ACTIVITY PROFILES OF PROFESSIONAL AND SEMI-PROFESSIONAL FOOTBALL PLAYERS WITH SPECIAL REFERENCE TO POSITIONAL DIFFERENCES

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ABSTRACT

Purpose: We tested the hypothesis that professional football players would run a further total distance (km), high speed distance (>5m/s) and perform more accelerations (>2m/s) and decelerations (>2m/s) than semi-professional football players over the course of the 2019/20 season. **Method:** 22 male League 1 and 24 Isthmian League Southeast Division football players were tracked using a 10Hz Playertek (Catapult, Australia) GPS devices during the 2019/20 season. The study examined retrospective data already gathered by the clubs for the respective games in the season. A Playertek GPS system was used to capture total distance (km), high-speed running distance (>5m/s) as well as the accelerations (2m/s) and decelerations (>2m/s) of all outfield players. Players were assigned into three different categories based on their position, which was either defender, midfielder or attacker. Statistical analysis was conducted using a mixed model ANNOVA using SPSS statistics (SPSS Inc., Chicago, IL, USA) with statistical significance set at $P < 0.05$. **Results:** Professional football players performed more statistically significant total running distance for both defenders (mean SD: professional, 11.78 ± 0.64 km; semi-professional, 9.13 ± 0.35 km, $P<0.01$) and midfielders (mean SD: professional, 11.91 ± 1.13 km; semi-professional, 9.60 ± 0.91 km, $P<0.01$). With semi-professional attackers completing more decelerations (mean SD: semi-professional, 214.32 ± 53.76; professional, 156.98 ± 18.36, $P=0.026$) than professional football players. No difference was noted for total distance for attackers and no difference in high-speed distance and accelerations for any position. For all variables there was also no difference found intra-team for all positions in both the professional and semi-professional team. **Conclusion:** There were evidently clear differences between professional and semi-professional football players in total distance and decelerations. However, this might not be as evident as first thought. This can be attributed to several external factors such as opposition quality, strategy, tactics and training level of the athletes. More research is needed to examine the differences between professional and semi-professional teams with an emphasis on more specific positional grouping to help differentiate positions better.

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Covid Impact statement

Covid hit the UK in early 2020 and still to this day the ongoing effects of its exposure on physical and mental health as well as the wellbeing of the country is felt. The first initial 'lockdown' begun in March 2020 and since then there have been multiple 'lockdowns' and changes in policy that have deeply affected the present study. Unfortunately, due to circumstances stemming from covid involving players and research staff isolating, it's unknown effects on health and particularly respiratory health it was decided that the study would be altered to allow the effect of covid on the study to be reduced. Meaning that the present study would instead look at retrospective data, that had previously been collected by both respective clubs for their football seasons. There was a high risk during the study that an insufficient amount of data would be collected as a result of participants not able to make it due to governmental covid regulations and isolation periods. The retrospective nature of the study reduced the risk to both participants and researchers for the study. In hindsight this was the correct measure to take to ensure completion of the study within the required time whilst also considering the health and wellbeing of all those involved.

INTRODUCTION

The real-world application of Global Positioning Satellite (GPS) is extensive. From its first conceptual use in the military to current modern-day use in phones, and most importantly to the current study in sports performance and analysis in a variety of team and individual sports (Alexandrow, 2008; Peterson et al., 2009). With the ability of GPS to quantify movement demands of players in training sessions and competitive games it allows for the prescription and monitoring of training loads whilst allowing sports scientist to understand demands their athletes undergo (Jennings et al., 2010; Scott et al., 2016). As a result, GPS is now commonplace in both practice and research in all levels of competition (Malone et al., 2017). The most common performance measures recorded by modern-day GPS devices are total distance, total high-speed runs as well as accelerations and decelerations (Aughey, 2011).

The present study aims at understanding differences in positional GPS performance indicators in football, and to further understand these differences across competitive leagues with a key emphasis on the positional differences in and between teams, in both a professional and semi-professional setting. GPS has presented itself as a relatively cheap but useful tool in a range of different sports that has developed significantly through technological improvements which have been shown to improve both reliability and validity of its outputs (Aughey, 2010; Cummings et al., 2013). GPS devices are classified by the rate at which they sample per second, with the first conceived GPS devices having a sample rate of 1Hz (one sample per second) (Scott et al., 2016). 1Hz and even 5Hz GPS devices, although useful in certain situations have prominent limitations that inhibit its practical application in a sporting context (Scott et al., 2016). A 10Hz GPS device has shown to have superior reliability and validity in its outputs when compared to a 15Hz device in the study of Johnson et al. (2014). Although more research needs to be conducted to confirm the findings. With the 10Hz device having been found to show no differences from criterion measures when replicating team sports movement including those specific to football (Vickery et al., 2014). Other options to

GPS are available in order to record similar data parameters. Video tracking is one such system, but doesn't provide a viable option for many, especially on a low budget and particularly semi-professional football clubs. As they are relatively expensive even though costs have decreased in the last 10 years through other competitive products (Barris & Button, 2008).

With football being the most popular sport in the world with more than 1.7 million active teams (Reilly & Williams, 2003; Wong et al., 2009) it is important to understand the differences in ability at the highest level of performance all the way through semi-professional down to amateur. The type of competition, which refers to how competitive the league is e.g., Premier League, or Non-League has a direct influence on the activity profiles of football players (Rienzi et al., 2000). With much current research only highlighting elite level performers in footballs top divisions (Premier League, Championship, League 1). There is a serious neglect of research into semi-professional football and the performance analysis of its players.

From the small amount of literature available, it has been shown that semi-professional players spend less of the match at high intensity when compared to elite players who spend 12.4 ± 2.5% more of their time performing high intensity activity (Bangsbo et al., 2006). A player's position will ultimately determine the demands they face during a game affecting their activity profile and physiological capacity (Reilly et al., 2000; Bangsbo, 2014). It is already evident from research that there is a significant difference in work rates between different playing positions ($P<0.05$) (Di Salvo et al., 2007). Many studies have concluded that midfielders will typically cover the most distance during a game, with defenders and in particularly center backs covering the least (Mohr et al., 2003). Central attacking midfielders, full-back and strikers were found to be the positions where high-intensity running activity occurred the most often and for the longest distance, with center-backs and defensive midfielders covering the least (Di Salvo et al., 2007). Although this is helpful research and assists in the understanding of individual positional differences in a competitive game, the vast majority of literature investigates elite level athletes with semi-professional football not well documented.

The present study aims at understanding differences in positional GPS performance indicators in football, and to further understand this difference across competitive leagues with a key emphasis on professional and semi-professional football. Currently there is limited research into semi-professional football and performance in general, with much of the literature outdated and therefore does not consider advancements in sports science and GPS technology. Moreover, gathering accurate data on players game-by-game performance in non-league or semi-professional football had previously been difficult (Dobson et al., 2000). Being able to understand semi-professional football and performance indicators through GPS analysis can help in clubs' recruitment of players from lower leagues. Additionally, an emphasis on positional differences will help this further by releasing more information about individual performance rather than whole team performance. The present study aims at understanding the activity profiles of both professional and semi-professional football players with a key emphasis on positional activity profiles and to examine differences if at all any, between competitive leagues and intra-team. Findings will help to understand the difference in physiological, and performance demands between players in a team and across leagues.

A study by Di Salvo et al. (2013) found football players in the championship (second division) performed more high-speed running and overall sprints than players in the highest football tier in England (Premier League). Other studies examining different leagues across the world have contradictory findings. Particularly that of Ekblom (1986) and Mohr et al. (2013). In which, both put forwards findings that suggest professional athletes in the highest division perform more high intensity runs whilst also highlighting that they also perform at a maximal speed for a longer duration than any league below.

There is currently a plethora or research studies and papers with a key emphasis on elite and professional football. In stark comparison there are a very finite number of studies examining semi-professional football and even less showing the comparisons between the two. The current study aims at filling this gap for several reasons. Firstly, this will assist clubs in both a semi-professional and professional setting. It can help in the recruitment of players from a lower league and higher leagues. When performance factors are examined, it will help to better understand those that are either underperforming or overperforming at their respective levels.

A lot of professional leagues 1 and 2 football teams will send first team players and academy scholars on loan to national league sides and lower in order to get experience and game time. This will help to understand if this is beneficial as its essential that the demands are at least similar for this to be somewhat beneficial.

Similarly, it will help professional clubs in terms of scouting lower league players who are at semi-professional level but have the capabilities of playing at a higher level and threshold. Likewise, this can be reversed and aid in scouting and recruitment of semi-professional clubs as previous performance data was relatively unknown. Additionally, it will help practitioners particularly in a semi-professional setting to effectively plan training programs around match performance.

The aim of the study is to create an understanding of the performance demands of semi-professional footballers and to compare this to professional elite football players. Moreover, it is to better comprehend the key differences in performance factors between both types of football players and what sets them apart and to comprehend if there are any differences in performance. The hypothesis of the study is that key activity profile parameters such as total distance, high-speed running distance, accelerations and decelerations be significantly greater for professional football players than semi-professional football players.

REVIEW OF LITERATURE

Popularity

Football is performed at a variety of different levels of experience by children, adults, men, and women (Stølen et al., 2005). Football is also the world's most popular played sport in almost every nation at the professional level (Reilly & Williams, 2003). Practiced by more than 300 million people with more than 1.7 million active teams throughout the world (Wong et al., 2009; Castillo-Rodriguez et al., 2020). Over the past two decades there has been an increase in interest in match-analysis within football and with this analysis comes the quantification of performance in individuals and teams and its ability in identifying physiological demands of the sport (Di Salvo et al., 2007).

Physiology

Physiological requirements of football performers lay much emphasis on skill rather than fitness as well as the difficult task of studying the sport scientifically (Tumilty, 1993). However, match performance is heavily determined by tactical, psychological/social, technical, and physiological capacity as well as the training and health status of athletes (Bangsbo & Michalsik, 2002; MacArthur & North, 2007). However, in addition to technical and tactical skills, endurance performance as well as other physiological factors also play an important role in success of football players (Sarmento et al., 2018). Moreover, not only will the football player walk and run but a multitude of energy demanding activities such as accelerations, decelerations, jumping, change of direction, getting up from the ground and static muscle contractions will be performed throughout a match (Bangsbo & Michalsik, 2002). A high number of specific skills with simultaneous cognition efforts are performed under high physiological stress over the duration of a competitive match (Mohr et al., 2020). Football players perform a range of different explosive and tactical movements which repeatedly requires complex physiological demand which is highly taxing on both aerobic and anaerobic energy systems (Dolci et al., 2018). The advancement in sport technology and tracking systems have resulted in a greater amount of data and information regarding football physiology and match performance (Dolci et al., 2020). Typical body fat percentages of football players in a team range from 9-16% (Reilly et al., 1990). This plays a role in the body shape and physique of football players, when doing so it is also important to consider limb girth, bone diameter and skinfold thickness measures as well as body mass and height. From recent reporting's of football players, it is evident that there is a lean towards a more mesomorphic body type; however, it is shown to vary considerably dependent upon the nationality and the level of play the performer is at (Reilly et al., 1990; Reilly, 2003). This is important and possesses many benefits in game performance with actions such as walking, turning, accelerating, kicking the ball and more, heavily benefiting from this muscular body type (Reilly, 2003). During a game blood lactate concentration will vary from 7-8 mmol/L and by the end of a game muscle glycogen stores will be empty, players be hypohydrated and have a significantly increased body temperature (Ekblom, 1986). A frequent challenge that most football players will face is that they must often focus on the concurrent development of several physiological parameters (Marin-Pagan et al., 2020). This becomes an even more pressing issue with the inclusion of Covid-19 considered. The impact of covid can now also effect physiology and general fitness depending on the length of the isolation-training period. Moreover, another physiological characteristic of professional football is the long recovery of performance and physiological systems after a game (Krustrup et al., 2011). As a result of the COVID-19 lockdowns professional players are required to play games with short recovery thus negatively impacting performance and increasing the risk of injury (Bengtsson et al., 2018; Rago et al., 2020). This change in not only physical performance but recovery period has differing effects in individuals and can vary by position, thus these reductions in physical outcomes should be monitored closely by clubs on an individual-by-individual basis (Varley et al., 2018). During the lockdown period there is likely to have been a great decline in football specific fitness due to the long duration and restricted possibilities to train (Mohr et al., 2020).

It's important to constantly monitor players physiology and performance as recent literature has suggested that between the 2006/2007 and 2012/2013 football seasons there has been an increase in 2% in total distance and 30% in high intensity runs; This demonstrates a clear evolution in the game and differing physical and physiological demands (Bush et al., 2015). This impact can be further altered by the effect of covid. The multifactorial physiological demands in elite football are linked closely to multiple physiological systems which as a result must be stimulated in training (Mohr & Iaia, 2014). An example of modern training methods to improve football-specific skills and physiological characteristics is High intensity interval training (HIIT) and Small Sided Games (SSG) (Kunz et al., 2019).

Movement Characteristics

Football is a complex sport that requires a high level of tactical, technical and physical ability to succeed (Dolci et al., 2020). During a competitive game a combination of powerful activities, together with technical and tactical gestures are performed intermittently over the duration of the game (Dolci et al., 2020). The ability to quantify change of direction along with acceleration and deceleration of an athlete during a match may be even more important for successful sporting performance (Lockie et al., 2011). This is important in many aspects of the game, as Withers et al. (1982) has shown that during a competitive football game a player will make on average 50 turns. Moreover, its importance is emphasized as in many sports including football, athletes are required to change their direction as well as accelerate and decelerate (Docherty et al., 1988). With these movements used in conjunction with other important football related movements such as passing, dribbling, and striking the ball (Sheppard & Young, 2006). In football, agility can be used to help anticipate direction and timing of the ball as well as be used to respond to cues such as action of opposition players which is crucial for success (Sheppard & Young, 2006). Agility is an essential component in team sports as well as football, with agility not having a global definition but often defined as the ability to change direction and start and stop quickly (Gambetta, 1996). Acceleration and deceleration are key components of agility as it assists in the performers ability to stop and start quickly.

As a result, there are similar morphological and biochemical determinants of agility, acceleration, and maximal speed (e.g., muscle fibre type proportions) with assumptions that these are all highly related and correlate closely to one another (Little & Williams, 2003). However, much investigation surrounding this area is still inconclusive and inconsistent in its findings, with this area requiring more investigation before a decisive conclusion can be presented (Little & Williams, 2003).

A football game will last 90 minutes in duration, with elite players running on average 10-13km every game with goalkeepers covering around 4km, with this intensity close to their anaerobic threshold for outfield players (80-90% of maximal heart rate) (Bangsbo et al., 1991; Stølen et al., 2005). Typically, throughout a game a sprint will occur every 90 seconds, with the average sprint lasting around 2-4 seconds (Bangsbo et al., 1991). Between 1-11% of the total distance covered during a competitive game is from sprinting, equating to 0.5-3.0% of effective play time (when the ball is in play) (Bangsbo et al., 1991; Helgerud et al., 2001; Mohr et al., 2003). There is a significant difference in work done between the first and second half in a competitive football match. With exercise intensity reduced and the distance covered between 5-10% less in the second half compared to the first half (Mohr et al., 2003). Movements in football are characterized with high intensity, short actions and breaks of differing duration (Gkonbalaj et al., 2018). With each player performing between 1000-1400 mainly short activities throughout the duration of a competitive game (Mohr et al., 2003).

The typical run intensity of team-sport athletes ranges from 80-140 $m.min^{-1}$ throughout a competitive match (Cummins et al., 2013). This equates to an average speed of 1.3-2.3 $m.s^{-1}$ which by most standards cannot be classified as high intensity (Delaney et al., 2018). This distinctively looks at mean speed which considers both high and low intensity runs and even times when players will be walking. Due to the nature of play involving both high and low intensity running, football is classed as an intermittent sport. Which can be described as exercise with high-intensity bouts (above lactate threshold) alongside periods of submaximal effort (below lactate threshold) over a prolonged period of time which utilizes both aerobic and anaerobic energy systems (Lemmink et al., 2004). Due to the length of a football match lasting 90 minutes, the main source of energy production is through aerobic metabolism, with work intensity throughout the match in elite athletes close to anaerobic threshold (Stølen et al., 2005). This in mind, elite football players need not have any extraordinary capacity within any areas of physical performance but a somewhat reasonably high level across all areas (Reilly et al., 2000). This is noticeable in many areas but specifically VO_2max in which elite male footballers have a mean value between 56-69 $ml \cdot kg^{-1} \cdot min^{-1}$ (Reilly, 1994 cited Bangsbo & Michalsik, 2002).

Professionals vs. Semi-professionals

Most teams within the football league system are classified as semi-professional. In the UK, there are the top 4 leagues which are classed as professional (levels 1-4) which is comprised of a total of 92 teams whereas semi-professional leagues (levels 5-8) have a combined total of 296 teams (Swallow et al., 2021). Due to budget limitations, semi-professional football teams in the past had reduced access to technology and sports science support. However, recent advancements including easier accessibility and more affordable technology has increased the ability to monitor the conditions of players at these levels (Swallow et al., 2021).

Studies have shown that activities profiles of football players and therefore match performance is influenced by the type of competition that the players are participating in (Rienzi et al., 2000). The high intensity running of elite football players will typically account for 8-10% of their total running distance (Mohr et al., 2003; Di Salvo et al., 2009). An elite top-class level player will perform approximately 150-250 intense actions per game and a high-intensity run (>19.8 $km \cdot h^{-1}$) every 72 seconds (Mohr et al., 2003; Bradley et al., 2009). Previous research had indicated that measurements of total distance covered and distance covered at high intensity of elite level players varies throughout the season but peaks at the end of the season (Mohr et al., 2003).

Although no measure of exact physical performance exists in elite football, the use of total distance and indeed high-intensity distance covered are useful indicators of this (Mohr et al., 2003). Previous studies have suggested that the quantity of high-intensity exercise is a valid measure of physical performance in football (Mohr et al., 2003). With much of this distance being covered by means of low-intensity running and walking but with the high-intensity periods of play proving the most pivotal; this factor proving to be the most distinguishable between elite and lower-level players (Bangsbo, 2014). This observation that elite football players perform higher amounts of high intensity running than players of a lower standard is well documented and strongly related to their training status (Krustrup et al., 2003). Research in the field shows that when playing against an opponent of a higher quality that both total distance and amount of high intensity running is higher when compared to lower quality opponents (Castellano et al., 2011; Di Salvo et al., 2009).

A study with findings on the contrary is that of Di Salvo et al. (2008), in which they have shown that the amount of high intensity running distance was also related to team success, with the bottom five (919 ± 128 m) and middle teams (917 ± 113 m) in the English Premier League completing significantly more (P=0.003) total high intensity runs than the teams in the top 5 (885 ± 113 m). The success of a team has the ability to influence the amount of high intensity activity that each position in a football team contributes, with previous activity in a game also having an effect (Di Salvo et al., 2008). Ultimately, Di Salvo et al. (2008) highlighted that overall tactical and technical effectiveness of a team can prove more important in determining success in football than possessing high levels of physical performance per se. This would strongly support reasoning as to why teams will lose to an 'underdog' or a team who are considered weaker as they could have simply prepared more tactically and effectively. In general, the relationship between physical capacity and match performance in football players is deeply complex and relies upon a multitude of intrinsic and extrinsic factors, some more controllable than others (Bradley et al., 2013). For example, there has been considerable research into 'home advantage' in football (Pollard, 1986). However, there has been limited research currently available which has considered how playing at home can influence work-rate and activity profiles of players in conjunction with other variables (Castellano et al., 2011). Regardless, there is still evidence suggesting that home teams cover a greater distance in low intensity running than away teams (Lago et al., 2010).

However, the findings of Di salvo et al. (2013) found that players in the second-tier league of elite football in the UK (championship) performed more high-speed running and overall sprints than players in the highest tier of professional football (Premier League). Moreover, they found championship players covered greater distances during jogging, running, high-speed running and sprinting. Similarly, the findings of Bradley et al. (2013) found that both players in the championship and league 1 performed more high-speed running (>19km/h) than players in the premier league (803, 881 & 681m respectively).

However, leagues in different countries across the world produce evidence on the contrary. With Mohr et al. (2003) highlighting international elite players perform 28% more high intensity runs (2.43 v 1.90 km) and 58% more sprints (650 v 410m) than players at a lower level. At higher levels of play in football there is an increase in the number of both tackles and headers with a greater percentage of the game performed at maximum speed (Ekblom, 1986). The study of Wisloeff et al. (1998) found results suggesting a positive relationship between maximal aerobic capacity, physical strength, and performance results in Norway's elite football league. Although leagues and therefore opposition, plays a part on the demands of performers, other factors such as tactical system, possession status, seasonal period, playing surface and environment can all influence match running demands (Carling et al., 2016). As playing against quality opposition has been associated with lower ball possession (Lago, 2009). With it possible that lower quality teams having to cover more distance at a higher intensity in order to regain possession (Bradley et al., 2013). Results from previous studies examining activity and physical profiles in professional football players across the top European leagues have been carried out by Bloomfield, Polman, Butterly, and O'Donoghue (2005); with much of the results highlighting significant variations in body mass, body mass index (BMI) and stature, leading to reports speculating different physical demands in each league (Dellal et al., 2011). Aerobic power, sprinting ability, and intermittent exercise performance have all been shown to vary significantly depending on not just playing position but level of competition in previous studies (Tamer et al., 1997). Moreover, other studies have highlighted similar differences between players in the same position and competitive playing standard (Jensen & Larsson, 1992).

There is an abundance of physiological data and activity profiles of elite level footballers from all around the globe. However, there are very limited studies examining semi-professional footballers. In one of the few studies examining semi-professional football performance, O'Donoghue et al. (2001) found that semi-professional football players performed more discrete movements (1427 ± 244) than elite players (1372 ± 130.1) during a competitive match. They defined a discrete movement as a movement with a single goal that involves a series of overlapping joint rotations e.g., passing, throw-ins etc. They also found that elite players spent 12.4 ± 2.5% of the match performing high intensity activity which was greater than that of semi-professional footballers (11.7± 4.3%). With both semi-professional and elite football players performing a significantly lower proportion of high intensity activity in the second half of a competitive match than the first half. The volume of high-intensity exercise is the pivotal factor which differentiates top and elite level football athletes from that of a lower and non-league standard (Bangsbo et al., 2006).

It is difficult to gather accurate data on players game-by-game performance in non-league or semi-professional football (Dobson et al., 2000). Much of the currently literature is outdated and therefore does not reflect advancements in football in previous years such as the easy availability of sports science academia available online. Coupled with new training methods and practices in non-league and semi-professional football, mean it is essential to research up to date activity profiles and to quantify and understand physiological demands of semi-professional footballers.

An objective and direct comparison of individual player performance across different leagues nationally and internally in England using results from published motion analyses or GPS studies is often difficult to use due to different data collection methods and threshold values for categories of movement intensities (Barros et al., 2007; Di Salvo et al., 2007). In order to maximize objectivity when comparing physical activity profiles between leagues and competition, the use of the same motion analysis or GPS software is essential (Drust et al., 2007). A difficulty lies heavily in obtaining sufficient data which allows for comparison with more emphasis lying on different clubs in their respective championships not using the same analysis system and not willing for their data to be shared publicly (Dellal et al., 2011). There is much research in current literature highlighting and quantifying physical demands and activity profiles of players in no more than one specific elite team with few examining and directly comparing performance between professional leagues (Dellal et al., 2011).

Positional specific

For the contemporary football player their physical profile in professional match-play is detailed and well described, especially when relating to their individual positions (Dellal et al., 2011). The success of an athlete in their chosen sport is directly related to anthropometric characteristics, body composition and their somatotype components (Carter & Heath, 1990). The position of a football athlete will determine their activity profile, demands and physiological capacity (Reilly et al., 2000; Bangsbo, 2014). There is shown to be a significant difference in work rates between different playing positions ($P<0.05$) (Di Salvo et al., 2007). The genetic characteristics of an athlete can influence their playing positions (Reilly et al., 2000). In the study of Stroyer et al. (2004), they found that in young elite football players in later puberty that due to their genetic characteristics they are highly specialized in their position on the field and the current level of competition they were playing at.

That said, the study of Bloomfield et al. (2005) which compared 4 European leagues in elite football found differences in body mass, stature, age, and BMI of players in different positions. With these differences attributed to differences in playing style, physical demands of the leagues themselves as well as different physical conditioning methods. Within a team there is an average individual difference of distance ran between each game of 0.92km, with no difference in the number of high-intensity activities between matches for each position and individual analyzed in the study of Bangsbo et al. (1991). Many studies have supported and presented unanimous differences in global positions (e.g., external defenders, central defenders, midfielders, and forwards) and have shown that their tactical position presenting itself as a key factor in the understanding and contributing factor to their physical activity profile (Braz et al., 2010 & Stølen et al., 2005). In the analysis of running intensity, distance covered, or activity profile of each player it was found to be directly dependent on their position and tactical function (Clemente et al., 2013).

Defenders

The primary directive of a defender in football is to stop opponents attack close to their own goal (Nyland, 2010). Typically, central defenders will cover less distance and produce fewer high intensity running plays and cover less total distance when compared to other positions, which can be attributed to tactical roles of each position but also lower physical capacity (Mohr et al., 2003).

In the study of Withers et al. (1982) they recorded fullbacks sprinting more than twice as much as central defenders with the average sprint lasting 2.5 times longer, with midfielders and attackers also sprinting significantly more than central defenders and for 1.6-1.7 times longer. In the study of Wisloeff et al. (1998) defensive players were found to have a significantly higher vertical jump height when compared to midfield players and found to have a similar jump height to forwards. With fullbacks performing the most high-intensity bouts ($P<0.01$). Moreover, defenders have been found to cover a significantly smaller distance in possession of the ball than any other position (Di Salvo et al., 2007)

Midfielders

Midfielders and fullbacks have the highest maximal oxygen intakes (>60ml·kg^{-1}·min^{-1}) due to the nature of their roles, also meaning they perform best on intermittent tests (Reilly et al., 2000). On the other hand, this leads to them also possessing the lowest amount of muscular strength when compared to other positions (Reilly et al., 2000). In the study of Dellal et al. (2011) they found that central defensive midfielders covered more distance than central attacking midfielders, with particular emphasis on the premier league but also finding that they performed the least amount of high-speed running and sprinting distance. External midfielders are found to cover the most high intensity running distance during a match (Carling et al., 2008). In terms of high intensity effort, wide midfielders have been reported to cover more distance and also have a reduced amount of recovery time between efforts compared to every position (Bradley et al., 2009; Di Salvo et al., 2009). Midfielders in general have been shown to spend the least amount of time performing low-intensity activity out of all the positions (Clemente et al., 2013).

Midfielders were found to cover 10% more ($P<0.05$) distance than forwards, with no significant difference found when comparing high intensity running (Bangsbo et al., 1991). Midfielders would typically cover the most distance, however specific playing styles would mean that there are some deviations in distance covered for certain positions (Bangsbo, 2014). Although this is the case there is a significant difference between players in the same position in midfield, this can be attributed to playing style and managerial tactics which explains the differences found between studies (Bangsbo, 2014). Whilst in possession, central attacking midfielders were found to cover the most high-speed running distance (Bradley et al., 2013). In football, the position of the player as well as previous activity in the game will determine the amount of high intensity activity in elite games, with the success of the team also though to play a part (Di Salvo et al., 2007). Additionally, in the French League 1, central-midfielders performed more high-intensity actions separated by short recovery times (<20seconds) while spending more time running at higher intensities during periods of recovery (Carling et al., 2016). This result was similarly echoed in the study of Bangsbo (2014), who highlighted central midfielders to cover the most high intensity running distance in a game (Figure 1). When in possession, external midfield players covered a significantly greater distance with the ball when compared to any other position (Di Salvo et al., 2007).

Forwards

Forwards covered the third most distance when in possession of the ball, below central and external midfielders. However, when comparing the first and second half of a competitive game, forwards were found to be the only position to cover significantly more ($P<0.05$) distance with the ball in the second half when compared to the first half (Di Salvo et al., 2007). With the position of goalkeeper excluded, forwards covered the least distance whilst not in possession (Clemente et al., 2013). When compared to every other position, forwards covered the most distance with the ball in possession (Clemente et al, 2013). Also spending the third largest amount of time in the low-intensity zone which was shown to be significantly different to that of midfielders ($P<0.01$) (Clemente et al., 2013). Both forwards and midfield players cover a larger total distance than defenders (Mohr et al., 2003)

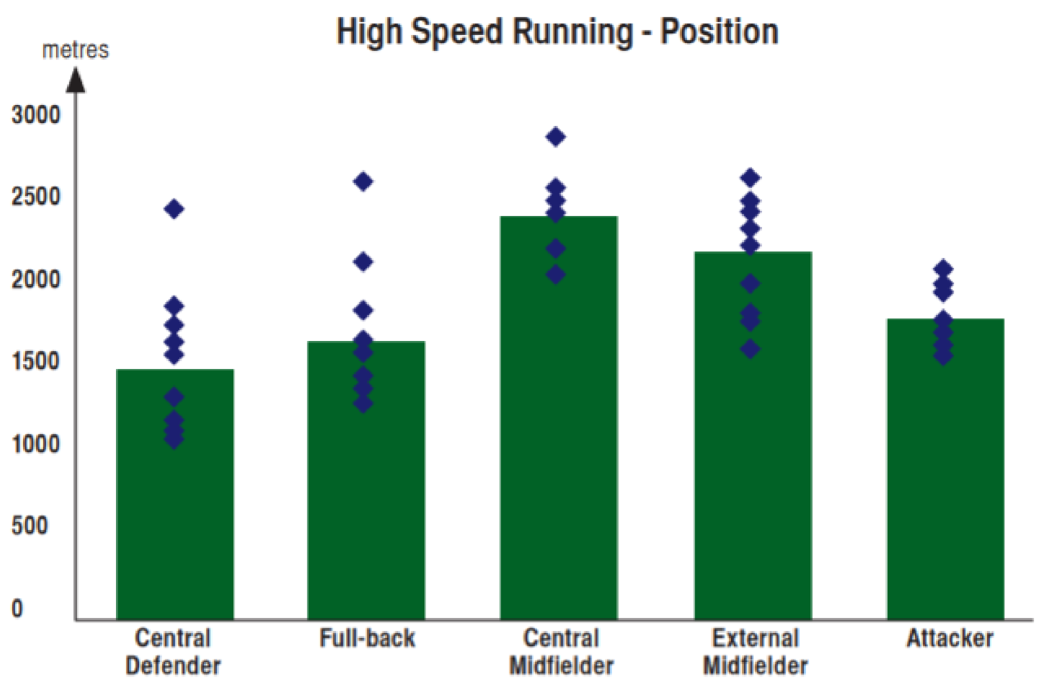


***Figure 1**. Distance covered with high-speed running during a game for players in different positions. Each player is represented by a symbol (Bangsbo, 2014).*

Top-class elite football players must be able to perform repeated high-intensity exercise. It's evident from several studies that the factors which influence the distance covered in a game is extensive; with technical ability, position, playing style, possession, opposition quality, environmental factors, playing surface, along with strategical and tactical roles in mind to name a few (Bangsbo et al. 2014). These internal and external factors will all play a role in previous and future research along with the present study and should always be considered when examining different data across leagues and countries.

GPS History over the years

The early work of 1944 Nobel laureate in physics Isidor Rabi made possible the use of modern-day global positioning system (GPS), through his breakthrough invention of the magnetic resonance method (Rabi et al., 1938; Aughey, 2011). This method would prove pivotal in the idea of an atomic clock before the second world war interrupted their work. The invention of the atomic clock was an integral part of the global positioning system, which helped pave the way for modern GPS (Rigden, 2000). The GPS works with the triangulation of signals from satellites, with the atomic clocks on board these satellites able to record the exact time as information, which would then be emitted by digital pulses (Rigden, 2000). The transit time in these low power radio signals were used to triangulate position of the GPS device (Witte & Wilson, 2004). This gives the position, with the displacement of this position allowing for other metrics such as velocity to be measured which sparked a keen interest of sports scientist, coaches and athletes alike in competitive sports (Aughey, 2011). The first instances of the practical uses of GPS technology came from its military application during the cold war, particularly for the US Navy and Air Force (Alexandrow, 2008). Much early work surrounding the application of GPS in a sports setting was based around its validity and precision at being able to measure steady state movement at varying velocities (Schutz & Chambaz, 1997).

These studies highlighted its practicality and usefulness, however its usefulness for research purposes was still limited due to its unreliability and inaccurate measures. In due course, years after initial studies investigating the validity and accuracy of GPS, technical improvements were made, through these advancements which brough with it core and essential improvements, came a shift towards methods to measure locomotion in both human and animal subjects (Hebenbrock et al., 2005; Larsson & Henriksson 2005).

GPS In Sport

GPS has been used to quantify demands of physical activity from training to competitive matches in football, rugby, triathlon, horse racing, Australian football and even orienteering (Petersen et al., 2009). GPS has the ability of quantifying the movement demands of players, which can provide invaluable information that can be used to understand the demands of competition in a competitive match or used to assess training loads through the development of individualized training programs (Jennings et al., 2010). In this sense, GPS data is used to prescribe, monitor, and alter an athlete's training load and helps in the understanding of demands faced by athletes during competitive matches (Scott et al., 2016). GPS data can enhance recovery programs and tailor training programs, making them match-specific and thus, leading to a reduction in the occurrence of injury and an overall improvement in performance (MacLeod et al., 2009). GPS holds the ability to enable sport scientists within clubs to analyze activity patterns of players and assess the characteristics of competition accurately (MacLeod et al., 2009). Furthermore, GPS allows the obtainment of accurate positional information about players, meaning this is of interest to coaches and support-teams due to its potential to relate performance to tactics allowing it to assist in the design of enhanced training regimes (Barris & Button, 2008). The distance covered by players each match which is recorded by GPS can be used according to their position to prescribe more specific training and has the ability to improve the efficiency of team training (Stølen et al., 2005).

Varying roles in sport science and medicine ranging from sports scientist to strength and conditioning coaches need to have a fundamental understanding of quantifying training loads internally and externally aiding in monitoring fatigue and optimizing performance (Impellizzeri et al., 2005). Data gathered from GPS can help in detailing and planning of periodization cycles (Scott et al., 2016). Moreover, it can help to understand specific and positional physiological demands of athletes in team sport (Cummings et al., 2013). The most common measures recorded by sports scientist are distance covered, total amount of high speed runs along with accelerations and decelerations (Aughey, 2011). From its first use, GPS was used to measure basic components of athlete's movement patterns including speed, distance and the total amount of accelerations and decelerations (Cummings et al., 2013). GPS integration in team sports is now commonplace in both research and practice, they are seen in both individual and team sports at all competitive and non-competitive levels (Malone et al., 2017). There has been much progress in advancing the capabilities of GPS over the years, with this and its usefulness in a sporting context there had been an exponential increase in the number of peer-reviewed research publications (Figure 2) since the very first paper which utilized GPS technology (Larsson & Henriksson, 2001; Malone et al., 2017). This exponential growth is seen particularly in PubMed databases which saw an increase in research outputs using GPS from 3 to 136 articles per year between 2001 and 2018 (Malone et al., 2020).

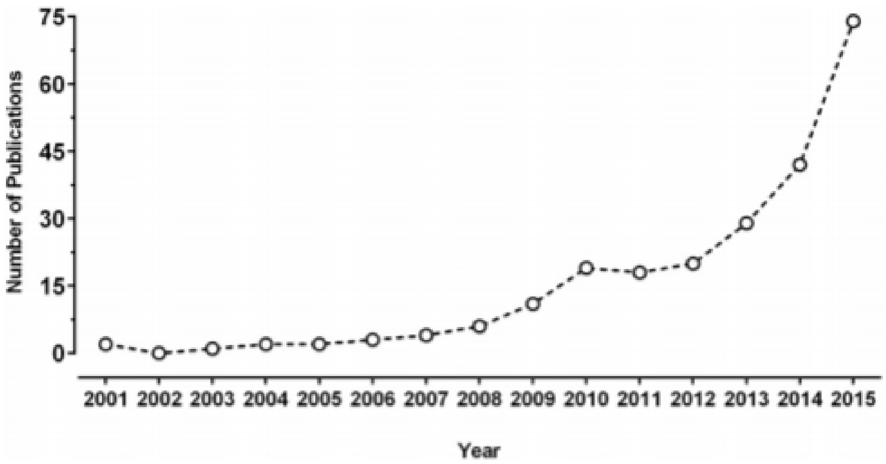


***Figure 2**. The number of research studies published using GPS devices from 2001 to 2015. The key words 'GPS sport' were used in the search and included studies involving human subjects in applied sporting studies only (Malone et al., 2017).*

GPS Validity

Limitations of GPS

Although the usefulness of GPS is extensive, there are both practical and technological limitations which need to be considered before implementing such a system within a team (Scott et al., 2016). Environmental objects surrounding participants wearing GPS devices such as tall surrounding buildings along with obstructions in the atmosphere e.g., debris, can lead to significant measurement error (Larsson, 2003). This is referred to as multi-path, meaning that reflective surfaces cause some of the signal reaching the GPS antenna to not travel on a direct path from the satellite (Higgins, 1999). Moreover, this reflectivity can alter on a day-to-day basis dependent on weather, with the reflection coefficient of the ground increasing on a wet day whilst on a dry day the reflectivity of the surface is greatly reduced (Mohamed et al., 2019). A more significant limitation lay within the number of satellites interacting with the GPS receiver as this directly influences the accuracy of position estimates (Misra & Enge, 2006 cited Scott et al., 2016). There is a fixed minimum of four satellites required to obtain a 3D position, with the geometrical alignment of the satellites relative to one another impacting the quality of GPS position (Witte & Wilson, 2004). A moderate negative correlation exists between the number of satellites interacting with a GPS receiver and the total distance error recorded (the difference between recorded and actual distance) (Gray et al., 2010). Moreover, velocity measures such as acceleration, deceleration and maximum speed can see an error increase due to fewer satellites (Witte & Wilson, 2004). The distribution of satellites is quantified in a measurement called dilution of precision (DOP), which is inversely proportional to the volume of a cone delineated by the position of the satellites and the receiver (Witte & Wilson, 2004). With the greatest accuracy of triangulation, an ideal DOP of 1 would be present only when one satellite is directly overhead leaving the remaining equally spaced around the horizon, meaning higher DOP values (maximum 50) lead to a more unreliable fix as a result of a tighter grouping of satellites (Witte & Wilson, 2004).

Advantages

Vast limitations with GPS can be heavily mitigated and avoided. When comparing it with other player tracking techniques, GPS stands out with its time efficiency and real-time feedback proving its practicality in team sports (Scott et al., 2016). Modern improvements in GPS technology in sport such is its miniaturization and enhanced battery life have enabled athlete-tracking to be more convenient and less time-consuming resulting in it becoming an increasingly popular method to quantify the physical demands and movement patterns in sport (Petersen et al., 2009). The only preparation needed for GPS is for devices to be placed in an open area for approximately 15 minutes to allow satellites to lock onto the devices, other than this there are no pre-requisites to GPS device usage (Duffield et al., 2010). It is important to note that with GPS technology that it is continually improving through its developments in data processing, software, and microprocessors (Malone et al., 2017).

Differences in GPS equipment - Varieties of GPS devices

Table 1. *The validity measurements of all studies using a GPS device with sample rate ranging 1-15 Hz, with total distance as a parameter.*

Reference	GPS device	Sampling rate	Task	Criterion measurement	Interpretation
Edgecomb & Norton 2006	SPI10	1Hz	Circuit running (138-1,386 m)	Trundle Wheel Pedometer	Good
Gray et al. 2010	WiSPI elite	1Hz	Linear & nonlinear running (200m)	EDM/theodolite	Good
Coutts & Duffield 2010	SPI 10, SPI elite, WiSPI	1Hz	Circuit running (128.5m)	Measuring tape	Good
MacLeod et al. 2009	SPI elite	1Hz	Hockey simulated circuit (includes 4 shuttle runs)	Trundle wheel pedometer	Good
Petersen et al. 2009	SPI 10	5Hz	Cricket-specific running (600-8.800m)	Athletics track	Good

Jennings et al. 2010	MinimaxX team v2.5	1Hz 5Hz	Sprint trials (10-40m, 20-40m interval)	Timing gates	Moderate-poor Good-moderate
Portas et al. 2010	MinimaxX team v2.5	1Hz 5Hz	Linear running	Trundle wheel pedometer	Good Good
Waldron et al. 2011	SPI-Pro	5Hz	Sprint (10-30m, 0-10m)	Tape measure	Good-moderate
Johnston et al. 2012	MinimaxX team v2.5	5Hz	Team sport simulated circuit	Tape measure	Moderate
Rampini et al. 2015	SPI-Pro MinimaxX v4.0	5Hz 10Hz	70m straight line running	Radar gun	Good
Castellano et al. 2011	MinimaxX v4.0	10Hz	15m & 30m sprints	Tape measure	Good-moderate
Rawstorn et al. 2014	SPI Pro X	15Hz	LIST shuttle (13,200m)	Calibrated surveyor's wheel	Good

Table 2. *The reliability measurements of all studies using a GPS device with sample rate ranging 1-15 Hz, with total distance as a parameter.*

Reference	**GPS device**	**Sampling rate**	**Task**	**Interpretation**
Edgecomb & Norton 2006	SPI10	1Hz	Circuit running (138-1,386 m)	Good
Gray et al. 2010	WiSPI elite	1Hz	Linear & nonlinear running (200m)	Good
Coutts & Duffield 2010	SPI 10, SPI elite, WiSPI	1Hz	Circuit running (128.5m)	Good
MacLeod et al. 2009	SPI elite	1Hz	Hockey simulated circuit (includes 4 shuttle runs)	Good
Petersen et al. 2009	SPI 10	5Hz	Cricket-specific running (600-8.800m)	Good
Jennings et al. 2010	MinimaxX team v2.5	1Hz 5Hz	Sprint trials (10-40m, 20-40m interval)	Moderate-poor Good-moderate
Portas et al. 2010	MinimaxX team v2.5	1Hz 5Hz	Linear running	Good Good
Waldron et al. 2011	SPI-Pro	5Hz	Sprint (10-30m, 0-10m)	Good-moderate

Johnston et al. 2012	MinimaxX team v2.5	5Hz	Team sport simulated circuit	Moderate
Rampini et al. 2015	SPI-Pro	5Hz	70m straight line running	Good
	MinimaxX v4.0	10Hz		
Castellano et al. 2011	MinimaxX v4.0	10Hz	15m & 30m sprints	Good-moderate
Rawstorn et al. 2014	SPI Pro X	15Hz	LIST shuttle (13,200m)	Good
Buchheit et al. 2014	SPI Pro X	15Hz	Standardized running routine	Good-moderate

Not all GPS devices are created equal, sample rate of devices, speed and effort duration and nature of the exercise task all influence the accuracy of GPS (Rampinini et al., 2015). There are multiple different manufacturers of GPS devices in which they will often promote several different models which all possess different or varying sample rates, chip sets, data-processing algorithms, and filtering methods (Malone et al., 2017). As a result of these notable differences from brands and its options of GPS models, it can often lead to data processing being different therefore requiring that both validity and reliability being determined (Malone et al., 2017). GPS devices measure velocity and distance, however there are different methods for calculating these (positional differentiation or Doppler-shift), with the devices accuracy to record and monitor distance between devices different to that of its own ability to measure distance alone (Malone et al, 2014). This will impact GPS's method of measuring distance, with some studies opting for latitude and longitude measures for recording distances between devices which ultimately result in the need for specific validation of these position measures (Goncalves et al., 2014). As sampling rate increases so does reliability and accuracy of measures up to a certain sampling rate, with decreases in reliability often a direct result of regular changes in direction and short accelerations (Coutts & Duffield, 2010).

GPS tracking devices for athletes were first actualized in 1997 and have since become widespread, with GPS classified by the rate at which they sample per second with the very first commercialized GPS devices having a sample rate of 1Hz (Scott et al., 2016). Over recent years, rapid improvements in sampling rates now allow for 5,10 and up to 15Hz GPS devices. Necessary improvements were required as specifically in team sports where most high intensity activities are of short duration, it would be unlikely that a 1Hz sample rate would allow for a sufficiently accurate measure (Spencer et al., 2005; Aughey, 2010). Validity is generally defined as the ability of a measurement tool to reflect what it is designed to measure (Atkinson & Nevill, 1998). In these early days of GPS usage within sports lay vast limitations, and only the 1Hz sample rate being used, this would severely hinder the use of GPS as it was not a reliable measure of recording training load. Literature suggests that GPS devices which possess higher frequency rate will allow for greater validity for measurements of distance (Cummings et al., 2013). However, it should be noted that the quality of GPS data will not be improved by sampling rate alone. With other factors such as position of GPS device on the participants body and chipset processer used all having an influence on the output (Malone et al., 2017). As a result of the differences and varieties of GPS equipment available and used in research, it is important that future researchers use validation studies which utilize the same GPS system and device as well as reporting the same metrics (e.g., distance, speed etc.) that is used commonly in practice (Malone et al., 2017). Recently in the past few years there has been the development and implementation of 18Hz GPS devices as seen in previous research (Nagahara et al., 2017; Malone et al., 2017). This research is limited, and it’s important to first consider whether a true sampling rate above 10Hz provides improvement in validity and reliability of GPS for measuring sport-specific movement (Hoppe et al., 2018). As notably, 15Hz devices show no superior validity and reliability (Scott et al., 2016). Furthermore, 15Hz devices investigated in previous studies have merely up sampled a 5Hz signal (Malone et al., 2017).

1Hz devices distance validity

GPS available currently, is offering sample rates of 1, 5 and 10Hz (speed of which the unit gathers data) (Cummins et al., 2013). When GPS technology became first commercially available and viable for sporting teams, devices with a 1Hz sampling rate were the only devices available for a period, resulting in large amounts of research regarding GPS validity to utilize these 1Hz devices (Scott et al., 2016). 1Hz GPS devices do have a place in a sports setting, as there are reports that support and endorse the use of it in player tracking in team sports. For example, in the study of Edgecomb and Norton (2006), which only found a 4.8% average error in GPS over 59 trails for total distance measured with total distance varying (128-1,286m). Although there is evidence to suggest the usefulness of a 1Hz GPS device in a sport setting this quickly becomes short-lived due to its inability to accurately record short distance walking, jogging, and running (10,20,40m) with all except the 40m walk having failed the acceptable levels of validity (Jennings et al., 2013).

1Hz devices speed/velocity validity

Being able to accurately record velocity measures is a fundamental necessity required from modern day GPS devices to properly understand player physiology, workload and demand. To replicate movement specific to general team sport movement the study of Portas et al. (2010) examined multidirectional movement along with changes in direction over 6 courses. With the findings suggesting that 1Hz GPS devices have good validity and standard estimate of error (SEE) in tracking walking distances (1.8-4.2% SEE) with moderate validity in normal running movements (2.4-6.8% SEE). With a GPS devices used during a 15m sprint the standard error over this distance was 10.9%. When comparing to both 1 and 5Hz GPS devices during a shorter 10m sprint the standard error was 32.4 and 30.9% respectively (Aughey, 2011; Jennings et al., 2013). In a study by Gray et al. (2010) they examined the intensity of movements over a linear and non-linear 200m course. They examined walking, jogging, running and sprit trails and found that movement intensity negatively effects GPS distance accuracy through inherent positioning errors and update rate therefore decreasing its reliability as movement intensity increases. Sprints in team sports are very high intensity actions which cover short distances, usually less than 20m (Spencer et al., 2004). Resulting in the likelihood that 1Hz GPS devices not possessing the ability to accurately report distances covered during high-speed effort resulting in an athlete’s performance measures being misrepresented in post-match analysis reports (Scott et al., 2016). It’s apparent that much of the current literature agrees with the notion that with a higher frequency rate comes a higher validity for distance measured (Cummings et al., 2013).

5Hz device distance validity

Due to the extended amount of time 5Hz GPS devices have been available for performance tracking commercially, there is a large amount of literature in the area assessing its validity, with most suggesting that 5Hz GPS devices can accurately quantity distances of players during team sports (Scott et al., 2016). 5Hz GPS devices have proven valid measurements when assessing position-specific distances in football defenders, midfielders, and forwards (SEE 2.2%, 1.5% & 1.5% respectively) and in a bout of high-intensity activity for 60 seconds (SEE 1.5%) (Portas et al., 2010). In the study of Schulze et al. (2021) they examined the accuracy of 5hz GPS devices during football-specific movements and found that for several different movements the total distance recorded was valid (SEE= 3.1%) and reliable (CV= 2%).

5Hz device speed/velocity validity

The study of Munoz-Lopez et al. (2017) found that despite a lower frequency rate when compared with higher frequency rate units that the 5Hz GPS unit showed both validity and reliability during medium sprints (30m) with the results highlighting that the frequency sample of 5Hz was enough to provide valid distance measurements over 30m sprints and more important in team sport movements. Moreover, it showed to be reliable even at high speeds (>20 $km \cdot h^{-1}$), something which other studies and investigations have suggested to be a cause of decreased validity (Munoz-Lopez et al., 2017). Similarly, 5Hz devices were found to be valid when covering distance in match-specific movement patterns (SEE 3.1%) with similar results for velocity (SEE 3.4%), proving that this GPS system although low-cost can be a valid and reliable tool for measuring physical load during football-specific movements (Schulze et al., 2021). Both 1 and 5Hz GPS devices have limitations in several important measures including high-intensity running distance, velocity measures and short linear running; whereas 10Hz GPS devices are proven to be the most reliable and valid sources in team sports as it appears to overcome the many limitations of earlier and lower frequency models (Scott et al., 2016). A low sample rate of 1-5Hz has distinct limitations when it comes to measuring high velocity runs, accelerations, and changes in direction (Malone et al., 2017)

10Hz device distance validity

The study of Vickery et al. (2014) replicated sporting movements of team sports including football and utilized 10Hz GPS devices to record and monitor measures of distances in a course that required 7 changes of direction totaling 40m. There was found to be no significant difference from criterion measures. However, it was found to be significantly different and altered from criterion measures when assessing a shorter running course which included multiple changes of direction and whilst during a 10-second team sport protocol. Moreover, this inaccuracy in 10Hz GPS devices is also seen in shuttle running. 10Hz devices were found to be recording inaccurate measures of distance with reports showing that this in turn can affect the ability of GPS in determining shuttle speed (Beato et al., 2016).

Castellano et al. (2011) measured 15m and 30m sprints analyzing the reliability and validity of 10Hz GPS devices. They found that the 10Hz device presents good levels of intra-unit reliability for recording both 15m and 20m distances (CV= 1.3% & 0.7% respectively). The study of Nikolaidis et al. (2018) further reiterates the validity of 10Hz GPS devices when it assessed the validity of in-line movement and change in direction, when measuring a 200m and 10m shuttle run endurance test. They found good intra-unit reliability for 200m and moderate to good reliability for 20m shuttle run, highlighting from the results that 10Hz GPS devices offer valid and reliable measures for monitoring training and performance.

From evidence collated in present literature it appears 10Hz GPS devices can quantify short to moderate distances (<60m) with an improvement in accuracy when compared directly to 1Hz and 5Hz devices (Scott et al., 2016). Moreover, there is no significant difference between criterion distance and total distance for a 10Hz GPS device when used in a team sport simulated circuit. This said, it is advisable to suggest players consistently wear the same device when possible as there are conflicting interunit reliability results with high-speed running even though all other interunit reliability measures appear good (Scott et al., 2016).

10Hz device speed/velocity validity

10Hz GPS devices have been found to be up to six times more reliable for measuring instantaneous velocity when compared to its 5Hz counterpart, proving that these newer devices are acceptable to measure velocity, acceleration and deceleration during straight line running and for its practical uses in the performance monitoring in team sports. In the study of Rampini et al. (2015), it was found that when compared to a 5Hz GPS device, a 10Hz GPS demonstrated sufficient accuracy in quantifying distance covered at higher speeds or time spent at very high power. Bataller-Cervero et al. (2019) found that although 10Hz GPS devices are adequate in its use in monitoring straight line running speed with inclusion of accelerations and decelerations, there can be small errors and bias in the results leading to an overestimation in speed estimates when compared to the gold standard of timing gates. Using timing gates to assess average velocity is based on limited sampling points (the number of gates), whereas another method which uses higher sampling criterion measures such as a radar gun will allow for a more sensitive measure of velocity, which is essential when measuring changes in velocity such as accelerations and decelerations (Malone et al., 2017). Despite limited research into 10Hz GPS devices, the suggestion from findings is initially positive. With 10Hz devices able to produce accurate measures for short sprints (Castellano et al., 2011). The findings of Rampinini et al. (2015) found that the 10Hz GPS devices had good accuracy for measures over moderate distances (70m) along with measures of total distance and total high-speed running distance with the only drawback resulting from very high-speed running with accuracy becoming an issue in this area. 10Hz GPS devices overcome most of the limitations of 5Hz devices which lay around accelerations and high velocity running with change of direction (Malone et al., 2017).

15Hz GPS device distance validity

Furthermore, the advancements in GPS technology are significant which paved the way for 15Hz devices being developed in recent times. However, research exploring the usefulness and validity of such devices are limited, as to date there are only a few studies which have published their findings on validity of distance measures of 15Hz devices (Scott et al., 2016). In the study of Rawstorn et al.

(2014) which examined the 15Hz GPS devices, they found that it produced significantly different measures from those required by criterion for both linear and curvilinear distance when used in a study to replicate football movement patterns. However, it presented itself to be a good measurement for walking, jogging, running and sprinting for both linear and curvilinear shuttle runs (mean error 2.95 to 3.16% & -2.20 to 1.92% respectively). The study further reiterates the major issue facing 15Hz GPS devices which is its inability to accurately and with absolute certainty record and monitor rapid directional change distance and advises caution when using any GPS technology to quantify rapid multidirectional movement patterns (Rawstorn et al., 2014). The study of Johnston et al. (2014) found that during a team sport simulated circuit there was no reported difference between total distance and criterion distance. Moreover, 15Hz devices are found to have good to moderate interunit reliability when reporting total distance along with low-speed and high sped running (CV=3%, 2% & 6% respectively) (Buchheit et al., 2014). However, it was strongly advised that caution be applied when comparing different models and/or units of GPS but does emphasizes the usefulness of the 15Hz GPS devices as a way of monitoring team sport players (Buchheit et al., 2014).

15Hz GPS device speed/velocity validity

Surprisingly, the findings in the study of Johnston et al. (2014) suggested that generally the 10Hz device measured movement demands with greater validity and interunit reliability compared to the 15Hz GPS device. Both 1Hz and 5Hz were still found to be worse when measuring movement demands when compared to its 10Hz and 15Hz counterparts (Johnston et al., 2014).

Although Buchheit et al. (2014) highlight the usefulness of 15Hz for team-sport players, they have advised caution especially concerning acceleration-derived indices from 15Hz devices. They found that accelerations greater than $3m \cdot sec^{-2}$ and $4m \cdot sec^{-2}$ presented very poor interunit reliability (CV= 31% & 43% respectively) with peak accelerations measuring poor (CV=10%). The same was found for decelerations with the same magnitudes showing very poor interunit reliability (CV= 42% & 56% respectively). A more recent study is that of Barr et al. (2019) in which they assessed the validity of

15Hz GPS devices in measuring workload for football players, in particular the ability for the device to measure accurately high velocity sprinting. They found the 15Hz device had good intra-unit reliability for the recording of distances at velocities from walking pace to sprinting and that it had good accuracy measures for high sprinting velocities. Furthermore, showing evidence as to the effectiveness of 15Hz GPS devices at providing valid and reliable information. However, in the study of Vickery et al. (2014), which assessed sport-movement patterns in team sports, cricket and tennis using a 5Hz, 10Hz and 15Hz GPS device, no significant difference or improvement in accuracy or reliability of GPS devices where sampling rate was increased.

The study of Johnson et al. (2014) published findings suggesting that a 10Hz device was superior to that of a 15Hz device. However, this study used interpolated data for the 15Hz device which proved to not be 'true' GPS sampling. This said, initial research into the newly developed 15Hz GPS devices have proved promising into its functional uses in sports and proven validity so far (Scott et al., 2016). More research is required to fully understand the capability of the devices along with more emphasis on short multidirectional sprint distance. The need for more research is evident in the fact that often due to prolonged time taken to undertake and publish studies that GPS devices themselves which are new are often quickly rushed to use in sport without allowing for independent information about the device and its accuracy and validity being available (Russel et al., 2016).

GPS alternatives - Comparison to Video Analysis

Advantages

Video tracking software is one of the most popular choice in official elite football matches for analysis of performance (Carling, 2013). Often GPS can be compared to video analysis, however the latter can only track one athlete's movement whilst GPS has the capability of tracking multiple athletes simultaneously (Aughey, 2010). Although video-analysis is used in several different sports ranging from football to rugby, the process time to analyze a game can take upwards of 8 hours, with findings suggesting that there is a difference of 27.5% in time spent in work when compared to other methods (Roberts et al., 2006; Petersen et al., 2009). Video analysis systems are designed to provide extrinsic feedback to coaches and athletes to enhance performance and training, however much of the video analysis available is not created equal (Barris & Button, 2008).

Semi-automatic computerized tracking technologies allows for a large collection of performance data more quickly and accurately than other visual estimation methods and allows for the simultaneous analysis of physical efforts, movement patterns and technical actions of players whilst also allowing for comparison of performance when in possession and out of possession (Carling et al., 2012). Video tracking systems record two-dimensional position data at high sampling rates (over 25Hz) (Beato & Jamil, 2018). Current research has shown Video tracking software to have high validity and accuracy proving pivotal for sports scientist who understand how crucial it is to have high amounts of accuracy, knowing fully well it limits any misleading interpretations (Beato & Jamil, 2018; Rawstorn et al., 2014). The study of Di Salvo et al. (2006) analyzed the validity of a video-based performance analysis system called Prozone™, a computerized tracking system that utilizes multi-camera technology that is custom fitted to sports grounds and stadiums. They analyzed data and compared it to timing gates for the same runs and for runs at 60m and 50m. They recorded an excellent correlation between timing gates and Prozone™ (r=0.999), this correlation was similarly translated also in 15-m sprint (r=0.970). The study represents the validity of motion analysis systems in analyzing movement patterns of football players. Stevens et al. (2014) showed that video tracking systems exhibit levels of accuracy acceptable for most of the average acceleration and deceleration measurements but limited accuracy in peak acceleration and peak deceleration. However, they emphasize with error margins considered that the system has usefulness in practice in the quantification of average acceleration and other parameter such as total amount of accelerations and time spent in acceleration zones.

With video tracking software there are believed to be some general advantages over GPS devices, for example players are not required to carry any additional equipment on themselves, therefore carrying additional weight which could be uncomfortable and leading ultimately to a hinderance to performance (Beato & Jamil, 2018). Furthermore, sampling rates for video tracking software (e.g., 25Hz) are substantially higher, which is an important consideration as sampling rates has been linked closely to validity and reliability of such devices (Carling, 2013; Beato & Jamil, 2018). Furthermore, the study of Pons et al. (2019) which examined and compared movement demands in a football game (total distance, distance per minute, average speed, maximum speed, and distance covered at different speed) found that multi-camera video technology slightly overestimated all variables except for average speed, maximum speed and walking variables. This acknowledges there was no significant difference between video technology and GPS and highlighted the usefulness of both along with their benefits for practitioners and researchers. Moreover, both GPS and video tracking systems can provide and perform posteriori evaluation on both locomotor demands and external load (Buchheit & Simpson, 2017). The use of both GPS and camera systems are commonplace within men's football with both these methods more efficient than traditional video-based time motion analysis as it provides greater objectivity and indeed volume of information (Randers et al., 2010). With both methods allowing for detailed evaluations of specific elements of players physical performance (Di Salvo et al., 2009).

Limitations of Video tracking

Some video analysis companies require players to wear special tracking devices which are often unsuitable for competition due to regulation and safety measures, whereas others require heavy intervention by operators to manually track players position frame by frame before providing information such as distance, accelerations, and other position specific information (Barris & Button, 2008). The amount of equipment required in the collection and processing of video analysis is extensive with multiple cameras required to film and document players in football, noticeable in the study of Iwase and Saito (2004) which used 15 cameras to monitor movement of 22 players and 3 referees. Moreover, the sampling frequency was low at 15 frames per second with only a brief playing sequence analyzed (500 frames/33.3 seconds). Similar limitations are visible in the study of

Muller and Anido (2004), in which only five cameras were used but required the processing power of 66 computers. All of which was required for a short segment in a professional football game. As a result of high processing power, it only allows for short playing sequences to be handled and with low frequency of tracked data resulting in a reduced number of frames processed leading to an influence in the movements recorded (Barris & Button, 2008).

Although there is a high quantity of commercially available motion tracking systems providing reasonable levels of accuracy and reliability, there is still significant intervention required for the process of data after capture with limitations also subsiding in the capture environment and the necessity for some requiring tracking devices to be worm, limiting it practicality and usage in competitive sports (Barris & Button, 2008). More problems can be faced with semi-automatic video tracking systems in which the analysis done requires manual correction on behalf of operators, with the quality of human intervention heavily dependent on their level of training and previous experiences with the software and device (Beato & Jamil, 2018). Video tracking software has a primary problem being that the tracking system quite often experiences difficulties when tracking several players in a congested area of a pitch (Barros et al., 2007). Which poses as a major problem, particularly in major official competitions in which several or all players will need to be simultaneously monitored throughout the duration of a match (Carling, 2008).

METHOD

Participants

22 professional League 1 (Level 3 on the football pyramid) football players (7 defenders, 8 midfielders, 7 attackers) and 24 semi-professional Isthmian League Southeast Division football (Level 8 on the football pyramid) players (6 defenders, 12 midfielders, 6 attackers) were tracked using Playertek GPS devices during the 2019/2020 Season. Due to the retrospective nature of the study all data had already been obtained by the club from the previous 2019/20 season. 41 games were recorded for the professional team, with 16 games recorded for the semi-professional side as a result of the season ending prematurely due to Covid-19. Only league fixtures were recorded and analyzed, with other competitions such as cups (FA) or friendlies excluded. Recovery time between games was not recorded by either club. Sample size was determined by the number of players each team had registered to pay for their respective club. Players who were brought in during the season on a permanent basis or on loan were included in the study.

All players participating in the study had already consented to the use of their GPS data to be used and owned by their respective club. Therefore, it was only required to obtain the GPS data through permission of its owners, this being the club directly. Having been given permission to use the data it was granted anonymously to preserve the privacy of all players and both teams in the Study. GPS data was then sent electronically to the researchers. The University of Kent's SSES ethics committee approved the research study.

The GPS data gathered will be from the 2019/20 season, with every position except from goalkeeper stored from all competitive league fixtures that both the professional and semi-professional played. Each positions data will be documented, however for it to be included they must reach a minimum criterion. Players must play a minimum of 70 minutes in a competitive fixture. Moreover, players who sustained a long-term injury during the season who are returning to play have also been omitted from the study also. A Playertek GPS unit had been fitted to the upper back of each player with the use of elastic harnesses. Both teams possessing the same type of devices, meaning that all data captured was at 10Hz throughout the duration of the game. Each club was responsible for fitting the units to their players for competitive games and for uploading the data to a laptop. Players were categorized into three different positional groups, depending on where they play for most of the competitive game time. These positional categories were defenders, midfielders, and forwards. The

Data

A data set from each respective club was sent to the researchers of the present study and was received in raw form. In order to interpret and analyze the data it had to be exported from Playertek into an Excel document for processing. With the only indication of each player given being their position within the team. Data preparation was undertaken to check and analyze any errors or anomalies that might have occurred. Here data was filtered in line with the minimum criterion set. All ineligible or redundant data was removed with everything else that was valid analyzed. Data processing involved accumulating the mean values for each variable for each player in their respective position for the season. These values allowed for the analysis of mean positional data for both teams and its statistical analysis. Over 25,000 individual data was organized in order to allow for it to be processed.

Statistical analysis

The main objective of the statistical analysis is to discover whether there are key differences in GPS variables and to ascertain whether this difference is significant between positions and between playing levels. The analysis will cover the following categories: Total Distance (m), this is the total distance ran throughout the period of a competitive fixture. High speed distance (m) which is defined classified by Playertek as running at speeds above 5 meters per second (m/s), accelerations (> 2m/s) and decelerations (> 2m/s). Statistical analysis was conducted using a mixed model ANNOVA using SPSS statistics (SPSS Inc., Chicago, IL, USA) with statistical significance set at $P < 0.05$.

RESULTS

The mean ± SD values of the 2019/20 seasons GPS metrics, including total distance (km), high-speed distance (>5m/s), accelerations (>2m/s) and decelerations (>2m/s) are presented in Tables 3 and 4. With Table 5 highlighting win ratio as well as average points per game and final league position of both respective teams. Professional defenders and midfielders achieved significantly better results for total distance, with semi-professional attackers achieving significantly better results for decelerations. No significant difference was noted for total distance for attackers and in any other variable for each position. There was also no significant difference intra-team.

Figure 3. *Mean ± SD data for Total distance (m) measures for professional and semi-professional football players.*

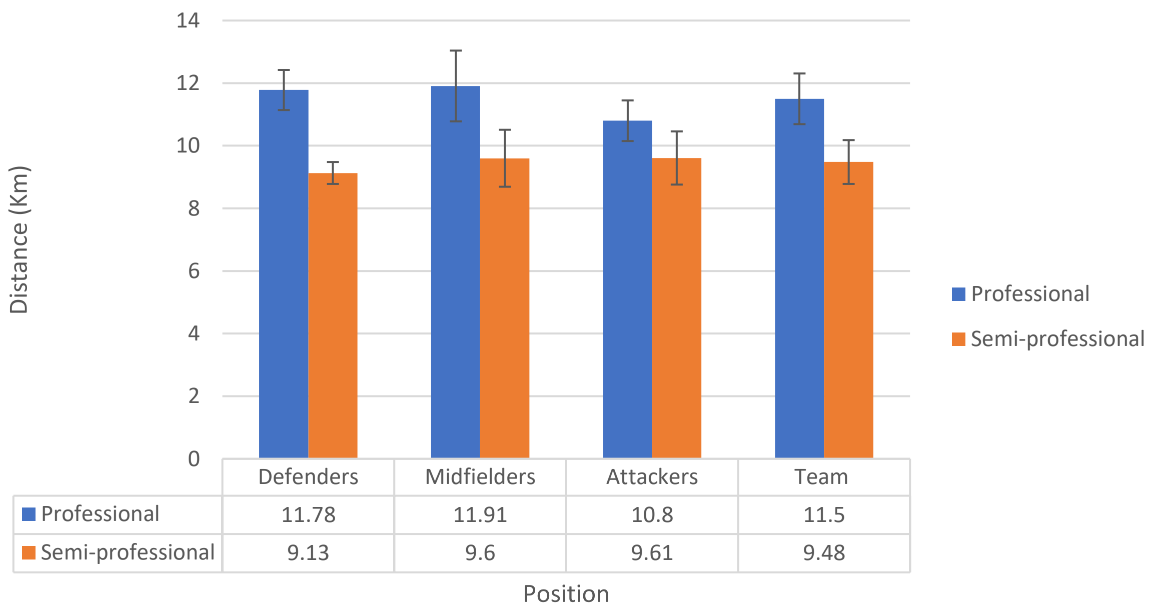


Figure 4. *Mean ± SD data for high-speed (>5m/s) distance (m) measures for professional and semi-professional football players.*

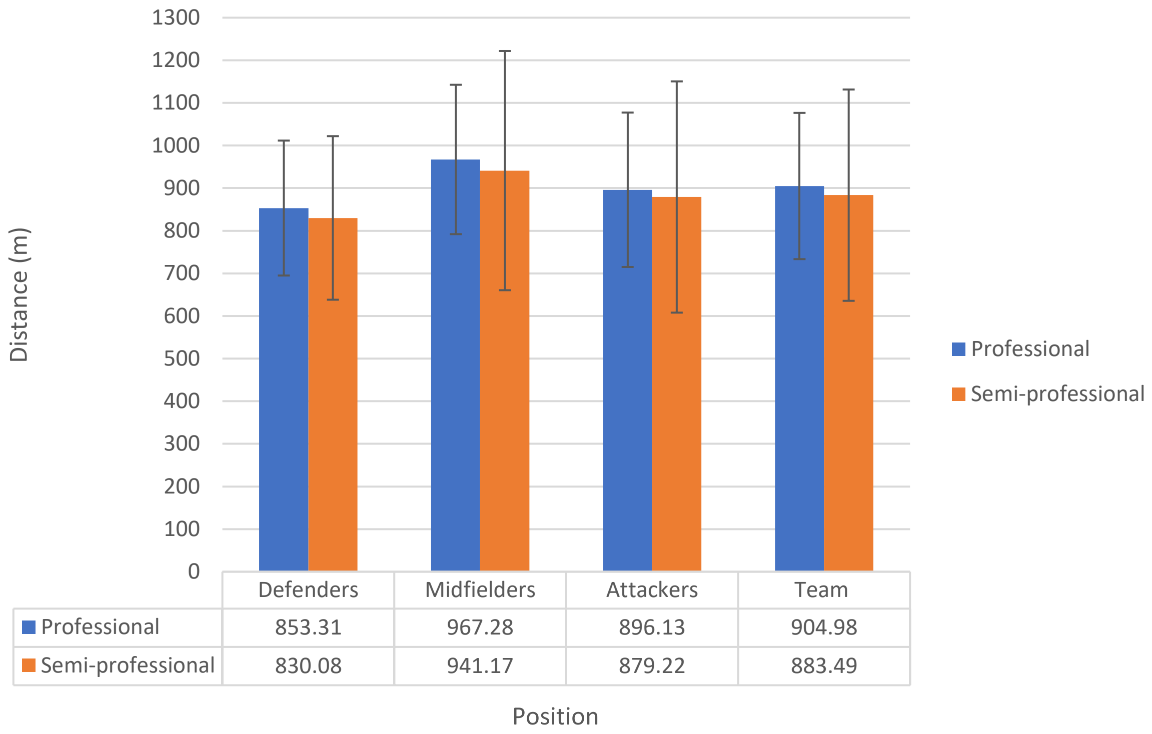


Figure 5. *Mean ± SD data for total distance (m) spent in acceleration zone (>2m/s) measures for professional and semi-professional football players.*

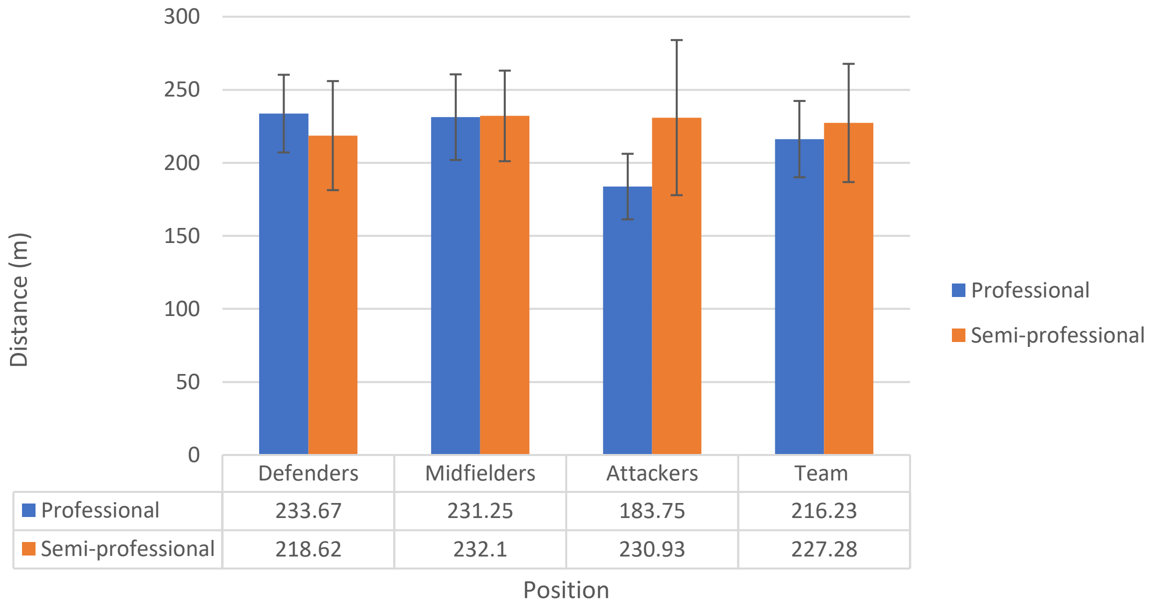
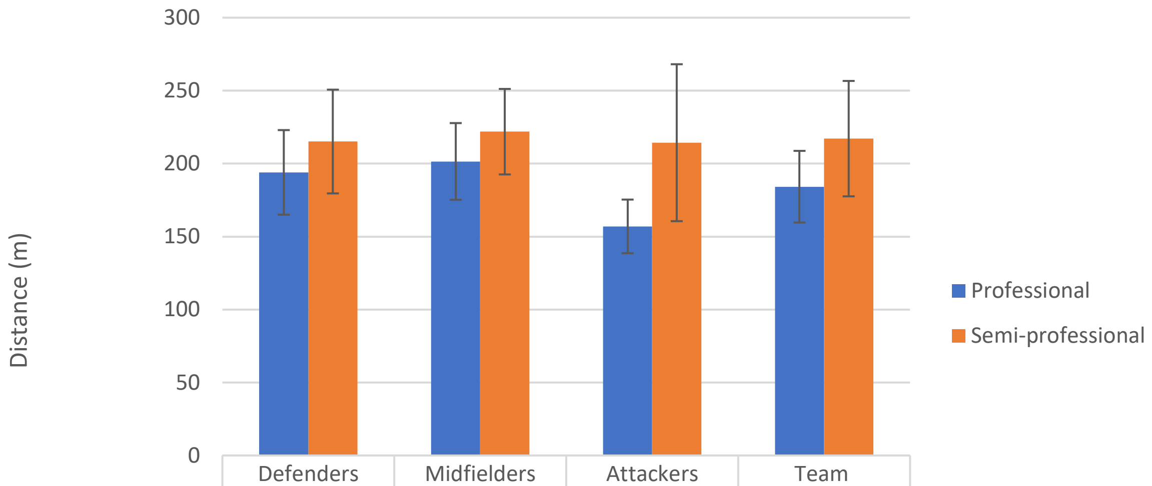


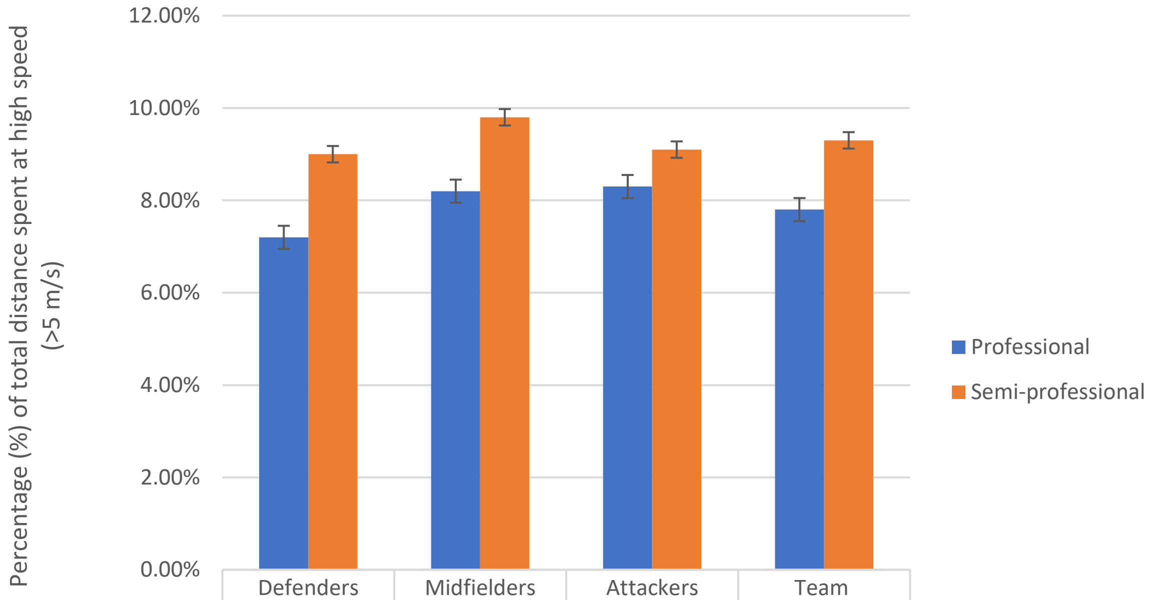
Figure 6. *Mean ± SD data for total distance spent in Deceleration zone (>2m/s) measures for professional and semi-professional football players.*



	Defenders	Midfielders	Attackers	Team
Professional	193.97	201.47	156.98	184.17
Semi-professional	215.12	221.87	214.32	217.1

Position

Figure 7. *Mean ± SD data for percentage of distance spent at high speed (>5 m/s) for professional and semi-professional football players.*



	Defenders	Midfielders	Attackers	Team
Professional	7.20%	8.20%	8.30%	7.80%
Semi-professional	9%	9.80%	9.10%	9.30%

Position

Table 3. *Win percentage data for professional and semi-professional football players and their final league position for the 2019/20 season.*

	Win	**Loss**	**Draw**	**Total No. of games**	**Mean points per game**	**Final League position**
professional	15 (37%)	13 (32%)	13 (32%)	41	1.46	10th (out of 24)
Semi-professional	2 (13%)	5 (31%)	9 (56%)	16	0.69	17th (out of 20)

Positional differences

Defenders

Analysis of defenders found a significant difference between professional and semi-professional for total distance (mean difference= 2.66, P<0.01), with professional players running further during a competitive match than semi-professional players (mean SD 11.78 ± 0.64; 9.13 ± 0.35 respectively). There was no significant difference found for high-speed distance (mean difference= 23.24, P= 0.4), accelerations (mean difference= 15.04, P= 0.31), or decelerations (mean difference= 21.05, P= 0.16), for professional and semi-professional footballers.

Midfielders

Analysis of midfielders found a significant difference for total distance for professional and semi-professional footballers (mean difference= 2.21, P<0.01), with professional players running further during a competitive match than semi-professional players (mean SD 11.91 ± 1.13; 9.60 ± 0.91 respectively). There was no significant difference found for high-speed distance (mean difference=26.11, P= 0.82), accelerations (mean difference= 1.05, P=0.94), or decelerations (mean difference= 20.40, P=0.13), for professional and semi-professional footballers.

Attackers

Analysis of attackers found a significant difference between professional and semi-professional for decelerations (mean difference= 57.34, P=0.026), semi-professional players were found to be completing more decelerations than professional players (mean SD: 214.32 ± 53.76; 156.98 ± 18.36 respectively) during a competitive match. There was no significant difference found for total distance (mean difference= 1.25, P=0.137), high-speed distance (mean difference= 16.91, P= 0.89) or accelerations (mean difference= 47.17, P=0.55) for professional and semi-professional footballers.

Intra-team

Intra-team statistical analysis, comparing the variables between the 3 positions within a team (defender, midfielder, and attacker) found no statistical difference in total distance, high speed distance, accelerations, and decelerations for professional and semi-professional players.

DISCUSSION

The results found demonstrate a significant difference in total distance, with professional defenders and midfielders covering a more significant distance during competitive games than semi-professionals (P<0.01). With other significant differences in decelerations, with semi-professional football players completing more than professional football players (P=0.026). What was also evident was no significant difference in any variable between positions within each team and no significant difference for either high-intensity sprint distance or accelerations when comparing positions across playing levels. In the present study, we hypothesized that all variables (total distance, high-speed distance, accelerations, and decelerations) would be significantly higher for professional footballers than semi-professional footballers. Interestingly, only total distance covered for professional defenders and midfielders was significantly more than semi-professional. Even more so, that semi-professional attackers performed significantly more decelerations. With remarkably no difference found intra-team when comparing each position to one another.

For the purpose of the present study goalkeepers were excluded, as this position is highly different to that of any outfield position in football. However generally speaking, goalkeepers have lower values of maximum oxygen uptake as well as a significantly higher body height, humeral breadth and body weight than outfield players, particularly in comparison to midfielders and attackers (Gjonbalaj et al., 2018). The data analyzed in the results omitted any player which didn't play 70% or more of game time. This is a result of evidence suggesting that the less game time a player has as a result of substitutions, allows for high-intensity activity to be sustained for longer and could potentially distort findings (Mooney et al., 2013). Moreover, players who sustained a long-term injury during the season who are returning to play have also been omitted from the study as football players had a significantly lower player performance rating immediately upon return to sport when compared to ratings from two games prior to injury (Verrall et al., 2006) with also psychological consequences dampening performance (Ruddock-Hudson et al., 2014).

Total distance

The results highlighted that for both defenders and midfielders there was a significant difference in total running distance ($P<0.01$) between professional and semi-professional football players with no difference seen for attackers ($P=0.137$). Although it was hypothesized that for all positions professional footballers would cover more distance, this evidently was not the case for attackers. As previous research had highlighted that professional players will run longer distances than non-professionals during a game (Stølen et al., 2005). Previous research had found that players from a lower league (Championship) covered a greater total match distance than Premier League players and covered greater distances during jogging, running, high-speed running and sprinting (Di Salvo et al., 2013). Initially, it was not believed that this similar relationship would translate as far down to semi-professional football. However, this was evidently the case and can be explained. Previous research had already established that total distance and high-speed running distance is significantly higher in defeated matches ($P <0.05$) (Gimenez et al., 2020). Perhaps this could be considerably evident in the case of strikers for the losing side in the present study. However, this would oppose the findings of Lag-Penas et al. (2021). In which they found the losing status increased total distance and high-speed distance of defenders with it actually having the opposing effect on attacking players. It is believed that for attackers, playing formation can significantly impact activity profiles (Bangsbo, 2014). Although the playing positions of both teams can't be accessed, it can be assumed that the playing position and tactical/strategic role of the attackers were both different due to the nature of opponent's skill level and coaching ability of management. This would give reason as to why total distance was not significantly higher for semi-professional attacking players when compared to a professional football player. This is because tactics and strategy have been found to heavily influence match performance and physiological activity profiles (Bangsbo & Michalsik, 2002; Stølen et al., 2005). Lower-standard players have also been shown to cover greater distances in an effort to regain possession of the ball and close in on players (Bangsbo, 2014). This is an important factor to consider as playing against opponents of a higher quality can result in a further distance being ran (Castellano et al., 2011; Di Salvo et al., 2008).

Plainly, the oppositions skill has become a contributing factor to the present results. It's important to also consider the semi-professional team finished 17th out of 20 teams and avoided relegation by one place. When looking at the professional team, they had a relatively strong final position of 10th, finishing in the top half of their respective table with the semi-professional team finishing in the bottom half. This becomes an important factor as by the final league position its clear the semi-professional team are one of the weakest teams in the league, barely scraping through a relegation battle. With the professional team appearing a strong opponent possessing a stronger squad in their league. Therefore, it highlights, similarly to the study of Clemente et al. (2013), that the activity profile of players can be directly dependent on their position and tactical function. But also, that the strength of the opposing team is an important determining factor when measurements like total distance are recorded (Gimenez et al., 2020).

In line with the current hypothesis, total distance ran was significantly higher for professional defenders and midfielders. There had been an established relationship between competitive ranking, quality of play, cardiorespiratory endurance and distance covered in a football game (Bangsbo & inguist; Impellizzeri et al., 2005). This aerobic power and intermittent exercise performance which has been shown to significantly vary based on level of competition has also been highlighted in other previous studies (Jensen & Larsson, 1992; Tamer et al., 1997). Understanding that professional athletes have a better training status than those of a lower standard coupled with a higher level of competition lead to the hypothesis that professional athletes would cover more total distance than semi-professional footballers which came to fruition for defenders and midfielders in the present study.

An observation from the study was that no difference was present for positions within their respective team. This was particularly interesting as previous research had always suggested that midfield players cover the most distance in a game. Bangsbo et al. (1991) highlighted that midfield players cover 10% more distance than both defenders and forwards ($P<0.05$). With this difference also reiterated in the study of Di Salvo et al. (2007), In which they also put forward findings to suggest defenders, in particular central defenders run the least distance compared to any other position with attackers running more than defenders but less than midfielders. The reason as to why midfielders were believed to cover the most distance is due to their training status and role within a team. They perform the best on intermittent test and have the highest oxygen uptake capacity similar to full backs (Reilly et al., 2000). However, in the study of Dellal et al. (2001) it was evident that great differences and deficiencies in a player's physiological metrics during a game were a result of their tactical positional role to fulfill during a match. This is true for the fact that although midfielders have been found to cover the most distance, that as a consequence of their playing styles in conjunction with tactics from managerial staff would result in distance covered fluctuating (Bangsbo, 2014). This is a relevant and important consideration for other positions within a team too (Bangsbo, 2014).

Another contributing factor lay in the amount of possession the team has of the ball during a game. With possession of the ball leading to some positions, particularly midfielders covering a significantly greater distance than any other position (Di Salvo et al., 2007). The study's findings strongly relate back the previous point made about the effect of a higher quality opponent on total distance. Although being out of possession can cause some positions to run longer distances in order to retrieve the ball (Bangsbo, 2014). This could in fact appear to have a negative effect on those who rely on running with the ball and their team being in possession. As although it's apparent that midfielders run the most distance whilst in possession this might not be the case when out of possession. This links strongly to managerial tactics as some teams play defensively, this involves sitting back and letting the opposition have the majority share of possession meaning that some positions will not run as far as expected. This significant difference in players physiological activity profiles has been evident in previous research and in particularly in the midfield position (Bangsbo, 2014).

A regular theme that could be a result of an inherent deficiency of the retrospective nature of the present study lay in a lack of positional specific detail obtained by both professional and semi-professional clubs. With this problematic situation discussed in the limitations section. A cause of no significant difference found could be due to a lack of specific positional information.

High-intensity sprint distance

Perhaps not as surprising as first believed is that there was no significant difference between both teams for high-intensity sprint distance (Defenders P=0.4; Midfielders P=0.82; Attackers P-0.89). Firstly, it is important to consider the findings of previous research into its bearing on the hypothesis. Previous research, including that of the study of Mohr et al. (2003) had highlighted that professional football players perform more high intensity runs and more time sprinting than those at a lower level. With Ingebrigtsen et al. (2012) taking it one step further showing that top professional teams similarly completed more high-speed running distance than those in the same league who are placed middle or bottom of the league. It was initially believed that from this previous research, professional footballers would run further at a high intensity. This was because it had been well documented that teams at the highest levels (English Premier League), and their respective professional athletes had a better training status than those of a lower standard as this was a full-time career rather than part-time (Krustrup et al., 2003). A key difference from the current study and previous research is that the highest league in England was used in previous research whereas the third highest (League 1) was used as a base for professional players in the present study. Thus, already presenting a difference in skill level and to an extent physiology of players.

The more recent study of Bradley et al. (2013) which underlines key differences between Premier League and League 1 football players conflicts with the findings of Mohr et al. (2003). With Bradley et al. (2013) suggesting League 1 players perform more high-speed running than Premier league players and also perform a similar amount to that of a Championship player. Whereas Mohr et al. (2003) indicates the opposite and suggests that top-class football players perform more high-intensity activity than moderate (lower level) professional football players.

There are limited studies into lower leagues of professional football, even more so into non-league and semi-professional football. A main take away point from previous research, particularly that of Bangsbo (2014) is that high-intensity exercise during a game is the main distinguishing feature that sets apart those who are elite level performers and those at a lower level. Bangsbo (2014) further elaborates that higher-standard players are more selective about their high-intensity effort therefore meaning that they could potentially perform less high-intensity bouts during a game.

In the present study a key contributing factor as to why no difference was shown could be a result of the performance and quality of opposition the semi-professional team faced. They finished close to relegation in the season and therefore can be classed as a weaker team within their respective league. This becomes an important consideration for high-intensity sprints as previous research highlighted that playing against an opponent of a higher quality can result in total distance and the amount of high intensity running to increase (Castellano et al., 2011; Di Salvo et al., 2008). Findings suggest that this might be the case for the semi-professional team in the present study. Di Salvo et al. (2013) showed albeit with professional players that those who played a lower standard professionally e.g., Championship, completed more high-speed running and sprints than those in the Premier League although this was a small. Similarly, Bradley et al. (2013) also found footballers in the second and third leagues of English football to perform more high-speed running and sprints than those in the Premier League.

The present study therefore does not currently agree with any study in terms of the volume of high intensity runs completed during a game. Although no significant difference between professional and semi-professional football players was found, much of the current literature presents itself as either leaning towards professional players completing more or lower-level players completing more. It's important to also understand that in the studies of Di Salvo et al. (2013) and Bradley et al. (2013) that the elite professional players they examined are at the top of the football pyramid, participating in the Premier League and only comparing it to players in the same league or one or two leagues below. Whereas the present study evidently has a big gap in terms of differences between leagues with a total of 5 leagues difference between the professional and semi-professional team examined. Therefore, meaning that although Di Salvo et al (2013) and Bradley et al. (2013) found a difference, that in the present study due to the significant gap in playing quality and league, that their findings were not repeated.

It had been highlighted from previous research that the position of the player in conjunction with previous activity in the game will be a determinant of the amount of high-intensity activity they perform in a game, as well as the success of the seam (Di Salvo et al., 2007). It should be noted that it is difficult for a decisive agreement in current literature for which position performs the most high-intensity sprints in a competitive game. Due to the nature of the present study, the findings don't coincide with much of the published research. Bangsbo (2014) had shown central midfielders to cover the most high-speed running during a game. Similar findings were published in Carling et al. (2016) for the French League 1. Whereas Bradley et al. (2013) had suggested that central attacking midfielders were found to cover the most high-speed running distance. Similar positional differences are also found in that of Di Salvo et al. (2009) which observed external (wide) midfielders to cover the most high-speed running distance. For each position their distances covered at high intensity are open to variations. However, typically most research agrees with the suggestion that central defenders complete the least amount of high intensity running distance during a match compared to other positions (Mohr et al., 2003; Di Salvo et al., 2009; Bangso, 2014). However, fullbacks were found in the study of Wither et al. (1982) to complete the most high-intensity sprints. With similar findings also reiterated in the study of Wisloeff et al. (1998). With attackers generally being second best, performing more high-intensity sprints than defenders but less than midfielders (Bangsbo, 2014).

Success has been noted as a contributing factor to the number of high-intensity sprints made by football players in a competitive game in the study of Di Salvo et al., 2007. Previous research hasn't highlighted which positions might be affected and by how much. As although being in possession and out of possession seems to also be a contributing factor (Bradley et al., 2013). It's not shown whether this is for a successful side that is winning or an unsuccessful side that is losing. An occurring theme is the successfulness of the side coupled with lack of positional differentiation. For example, fullbacks are classed as defenders in the present study and could cause defenders overall activity profile to be higher than if you were to separate fullbacks and central defenders, particularly for high-speed distance. This would help to understand the reasoning behind no significant difference found between positions within a team.

Accelerations & Decelerations

In team sports it's essential that players have the ability to accelerate, decelerate and change position due to spatial constraints imposed by opposition players and field dimensions (Kempton et al., 2015). Although previously, GPS technology allowed the quantifying of these capacities during competition and training, due to the rapid nature of the movements it was thought to be difficult to capture these measurements accurately with such devices (Varley et al., 2012). Recently with improvements and with 10Hz systems implemented, it allows for sufficient accuracy in quantifying acceleration and deceleration in team sports (Varley et al., 2012), with identical Hz used in the present study. No differences were found for accelerations for defenders, midfielders, or attackers (. Similarly, there were no differences found for deceleration for only defenders and midfielders. A significant difference was found for decelerations for attackers. In particularly that semi-professional football players completed more decelerations than professional players.

There is a significantly sparce number of studies on acceleration and deceleration running (Osgnach et al., 2010). This is reiterated by Russell et al. (2016), stating that both acceleration and deceleration demand in competitive football is not well understood currently. Furthermore, if accelerations and decelerations are ignored an important component to players load may be overlooked, highlighting the importance of examining it (Akenhead et al., 2016). As a result, there are few comparisons about both acceleration and deceleration in professional sport and even fewer in semi-professional, particularly in competitive matches. The lack of research is furthered as previous studies don't specifically analyze individual positions, rather a whole teams' accelerations and decelerations.

Acceleration is a pre-cursor to high-speed running as it requires a high rate of force development (Osgnach et al., 2010). This could therefore mean that high-speed running is closely correlated to the number of accelerations in a match and as there was no difference seen for high intensity running this is mirrored for accelerations also. The current understanding is that this is the first study to examine and compare acceleration and deceleration activity profiles of semi-professional and professional football players. Although a similar difference was not found in the present study it can be attributed to certain factors. In football its apparent that tactical roles and available space on the pitch will influence the number of and distance of high-intensity action a player is involved in, including accelerating and decelerating (Dalen et al., 2016). Moreover, when comparing results to other studies, different methods, GPS tracking systems and a variation in classifying accelerations often make it difficult to conclude (Randers et al., 2010). Moreover, different styles of play, match score and quality of opposition can all impact the values of acceleration and deceleration (Varlet & Aughey, 2013; Dalen et al., 2016).

Between positions within each respective team there were no significant difference found between any position for professional and semi-professional teams. The study of Oliva-Lozano et al. (2020) found that positional differences exist for most variables of acceleration. They found that players on the lateral side of the pitch (fullback, wide midfielders/wingers) completed more accelerations and decelerations than those in central laying positions such as central midfielders and central defenders. Similarly, Dalen et al. (2016) found that full backs and wide midfielders accelerate more than any other position in a match and that central defenders and central midfielders decelerate the least when compared to other positions. Contrary to this, the study of Rhodes et al. (2021) found that central attacking players (forwards) as well as fullbacks completed the greatest frequency of accelerations and decelerations. However, this only examined one team within League two of the EFL and therefore their sample size was considerably small. There is an indecisiveness amongst the current literature as to what position performs the most accelerations or decelerations and the present study continues this in the sense that no difference was found between positions intra-team.

Semi-professional attackers were found to complete significantly more decelerations than professional attackers (P=0.026), which was an interesting outcome considering that decelerations are just as common as accelerations in football (Osgnach et al., 2010). The significantly increased decelerations from a physiological standpoint occur as a result of greater utilization of eccentric muscle action when decelerating which also for faster changes in velocity due to a higher force generation (Enoka, 1996). Regardless, there is current literature supporting the argument for the semi-professional team to perform more decelerations than the professional and as to why there was a significant difference for deceleration and not accelerations. In the study of Rhodes et al. (2021) they examined the effect of accelerations and decelerations on match outcome in professional football (League 2). They found that regardless of match performance outcome, there was a significant difference between high-intensity decelerations compared to accelerations with the greatest difference observed for matches lost. This would help to support the current findings and justify why semi-professional forwards performed more decelerations than professional players. Drawing from this it could be apparent that the semi-professional teams lack of form, which resulted in the team losing a vast number of games could have impacted and resulted in a substantial number of decelerations and significantly more than the professional team who had better match outcomes and won a lot more matches overall. Although this would support the findings it doesn't explain as to why no difference was found for either defender of midfielders. This would also contradict the previous suggestion that both accelerations and decelerations occur as common as one another (Osgnach et al., 2010). On the other hand, a study by Dalen et al. (2016) found that accelerations contributed to more total player load for all playing positions compared to decelerations. However, they examine a professional Norwegian team over the course of 3 seasons in their topflight which alone presents a noteworthy difference from the present study.

The greatest cause for decelerations to occur is due to more defensive agility actions required in which high intensity pressing or alternatively sharp braking movements are essential in order to close down attacking players which consequently results not only in an increase in decelerations but also higher magnitudes of braking forces (Spiteri et al., 2014). The study of Mara et al. (2017) found that deceleration demands for defenders and midfielders are similar with a maximum distance of 7.5m which is far shorter compared to attackers who have deceleration distances of 10.5m.

These high-intensity decelerations often occur within constrained spaces in order to meet tactical and technical demands (Harper al., 2019). Whereas accelerations may be instigated from a rolling start (player changing speed whilst running) or static start which could consequently influence the volume of high-intensity acceleration performed during a competitive match (Russell et al., 2016). This said, match performance is not restricted to match outcome and other factors such as playing position can influence performance metrics such as physical performance outcomes (Teixeira et al., 2021). The study of Teixeira et al., (2021) highlighted that match outcome strongly influences physical performance metrics and those differences are present in positional outputs. Further differences in decelerations occur due to age differences, particularly between elite and U20 and elite and U17 for all playing positions (Griffin et al., 2020). This can be attributed to the intensity of matches and physical attributed of the players (Ramos et al., 2019). Most accelerations have been shown to occur from a low starting speed (<12 $km \cdot h^{-1}$), whereas decelerations have been shown to be more variable occurring across a range of low and high speeds (12-19 $km \cdot h^{-1}$), which can contribute to more decelerations occurring (Mara et al., 2017). The initial speed before an acceleration or deceleration is important, therefore it may be useful for sports scientist to further categorize accelerations and decelerations in future based on the velocity preceding the movement (Sondereger et al., 2016).

Practical implications

The importance of accelerations and decelerations in match outcome cannot be underestimated, it allows for players to adapt to demands, essential to win duals and create/defend goals attempts, all of which are essential in determining match outcome (Rhodes et al., 2021). These high-intensity actions which allow rapid changes in direction are crucial for physical performance in football (Granero-Gil et al., 2020). The implications of this can cause reduced deceleration capacity resulting in players not being able to change direction quickly or perform sharp maneuvers which could lead to detriments in team tactical goals, negatively influence performance outcomes and increasing the risk of injury (Rago et al., 2018). The eccentric force production and regulation required for deceleration at the hip, knee and ankle extensors work eccentrically to increase braking forces and the failure of the working muscles to produce this force at the required times can lead to not only compromised performance buy also increased injury (smith et al., 2009).The caution to a high amount of exposure to decelerations is reiterated in Loturco et al. (2019) in which they emphasize the need for carefully tailored training programs in order to best prepare athletes for decelerations in which would allow for reduced risk of injury and maximize performance. As a result of this, careful consideration needs to apply to prepare players for the demands of high-intensity decelerations. Further specific positional demands of high-intensity accelerations and decelerations are also important to consider when planning conditioning programs throughout the season (Rhodes et al., 2021).

The high-intensity actions of accelerations and decelerations require significantly high rates of force development which utilized eccentric muscle contractions and is coupled with rapid and highly coordinated neural activations (Cohen et al., 2015). As a result, these actions can contribute to induced muscle damage and reduced neural drive whilst also causing mechanical fatigue all of which can negatively influence performance outcomes (Akenhead et al., 2013; Pandy et al., 2021).

Another important and practical consideration is that declines in high-intensity accelerations and decelerations could potentially be due to accumulative fatigue which could stem from a failure to recover from previous competitive matches or training (Rhodes et al., 2019). In order to ensure players are match-fit, sport science and medicine practitioners need to ensure that players are adequately exposed and prepared for repeated high-intensity decelerations during match and should also monitor this to ensure optimal player load management (Rhodes et al., 2021).

As a result, monitoring players on their own relative physical capacity is vital with training practice taking into account the effect that high-intensity actions have on match outcome in order to prepare players for the demands of competition and reduce the likelihood and occurrence of injury (Rhodes et al., 2021). Ultimately, the data highlights the important of both eccentric and concentric conditioning to football performance with its relation to accelerations and decelerations and would therefore benefit practitioners in using the data to design and prescribe appropriate match-specific training ensuring a suitable amount of both acceleration and deceleration stimulus included (Akenhead et al., 2013).

Limitations

Covid-19 had massive ramifications for the present study. Covid-19 had reduced the number of matches which were played and therefore data gathered for the semi-professional team, thereby reducing the sample size for each position. The number of collected data for the semi-professional team was greatly reduced and substantially less than that of the professional team who were allowed to carry on their season after due time. This small sample size has been seen in other recent studies. Notability the study of Rhodes et al. (2021) examined professional football but only examined one team for a season. In which they too also highlighted a major limitation of the study was only having the ability to study one professional team. Moreover, the study of Akenhead et al. (2016) explained that having even two clubs for their study presented insufficient data as a result of lack of sample size.

Due to the retrospective nature of the study, with data already gathered by the relevant clubs, obvious limitations were imposed from the beginning. Firstly, data collection. The way the data was collected could not be verified by the research team. Moreover, some aspects of data information gathering was lacking, particularly that of positional information about each player. GPS data obtained from the professional club only possessed vague positional information e.g., defender, midfielder, and attacker. Rather than in depth positional information allowing differentiation between positions e.g., full-back and center-backs for defender. It presents it-self as a short coming in the sense that it hindered the amount of information and data we were able to compare in the results and discussion.

Conclusion

To conclude, the results of the study highlight significant differences between professional and semi-professional athletes, notably total distance and decelerations. And thus, provides partial support for our initial hypothesis. The study reveals clear differences between the two but also pinpoints key similarities of performance. Whilst this is the case, the majority of assessments examined showed no real difference between professional and semi-professional football players. The main differences were shown for professional defenders and midfielders, running a higher total distance and semi-professional attackers performing more decelerations. The present study highlights the difference in activity profile metrics for professional and semi-professional football players, helping to better understand the similarities and differences in performance measures during a competitive match and could be used in future for scouting purposes and promoting youth players into the first team. The limitations of the study should be taken into careful consideration and catered for in possible future research, notably having an increased sample size and differentiation for each position will allow for more in-depth and powerful results. More research is needed, particularly in semi-professional sports and football in particular in order to better understand their activity profiles and physiological output during competitive fixtures.

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APPENDICIES

APPENDIX A: Signed ethical clearance form

School of Sport & Exercise Sciences
Research Ethics and Advisory Group (REAG)
University of Kent at Medway
Chatham Maritime
Kent
ME4 4AG

Ethics Reference:
12_20_21

Date: 27/05/21

Dear Olusegun, Thomas and Jacob

Re: The effect of a congested season on the activity of professional and semi-professional soccer players

I am delighted to confirm that SSES REAG has approved your research study (REF No.) and you are now permitted to recruit participants and commence your research.

If you need to amend any aspect of your research, please ensure you inform SSES REAG by completing a request for amendment form and submitting all revised paperwork (e.g. participant information sheet, questionnaires).

If there should happen to be any adverse event during your study, please also ensure SSES REAG is kept informed.

I hope your study is successful.

With kind regards,

Karen Hambly

(Chair SSES REAG)