opposed to using group mean data which is used heavily in past research.

The demands of elite soccer match play and intensity distribution has been heavily documented in previous research (Bangsbo, Mohr & Krustup, 2006; Mohr, Krustup & Bangsbo, 2011; Rampinini et al., 2007; Di Salvo et al., 2009). Total distance covered as an absolute measure is widely accepted as
an indicator of match volume and demands of the game without reference to intensity. Despite large match-to-match variation, early research documented high speed running as a key performance indicator and a parameter to measure intensity distribution throughout a game (Mohr et al., 2003; Gregson et al., 2010), with it being reported as a discriminant for successful performance within some research (Rampinini et al., 2007). A large volume of past research made conclusions on match intensity distribution data using fixed speed thresholds that were either pre-determined by the manufacturing company of the time motion analysis software, or similarly chosen in accordance with past research. Many studies have referenced the work of Bangsbo, (1991) for justification of their speed zone choices, however these were originally chosen to categorise different locomotor characteristics rather than speed zones to define intensity transition. Although fixed speed zones have the advantage of between study contrasts and ease of implementation, the use of player dependant thresholds has been reported in more recent research (Abt & Lovell, 2009; Mendez-Villanueva et al., 2010). The advantage of individualised thresholds is that key transitions between high, very high and sprint speeds are anchored by performance characteristics of each individual which can be easily measured and monitored to give a more accurate reflection of the players external load according to their fitness and training characteristics. If the purpose of using TMA during training and match stimuli is to monitor external load demands, then using player independent speed zones may mask important information which could affect training and recovery prescription (Abt & Lovell, 2013). Although absolute distance covered was measured and has been reported (Table 8) in this study, all
results were discussed as a relative distance which more accurately accounts for positional and style of play differences in volume between players and teams alike (Carling, 2013), results presented by Bucheit and Mendez-Villanueva (2013) also took this approach when presenting their results. The few studies which have published data using individualised speed zones have used one fitness characteristic to anchor all locomotor categories. Players MSS has been applied using both individual (Cahill et al., 2013) and squad mean (Harley et al., 2010) characteristics. It may be tempting to say that the use of MSS as a stand-alone measure for speeds within different locomotor categories, encompassing low level aerobic to high load anaerobic performance could be too ignorant of individual phenotype which may complicate its use and subsequent interpretation. As a result, it would be hard to rationalise and justify the use of sprint speed alone to individualise locomotor profiles at lower speed which predominantly uses aerobic energy sources to fuel the action (Weston, 2013). underestimated distance covered at high speed (%HSR) by 26.2% and 17.9% and SP by 157% and 125% compared to and MSS analysis methods respectively. If we take a player with a high MSS and therefore anaerobic bias, they are likely to ‘bypass’ distance covered at high speed as they are able to somewhat skip this threshold and achieve greater distances VHSR with relative ease at a cruising pace. Results would justify this with overestimating VHSR (%VHSR) when compared to and MSS. Due to the reported time and recovery processes which are associated with all out exercise, when a player with a more anaerobic disposition reaches speeds at their upper limits of anaerobic performance (VHSR/ SP distance), it takes them more time to recover
(compared to a player with a more aerobic bias), with the likelihood of this recovery time resulting in distance covered at low speed, and in turn a decrement in total high speed running (THSR) performance (Madden, Hunter & Lovell, 2013; unpublished data). This would suggest that when a player with an anaerobic phenotype reaches their SP speeds, the all-out effort cannot be repeated in quick succession due to the associated recovery processes and compromised repeated sprint ability performance (Glaister, 2005). If MSS is to be used in future research, it may be worth considering using different percentages of a players MSS, based on their dominant phenotype. Mendez-Villanueva et al., (2010) reported the use of the MAS to MMS ratio as a tool to identify an individual player’s metabolic specialisation and therefore their likely phenotype. The use of such tool would help researchers an field practitioners choose individualised techniques more carefully and accurately taking into account each player’s locomotor profile. Based on a review of current research, a suggested criteria could be that a player who achieves a MSS of > 32.4km.hr⁻¹ uses the following thresholds: 0-54% (LSR), 55-64% (HSR), 65-74% (VHSR) and >75% (SP), as an example only.

Results show that the method overestimated distance covered LSR. If the entry percentile of MSS for HSR is reduced, this may go some way to bringing distances covered at low speed in line with the other individualised methods used, especially ARB (2.23; CI: 1.34 to 3.13; ES:0.6) and (2.73; CI: 0.35 to 5.10; ES: 0.6) and in turn may increase the distance covered %HSR which was underestimated using the threshold outlined in this study (60%MSS – 80%MSS). When critiquing past research, it seems the average MSS for the 12 participants in this study was higher than that reported in previous
research, with all 12 recording higher MSS than speeds reported by Mendez Villanueva et al., (2010), 9 being higher than speeds reported by Bradley, Lago-Penas, Rey and Gomez Diaz (2013b), and Mendez-Villanueva et al. (2010). It could be easy to conclude that a large percentage of players used in this study had a more anaerobic speciality which is likely to have exaggerated the reported overestimation of %LSR and %VHSR and underestimation of %HSR and SP distance. This is more likely to account for the speed capabilities of a player who possesses anaerobic energy production. In contrast, a player with an aerobic based metabolism has the reported ability to withstand distance above >85% of their MSS for a prolonged duration and therefore can work at a higher percentage of their MSS with a lower intensity demand on the player (Saltin, 1979). As already suggested above for players who reach a MSS > 32.14 km.hr⁻¹, a player who reaches a MSS below this absolute sprint speed could have higher adjusted thresholds to compensate for their superior buffering and high intensity exercise tolerance (Glaister, 2005; Saltin, 1979). Suggested thresholds could be as follows: 0-64% (LSR), 65-74% (HSR), 75-84% (VHSR) and > 85% (SP), again as an example only. If MSS could be used as a performance characteristic measure to base speed zones with greater accuracy it would be advantageous due to the ease of measuring it in a training modality with limited disruption to a player’s routine.

Similar trends were found when MAS calculations were applied to match activities. Unlike MSS, the use of MAS is likely to underestimate distance above high speed for individuals with an aerobic phenotype with a consequential overestimation of the distance at this speed for anaerobic based players. Results from this study show that the use of MAS to
individualise group match activates very likely and possibly underestimates distance ≥TVHRS when compared to both (6.3%) and ARB (26.8%) speed zones respectively. As previously mentioned, participants within this study had a higher MSS compared with speeds reported previously in literature suggesting a more anaerobic persuasion. We already know that players who possess higher MAS can resist fatigue better during a game and therefore remain at a higher intensity throughout when compared to a player with lower MAS (Madden, Hunter & Lovell, 2013). The underestimation of distance at %TVHRS is especially prevalent when looking at %SP distance compared to (81.2%) and ARB (52.7%). SP distance within the was calculated as distance covered >140% MAS. Table 7 shows that the average speed used to delimit SP distance within the analysis method was 5% (vs. ) to 14% (vs. and) higher than other IND methods showing the use of 140% MAS may have been too high. This is attenuated within a group of players who have a more anaerobic favouring, meaning the ability to repeatedly perform at this percentile of their lesser favourable metabolism (aerobic) may be unrealistic. This again suggests that basing speed thresholds that encompass aerobic/anaerobic speeds, accounting for the full speed range of a player may be problematic for a group of player’s if only one physiological marker is used. MAS does not characterise the individual nature of transition speed to a very high intensity domain.

A further finding was that the speed used to represent %VHRSR was underestimated by all 4 IND methods when compared to distances reported when ARB speeds were applied. A large effect size was found when comparing ARB %VHRS as a criterion measure versus both and &MSS, with
the statistical inference being very powerful; *most likely* and *very likely* respectively. Table 7 shows the speeds used to represent the transition from %HSR to %VHSR in all analysis methods. The large band width between VHSR and SP distance observed with ARB speeds may explain the reported underestimation of distance covered at this speed when compared to &MSS. The band width for ARB analysis method represented a 7.0km.hr⁻¹ difference which was reduced when the same calculations were applied to (6.3km.hr⁻¹) and &MSS (3.77km.hr⁻¹). The small band width between VHSR and SP distance observed with the application of &MSS to the time motion data supports the *most likely* statistical inference made.

When critiquing past research, 19.8km.hr⁻¹ has been used previously to represent VHSR distance during ARB techniques (Carling, Le Gall & Dupont, 2012; Bradley et al., 2011; Weston et al., 2011), despite recommendations to use a lower speed (Abt & Lovell, 2009). When re analysing THSR distance in this study using the higher arbitrary speed of >19.8km hr⁻¹ would have led to an underestimation of THSR distance by 1268m (340% decrease) compared to using the lower arbitrary speed of >15.0km.hr⁻¹ recommended by Abt and Lovell (2009), and used in this study. The average speed used to represent VHSR for all 4 IND techniques during data analysis was 18.79km.hr⁻¹, which represents a 4.2% increase when compared to the ARB speed of 18.0km.hr⁻¹. When the average IND VHSR speed of 18.79km.hr⁻¹ is contrasted to the popular use of 19.8km.hr⁻¹, the latter speed represents a 5.1% increase and leads to a much bigger discrepancy in VHSR distance. It would be tempting to suggest that conclusions made by Abt and Lovell (2009) which were applied to results in a latter study by the same authors (Abt & Lovell, 2013)
suggesting 18.0km.hr⁻¹ was a better representation of VHSR speed when contrasted to the previously documented 19.8km.hr⁻¹ were indeed correct. However, the lower speed of 18.0km.hr⁻¹ may be too low when compared to speeds attained at physiological events used in this study (MAS and 60%MSS), which represent the transition of exercise from a more- to a less aerobic based speed when applying individualised technique. It would be tempting to recommend the use of 18.79km.hr⁻¹ to represent VHSR as part of ARB analysis in future studies using elite u18 soccer players and indeed in a practical setting.

Strangely, when critiquing arbitrary speed zones used in past research to represent SP distance, the most commonly used speed is > 25.0km.hr⁻¹ (Bradley et al., 2011; Di Salvo et al., 2010; and Weston et al., 2011), which results in only a 5.2 km.hr⁻¹ difference between HSR speed and SP speed in some of the aforementioned studies (Bradley et al., 2011; Weston et al., 2011; and Carling, Le Gall & Dupnot, 2012) which seems very low and possibly insensitive to the metabolic shift from HSR to SP speeds and its subsequent metabolic demands on the athlete (Osgnach et al., 2010). The ARB speed of 25.0 km.hr⁻¹ used to represent SP in previous research correlates well with both ARB speed used in this study (> 25.0km.hr⁻¹) and the average speed used when employing IND methods (24.19km.hr⁻¹). It is therefore very tempting to agree with conclusions made by Abt and Lovell (2009) recommending practitioners and researchers alike when using ARB thresholds to strongly consider employing lower speeds for distance covered HSR and VHSR which are more closely linked with physiological markers of fitness status and functional speeds. Further, this study makes a
recommendation that using the default speed of 25.0 km.hr⁻¹ is sensible with its positive correlation with physical markers of sprint performance (80% MSS, 140% MAS, 30% ASR). When looking at the ARB speeds chosen to represent HSR, VHSR and SP distance in this study, it ties in closely with the speed used for all 4 IND methods to represent the same locomotor speed. The average speed used to represent HSR for all 4 IND methods was 14.97 km.hr⁻¹. Similarly, ARB speed to delimit VHSR was 18.0 km.hr⁻¹ which was only 0.79 km.hr⁻¹ lower than the average IND speed used for the same speed threshold. SP speed conforms to the same trend with ARB speed being only 0.81 km.hr⁻¹ faster than the average speed of all 4 IND methods (25.0 km.hr⁻¹ vs. 24.2 km.hr⁻¹ respectively). As a result, it may be fair to suggest that ARB speed zones may provide coaches with an accurate representation of player’s physical activities in a game if the speeds are chosen with a cute consideration, using a cohort of research recommendations. This method would be easy to implement in a practical setting were equipment, time and expertise are limited. Never the less, this method should only be used when comparing a player on an independent basis and should be used with caution if comparing players within a team. Using MSS as a single performance metric to individualise all locomotor categories resulted in interpretation errors, especially when compared to and suggests this technique shouldn’t be applied in future research or applied settings alike.

Another approach explored in current literature is the use of ventilatory thresholds, with particular reference to RCT to demarcate THSR (Abt & Lovell, 2009; Abt & Lovell, 2013). Using these fitness characteristics may give us a better indication of aerobic performance but may not be sensitive to
distance covered at VHSR and SP where a player’s anaerobic functionality is pertinent. Lacome et al., (2013) and Mendez-Villanueva (2013) used multiple fitness characteristics to represent HSR, VHSR and SP distance. The latter study estimated MAS and MSS from field based measures. This method may be favourable, especially to practitioners due to practicality and ease of implementation. The use of RCT, and MSS was used within method as a means to correctly represent the transition in speeds from high, to very high and maximal/ supra maximal exercise. Similarly, &MSS used two performance measures to demarcate LSR and HSR (MAS), VHSR (MAS – 29%ASR) and SP distance (30%ASR- MSS).

analytical approach is seen to be sensitive to changes in aerobic (see case study #4) and anaerobic (see case study #2) fitness characteristics both between participants and within season variation. The use of sophisticated laboratory equipment and expertise to both measure and interpret laboratory assessments means this method may not be widely accepted by sport practitioners although may be useful for practitioners in a research setting. Similar findings were shown when looking at 2 players (#8 and #12) who both operated in the same tactical position and both covered similar distances during matches within the respective match cluster (±350m). Due to physical attributes pre disposing players to certain positions (Di Salvo et al., 2007; Di Salvo et al., 2009) both players recorded very similar speeds at MSS (± 0.2 km. hr⁻¹); MAS (± 0 km. hr⁻¹) and (± 0.2 km.hr⁻¹), however their RCT (used to demarcate HSR within technique) was 10.8% different. As expected, the interpretation of intensity distribution using &MSS compared to ARB was meaningless, however when was applied, %THSR increased by 4.1% as a
result of the lower RCT speed. Although, &MSS seems a practical method to use within sport environment, and characterises match intensity distribution, especially at VHSR and SP speeds, its inability to detect a compromised aerobic fitness based change means speed used to represent HSR needs rethinking.

A novel approach to data analysis was seen when contrasting the effect of using as opposed to MAS to represent VHSR for the and &MSS techniques respectively (see Table 5). The use of 29% ASR to delimit the upper limit of VHSR for both and &MSS (Table 5) was deliberate to understand the differences in using and MAS on the distance covered VHSR and offer some recommendations for future researchers. It was hypothesized that the use of MAS would result in a greater distance covered VHSR with a concomitant reduction in SP distance due to higher speeds associated with MAS compared with . As expected, MAS was higher than (18.87km.hr⁻¹ vs. 18.61 km.hr⁻¹), resulting in a 22m group based average increase in VHSR when employing . If was used as opposed to MAS to delimit VHSR in &MSS technique, the overestimation of distance covered at high speed may have been reduced slightly and fall more in line with distances reported when applying ARB and speed thresholds. However, the underestimation of distance covered VHSR of 22m during &MSS analysis versus results in less than a 0.5% relative distance covered when TDC is accounted for. A relative underestimation of <0.5% (THSR) when using MAS is negligible given the inaccuracies of distances covered at high speed and above associated with the use of GPS within team sports. This has been reported to be 1-10% with the higher percentages attributed to higher running speeds (Gray et al., 2010).
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It is suggest that the extra cost associated with testing may not outweigh the difference in speeds between and MAS with the detection of MAS less costly and less obtrusive to the individual who may experience discomfort and possible side effects when exercising to complete exhaustion in an unfamiliar laboratory setting. MAS can be estimated more easily in field based conditions using a ‘Vam – EVAL’ method outlined in Bucheit et al. (2010), using a modified version of the University of Montreal Track Test (Leger & Boucher, 1980), with this method producing a low typical error (3.5%, CI: 90%) reported by a more recent study (Bucheit & Mendez-Villanueva, 2013). Furthermore, given the sophisticated laboratory requirements for \( \dot{V}_\text{O2} \) assessment and its sensitivity to the determination protocol (Buchheit & Laursen, 2013), the method incorporating MAS is economical and practical in squad-based sports and characterises the match intensity distribution, particularly in the VHSR and SPR categories.

Case study 4 further highlighted the issues when using squad based means with it masking subtle changes within the data which effect the overall interpretation of external match demands. Again, Player #6 showed a decrement throughout the season whilst his MAS stayed relatively stable. The estimation of MAS from the peak treadmill speed reached upon achieving a test termination criteria meant that distance at VHSR within the &MSS method was possibly underestimated when compared to applying due to a reduction in speed at within this method. The application of &MSS did in fact successfully identify an increase in %TVHSR during the season due to a decrease in the fitness of the player from test 1 to test 4; however it was not
as sensitive to changes when compared to methods and therefore underestimated when compared to method. The above may suggest the use of provides a more valid measure of VHSR due to its increased sensitivity to fitness changes. This would somewhat contrast the work of Bucheit et al. (2013) who exclaimed the importance of MAS and its association with repeated sprint performance, with improvements in this being closely linked to increased repeated high speed running performance. The pertinence of the aerobic capacity and running economy in the successfulness of RSA occurrences has being reported (Bucheit et al., 2012). Due to increased recovery processes between bouts, it could be argued that the use of MAS to individualise TMA data possess more ecological validity when compared to measures. To our knowledge, this study is the first to report unallocated distance numerically (distance covered above the upper limit of SP distance) for all match cases. When MSS was used as the endpoint of the SP speed threshold, a total of 383m was reported as unallocated either due to false movement (poorly fitted vests) or players covering distance at a speed higher than their recorded MSS achieved during the testing period. In contrast, when the higher, fixed value of 35.0km.hr⁻¹ was employed to represent the upper limit of the SP threshold, unallocated distance reduced to 174m. When MSS was applied as the terminate speed for SP distance, we made a presumption that players did indeed reach their maximum speed during testing. Further, it would be tempting to infer that the higher speed of 35.0km.hr⁻¹ for the capture of ‘supra maximal’ performance during a game where the motivational stimulus both intrinsically and extrinsically is much greater than a linear sprint test in an un-competitive environment. Although using 35.0km.hr⁻¹ may enable
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Supra maximal performance to be accounted for, some of the reported ‘unallocated’ distance may have been achieved due to the aforementioned unit movement artefact which may result in misleading distances at the top end of a players speed range. It may be recommended that further research into match activities use a players MSS +10% to represent the upper limit of the SP threshold to account for the differences between testing and playing conditions which may result in distances covered above the players field tested MSS due to either failure to reach their true MSS during testing, or the effect of supra maximal performance in an applied competitive setting. Of course there is no scientific justification of using +10% MSS, however intuitively this would seem sensible, representing ~ 3.14km.hr⁻¹ increase in a players field measured MSS (using performance data noted in Table 6).

Case Study #1

Mendez-Villanueva et al. (2011) reported that players with a higher MSS (> 35km.hr⁻¹) reach a lower percentage of their MSS capacity compared to their slower counterparts (< 32.0km. hr⁻¹), who reached a higher percentage during games (89 vs. 84% respectively). Further to this, an improved MAS and MSS during the season results in an increased running performance during a game based on absolute thresholds (Buchheit, Simpson & Mendez-Villanueva, 2013). Although this seems obvious, it would be tempting to infer that a player who improves their physical match performance during the season would be a result of increased MAS or MSS speeds, necessitating lower match running performance demands (Mendez-Villanueva, Bucheit,
Simpson & Bourdon, 2012). Using ARB thresholds, or single anaerobic biased performance measure would prohibit these changes to be accounted for and does not factor in-season improvements/ decrements in aerobic and anaerobic performance (see Table 12), which is seen with regular training stimulus (Krstrup et al., 2003). When comparing a player who attained the highest MSS during the testing period (Player A) with a player who achieved the lowest MSS (Player B) in this study, the average distance they covered (according to the MSS technique) THSR and SP for all games was lower for Player A, compared to the ‘slower’ Player B; 974 vs. 2085m, and 51 vs. 118m respectively. The difference was also apparent in relative terms with %THSR being 11% (player A) and 19% (player B) and %SP 0.6 and 1.1% for player A and B respectively. The constraints of playing position and technical ability on distances covered above high speed, and the reduced ability to cover distance at MSS (achieved in a linear, un-functional setting) has been heavily documented (Bradley et al., 2009; Bucheit, Simpson & Mendez-Villanueva, 2013; Di Salvo et al., 2007), which could have had an impact on the above results. Bucheit, Simpson & Mendez-Villanueva (2013) found for some positions, on field running performance and physical capacities is essentially position dependant with the magnitude of correlations between match running performance varying between tactical positions with it being especially large for forward players, while for other positions very low/ non-significant (centre backs). Bradley et al. (2009) extended this reporting centre backs to hit a much lower maximum speed in a game compared with attacking midfield players; 26.32 km.hr⁻¹ vs. 28.55km.hr⁻¹ resulting in a 8% reduction. This is mirrored well in our study with Player A being a centre back and Player B
being an attacking midfield player, and could somewhat attribute the lower distance achieved by the quickest players in a team. Moving forward, it could be argued that MSS would provide a more accurate method of individualising match activities if it was measured in the players ‘playground’ using a maximum speed attained during competitive match play (maximum match speed; MMS) as opposed to a linear conformity. The only disadvantage of this suggestion would be that practitioners and coaches would need a library of game data for all players before they could calculate appropriate speed thresholds. It may however provide a more accurate picture of a player’s activity which sees positional demands effecting the ability to execute at the top end of their maximum speed capabilities, especially for centre backs who are normally only seen to sprint maximally if they are caught either out of position, or a 30–40m maximal linear recovery run is necessitated. Results from this study indeed correctly individualise match activities based around maximum performance characteristics, but a more accurate approach may use ‘on field’ maximum performance measures, which is achieved in the environment where players are judged.

Case Study #2

Although, using a player’s games specific sprint speed may give more functional validity, it would only seem suitable to demarcate distance covered >VHSR which uses anaerobic energy to fuel bouts of exercise, and would have to be viewed with caution if it were to be used to individualise activities from low speed through to sprinting. Case study #2 provides an illustration of
this comparing relative match intensity distribution for two players who have similar aerobic functionality combined with differences in their sprint ability (see Table 10). When applying ARB thresholds to define locomotor categories both player #8 (lower MSS) and player #16 (higher MSS) displayed similar relative match distribution at %TVHSR and %SP. However, when MSS were used to anchor the locomotor categories, player #16 %TVHSR was underestimated when compared to player #8. Using MSS as a single measure of performance per se is erroneous as it presumes anaerobic energy production fuels all activity within a players speed range and neglects the role aerobic energy production has in supporting recovery from maximal bouts. Both MSS integrate aerobic and anaerobic measures of performance to reflect HSR, VHSR and SP distance and in the case of player #8 and player #16 more accurately reflects their intensity distribution with the underestimation of %TVHSR when using MSS and the neglect of any difference in intensity when applying ARB is non-apparent.

**Case Study # 3**

Table 11 shows that when match activities are individualised according to thresholds, the change in interpretation and subsequent rank of a player within a team is the largest. Abt and Lovell (2009) reported similar findings when comparing the effect of using methods as oppose to ARB thresholds. Table 11 shows that the interpretation of a player’s distance covered at HSR was the same for all methods except which saw Player A, who was ranked for all other methods drop to rank, similarly Player Ds rank changed 2 places
Intensity distribution determination methods in soccer.

when thresholds were applied. It is not surprising that the players showed a correlation with the change in rank. Player C (13.81km.hr\(^{-1}\)) and Player D (13.79km.hr\(^{-1}\)) had the lowest, with Players A and B having the highest (16.2 and 15.59 km.hr\(^{-1}\) respectively).

Limitations/ Future recommendations
One consideration for future research would be to investigate the maturation state/biological age of the players involved in the cohort. The physiological make up and external response of adolescent players is markedly different to that of an adult player as their physiological performance characteristics are still developing (Wells & Norris, 2009). Within youth age players, maturation can have a significant effect on performance with its effect on (Mirwald & Bailey, 1986), power output (Martin et al., 2004), maximum strength (Tonson, Ratel, Le Fur, Cozzone & Bendahan, 2008; Temfemo, Hughes, Chardon, Mendengue & Ahmaidi, 2009) and speed (Matthys et al., 2012) being reported to date. Although elite youth soccer player are more mature than the general population (Sherar, Baxter-Jones, Faulkner & Russell, 2007), and late maturers are less represented by older age groups within an academy (Hirose, 2009), the effect of maturation and chronological age needs to be accounted for due to its effect on performance characteristics, for late developers. A simple approach to monitoring maturation state within elite youth performers was outlined by Matthys et al. (2013). This process used adult stature prediction model using values derived from a predicted adult stature calculation (Sherar et al., 2005) and age at peak height velocity calculated with the Mirwald et al. (2002) method which concludes if the players have, or haven’t reached full maturation status. Maturation status or biological age could be used as a criterion measure to individualise thresholds, and may be an interesting development area from this research.

Taking a more holistic approach to intensity distribution, determination of and successful performance in soccer would surely merit the inclusion of high load intensity bouts which sees the players change speed rapidly over 0-10m but
fail to reach the speed which anchor > HSR. Although using results from laboratory tests and their application to match activities are useful, it shouldn’t be used solely to predict overall successfulness of performance due to the complexity of the demands of a soccer game (Svensson & Drust, 2005). It may be fair to say, that this study, as well as previous research into match intensity demands in soccer focus solely on extensive demands when a player has distance and space to travel at higher speeds. Although extensive evidence has been provided stating high intensity actions are successful discriminants of performance, a large amount of high load actions in a game may have been disregarded in previous research which actually present a major metabolic stress on the player (Osgnach et al., 2010) and actually have a higher physiological impact to the player. If we are looking to gain a true representation of match play, future research may want to consider bouts of high intensity which sees players change speed rapidly, over a set time period, over short distances (>3.0m.s.s) alongside distances covered >HSR.

The modern game, especially at the elite level is changing with technical ability of players improving and tactical constraints placed upon the players increasing (Bucheit et al., 2010); meaning space to exploit is less apparent. Similarly, high load accelerations and decelerations require large breaking and propulsive forces and therefore the muscular endurance capacities of muscles (leg muscles in particular) have a great bearing on the ability of the player to perform high intensity actions and distance near the end of the game under fatigued conditions, with the actions requiring high quadriceps strength during initiation of the movement and high hamstring strength upon stopping the action (Silva et al., 2013). Some TMA software manufacturers have
already integrated such calculations within their software as the appreciation of high load accelerations and decelerations is becoming more prevalent. One manufacturer uses the incident of high metabolic load distance, which summates distance covered >HSR in addition to distance covered whilst acceleration and deceleration (>3.0m.s.s). This may become more useful in the future as GPS technology advances and hopefully becomes more reliable with shorter changes in speed and direction in an applied setting.

It could be that speed thresholds are more easily individualised by doing a simple performance test to determine the metabolic favouring of a player. It has been shown before that players who have a MSS < 32km.hr\(^{-1}\) have a more aerobic performance persuasion, whereas players who reach MSS > 35km.hr\(^{-1}\) have an anaerobic bias (Mendez-Villanueva et al., 2011). Integrating a simple aerobic, anaerobic and RSA test within a periodised training plan could help understand a player’s performance bias and as a result could help more accurately choose what individualised method to use with different phenotype players (aerobic vs. anaerobic).

One recommendation for future studies within this domain would be to consider using Vam-EVAL approach presented by Bucheit et al. (2010) as a prediction of MAS, which may compensate for players who fail to complete the last stage of a test due to one of the test termination criteria’s being met. An altered equation was used if a player failed to complete a ‘stage’ of the test; \[-\text{Eval} = S + (t/60*0.5)\] where \(t\) is time in seconds of the uncompleted stage. In the present study, data from the last completed stage was used for data analysis, with data from an incomplete stage disregarded. Although this was
consistent for all players, it may be unfair for a player who is very close to completing the next stage of the test and would present MAS data which is lower than the athlete’s true maximum.

To conclude, this study supports the findings of Abt and Lovell (2009) recommending that speed thresholds are individualised in order to gain a true representation of the players daily, weekly and monthly training load. This could impact heavily on the processes at a Football Club including modified training, exercise prescription and recovery processes. These speed zones need to be chosen with careful considerations using performance measures accounting for aerobic and anaerobic performance equally. The use of or &MSS would be recommended with having the advantage of being more sensitive to changes in aerobic fitness and therefore HSR profiling. However, if a field based test to accurately predict is developed, &MSS would provide a more ecologically valid method which is easier to implement in a practical setting with all, MSS and subsequent ASR calculations being achieved in a field environment.

Concluding Messages –
1 - It would be beneficial for similar research to be conducted examining the difference in using maximum performance sprint speed instead of maximum linear sprint speed to use as part of the calculations. It would be predicted that this will not only account for the individual characteristics but also the style of play and position of that player in their match specific environment. Further to this, the use of MSS +10% should be examined as an end point for SP distance aiming to encompass supra maximal performance, whilst still eliminating erroneous distance covered due to unit movement artefact.

2 – If ARB analysis is to be used, suggest using a higher speed of 18.79 km.hr⁻¹ to represent VHSR distance which more accurately represents speeds achieved at 100% MAS and 60% MSS used to represent the transition from a more to a less aerobic speed in player dependant speed zones.

3 – Use of MSS/ MAS as a single measure to base a player’s full speed range around is misleading due to difference in individuals physiological make up which leads them to have a certain metabolic favouring.

4 – We suggest using thresholds based around a player’s metabolic bias would somewhat reduce this flawed intensity distribution and would go some way to apply individualised thresholds to individuals in a team with careful consideration of aerobic/ anaerobic strength as oppose to a blanket individualised technique being used for a squad regardless of metabolic favouring.

5 – AND &MSS could both be used in a research and practical setting respectively. However, a field based detection of RCT would be desirable to
Intensity distribution determination methods in soccer.

sensitise &MSS analysis technique to changes in aerobic fitness and therefore better represent distance at high speed.

6 – The use of MMS to MAS ratio (Mendez-Villanueva et al., 2013) in conjunction with the IND thresholds used in our study may allow practitioners to select the individualised technique more appropriately (see concluding message #4) for each player to avoid over- under estimation of distances > %HSR due to phenotype favouring.

References:
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**Appendix 1**

**University of Hull**
Department of Sport, Health, and Exercise Science

**PARTICIPANT INFORMATION SHEET**

| Project Title | Variations Between Match Activities According to Arbitrary and Individualised Thresholds. |
### Purpose of Study and Brief Description of Procedures

*(Not a legal explanation but a simple statement)*
Introduction
Soccer is the widest participated sport in the world; recent growth has seen it become the most lucrative and supported sport worldwide. As a result, the amount of soccer specific research has increased. Over the last 2 decades, interest into the area of match analysis has increased with the physical demands of soccer match play becoming well publicised within the male version of the game. However, the vast majority of research uses set values to categories such activities as running and sprinting and do not take into account individual physiological differences.

Purpose of the study.
The purpose of this study is to determine the activity profile of male elits scooer players according to individualised thresholds.

The study will analyse the following:
- Total distance covered
- Total distance covered at 6 different speed intensities; standing, walking, jogging, low intensity running, high intensity running and sprinting.
- Positional differences between the following techno tactical positions; external defenders, central defenders, central midfielders, external midfielders and forwards
- Variation between matches due to factors such as opposition, tempo, tactics etc. (coefficient of variance)

Data Collection:
- Firstly, you will be fitted with a GPS unit, which will be situated between the shoulder blades and held in place by a custom fit vest.
- You will be required to wear this for the full duration, or the full time that you spend on the pitch.
- The unit will then be removed from the vest at the end of the game and you will be asked to remove the vest.
- Your information will then be analysed to obtain the necessary variables.

Your rights as a participant.
Your participation in this study is voluntary. You are free to refuse to commence the testing or withdraw at any time in the proceedings without penalty or prejudice and without giving any reason for so doing. No disadvantage will arise from any decision to participate or not.

The results of the research may be published, but your name will not be used, and no individual identifying information will be provided. All data collected will be coded to retain anonymity, and any personal details will be stored in a locked filing cabinet with access limited to the investigator.

It has been made clear to me that, should I feel that these Regulations are being infringed or that my interests are otherwise being ignored, neglected or denied, I should inform Professor Lars McNaughton, Chair of the Department of Sport Science Research Ethics Committee (Tel: 01482 466927) who will undertake to investigate my complaint.
Intensity distribution determination methods in soccer.

and Exercise Science

Informed Consent Form

Name of test(s): *The optimal intensity for a half time re warm up in soccer for maintaining first half intensity: the assessment of endurance performance*

The participant should complete this sheet himself / herself

1. Have you completed the pre-exercise medical questionnaire? YES / NO
2. Do you understand that your information will be treated as confidential? YES / NO
3. Have you read the participant information sheet? YES / NO
4. Have you had the opportunity to ask questions and discuss the test? YES / NO
5. Have you received satisfactory answers to all of your questions? YES / NO
6. Have you received adequate information about the test? YES / NO
7. With whom have you discussed the nature of the test?

8. Do you understand that you may withdraw from the test:
   - At any time
   - Without needing to give reason
   - Without prejudice YES / NO
9. I have read, discussed and fully understand the requirements, procedures, and potential risks involved in the test and give consent for my participation.

Signature……………………………………………     Date…………………………..

Test Administrator……………………………………   Date…………………………

Parent/Guardian if Minor………………………………………..   Date…………………………
VO2 Max Test - Informed Consent Form

Name of test(s): Maximal Oxygen uptake test on a treadmill ergometer.

The participant should complete this sheet himself / herself

1. Have you completed the pre-exercise medical questionnaire?   YES / NO
2. Do you understand that your information will be treated as confidential?  YES / NO
3. Have you read the participant information sheet?   YES / NO
4. Have you had the opportunity to ask questions and discuss the test?   YES / NO
5. Have you received satisfactory answers to all of your questions?  YES / NO
6. Have you received adequate information about the test?  YES / NO
7. With whom have you discussed the nature of the test?  
8. Do you understand that you may withdraw from the test:
   • At any time
   • Without needing to give reason
   • Without prejudice   YES / NO
9. I have read, discussed and fully understand the requirements, procedures, and potential risks involved in the test and give consent for my participation.

Signature…………………………………………………..     Date…………………………..

Test Administrator……………………………………   Date…………………………

Parent/Guardian if Minor………………………………………..   Date…………………………
Pre-Exercise Medical Questionnaire
The information in this document will be treated as strictly confidential

Name: ...............................................................................................................................................

Date of Birth: ...................... Age: .............. Sex: .....................................................................

Blood pressure: ................. Resting Heart Rate: .....................

Height (cm): ............ Weight (Kg): ............

Please answer the following questions by putting a circle round the appropriate response or filling in the blank.

1. How would you describe your present level of exercise activity?
   Sedentary / Moderately active / Active / Highly active

2. Please outline a typical weeks exercise activity
   ...............................................................................................................................................
   ...............................................................................................................................................
   ...............................................................................................................................................

3. How would you describe your present level of lifestyle activity?
   Sedentary / Moderately active / Active / Highly active

4. What is your occupation? ...........................................................................................................

5. How would you describe your present level of fitness?
   Unfit / Moderately fit / Trained / Highly trained

6. Smoking Habits Are you currently a smoker? Yes / No
   How many do you smoke .......... per day
   Are you a previous smoker? Yes / No
   How long is it since you stopped? .......... years
   How many did you smoke? ........... per day
Intensity distribution determination methods in soccer.

7. Do you drink alcohol? Yes / No
   If you answered Yes and you are male do you drink more than 28 units a week? Yes / No
   If you answered Yes and you are female do you drink more than 21 units a week? Yes / No

8. Have you had to consult your doctor within the last six months? Yes /
   If you answered Yes, Have you been advised not to exercise? Yes /
   No

9. Are you presently taking any form of medication? Yes /
   If you answered Yes, Have you been advised not to exercise? Yes /
   No

10. To the best of your knowledge do you, or have you ever, suffered from:
    a Diabetes? Yes / No  b Asthma? Yes /
    No  c Epilepsy? Yes / No  d Bronchitis? Yes /
    No  e Any form of heart complaint? Yes / No  f Raynaud’s Disease Yes /
    No  g Marfan’s Syndrome? Yes / No  h Aneurysm / embolism? Yes /
    No  i Anaemia Yes / No

11. Are you over 45, and with a history of heart disease in your family? Yes /
    No

12. Do you currently have any form of muscle or joint injury? Yes /
    No  If you answered Yes, please give details…………………………………………………………
    ................................................................................................................................................
    ................................................................................................................................................
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13. Have you had to suspend your normal training in the last two weeks? Yes /
    No  If the answer is Yes please give details…………………………………………………………
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106
14. ★ Please read the following questions:
   a) Are you suffering from any known serious infection? Yes / No
   b) Have you had jaundice within the previous year? Yes / No
   c) Have you ever had any form of hepatitis? Yes / No
   d) Are you HIV antibody positive Yes / No
   e) Have you had unprotected sexual intercourse with any person from an HIV high-risk population? Yes / No
   f) Have you ever been involved in intravenous drug use? Yes / No
   g) Are you haemophiliac? Yes / No

15. As far as you are aware, is there anything that might prevent you from successfully completing the tests that have been outlined to you? Yes / No.

IF THE ANSWER TO ANY OF THE ABOVE IS YES:
   a) Discuss with the test administrators or another appropriate member of the department.
   b) Questions indicated by (★) answered yes: Please obtain written approval from your doctor before taking part in the test.

PLEASE SIGN AND DATE AS INDICATED ON THE NEXT PAGE

Participant Signature: .............................................Date..........................

Test Administrator: .........................................................Date.....................

Parent if Minor: .............................................................Date: .....................
The departmental laboratories and equipment get used frequently and we need to know what facilities you need to complete your dissertation, when you will be using the facilities, and for how long. In some cases, consumables will need to be ordered for your dissertation.

So that we can plan in advance, this form needs to be submitted with your Ethics Application forms.

If your dissertation does not require the use of the labs, equipment, consumables, etc, please tick the following box and sign and date the form at the bottom of the page.

<table>
<thead>
<tr>
<th>1. Student's name</th>
<th>Frances Hunter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student's email</td>
<td><a href="mailto:scaryspice1@hotmail.co.uk">scaryspice1@hotmail.co.uk</a></td>
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<td>2. Supervisor's name</td>
<td>Ric Lovell</td>
</tr>
<tr>
<td>3. Location of testing (please tick)</td>
<td>a. Applied physiology lab</td>
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<td></td>
<td>b. Human performance lab X</td>
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<tr>
<td></td>
<td>c. Both labs</td>
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<tr>
<td></td>
<td>d. Field testing X</td>
</tr>
<tr>
<td>4. Equipment required</td>
<td>10 x GPS units</td>
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<tr>
<td></td>
<td>10 x Custom fit Catapult Vests</td>
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<tr>
<td>5. Consumables required</td>
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<td>6. Dates (please note that all testing in the human performance lab needs to be completed before Semester 2 starts)</td>
<td>a. anticipated date of starting testing 01/01/2010</td>
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<tr>
<td></td>
<td>b. anticipated date of finishing testing 01/04/2012</td>
</tr>
<tr>
<td></td>
<td>c. anticipated number of lab hours (if applicable)</td>
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<td></td>
<td>d. Ethics committee approval date /2011</td>
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Intensity distribution determination methods in soccer.
RISK ASSESSMENT PRO FORMA

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Test of maximal oxygen consumption using an incremental protocol on a motorised treadmill. Expired gases collected during exercise. Test carried out to volitional exhaustion.</th>
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<tbody>
<tr>
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<td>Date Assessed</td>
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<td>Signed</td>
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<table>
<thead>
<tr>
<th>Hazards</th>
<th>Risks and Specific Control Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Musculoskeletal Injury</td>
<td>LOW (C1 X L2) = R2 Extra demand is placed on the musculoskeletal system when performing intense physical activity enhancing risk of strains sprains or joint injury. <strong>CONTROL MEASURES:</strong> Pre-exercise screening to identify old or existing injury, Thorough warm up prior to test and stretching if required. Ice pack kept in lab in case of injury</td>
</tr>
<tr>
<td>Cardiorespiratory complications</td>
<td>MEDIUM (C3 X L1) = R3 Extra strain is placed on the cardiorespiratory system with increasing exercise intensity. In certain individuals this may increase the likelihood of Myocardial Infarction or related incident in a predisposed individual. <strong>CONTROL MEASURES:</strong> Pre-exercise screening, including age, family health history and current level of physical activity to identify ‘at risk’ individuals. Subjects should be accustomed to regular high intensity exercise.</td>
</tr>
<tr>
<td>Condition</td>
<td>Probability</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Nausea/vomiting</td>
<td>LOW (C1 x L2) = R2</td>
</tr>
<tr>
<td>Trip/fall</td>
<td>MEDIUM (C2 x L2) = R4</td>
</tr>
<tr>
<td>Feinting</td>
<td>LOW (C1 x L2) = R2</td>
</tr>
<tr>
<td>Bacterial / viral infection from respiratory equipment</td>
<td>LOW (C2 x L1) = R2</td>
</tr>
</tbody>
</table>
## Risk Evaluation (Overall)

- Medium Risk

## General Control Measures

1. Pre-exercise medical questionnaire.
2. Informed consent form.
3. Strict adherence to test protocol including warm-up and cool-down.
4. Close monitoring of subject by a test administrator.
5. Heart rate and oxygen uptake is continuously monitored to give an indication of demand being placed on the participant.
6. Visual communication is maintained between the subject and the experimenter throughout the exercise test.
7. All breathing apparatus must be cleaned and sterilised following standard departmental procedure.
8. A minimum of 2 people involved in conducting the test.

## Emergency Procedures

Emergency first aid is available if the subjects faints, falls or experiences cardiovascular complications. All test administrators have full knowledge of action in an emergency outlined in the departmental health and safety policy. Cleaning agents and equipment readily available to clean up any sweat, saliva, or vomit. Emergency contact number ext 5555.

## Monitoring Procedures

Continuously monitor the participant during and immediately after the test procedure. Participant should be advised not to leave the lab until physiological variables return to near normal.

## Review Period

- Annual

<table>
<thead>
<tr>
<th>Reviewed By</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>January 2011</td>
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### Department of Sport Science Research Ethics Committee

#### Risk Assessment Pro Forma

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<th>Procedure</th>
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<table>
<thead>
<tr>
<th>Hazards</th>
<th>Risks and Specific Control Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Musculoskeletal injury</td>
<td>LOW (C1xL1=R1) Extra demand is placed on the musculoskeletal system when performing physical activity. <strong>Control measures</strong>: pre-screening for old/existing injuries and a thorough warm up prior to exercise.</td>
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<tr>
<td>Cardiovascular complications</td>
<td>MEDIUM. (C3xL1=R3) Extra strain is placed on the cardiovascular system when exercising. <strong>Control measures</strong>: pre-screening questionnaire to assess the participant’s current level of fitness and status of health. At least one trained first aider to be present during the test.</td>
</tr>
</tbody>
</table>
### Risk Evaluation (Overall)

<table>
<thead>
<tr>
<th>LOW/ MEDIUM</th>
</tr>
</thead>
</table>

### General Control Measures

1. Pre-screening health and fitness questionnaire. 2. Strict adherence to the agreed protocol put in place by soccer club including a warm up and warm down. 3. First aid/physiotherapist on hand in case of injury. 4. Heart rate is continuously monitored to identify when the subject is exercising maximally. 5. Visual communication is maintained between the subject and experimenter throughout the exercise test.

### Emergency Procedures

Emergency first aid if the subject faints or experiences cardiovascular complications. A spillage kit is always present to swab up sweat, saliva or vomit. Experimentors have full knowledge of departmental emergency procedures. If first aid support or emergency medical support is required contact university report centre ext 5555.

### Monitoring Procedures

Continuously monitor the participant throughout and after the exercise test.

### Review Period

<table>
<thead>
<tr>
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<th>Date</th>
</tr>
</thead>
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<td></td>
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</table>
### Procedure
Wearing GPS units during games.

### Assessment Number
3

### Date Assessed
January 2011

### Assessed By
Signed

<table>
<thead>
<tr>
<th>Hazards</th>
<th>Risks and Specific Control Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS causing injury under a collision from an opposing player</td>
<td>LOW ((C1\times L1=R1)) The custom fit vests are made for the comfort of the players and are made with extra protection around the GPS pouch to prevent any discomfort pain to the player and similarly opponent. <strong>Control measures:</strong> Make sure the GPS unit is fitted correctly in the vest and fully inserted before commencement of game and data collection.</td>
</tr>
<tr>
<td>GPS unit dislodging during the game.</td>
<td>LOW. ((C1\times L1=R1)) The GPS unit could potentially come out of the custom fit vest and present a trip hazard to the players on the pitch or cause the game to stop until the GPS unit is removed from the pitch or secured back in the vest. <strong>Control measures:</strong> Ensure the GPS unit is full secured in the vest before the game starts. Ensure the flap is fully covering the GPS unit making it extremely difficult for the GPS unit to move during physical activity.</td>
</tr>
</tbody>
</table>
### GPS Units injuring an opponent under a collision/ impact

**LOW (C1xL1=R1)** An opposing player may get injured if challenging the player wearing the GPS unit e.g. challenging for a header.

**Control Measures:**
The GPS units are secured between the shoulder blades of the player. This is an area which would very rarely come under contact by an opposing player during a collision due to its locality. Also, the vests are designed purposefully to reduce any potential of injury to both the wearer and opponents.

### Risk Evaluation (Overall)

**LOW/ MEDIUM**

### General Control Measures

1. Ensure GPS units are fitted correctly before the start of the game.
2. Make sure the participant has a correctly fitted vest to prevent any extra movement in the GPS unit and to prevent it becoming lose, the vest should hug the player, it should feel tight but comfortable.
3. 

### Emergency Procedures

### Monitoring Procedures

Ask the players to feedback after games on the comfort and if they experience any discomfort during collisions. Also feedback regarding the sizes of the vests and if they are the correct size for the individual.

### Review Period

<table>
<thead>
<tr>
<th>Reviewed By</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>January 2011</td>
</tr>
</tbody>
</table>
**Intensity distribution determination methods in soccer.**

### Department of Sport Science  
**Research Ethics Committee**  
**Risk Assessment Pro Forma**

<table>
<thead>
<tr>
<th><strong>Procedure</strong></th>
<th>Working with Minors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assessment Number</strong></td>
<td>4</td>
</tr>
<tr>
<td><strong>Date Assessed</strong></td>
<td>January 2011</td>
</tr>
<tr>
<td><strong>Assessed By</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Signed</strong></td>
<td><strong>Position</strong></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Hazards</strong></th>
<th><strong>Risks and Specific Control Measures</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Children coming in to contact with potentially dangerous others.</td>
<td>LOW <em>(C1xL1=R1)</em> The players will be under constant supervision by coaches and officials from the club whom all hold necessary certification and police background checks. <strong>Control measures:</strong> When away from the coaching staff or away from usual environments (training ground/match days) monitor who comes in to contact with the players and make sure I am with them at all times and no one is left alone with the players.</td>
</tr>
<tr>
<td>Cardiovascular complications</td>
<td>MEDIUM <em>(C3xL1=R3)</em> Extra strain is placed on the cardiovascular system when exercising. <strong>Control measures:</strong> pre-screening questionnaire to assess the participant’s current level of fitness and status of health. At least one trained first aider to be present during the test.</td>
</tr>
<tr>
<td>Risk Evaluation (Overall)</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td></td>
</tr>
<tr>
<td>LOW/ MEDIUM</td>
<td></td>
</tr>
</tbody>
</table>

General Control Measures

1. Make sure persons whom come in to contact with minors have a CRB background check, or someone CRB checked are in attendance whenever an individual is in contact with the minors.

<table>
<thead>
<tr>
<th>Emergency Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Monitoring Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keep an up to date CRB background form with you at all times incase others wish to check suitability to be working with the minors.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Review Period</th>
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</table>

<table>
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<tr>
<th>Reviewed By</th>
<th>Date</th>
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<tbody>
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<td></td>
<td>January 2011</td>
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</tbody>
</table>
**Intensity distribution determination methods in soccer.**

Appendix 10

University of Hull
Department of Sport, Health, and Exercise Science

RISK ASSESSMENT PRO FORMA

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Expired gas analysis general assessment (No Subjects)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment Number</td>
<td>5</td>
</tr>
<tr>
<td>Date Assessed</td>
<td>January 2011</td>
</tr>
<tr>
<td>Assessed By</td>
<td></td>
</tr>
<tr>
<td>Signed</td>
<td>Position</td>
</tr>
<tr>
<td>Hazards</td>
<td>Risks and Specific Control Measures</td>
</tr>
<tr>
<td>Bacterial / viral infection from respiratory</td>
<td>LOW (C2 x L1) = R2</td>
</tr>
<tr>
<td>equipment</td>
<td>Because over a number of tests there will be multiple users of the same mask there is a risk of cross infection from bacteria / viruses etc.</td>
</tr>
<tr>
<td></td>
<td>CONTROL MEASURES: face masks and rotary flow sensors must be cleaned and then sterilised in a Milton bath and then thoroughly dried as soon as possible and between each test participant.</td>
</tr>
<tr>
<td>Electrical Hazard</td>
<td>LOW (C1 x L1) = R1</td>
</tr>
<tr>
<td></td>
<td>Measurement utilises electrical equipment</td>
</tr>
<tr>
<td></td>
<td>CONTROL MEASURES: electrical equipment checked prior to use for safe use and only equipment that has been safety approved is used.</td>
</tr>
</tbody>
</table>

Risk Evaluation (Overall)
### General Control Measures

1. Pre-exercise medical questionnaire.
2. Informed consent form.
3. Strict adherence to test protocol including warm-up and cool-down.
4. Close monitoring of subject by a test administrator.
5. Heart rate and oxygen uptake is continuously monitored to give an indication of demand being placed on the participant.
6. Visual communication is maintained between the subject and the experimenter throughout the exercise test.
7. All breathing apparatus must be cleaned and sterilised following standard departmental procedure.
8. A minimum of 2 people involved in conducting the test.

### Emergency Procedures

Emergency first aid is available on site.
All test administrators have full knowledge of action in an emergency outlined in the departmental health and safety policy.
Cleaning agents and equipment readily available to clean up any sweat, saliva, or vomit.
Emergency contact number ext 5555

### Monitoring Procedures

All equipment checked regularly prior to use for correct and safe functioning.

<table>
<thead>
<tr>
<th>Review Period</th>
<th>Annual</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Reviewed By</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>January 2011</td>
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</tbody>
</table>
Introduction and Pre-Amble

In designing research involving humans, researchers should demonstrate a clear understanding of what is being undertaken and why this will be of benefit to society.

The research should be based on sound Ethical Principles, and these criteria will be considered by the Ethics Committee before approving a project.

When completing this form, please do so carefully and provide as much information as possible, for example, provide Letters of Support/Permission if you are conducting research off campus, or provide your relevant qualifications if you have them and the research is dependent upon them e.g. First Aid Certificate.

ALL of the following details must be provided, word-processed and in 11 point font.

NOTE: Once you have received ethical approval for your research, YOU MUST NOT change any aspect of the research, including METHODOLOGY, without approval. Failure to do so will mean a FAIL of the DISSERTATION.
**Intensity distribution determination methods in soccer.**

Please either tick the appropriate box or provide the information required.

<table>
<thead>
<tr>
<th>1. Date of Application</th>
<th>28.12.2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Anticipated Date of Completion</td>
<td>December 2012</td>
</tr>
<tr>
<td>3. Title of Investigation</td>
<td>To Compare the Differences Between Match Activities Determined Using Arbitrary and Individualized Thresholds.</td>
</tr>
<tr>
<td>4. Subject Area</td>
<td>Performance Physiology</td>
</tr>
<tr>
<td>5. Student Investigator</td>
<td>Frances Hunter</td>
</tr>
<tr>
<td>6. Student number</td>
<td>200703865</td>
</tr>
<tr>
<td>7. Email address</td>
<td><a href="mailto:Scaryspice1@hotmail.co.uk">Scaryspice1@hotmail.co.uk</a></td>
</tr>
<tr>
<td>8. Telephone/mobile number</td>
<td>07824533501</td>
</tr>
<tr>
<td>9. Principal Investigator</td>
<td>Dr Ric Lovell</td>
</tr>
<tr>
<td>10. Email address</td>
<td><a href="mailto:r.j.lovell@hull.ac.uk">r.j.lovell@hull.ac.uk</a></td>
</tr>
<tr>
<td>11. Telephone/mobile number</td>
<td>07866683148</td>
</tr>
</tbody>
</table>

11. Is this

<table>
<thead>
<tr>
<th>11.1 an Undergraduate project?</th>
<th>Unit Name</th>
<th>Unit Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.2 a Postgraduate project?</td>
<td>X</td>
<td>MSc Research</td>
</tr>
</tbody>
</table>

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### 12. Purpose and benefit of investigation

*Statement of the research problem with any necessary background information.*

(No more than 1 side of A4) ALL references used must be included in the Reference List (not included as part of the 1 page A4 limit)

**Introduction:**

Soccer is the widest participated sport in the world; recent growth has seen it become the most lucrative and supported sport worldwide. As a result, the amount of soccer specific research has increased. Over the last 2 decades, interest into the area of match analysis has increased with the physical demands of soccer match play becoming well publicised within the male version of the game (Mohr, Krstrup and Bangsbo, 2003; Krstrup et al., 2003; , Krstrup et al 2006; Di Salvo et al 2007; Meyer et al 2000; Stroyer, Hansen and Klausen 2004; Bangsbo 1994.

Mohr, Krstrup and Bangsbo et al (2003) analysed the distances covered by top class soccer players (TCP). It was reported that top class players covered a total distance of 10.86 ± 0.18 km per game. Further to this, it was found that TCP covered a distance of 2.43 ± 0.14km and 0.65 ± 0.06km high intensity running and sprinting respectively.

Mohr et al (2003) also looked at performance within a game. Activity profiles of elite TCP were determined by coding time motion analysis, and splitting activity levels into the following locomotor categories: standing (0 km.hr⁻¹), Walking (6 km.hr⁻¹), jogging (8 km.hr⁻¹), low-speed running (12 km.hr⁻¹), moderate speed running (15 km.hr⁻¹), high speed running (18 km.hr⁻¹), sprinting (30 km.hr⁻¹). The study found that top class male soccer players spend 19.5 ± 0.7, 41.8 ± 0.9 and 29.9 ± 1.3 of the game time standing, walking and low intensity running respectively. Further to this, it was concluded that the 8.7 ± 0.5 and 1.4 ± 0.1 of the game was spent in the high intensity running and sprinting categories respectively. The same study also looked at differences between half and half performance. The top class players ran more at both high and low intensity in the half vs half (31.1 ± 1.3 vs 28.4 ± 1.4 and 9.0 ± 0.4 vs 7.7 ± 0.5). Similarly, top class players were found to sprint more in the vs half and also performed more bouts of low and high intensity runs in the half.

**Importance:**

The importance of quantifying match activities of elite youth soccer players is paramount for player development and for a greater understanding on the physiological make up of a soccer performance. Research has strongly backed the notion that the greater amount of high intensity running performed by an individual or team, the higher level the individual/ team is performing. Further to this, coaches can use the information received from match feedback to critique and help players improve their physical performance during games. Similar to this, it can help coaches develop match specific fitness and when deficiencies become apparent in an individuals physiological game pattern, these can be identified and improved during training time.

The importance of this research is to realise the accuracy of past research findings that have used arbitrary thresholds and possibly make future research more accurate and objective. Alternatively, the research could conclude that the variation and difference between match activities according to arbitrary or individualised thresholds are not statistically different. This could make research using standardised thresholds valid and make research less complex and time consuming.

**Research Problem:**

In light of the above problems, there is need for research which compares match activities using arbitrary values and individualised values. The importance of match activities in team sports is well publicised however; the accuracy of the conclusions drawn can be questioned due to the standardised nature of the methodological procedures. Therefore the aim of this study is the compare the differences in physiological performance indicators during elite youth soccer games using individualised thresholds and arbitrary thresholds.
13. Is this study

<table>
<thead>
<tr>
<th>13.1 Collaborative? e.g as part of Staff Research Project</th>
<th>If yes, say with whom (Provide details if Staff Member)</th>
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<tbody>
<tr>
<td></td>
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</table>

| 13.2.1 Replication of | |
| 13.2.2 New | X |

14. Participants

<table>
<thead>
<tr>
<th>14.1 Number</th>
<th>Squad Based Research (15)</th>
</tr>
</thead>
</table>

| 14.2 Criteria for inclusion and exclusion of the Participants: | The subjects must be elite male players who are currently competing as part of a scholarship offered at a professional Youth Team and will be aged between 16-18 years. The subjects must be fit and injury free so not to prohibit match intensity. Data to be used in the research study will be that of players who have completed the full 90 minutes of the game. Game data will be taken from the FA Youth Alliance League and will not include any Cup/ friendly matches. All participants are apparently fit and healthy individuals. |
|---------------------------------------------------------------|

| 14.3 Are these normally 'pre approved' within Ethics Guidelines | Yes | X | No |

15. Details of the design and protocol(s)
15.1 Provide details:

**Procedure:**
In order to collect data, 10 outfield players will be fitted with a 5 Hz GPS unit (MimimaxX, Catapult, Australia) throughout the competitive 2010-2011 and 2011 - 2012 seasons. The development of portable non-differential Global Positioning System (GPS) devices has provided a method to quantify match-play workload in open field environments. The GPS units will be situated between the subjects shoulder blades and positioned throughout the game using a custom fit vest. The GPS units will be turned on 15 minutes prior to kick off time to acquire adequate signals for the data to be used (6 satellites required). In order for the units to maintain the signal, they will be kept outside with a clear view of the sky, until fitted into the vests prior to kick off.

The kick off time, along with half time, start of the second half and full time will be recorded for analysis purposes. Also, substitutions and time of substitutions will be noted.

At full time, the units will be switched off and placed back into the holder case. One unit will be used to mark the dimensions of the pitch so that the players movement can be tracked in relation to the specific pitch size. To do this, the unit will be switched back on and will be held in each of the following 4 areas for a period of approximately 15 seconds; centre of the goal, centre of the opposite goal, the spot where the half way line meets the touch line and the same at the opposite side (see diagram below).

![Diagram of pitch dimensions](image)

Figure 1 – Shows the 4 places were the GPS unit is held to determine pitch dimensions.

All GPS units have a number on the back, therefore the unit number will have to be recorded with which player/ playing position uses it, in order for playing variations/ match to match variations (Coefficient of variance) to be obtained.

Variables measured will be total distance covered, and time spent in each one of 6 different locomotor Categories. These categories will be standing, walking, jogging, low intensity running, high intensity are running and sprinting, with the speed thresholds described by Mohr et al (2008).

The playing positions will be determined using the following categories; external defenders, central defenders, central midfielders, external midfielders and forwards (Di Salvo 2007). Also recorded will be player load.
Intensity distribution determination methods in soccer.

Figure 2 – Shows the different playing position in relation to a soccer pitch (Taken from Di Salvo et al 2007).

Individualising Thresholds:

In accordance with Abt and Lovell, (2009) the players individualised thresholds will be calculated using a incremental ramp protocol on a treadmill ergometer (ELG55, Woodway, USA). The test will be used to determine maximal oxygen uptake ($\text{max}$), peak treadmill speed, second ventilatory threshold ($\theta$) and total test time. Before test commencement, all participants will partake in a 10 minute warm up on a cycle ergometer (Monark, Vaberg, Sweden).

The participant will begin the test at 7km.hr for 3 mins with the speed increasing by 0.2 km.hr every 12 seconds thereafter.

As the players are used to competing outside, the treadmill will be set at a 2% gradient to compensate for such things as air resistance and terrain which the participants would have to overcome in their ‘normal’ environments. A breath – by – breath analyser (Quark b2, Cosmed, Rome, Italy) and a heart rate (HR) monitor (Polar Electro Oy, Finland) will be used during testing. The breath – by – breath analyser will be calibrated at the start of every trial in line with the manufacturer’s instructions. Participants will be encouraged throughout the test with a test termination criterion of either; volitional exhaustion or a plateau of $\text{max}$ (change of less than 0.2 l.min despite further increases in speed).

will be calculated using the same method as explained in Foster, Hoyos, Earnest and Lucia, (2005) and will be determined using visual inspection by an experienced physiologist. Upon determining $\theta$, the speed at which this occurred will be noted and used as $\theta$ (the speed will be noted to the nearest, but lower 1 km.hr).

Sprint Testing:

All players will complete a thorough warm up before the start of the Sprint Testing. Each participant will complete 5 x 20m sprints with a 2 minute rest in between trials. Timing gates (SmartSpeed Timing Gates, Fusion Sport, HaB International Ltd, Warwickshire, UK) will be placed at the 10m and 20m mark to allow a ‘flying’ 10m sprint time to be obtained, using the fastest recorded sprint time. This process was used in the study by Harley, Barnes, Portas, Lovell, Barrett, Paul and Weston, (2010), with Carling, Bloomfield, Nelsen and Reilly, (2008) validating the distances used to determine the ‘flying’ sprint time as they found soccer players rarely completed a sprint bout exceeding 20m. This will be used for the ‘sprinting’ threshold when coding match activities.

All laboratory testing will be repeated every 4-6 weeks. This will be repeated on the same day and same time.
15.2 Are these normally 'pre approved' within Ethics Guidelines | Yes | No ✗

16. Indicative methods of analysis

Data Analysis:
Differences between team positions will be tested by a one-way analysis of variance. Differences between arbitrary and individualised thresholds will be determined using the Student’s paired t-test.

17. Intended duration and timing of Project (Start and End Date) | Dec 2010 – Dec 2012

18. Location of project (If External to HU, provide a letter of support or approval to undertake work) | Hull City AFC Training Ground – Ideal Standard

19. Substances to be administered (If NONE, state NIL) (Make sure you complete a Risk assessment Form)

State their potential hazards, if any, and the precautions to be taken | NIL

20. Degree of discomfort that participants might experience (make sure you complete a Risk assessment Form)

The participants will experience minimal discomfort during testing. Participants will experience expected exhaustive discomfort associated with high intensity aerobic exercise, VO2 max tests and possible match specific fatigue.

21. Who will be present during testing? Please indicate their skills (eg First Aid/Coaching Certificate)

Youth team head coach
Youth team assistant coach
Ric Lovell (Lab testing)
Lab Technician (Lab Testing)
Student investigator as outlined in part 5
Team physiotherapist

The head and assistant coaches along with the Student Investigator all have CRB clearance. The participants will not be allowed to have contact with any other individual unless a person with CRB clearance is present at all times. The team physiotherapist, student investigator and the two coaches all have up to date first aid training.

22. Signature
## 23. Attachments

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>23.1</td>
<td>Risk Assessment(s) (MUST BE INCLUDED)</td>
</tr>
<tr>
<td>23.2</td>
<td>Participant Information Sheet (MUST BE INCLUDED)</td>
</tr>
<tr>
<td>23.3</td>
<td>Informed Consent Form (MUST BE INCLUDED)</td>
</tr>
<tr>
<td>23.4</td>
<td>Pre-Test Medical Questionnaire (MUST BE INCLUDED)</td>
</tr>
<tr>
<td>23.5</td>
<td>Dissertation Testing Requirements (MUST BE INCLUDED)</td>
</tr>
<tr>
<td>23.6</td>
<td>Collaboration evidence/support (see 13)</td>
</tr>
<tr>
<td>23.7</td>
<td>Collaboration facilities (see 18)</td>
</tr>
</tbody>
</table>

*(Place a tick in the appropriate description)*
Intensity distribution determination methods in soccer.

24 STAFF SUPERVISOR/INDEPENDENT REVIEWER

I am the Principal Investigator mentioned on page 2 of this document and have read this project and discussed the implications with the student mentioned on page 2 as the Student Investigator.

I believe that this project CAN be given Ethical Approval with Minimal Input from the Department of Sport, Health and Exercise Science, Human Ethics Committee.

NAME: ____________________________
DATE: ____________________________
SIGNATURE: ____________________________

I have independently reviewed the above project and believe it CAN be given Ethical Approval with Minimal Input from the Department of Sport, Health and Exercise Science, Human Ethics Committee.

NAME: ____________________________
DATE: ____________________________
SIGNATURE: ____________________________

I am the Principal Investigator mentioned on page 2 of this document and have read this project and discussed the implications with the student mentioned on page 2 as the Student Investigator.

I believe that this project CANNOT be given Ethical Approval with Minimal Input from the Department of Sport, Health and Exercise Science, Human Ethics Committee.

NAME: ____________________________
DATE: ____________________________
SIGNATURE: ____________________________

26. ETHICS COMMITTEE APPROVAL

CHAIR ETHICS COMMITTEE: ____________________________
APPROVAL GIVEN ON (DATE) ____________________________