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THE EFFECT OF A CONGESTED SEASON ON THE MATCH ACTIVITY OF PROFESSIONAL FOOTBALL PLAYERS

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A dissertation submitted in partial fulfilment of the requirements for the master’s by research Sport and Exercise Science

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ABSTRACT

The effect of fixture congestion in football has been researched extensively over the years. There have only been studies over congested fixture periods, none have investigated a whole fixture congested season. This is primarily due to there not being a pandemic that has affected the football season before as it did the 2020/21 season. To our knowledge there has not been a study to investigate the effect of COVID-19 and the subsequent fixture congestion that was caused the following season after that. Thus, the purpose of this study is to ascertain whether there has been an effect on the activity of professional football players due to the 2020/21 congested season. The study included 65 players from a team in the English Football League One over three seasons that met a specific involvement criterion. This study used a data analysis method to look at three different periods of this season and compare those same periods with a counterpart from previous seasons, using the metrics provided by the Global Positioning System (GPS) data. The metrics to be looked at include high speed distance (HSD) and total distance (TD). As a whole season across all three periods there was no significant differences for TD or HSD between 2020/21 and 2019/20 season ($P = 0.88$ and $P = 0.28$, respectively). However, mean TD and HSD from 2020/21 (24784 ± 10111; 2055 ± 905, respectively) were only slightly higher than those of 2019/20 (24280 ± 11860; 1885 ± 890, respectively) in both instances. In conclusion, this current study has shown that there was no effect for TD and HSD, this is in line with previous research, but more research is needed on the topic.

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DEFINITIONS

- ATP – Adenosine trisphosphate
- B[La] – Blood lactate concentration
- BL – Body load
- CV – Coefficient of variation
- FCSen – Fixture congestion scenario
- GPS – Global positioning system
- HR – Heart rate
- HSD – High speed distance
- MEMS – Micro electro mechanical system
- O_2 – Oxygen
- PCR – Phosphocreatine
- TD – Total distance
- TL – Training load
- VO_2 – Rate of oxygen uptake
- VO_{2peak} – Maximal rate of oxygen uptake

CHAPTER I: INTROUDCTION

Intermittent sports, such as football, consist of periods of short, high intensity efforts, interchanged with periods of low intensity activity and rest (Tschakert & Hofmann, 2013). Therefore, football and many intermittent sports depend on the ability of an athlete being able to perform a high number of repeated sprints. An individual's ability to perform repeated sprints depends on aerobic fitness (Hamilton et al., 1991), the ability to buffer H^+ ions (Bishop et al., 2004), and the distance and recovery duration of the sprints (Balsom et al., 1992a; Balsom et al., 1992b). As a result, several physiological systems (the cardiovascular system, the endocrine system, the muscular system, the nervous system, the respiratory system, and the skeletal system) are used during a match, which is often complemented by strenuous training sessions (Reilly, 2006).

The capacity to recover from intense training, competition and matches is often considered an important determinant of subsequent performance (Odetoyinbo et al., 2008). But what if the ability to recover in the usual amount time was shortened and not just for a succession of matches (Kovacs et al., 2020; Odetoyinbo et al., 2008; Rey et al., 2010) but for much of the season? This was the case in the 2020/21 season as the previous football season was affected by COVID-19. Some were ended prior to full conclusion of season, others were postponed and re started in a condensed manner. However, after the 2019/20 season ended all that was assured was that the 2020/21 season would start later than usual and would need be condensed down so the season could finish in usual month of May. Thus, allowing the usual season to start and finish in the normal time frame for the 2021/22 season.

This meant there would not just be congested period but the whole season would face congestion. The season would have more Matches packed together, and effectively play every 3 – 4 days for much of the season. This would cause more strain and load on the players having to play roughly the same number of matches in a shorter period, hence the importance of global positioning system (GPS) monitoring became a bigger factor this season. In a normal season there are 6 days between matches with a few 3 – 4 days sporadically throughout the season.

Performance analysis has become a huge factor in sport. Performance analysis of sport is the investigation of actual sports performance or performance in training (O'Donoghue, 2009). This can include observational data, quantitative data, qualitative data, notational analysis, perceived exertion, heart rate (HR) responses and time motion analysis systems such as GPS and semi-automatic video tracking. Time motion analysis being the more used form of performance analysis in modern football. Over the years numerous semi-automatic video tracking and GPS analysis have been used to determine the physical profile of football players (Casamichana et al., 2012; Di Salvo et al., 2007; Mohr et al., 2003; Krustrup et al., 2003; Krustrup et al., 2005; Suarez-Arrones et al., 2014). From previous research such things have been understood. For example, a typical total distance covered during a match is 10 -13km, most of this distance is covered by walking and low-intensity running, hence making the high-intensity exercise periods important in terms of energy production (Bangsbo et al., 2006). Another example is, it has been generally recognised that midfielders cover greater distances in a game than defenders and forwards (Di Salvo et al.,2007; Mohr et al., 2003; Suarez-Arrones et al., 2014). Thus, with these activity profiles for football already being created GPS looks set to increase our knowledge by revealing how players physical profiles evolves with age, how it varies according to position, how it varies across whole seasons and between competitive versus training contexts (Buchheit et al., 2010; Casamichana et al., 2012; Malone et al., 2015; Mendez-Villanueva et al., 2013; Ritchie et al., 2016).

Knowing theses activity profiles, it is of interest if these profiles would be affected by fixture congestion. In a study by Odetoyinbo et al. (2008), the authors examined the effect of a succession of matches on the activity profiles of professional football players when three matches were played in five days. Their findings suggested that the activity profiles were not influenced by the short recovery periods between matches. The findings were supported by Djaoui et al. (2014); Rey et al. (2010); Varley et al., (2018). The studies all used different ways to show congestion, but all the studies used semi-automated tracking systems. When studies researching the effect of congestion used GPS devices there were contrast in the results to previous research. Kovacs et al. (2020) found elite youth football players produced low physical performance outputs during a fixture congestion across 3 matches. Furthermore, Jones et al. (2018) reported a small but significant effect within match patterns of total distance, low intensity distance, and sprint distance across the three fixture congestion scenario (FCSen). More research is needed on the effect of congestion using GPS devices as there are fewer studies. This is due to the rules of GPS technology being approved for use in competition only being approved in 2015 (Fédération Internationale de Football Association (FIFA), 2015).

For the purpose of this study the team analysed are in the English Football League One and due to the effect of COVID-19, it Condensed the 2020/21 down to 35 weeks compared to 39 weeks in 2018/19 season which was the last full season. In football terms 4 weeks could mean an extra 8 matches being spaced into those weeks but instead would be condensed down. Additionally, in the 35 weeks the club would need to complete all competitive league and cup matches. In total they played 55 matches in 35 weeks, compared to 55 matches in 39 weeks in the 2018/19 season. Therefore, GPS match analysis would allow players to be monitored in matches and training to see if there are any differences in their activity levels, so that adjustments could be made.

Although there has been quantification of load across whole seasons using GPS (Anderson et al., 2016; Malone et al., 2015; Ritchie et al., 2016) only over congested periods (Jones et al., 2018; Kovacs et al., 2020), there has not been any over a congested whole season only. To our knowledge there has not been a study to investigate the effect of COVID-19 and the subsequent congestion that was caused the following season after that. Therefore, this present study will look to follow on from the work of Jones et al. (2018) and Kovacs et al. (2020) which used GPS as a way of analysing the effect of congestion on football players and to determine if there is an effect as suggested by the studies. This study will also use similar methods to Djaoui et al. (2014) by using separate periods of the season and comparing those periods with previous years to see if there has been any significant difference in each period and as whole season.

Thus, the purpose of this study is to ascertain whether there has been an effect of a congested season on the activity of professional football players. Using a specific protocol that allows comparisons to be made with previous seasons to see if there have been any significant differences. This allowing us to answer the specific research aims to determine whether there is an effect on elite football players match activity due to a more congested 2020/21 season compared to previous seasons. Therefore, will determine:

1. If there has been a greater total distance (TD) and high-speed distance (HSD) placed on the players in the congested season compared to previous
2. If there are any significant differences in individual positions match activity in the congested season compared to previous
3. If there has been an increase in the frequency of injuries in the congested season compared to previous.

Chapter II: REVIEW OF LITERATURE

Introduction

Football and performance analysis have been intertwined consistently, as the main reason for performance analysis is to enhance sport performance (O'Donoghue, 2014). Football is an intermittent sport that is performed with a combination of brief periods of maximal and near maximal efforts, where players have highly complex movement patterns that are unpredictable and dictated by numerous variables (Krustrup et al., 2006; Mohr et al., 2003; Rampinini et al., 2007a; Rampinini et al., 2007b). The detailed analysis of the activity profiles of football match can be determined through estimation of distance covered and fluctuations in running intensity (Mohr et al., 2003; Rampinini et al., 2007a). Therefore, individual physical performance profile can be created, which can be used to define training orientations and/or design football specific training drills (Di Salvo et al., 2007). Furthermore, the quantification of physical demands of training sessions is integral in monitoring players and training load (TL) management (Malone et al., 2015; Ritchie et al., 2016; Scott et al., 2013). Thus, monitoring players' physical activity has become the norm in professional football (Carling, 2013). The three methods commonly used to monitor players in football are manual video based time motion analysis, multiple camera semi-automatic systems and GPS.

This review attempts to summarise intermittent physiology, highlighting the aerobic and anaerobic contributions. The review will attempt to introduce performance analysis underlining the key fundamental area that are related to football. The review will then explore the different performance analysis methods in relation to football. In doing so, we then aim to provide an extensive review of performance analysis methods and in particular GPS.

Intermittent sports physiology

Intermittent sport physiology is an area that has been heavily researched (Bangsbo et al., 2006; Mohr et al., 2003; Spencer et al., 2005). Intermittent sports consist of periods of short, high intensity efforts, interchanged with periods of low intensity activity and rest (Tschakert & Hofmann, 2013). This is essential in many team sports such as football, rugby, and basketball. The different intensities associated with intermittent exercise means that the aerobic system cannot cope alone with the energy demands. Previous studies have shown that aerobic loading is high throughout the competition and that anaerobic energy turnover is extensive during periods of competition. (Krustrup et al., 2006; McInnes et al., 1995).

Football and many intermittent sports depend on the ability of an athlete to be able to perform a high number of repeated sprints. An individual's ability to perform repeated sprints depends on aerobic fitness (Hamilton et al., 1991), the ability to buffer H^+ ions (Bishop et al., 2004), and the distance and recovery duration of the sprints (Balsom et al., 1992a; Balsom et al., 1992b). Edwards et al. (1973) also found that Lactate concentration were higher during intermittent exercise in comparison to continuous exercise. During protocols where there was work periods of 10s or 30s, both with 30s recovery intervals, and once continuously. In a study by Bishop & Spencer (2004), when recovery periods were less than 30s between sprints, it is thought that the restoration of power output from the following sprints are reliant on factors other than peak rate of oxygen uptake (VO_{2peak}) and phosphocreatine (PCr) resynthesis.

Additionally, Dupont et al. (2004) highlighted that when intermittent activity (15s exercise & 15s recovery) is combined with passive recovery, time to exhaustion was over twice as long as when combined with active recovery (40% VO_{2peak}); (962 ± 314 s vs. 427 ± 118 s). This could be explained by the slower deoxygenation, the lower energy constraint and faster oxygen replenishment during passive recovery, as metabolic power was lower than when active recovery was carried out. However, another study found that active recovery led to a higher peak power output than passive recovery (Signorile et al., 1993). Whilst these studies demonstrate the benefits of each recovery method over the other, the measurement criteria used in both studies differ. More important the studies show that in intermittent sports the recovery period is crucial for maintaining and synthesising power output over the duration of the activity. From the above it could be suggested that at least 30s of recovery (must include a portion of active recovery) is needed to restore power output over the duration.

As previously stated, during intermittent activity energy is obtained from both anaerobic and aerobic metabolism (Lemmink et al., 2006). Furthermore, many of the sports have a duration between 20 minutes and 90 minutes (Silva et al., 2018). This means that the aerobic energy system is the main regenerator of adenosine triphosphate (ATP) as it is effective for up to 2 hours (Tumility, 1993). Therefore, muscle glycogen is the most important substrate for energy production and the depletion of these stores will lead to fatigue as activity goes on (Bangsbo et al, 2006). The ability to regenerate ATP is extremely important in the recovery periods as most of the ATP and PCr depleted in the muscle are restored, with 70% of the phosphagens restored within 30s and 100% restored within 3 to 5 minutes (Hultman et al., 1967, cited in Tomlin & Wenger, 2001). If ATP replenishes completely, it will mean more ATP is available for anaerobic periods of activity, which reduces relying on the PCR which has a more limited ATP production.

A study by Drust et al. (2000) investigated football players using an intermittent football specific protocol. The protocol devised for the study was performed on a motorized treadmill (Quinton, Washington, USA) and consisted of the different exercise intensities that are observed during a football match (e.g., walking, jogging, cruising, sprinting). The findings from the intermittent football specific protocol were that the participants worked around 68% of their VO_{2peak}. In addition, Bangsbo et al. (2006), completed a review article on the physical and metabolic demands of training and match-play in the elite football player. It was suggested that the average VO_2 by football players in a game is around 70% VO_{2peak}. This suggestion was considered in consideration of dehydration, hyperthermia, and mental stress elevation of heart rate (HR) without affecting oxygen (O_2) uptake. The results are parallel to those of Drust et al. (2000) and they suggest as the game progresses in duration, free fatty acids present in the blood increases which may indicate increased fat oxidation as glycogen levels deplete (Bangsbo et al., 2007). The contribution of the aerobic system has also been stated by using HR. Although HR may indicate intensity, it does not directly reflect aerobic energy contribution. Therefore, the HR values can be converted to VO_2 using the relationship between HR and VO_2 obtained in treadmill running (Esposito et al., 2004; Krustrup & Bangsbo, 2001). Mean and peak values of HR were reported at 85 and 98% respectively (Ali & Farrally, 1991; Andrews & Itsiopoulos, 2016; Bangsbo et al., 2006). Furthermore, a study showed football players worked at a mean of 85 ± 2% of HR peak during friendly matches (Mohr et al., 2004). This shows that either in a laboratory or in field similar physiological work intensities were being achieved, therefore, justifying the use of HR values and the conversion to O_2 uptake as many studies have attained similar results.

These studies show the aerobic contributions in intermittent sports such as football, and other intermittent sport such as basketball have shown similar contributions. Basketball is a sport that involves high amounts of accelerations and decelerations. McInnes et al. (1995), completed an investigation on basketball players during matches. Players achieved a mean of 89 ± 2% of HR peak (which was attained in a laboratory test) for the duration of the match. Furthermore, the study found that both females and males worked at 66.7 ± 7.5% and 64.7 ± 7.0% of VO_2 max respectively (Narazaki et al., 2009). These values are similar to football, which suggest a high reliance of aerobic energy supply. All these findings establish that aerobic energy system contributes for the largest proportion of energy usage in intermittent sports, especially football.

Intermittent sports also have highly important anaerobic periods. As stated above lactate concentration has been found to be higher in intermittent exercise. Therefore, blood lactate concentration (B[La]) has been used as an estimate of anaerobic contributions to the energy demands of intermittent sports (McLean, 1992; McInnes et al., 1995). McInnes et al. (1995), stated B[La] has a balance between lactate entry into and removal from blood and although it cannot directly quantify the extent glycolysis, despite this it is used as a crude indicator of glycolytic involvement. Although B[La] can be used as an indicator it is not always accurate. This is due to the collection of blood samples in intermittent sports only being taken in stoppages and not the intensive plays. Therefore, this leads to underestimation of B[La] due to B[La] being metabolised during low intensity periods and not intensive periods (Mclean, 1992). Krustrup et al. (2006) completed a study where players took part in three friendly football matches. B[La] was taken after intense periods at different stages of the match. B[La] in 20 football players was found to be 6.0 ± 0.4mmol/L and 5.0 ± 0.4mmol/L, in the first and second half, respectively. The B[La] being lower in the second half may be due to the decreasing rate of glycolysis as a result of a reduction in glycogen levels of individual muscle fibres. The is a decrease in the blood lactate as the match progressed could also be because the match analysed in the study was a friendly match and therefore the intensity of the match could have dropped off or not as many sprints completed in the second half. Hence, a lower B[La] in the second half. These values were similar to those found in Drust et al. (2000) where values of 7.7 ± 0.6mmol/L were observed during the intermittent football specific protocol.

Furthermore, McLean (1992) also found high B[La] in rugby union players which ranged from 5.8 – 9.8mmol/L. The B[La] was taken during passages of penalty kicks and injury stoppages. This may allow for underestimation of the values as stated previously. Though values may be underestimated, the research are an indication of high anaerobic energy production during intermittent exercise. The wide range in B[La] was also in McInnes et al. (1995) where it was attributed to varying intensities of the game, the different physiological characteristics of the subjects and possibly the amount of time played. Furthermore, McInnes et al. (1995) reported that the lower B[La] recorded during some periods of play may indicate that the predominant sources of energy during such periods were PCr stores and aerobic metabolism. Prolonged periods of play without frequent interruptions are likely to have resulted in an increased dependence on anaerobic glycolysis, as inadequate time between sprints will lead to

ATP not fully being resynthesised by the oxidative pathway. Hence the use of anaerobic glycolysis as main generator to maintain performance, resulting in relatively high B[La], as metabolic requirements associated with the maximum period (13.5s) of uninterrupted high intensity activity are likely to be considerable.

Other methods estimating anaerobic energy production include muscle biopsy. Muscle biopsies have been obtained before and after intense exercise. Studies have obtained muscle biopsy to estimate the decrease in muscle ATP and PCr, as well as accumulation of metabolites like pyruvate and lactate (Medbo & Tabata, 1993; Nevill et al., 1996). Muscle biopsy samples have been shown to be analysed for total water content by weighing the samples before and after freeze drying (Bangsbo et al., 1996; Hellsten et al., 1999). Subsequently the samples are analysed for PCr, lactate and glycogen by fluorometric assays (Lowry & Passonneau, 1972, cited in Bangsbo et al., 1996). However, determining the anaerobic energy turnover during whole body exercise such as cycling from a muscle sample is difficult, because the mass and the activity of the muscles involved are unknown. The metabolic response of the sample may also not be representative of all muscles included in the exercise (Bangsbo, 1998). During intermittent sports, Krustrup et al. (2006) obtained muscle biopsies after intense exercise periods in friendly football matches. Reporting PCr values of 70% higher than those of rest, but this is likely due to a delay (15-30s), from having to get to the side of the pitch or waiting for a stoppage, in obtaining the biopsy. The delay creates another difficulty in attaining accurate results and the process longer than attaining B[La].

Additionally, in intermittent sports there are a variety of different explosive movements that fall into the category of anaerobic movements. The most prevalent in intermittent sports including football is repeated sprinting. Intermittent sports do not involve singular sprints followed by significant periods of rest but more accurately involve low-intensity continuous activity combined with frequent maximal sprinting, turning, acceleration and deceleration (Mohr et al., 2003). There have been many studies into influences of repeated sprints such as Bogdanis et al. (1995), who investigated the recovery of power output and muscle metabolites after a 30s maximal sprint cycle. Participants performed two 30s maximal sprints on a cycle ergometer separated by 1.5, 3- and 6-minutes periods of recovery. The results revealed that after sprint 1, PCr replenishment was extremely rapid, reaching 65.0 ± 2.8% of rest PCr after 1.5 minutes. However, peak power output and total work done diminished in comparison to the first 30s sprint. Another study by Bogdanis et al. (1996), specifically analysed the contribution of PCr and the aerobic energy system during repeated sprints. Participants had an initial 30 second sprint followed by a 4-minute recovery period then either a 10 or 30s sprint. After the recovery period, PCr was only resynthesized to 78.7 ± 3.3% of the resting value. During the second sprint, there was a 41% decrease in anaerobic energy output which decreased the total work done in the second sprint by 18%. This suggests that the power output was maintained via an increase in aerobic energy output. These findings demonstrated that the contribution of the aerobic system changed significantly from the first sprint.

Although these studies (Bogdanis et al., 1996; Mohr et al., 2003) investigated repeated sprinting, both the sprinting duration and recovery times used as conditions do not reflect that of intermittent sport such as football. Andrzejewski et al. (2013) stated that football mainly involves high intensity sprints that are below 5s with short active recovery periods between them. A study by Gaitanos et al. (1993), investigated muscle metabolism during ten 6s maximal sprints on a cycle ergometer with each sprint separated by a 30s recovery period. It was reported that by the tenth sprint, power output was 73% of the initial sprint. The results further detailed that relative PCr contribution was similar in the first and last sprint, with aerobic metabolism increasing as the sprints went on. This was supported by Dawson et al. (1997), which was similar in nature and concluded that although the depletion of PCr in the repeated sprint condition was greater than the single sprint condition. Although the rate of replenishment of PCr in the repeated condition was significantly greater compared to the single sprint condition at each time point where data was collected (15.73 vs 10.77 mmol/kg DM for 10s – 30s; and 28.50 vs 16.40 mmol/kg DM for 30s – 3 min).

The replenishment of PCr stores is partially related to oxygen availability as it is resynthesized using ATP that is produced through oxidative pathways (McMahon et al., 2002). The type of recovery is a factor that greatly influences PCr replenishment. Intermittent sports involve active recovery periods through walking and low intensity jogging rather than periods of passive recovery. Active recovery has detrimental effects on repeated sprinting, whether that diminishes the replenishment of PCr or peak power output (Spencer et al., 2006; spencer et al., 2008). This is due to the PCr replenishment being limited by an increased oxygen demand to meet submaximal energy requirements (McMahon et al., 2002). Lactic acidosis would develop at work rates at which O_2 supply is probably inadequate to meet total O_2 demand of all contacting units (Wasserman et al., 2012). This would cause an even bigger issues such as cramps. Muscular cramps are an involuntary, intense and painful sustained contraction of skeletal muscle, which in exercise result from disturbances of fluid and electrolyte balance resulting from excessive sweat loss (Maughan, 1986). Additionally, Not only does active recovery effect power output, but varying recovery times greatly effect total work done as well. Billaut & Basset (2007) attributed this to increasing and decreasing patterns of recovery affecting both the energy systems and neurological mechanisms. These studies greatly reflect intermittent sport recovery patterns as there is no consistency in both the type and duration of recovery.

In summary, the research has shown that intermittent sports have high physiological demands, running an average of 10 – 13km at an average VO_2 in football match at around 70% $VO_{2peak,}$ whist using multiple energy systems. The use of the systems may be used at different periods of the match or concurrently. The high demands of both energy systems have been shown in the previous studies stated in this review. A percentage of an athlete VO_{2max} is the most appropriate way of showing the aerobic contributions to an activity. Due to the nature of intermittent sports, it is not feasible to directly measure VO_2, therefore HR can be used to estimate it. Moreover, a conversion is not always needed as many previous studies have used HR, values therefore can be compared together to see if similar or different. As for the anaerobic contributions to intermittent sports B[La] is often used. B[La] is used as a crude indicator as not always accurate with intermittent sports due to the collection of samples not at points of high intensity. Muscle biopsy is another method in measuring anaerobic contributions. Though more accurate in measuring the anaerobic contribution in a sample it is not indicative for all the muscles involved in the exercise. There is also a delay in accruing the samples, which is not present in accruing Blood lactate samples. Furthermore, the muscle biopsy is accurate for specific muscle area but when dealing with intermittent sports, that use whole body movements with no real stoppages other than half time, it is not very effective in measuring anaerobic contributions throughout the exercise. Nevertheless, B[La] does reflect the anaerobic production in intermittent sports but should be interpreted carefully. Lastly, the importance of athlete’s ability to perform a high number of repeated sprints has been stressed throughout. This is due to repeated sprinting being the movement most performed in intermittent sports. Therefore, as athletes complete more repeated sprints, due to the time and type of recovery in intermittent sports not being adequate, the oxidative pathway may not fully resynthesise. Thus, the anaerobic glycolysis becomes a greater importance to gain short burst of intense work. Although, if too many sprints in same amount of time, it may not be adequate time to gain full force in sprints using anaerobic glycolysis. Consequently, as sprints accumulate there is a small contribution of an athlete’s aerobic metabolism in those sprints. This reaffirming the importance of both energy systems working together in intermittent sport.

Training Load

To measure TL, there is a requirement for the relationship with the outcome parameter. Outcome paraments are the set of outcomes that are used to evaluate what has occurred, whether the outcomes produce a response wanted or prevent a response we would like to avoid. The TL is the prescribed exercise and the response of interest in football is the associated fitness gain, fatigue accrued or injury risk (Akubat & Van Winckel, 2014). To measure the training outcomes physiological test are commonly used, even though the external load (training prescribed by coaches) is often described as the training process (Impellizzeri et al., 2005). The external load induced adaptation is the actual physiological stress (i.e., internal load) imposed on the athletes by the external load (Booth & Thomason, 1991; Viru &

Viru, 2000). Furthermore, Bouchard & Rankinen, (2001) stated that other factors such as the genetic background and starting fitness level could influence the internal load imposed of the individual, even though the external load is the main determinant of the internal load, and consequently, the TL.

To give an example of the training process, two adult males run a 5km at the same pace and the finish together. One a trained athlete and the other and untrained athlete. The trained athlete would find it less demanding compared to the untrained athlete. Further tests of HR data or lactate would confirm this notion. Furthermore, in football related when two athletes complete the same movement unless their characteristics is the same, they would not show the same response. Therefore, the internal load acts as the stimulus for training outcome. The training process has been conceptualized by Impellizzeri et al. (2005). Figure 2.1 shows how the prescribed training and the characteristics of the individual together combine to for the internal TL.

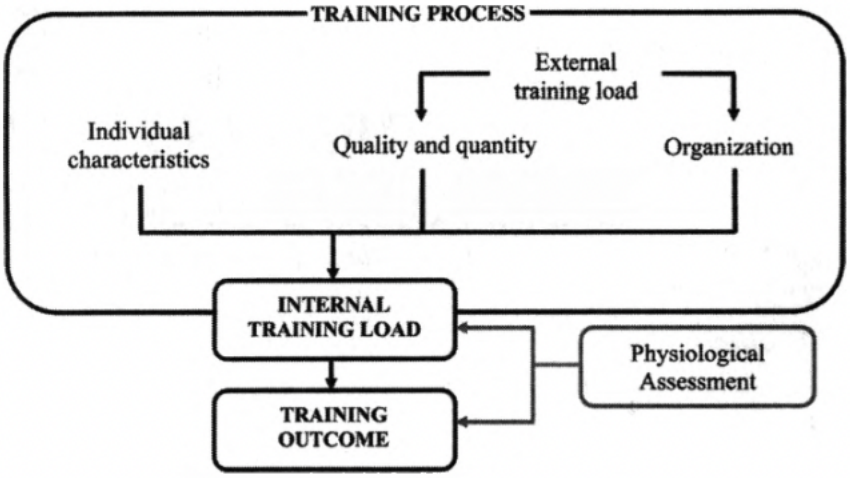

Fig. 2.1. The Training Process (Impellizzeri et al. 2005)

Measuring TL is particularly difficult in sports such as football, because different exercise designs lead to different physiological and mechanical demands, and there are inter-individual responses to the prescribed exercise (Bangsbo et al., 2006). If TL is difficult to measure in football, why do we do it? Akubat & Winckel, (2014) described the reasoning as, whether it be injury or a fitness test score, we generally react when the response has happened. Given that we want to avoid injuries and frequent testing, due to time constraints, understanding the response to a given training exercise enables us to be proactive in achieving our aims as coaches. To achieve the aims internal and external load are measured to gain a measurement of TL.

Internal Load

The assessment of internal TL requires quantification of the intensity of the physiological stress imposed on the athlete and its duration. While the duration of a training session is easily measurable as time in minutes, intensity can be determined with different methods, such as HR and ratings of perceived exertion (RPE) (Impellizzeri et al., 2005). comparing different players. One of the most widely used HR -based methods to determine internal TL is the ''training impulse'' (TRIMP) described by Banister (1991). It is calculated by multiplying training session duration by its average intensity (percentage of HR reserve) and by a sex-specific coefficient. This method allows physiologists to quantify internal TL in a single term balancing exercise duration and intensity. Although this model is limited using generic equations for males and females, that implies gender is the only differing factor for athletes and doesn’t take into account the individual differences that affect training as shown the model above (Fig. 2.1.). furthermore, the calculations uses mean HR which may not reflect the fluctuations in the HR that occurring during an intermittent exercise, such as football.

Another method to quantify internal TL is that proposed by Edwards (1993), which entails measuring the product of the accumulated training duration in five HR zones by a coefficient relative to each zone (from 50 – 60% of HRmax = 1 to 90 – 100% of HRmax = 5) and then summing the results. Further methods have tried to validate themselves through their relationship to this method. This has been done on the basis that HR is a valid measure of intensity (Bot and Hollander, 2000). Although, this method gained popularity the coefficients lacked any physiological underpinning and the zone limits remain predefined and lack metabolic or physiological performance thresholds and implies that training adaptation in zone 5 is five times greater than in zone 1, but no study to date has proven this to be the case. (Akubat & Van Winckel, 2014). Furthermore, the same issues provided here occur in a similar approach is to classify the exercise intensity by Lucia et al. (2003). The method based their measure of TL around the first and second ventilatory thresholds (VT1 & VT2). The method provides three zones: low (below VT1), moderate (between VT1 and VT2) and high (above VT2). Each zone is given a coefficient of 1, 2 and 3, respectively. The time spent in each zone is multiplied by the relevant coefficient and summated to provide a TRIMP score.

A modified version of Banister's TRIMP known as TRIMPmod was developed by Stagno et al. (2007) in an attempt to quantify TL for field hockey. Rather than use a generic equation to reflect a hypothetical blood lactate profile, these authors directly measured the blood lactate profile of the hockey players. The weightings they used therefore reflected the profile of a typical blood lactate response curve to increasing exercise intensity for the specific population, in this case the hockey team. While not truly individualized, their method used the mean blood lactate profile from all of the players to generate the weightings, providing at least some degree of individualization. They then anchored five HR zones around the lactate threshold (LT, 1.5 mmol) and the onset of blood lactate accumulation (OBLA, 4 mmol), with the resulting zone weightings being 1.25, 1.71, 2.54, 3.61 and 5.16. The accumulated time in each HR zone was then multiplied by its respective zone weighting to derive an overall TRIMPmod. The research quantified the TL in hockey and established relationships between TRIMPmod and various fitness parameters during the course of a season. Stagno et al. (2007) used the blood lactate responses at four different speeds from their player sample to create an equation for the weightings or the 'Y' value as defined by Banister. Zones 2 and 4 were created around the mean HR at LT and OBLA. A zone width of 7% fractional elevation was formed at these points. Zones 1, 3 and 5 were then created around zones 2 and 4. The pre-requisite for the use of this method was that the HR at LT and OBLA for all players fell within the created zones. Akubat & Van Winckel. (2014) found with a larger squad of players this pre-requisite could not always be met. It must be highlighted that although the zones are based on metabolic criteria, they are created with arbitrary values of lactate and are therefore not individualised to the person but to the team. Another issue with using weighting individualised to a team is that it still does not account for individual differences. However, at the time this study was very useful. These weightings are specific to that team and to use this approach successfully you would have to do the same testing to produce the weightings specific to your team, but this point was often missed. Furthermore, this study also highlighted that individualisation was needed.

A group of Italian researchers mainly led by Vincenzo Manzi are the first and most prominent researchers of using the method known as iTRIMP. ITRIMP weighting is based on the individual's own HR–blood lactate response to incremental exercise, as measured during a standard lactate threshold test protocol. Furthermore, Manzi, et al. (2009) did not use HR zones or mean HR as previous methods had. The iTRIMP scores were calculated for each HR reading and summated to give an overall iTRIMP score. In comparison to methods employing zones this meant they had effectively created a zone for each HR reading from HRrest to HRmax. Therefore, they had individualised the weighting to the athlete, which goes beyond the individualisation by gender (Banister, 1991) or group (Stagno et al., 2007). Furthermore, the iTRIMP weighting is not arbitrary as in the case of Edwards (1993) and Lucia et al. (2003). Consequently, this method overcomes many of the limitations of previous methods.

Session RPE has been proposed and validated as a method for quantifying internal TL (Foster et al., 2001). Session RPE is a subjective method of quantifying the load placed on an athlete. It is calculated by multiplying the session intensity by the duration to provide a measure of load in arbitrary units. The intensity is described as a number (0-10) on the CR-10 Rating of Perceived Exertion (RPE) scale originally proposed by Borg et al. (1987). To verify the utility of Foster's RPE method as an indicator of aerobic TL in soccer, Impellizerri, et al., (2004) compares the session RPE method with various HR based methods: Banister's (1991), Edwards' (1993) and Lucia, et al. (2003). Suggesting the usefulness of RPE to monitor internal TL in soccer, they found significant individual correlations between HR based TL and Session RPE(r = 0.50 – 0.85; P 50.01). In addition to physiological variables, several psychological factors (e.g. anxiety and depression) can influence RPE during exercise (Morgan, 1994). The psychobiological nature of the RPE (Borg, 1982) could be particularly useful in preventing overtraining or over-reaching, because of the well-known multifactorial nature of these syndromes (Kentta & Hassmen, 1998; Morgan, 1994). Although the simplicity of session RPE cannot be denied, the limited usefulness of the information it provides has to be questioned. Furthermore, those studies claiming to assess RPE's validity against HR based methods fail to assess the validity of the HR based methods (Akubat, 2012).

External Load

The measurement of external load in soccer goes as far back as 1952 (Winterbottom, 1952) when hand notation methods were used to estimate the external demands of a game through the use of distance covered during a match. Reilly & Thomas (1976), were first to study the classical method, which used a camera to measure each player. The subject was videotaped for references purposes whist performing specific activities from walking to sprinting, in order to code for various match activities performed (Carling et al., 2008; Reilly, 2003). . In more recent history the use of automated camera systems brought the use of distance and break downs of the velocities at which distances were covered to the fore. This method allowed determination of positional differences (Di Salvo et al., 2007), levels of play (Mohr et al., 2003) and the match-to-match variation (Gregson et al., 2010). In more recent times, the invention and use of GPS has changed the way we are able to track, monitor load on players and performance. The use of these devices has also bought many challenges as they are also now equipped with accelerometers, gyroscopes, magnetometers meaning the wealth of data that you can end up with is considerable. In conclusion all methods are used to analysis the performance that has taken place whether at training or during a match.

Performance Analysis

Performance analysis has become a huge factor in sport over the last 40 years, from analysing simple observation of movements to analysis of play at multiple different angles. Performance analysis of sport is the investigation of actual sports performance or performance in training (O'Donoghue, 2009). O'Donoghue (2009), proposed that any research that involves analysis of actual sport in training or competition can be classed under performance analysis. That this was not limited to observational data but quantitative data, qualitative data, notational analysis, perceived exertion, HR responses and time motion analysis systems such as GPS and automatic video tracking. Furthermore, the main reason for performance analysis is to enhance sport performance although there are uses in rehabilitation, academic, media, and judging contexts to sports performance analysis (O'Donoghue, 2014). Moreover, it was identified that the five purposes of sport performance analysis were analysis of technique, analysis of effectiveness, tactical analysis, analysis of movement and analysis of decision making. (Hughes, 1998, cited in O'Donoghue's, 2009). O'Donoghue (2014) description of the above purposes are as follows. Analysis of technique focuses on the mechanical details of the skills performed. Whereas analysis of effectiveness considers how well the skill is performed according to the outcome. Tactical evaluation is able to be made through analysing patterns of events based on skills performed, location of events, timing and the players involved. Through these observational analysis and indirect way of analysing tactical decisions can be made. Decision making coincides with tactical evaluation as it includes the tactical choices made by players. The reason for the separate category is too also cover the decisions of match officiators. The analysis of movement is more focused in gaining an understanding of the physical activity profile of sports, tactical elements as well as injury risk within those sports (O'Donoghue, 2008)

Although each purpose is important for this review the focus will be on the analysis of movement. The most common way analysis of movement is analysed is through time motion analysis. Time motion analysis refers to the locomotive movements performed by athletes and how these indicate the physical activity profile of the game. Where time motion analysis is concentred with the whole game not just on the ball movement (O'Donoghue, 2009). This has allowed the energy systems involved in racket sports (Richers, 1995, cited in O'Donoghue, 2009) and field games (Spencer et al., 2004) to be estimated. There are different ways time motion analysis can be attained. One way is to analyse distribution of match time among different movement classes (O'Donoghue, 2014). This can be done broadly by assessing a few movement classes (Reilly & Thomas, 1976, cited in Reilly, 2003) or with more detailed movement classes. The more detailed classes were classed by Bloomfield et al. (2004), who including details of straight and arced movements, direction of movement with respect to aspects faced by the player, turns and swerves. Another way to analyse movement is to track player location, this can be attained through GPS systems or semi-automatic tracking data systems (Buchheit et al., 2014; Coutts & Duffield, 2010; Randers et al., 2010; Wisbey et al., 2010). Professional football is a result driven sport and any advantage to enhance sport performance is encouraged. Thus, monitoring players' physical activity has become the norm in professional football (Carling, 2013). The three methods commonly used to monitor players in football and will be discussed further are manual video based time motion analysis, multiple camera semi-automatic systems and GPS.

Time motion analysis

Time motion analysis as stated above, refers to the locomotive movements performed by athletes and how these indicate the physical activity profile of the game (O'Donoghue, 2009). The classical method which was first study by Reilly & Thomas (1976). The method involved positioning video cameras at the side of the pitch, in line with the middle of the pitch. The cameras were positioned approximately at a height of 15m and a distance of 30 – 40m from the touchline. Each camera is used to film a separate player. The subject was videotaped for references purposes whist performing specific activities from walking to sprinting, in order to code for various match activities performed (Carling et al., 2008; Reilly, 2003). The duration of each activity was recorded, total time summed, and frequency of activity calculated to separate time blocks. The product of mean velocity and total time spent in activity, was the distance covered at each velocity within each time block. Finally, total distance covered during a match was calculated as the sum of the distances covered during each individual type of locomotor activity (Carling et al., 2008).

This method has been used and adopted in later research (Krustrup et al., 2003; Mohr et al., 2003; Randers et al., 2010). These studies used the same position and distance from the field for the cameras. They movement patterns were then categorised in locomotive categories in accordance with Bangsbo et al. (1991). The categories were standing (0 km/h), walking (6 km/h, jogging (8 km/h), low-speed running (12 km/h), moderate-speed running (15 km/h), high-speed running (18 km/h), sprinting (30 km/H), and backward running (10 km/h). Thus, the time for the player to pass pre-markers in the grass, the centre circle and other known distances was used to calculate the speed for each activity of locomotion. The above activities were later divided into four locomotor categories: (1) standing; (2) walking; (3) low-intensity running, encompassing jogging, low-speed running and backward running; and (4) high-intensity running, consisting of moderate-speed running, high-speed running and sprinting. The rest is the same as Reilly & Thomas (1976), in terms of spitting activity into blocks, how distance covered each activity and total distance is calculated.

Furthermore, the only advances in this method include better quality cameras and advanced input coding methods due better computer software. The new computer software allows for manual coding which in turn automatically calculates the time spent in each defined movement activity (Carling et al., 2008). These methods have been demonstrated to have high levels of reliability, objectivity, and validity (Carling et al., 2005 cited in Carling et al., 2008). Nevertheless, limitations occur from human error through inaccurate data entry, variable observe reaction to events being performed and different interpretations of performance by different observers, as inter observer consistency is considered crucial in establishing reliability of motion analysis (Barris &

Button, 2008; Bloomfield et al.,2007; Duthie et al., 2003 cited in Barris & Button, 2008). Moreover, this method is restricted to filming and analysis of one single player. They also do not allow for real time analysis and are very labour intensive in terms of capture and analysis of data (Carling et al., 2008). Finally, this type of analysis may be subject to errors due to changes in gait during game movements (Edgecomb & Norton, 2006) and that they only provide low spatial and temporal resolution (Barros et al., 2007).

Semi-automated multi camera tracking systems

Recent technological developments have meant that sophisticated systems, capable of quickly recording and processing the data of all players' physical contributions throughout an entire match, are being used in football (Carling et al., 2008; Randers et al., 2010). These new systems have the ability to analyse all players in a team throughout the whole match, tracking players when they are on and off the ball (Liebermann et al., 2002). In football the two biggest tracking systems are Amisco® (Sport Universal, Nice, France) and ProZone® (West Yorkshire, England).

The multi-player tracking systems such as the ones mentioned above require several cameras fixed at calculated positions to cover the whole pitch. The layout ensures that every player is captured on video, every second of the match. The stadium and pitch are calibrated in terms of height, length and width and transformed into a 2-dimensional model to allow player positions (x, y coordinates) to be calculated. Complex trigonometry, propriety mathematical algorithms, image-object transformation methods for obtaining 2- or 3-dimensional space coordinates such as Direct Linear Transformation from video footage of football play, as well as various image processing and filtering techniques, can all be used to identify each player's location on the pitch. The individual's movements can then be tracked on the video by computer software through either manual or automatic operation, at every single moment of the game. The technology is facilitated by supportive information such as shirt colour, optical character recognition of shirt numbers and prediction of running patterns to help maintain accurate player identification and tracking (Carling et al., 2008). These systems provide a passive (marker-less) tracking system that measures all moving objects on the football pitch and Sample at between 10 and 25 Hz (dependent on the system), real-time information is provided from the multiple capture systems installed around the stadium (Castellano et al., 2014; Di Salvo et al., 2007; Setterwall, 2003).

The advantages of semi-automatic multi camera tracking system is that they do not require players to carry any electronic transmitting device (Carling et al., 2008). Although, the tracking systems have provided enhanced motion tracking capability some still require significant manual intervention (Barris & Button, 2008). These include experienced analysts are required to code all events, such as, passes, duels, shots fouls, offsides and cautions that occur throughout the game (Castellano et al., 2014; Di Salvo et al., 2007; Setterwall, 2003). Additionally, continual verification by an operator to make sure players are correctly tracked by computer program is needed (Carling et al., 2008). Finally, the biggest disadvantage of semi-automatic multi camera tracking system is the high costs, the necessity of installing multiple cameras and a computerized network with at least one operator to organise date collection and further operator to perform the analysis (Di Salvo et al., 2006).

GPS

The development of GPS technology allows for the activity profile of practice and competition in contact team-sport to be quantified by the tracking of player activity profile (Aughey, 2011; McLellan & Lovell, 2012). GPS technology has had a huge impact on the analysis of performance in elite football, but the original use of GPS technology was designed for military (Randers et al., 2009). Typically, a GPS receiver is placed inside a pouch sewn into a sleeveless under shirt, but some may be different. Larsson et al. (2003), quantified GPS technology requires a receiver to be worn by each athlete, which draws from signals sent from 27 satellites equipped with atomic clocks in orbit of the earth but at least three earth orbiting satellite are needed to determine positional information and calculate movement speeds, distances and pathways. Usually, in football we have seen the use of total distance and high intensity distance (HID) as measure of external load or performance. HID has gained some credibility as a measure of exertion and performance through construct validity when comparing moderate level to elite level players (Mohr, et al., 2003). Although It has also been shown to vary greatly from game to game (Gregson, et al., 2010). Others argue the reason for changes game to game are stimulus driven expenditure determined by factors such as state of play, position and tactics (Impellizzeri, et al., 2005; Rampinini et al., 2007a; Rampinini et al., 2007b). It has been suggested TD and HID maybe valid indicators of load as soccer players will run as far as possible in games.

What makes GPS devices so commonly used is the ability to provide data on work rate characteristics such as total distance and time spent in various movement categories, the latest versions are able to coordinate biofeedback to accompany the traditional physical feedback. With such GPS units as the SPI Elite® capable of monitoring HR and information frequency and intensity of impacts (Carling et al., 2008). The data relayed has also been shown to be highly accurate and reliable with two previous papers of Coutts & Duffield (2010) and Edgecomb & Norton (2006), both demonstrating accuracy levels of under 5% for error rate in measured distance. Additionally, GPS is time efficient and allows for real time feedback, allowing for greater practicality in team sports (Scott et al., 2016). Although, GPS receivers have been shown to have been accurate and reliable, there are still problems accuracy, as the magnitude of error depends on land configurations and the number of available satellite connections (Carling et al., 2008). Furthermore, they also have some practical limitations such as satellite signals being blocked by the atmosphere and local environmental objects (Larson et al., 2003).

Reliability and Validity of GPS

GPS data have been researched and analysed extensively over the years. Even more so the reliability and validity of the GPS devices has been a topic of interest. Coutts and Duffield (2010) tested the validity of three different 1 Hz GPS devices on two moderately trained males. They completed eight bouts of a standard circuit and each bout consisted of six laps around a marked 128.5m running circuit involving walking, jogging, fast running, sprinting and standing still, to reflect all activity profiles of team sports. One minute was allowed to complete each lap. Each lap was hand timed, and feedback was provided to the participant regarding remaining time before the commencement of the next lap. There was 5–15s recovery between the completion of the circuit and the commencement of the next lap. Although there were significant differences between the three models, all models had an error rate less than 5% of actual measured distance. This shows all models to have a good level of accuracy. These results of a small error rate were supported by Edgecomb & Norton (2006) who completed validity checks for 59 trials where a player was monitored via a 1Hz GPS and instructed to move around a predetermined marked circuit. The results of a test of accuracy showed a 4.8% error rate in measuring total distance covered and a test of intra-tester reliability reported a technical error of measurement of 5.5%. Future papers that used similar models also agreed with similar results in terms of reliability and validity, but all had the same issue of poor reliability as distance speed increased to the higher threshold speeds (Colino et al., 2019; Coutts & Duffield; Edgecomb & Norton; Felipe et al., 2019; Jennings et al., 2010; Vickery et al., 2014). The poor level of intra-model reliability as running speeds enter the very high intensity speeds is a concern for the 1Hz models as those measures have been seen to be important measures for match running performance (Mohr et al., 2003; Rampinini et al., 2007b). It was proposed that the reason for poor reliability as speeds increased was that the large coefficient of variation (CV) of all models suggest that GPS devices that sample at 1Hz may be unable to detect important changes in running distances at speed >20kmh^{-1}.

Therefore, higher sample rate GPS devices have been developed to counteract this issue, as studies have shown the 5Hz GPS devices to be more reliable and valid than the 1 Hz GPS devices (Duffield et al., 2010; Johnston et al., 2012). 5Hz GPS devices have also been tested intensively and have been found to provide a comparable validity result to 1 Hz GPS devices. In terms of reliability the 5Hz was more accurate and only differed by small amounts (approx. 0–2%) for all courses (Portas et al., 2010). These findings are consistent with the findings by Duffield et al. (2010), who reported that GPS underestimates distance in confined spaces, but that

5Hz was more accurate at higher speeds in small spaces than 1Hz. However, there are still concerns over the accuracy of the moderate distances during high and very high-speed running. A study by Rampinini et al. (2015) found the validity of distance measures for high-speed running were moderate (CV = 7.5%) and worsened greatly during very high-speed running (CV = 23.2%). Although there seem to be similar limitations for the 5Hz as for the 1Hz GPS devices, other research findings allude to a more complicated picture about the accuracy of the 5Hz GPS devices when at High-speed running (Scott et al., 2016).

Recent developments in higher sampling rates of 10 and 15Hz GPS devices have led to examinations if they would be more valid and reliable than 1 and 5Hz GPS devices. Johnston et al. (2014) when testing the reliability and validity of 10 and 15Hz GPS devices found them to be more reliable and valid than 1 and 5Hz GPS devices. This is particularly valuable as the two GPS devices used in this study are 10 and 15Hz. There has been limited research on 10Hz GPS devices, but Vickery et al. (2014) found that measures of distance recorded by a 10Hz GPS unit did not differ significantly to criterion measures during a 40m running. However, distance measures from a 10Hz GPS unit were significantly different from the criterion measure during a shorter running course involving several tight changes of direction. Despite this, Johnston et al. (2014) when using a team sport simulated circuit there was no significant difference between the criterion distance and the total distance reported by a 10Hz GPS unit. Although Vickery et al. (2014) found that the 10Hz GPS devices may provide significantly different results to criterion measure during a tight change of direction course, it would seem that 10Hz GPS devices are able to quantify short to moderate distances (<60m) with higher accuracy when compared with the 1 and 5Hz GPS devices (Scott et al., 2016).

In addition, Rampinini et al. (2015) found that during intermittent shuttle running over moderate distances (70m), measures of total distance and high-speed running distance from a 10Hz GPS device had good accuracy (CV = 1.9% and CV = 4.7%, respectively). However, accuracy worsened and became poor during very highspeed running (CV = 10.5%). Although, this is significantly better CV compared to the 5Hz GPS device in the same study for high-speed running. Moreover, 10Hz GPs unit have been shown to have good interunit reliability, with CV being 1.3% and 0.7 when measuring sprints of 15m and 30m, respectively (Castellano et al., 2011). Conversely, it had been suggested that during high-speed running 10Hz GPS devices would ben unadvisable, although all other interunit reliability measures are good, therefore it is suggested to use caution when comparing and interpreting high speed running between devices (Scott et al., 2016).

The research on 15Hz GPS devices is more limited as its development as only come of recent. It is important to know that higher frequency actually sample at lower frequency and then use interpolation from tri-axial accelerometer to increase sample frequency. For example, 15 z GPS device (SPI HPU, GPSports, Canberra, Australia) collects data at 5Hz then uses the accelerometer to interpolate that frequency to 15Hz (Tessaro, 2017). From the limited research it was found that during a running shuttle protocol designed to recreate football movements both linear and curvilinear distance was significantly different from criterion measures (Rawstorn et al., 2014). In support of this Vickery et al. (2014), found that 15Hz GPS devices differed significantly on distance measurements to criterion measures during a gradual change of direction course. However, during a multidirectional 10s bout of team sport movements 15Hz GPS devices did not differ significantly to criterion measures.

Furthermore, Vickery et al. (2014) found that 15Hz GPS devices were not significantly different from criterion measures during short high-intensity linear-based running. Likewise, Johnston et al. (2014) found no significant difference between the criterion distance and the total distance reported during a team sport simulated circuit. To assess the validity and reliability of a GPS device, Barr et al. (2019), carried out a series of cohort experiments where the key finding was that the GPS device was accurate in measuring linear high velocity sprinting in football players. Additionally, the study found inter-unit reliability was found to be for peak velocity (1.0%) total distance (1.4%), walking distance (3.2%), sprinting distance (4.8%) and jogging distance (7.8%) which are all in the acceptable limits. Johnston et al. (2014) who used the similar type of device in his study, found all results to be similar except for a lower reliability for peak velocity (8.1%) compared to Barr et al. (2019). This may have been due to Johnston et al. (2014) using less devices or there being further updates (Barr et al., 2019). The validity and reliability of this GPS device is further supported by Williams & Tessaro et al. (2018) who found the Rate of mean square to be ± 2%. For GPS systems and other technical devices used during exercise, measures of validity (i.e., error values) less than 5% are considered good (Scott et al.,2016). There have not been many studies on the reliability of this device but the studies that have been completed show that the device has relatively valid reliable in different situation with a low error value.

As stated above higher Hz GPS devices use accelerometer to increase to a higher frequency to get more reliable data. This is due the accuracy of GPS is limited by the high dynamics of sports. Such quick changes of satellite constellation the render the carrier-phase ambiguity resolution difficult or even impossible. Thus, to overcome this and to be able to observe reliable accelerations and oritentaions, inertial and megentic sensors are integrated with GPS (Waegli et al., 2007). For GPS that is worn on the body micro electro mechanical systems (MEMS) are used due to the small size, low cost and power consumption (Frosio et al., 2009; Waegli et al.,2007). MEMS accelerometers are integrated with gyroscopes or detailed models of the moving body and their output has to be integrated over time (Frosio et al., 2009). If the devices are using MEMS accelerometer to produce data at higher frequency does that not make the devices MEMS devices as that is what is producing the data.

The literature suggest all GPS devices are capable of tracking athlete distances and have acceptable interunit reliability, no matter the sampling rate. However, all the different sampling frequencies have some limitations. At this moment 10Hz GPS devices would be the optimal as it mitigates the limitations the most. It overcomes the limitation of validity of the seen in 1 and 5Hz GPS devices. The 15Hz GPS devices have shown equal benefit to the 10Hz, although need more research to confirm the reliability and validity, since very little research has been done so far (Scott et al., 2016). What was also concluded was that if an accelerometer is used in the device, it is a MEMS devices not a GPS.

GPS in making activity profiles

A great benefit of GPS devices for a sport such as football is that it allows for activity profiles to be created for individual players, positions and whole teams. This is normally characterised by using high-intensity activity (sprinting, running, kicking, jumping, and tackling), interspersed with lower intensity actions (jogging and walking) and active or passive recovery as a marker (Bloomfield et al., 2004). This allows an evaluation of performance from the frequency of each type of movement and time spent or distance run in each movement (Carling et al., 2008). Over the years numerous time motion analysis and GPS analysis have been used to determine the physical profile of football players (Casamichana et al., 2012; Di Salvo et al., 2007; Mohr et al., 2003; Krustrup et al., 2003; Krustrup et al., 2005; Suarez-Arrones et al., 2014).

The introduction of GPS looks set to increase our knowledge by revealing how players physical profiles evolves with age, how it varies according to position, how it varies across whole seasons and between competitive versus training contexts (Buchheit et al., 2010; Casamichana et al., 2012; Malone et al., 2015; Mendez-Villanueva et al., 2013; Ritchie et al., 2016). From the research it is understood that a typical total distance covered during a match is 10 – 13km most of this distance is covered by walking and low-intensity running, hence making the high-intensity exercise periods important in terms of energy production (Bangsbo et al., 2006). Bangsbo et al. (2006) further stated that the amount of high-intensity exercise separates top-class players from players of a lower standard. A study by Mohr et al (2003), supported this when demonstrating that international players performed 28% more ($P < 0.05$) high intensity running (2.43 vs. 1.90km) and 58% more sprinting (650 vs. 410 m) than professional players of a lower standard. Thus, it has been suggested that the amount of high intensity exercise is a valid measure of physical performance in football (Krustrup et al., 2005; Mohr et al., 2003; Mohr et al., 2005). Another important fact of activity profiles is allowing understanding of workload imposed on certain positions during matches to be able to develop sport specific training protocol (Di Salvo et al., 2007). Therefore, it has been generally recognised that midfielders cover greater distances in a game than defenders and forwards (Di Salvo et al.,2007; Mohr et al., 2003; Suarez-Arrones et al., 2014). Nevertheless, it should be accounted that for each playing positions there can be variation on physical activity profile, depending on tactical role and the physical capacity of the player (Carling et al., 2008).

Knowing theses activity profiles, it is of interest if these profiles would be affected by congestion. In a study, Odetoyinbo et al. (2008) examined the effect of a succession of matches on the activity profiles of professional football players when three matches were played in five days. Their findings suggested that the activity profiles were not influenced by the short recovery periods between matches, while some fatigue may be apparent that affects certain high-intensity aspects of play. This finding was supported by Rey et al. (2010), who also found the activity profiles of elite Spanish football players who played two matches in five days. These previous papers were limited in that they only looked at the effect of congestion on one period. Djaoui et al. (2014), on the other hand analysed 4 successive congested periods (2 matches per week) separated by periods of international truce and normal one-game per week microcycles over a 5-month period. The congested periods were then compared to the non-congested periods, where the main finding was that no significant differences between congested and non-congested periods were observed in distances covered at the running intensities over 18 km/h for all playing positions. Varley et al., (2018) also agreed with previous research but suggests that individuals will respond differently and individual monitoring is required.

In contrast to previous research, Kovacs et al. (2020) found elite youth football players produced low physical performance outputs during a fixture congestion across 3 matches. Although compared to the previous research the players had 72h of recovery between matches which they did not in Kovacs et al. (2020) thus, not allowing sufficient recovery for players to maintain physical performance outputs. Furthermore jones et al. (2018) reported a small but significant effect within match patterns of total distance, low intensity distance, and sprint distance across the FCSen. The three FCSen were groups according to the number of days between successive matches. The first group comprised of players completing a single match performed in a weekly microcycle with no additional match performed within four days of this match. The second group encompassed data from the second match of a two match weekly micro cycle whereby two matches are performed with less than 4 days between matches. The third group used data from the third match of a three-game weekly mircocycle where matches were performed with less than 4 days between each match. Moreover, a major difference from the two studies that found differences in performance when there were congested periods, were the ones that used GPS to monitor performance whereas other used camera tracking systems. This was likely due to the rules of GPS technology being approved for use in competition only being approved in 2015 (FIFA, 2015). Therefore, such differences between video tracking systems and GPS systems could be one reason for the difference in findings.

COVID and impact of demands in football

The previous football season was affected by COVID-19, which affected different leagues in different ways. Some were ended prior to full conclusion of season; others were postponed and re started in a condensed manner. However, when the 2019/20 season ended all that was assured was that the 2020/21 season would be condensed more than ever before, so that footballing season could restore to their normal ways from the 2021/22 season. This meant there would not just be congested periods in the 2020/21 season but the whole season would face congestion. For the purpose of this study, the team analysed were in the English football league one and due to the effect of COVID-19, it Condensed the 2020/21 down to 35 weeks compared to 39 weeks in 2018/19 season which was the last full season. In football terms 4 weeks could mean an extra 8 matches being spaced into those weeks but instead would be condensed down. Additionally, in the 35 weeks the club would need to complete all competitive league and cup matches. In total they played 55 matches in 35weeks, compared to 55 matches in 39 weeks in the 2018/19 season. This meant the season would have more matches packed together, with a match played every 3-4 days. This would cause more strain and load on the players having to play the same number of matches in a shorter period, hence the importance of GPS monitoring became a bigger factor this season. In a normal season there is 6 days between matches with a few 3 – 4 days sporadically throughout the season. To make sure players were not over overworked and injuries were kept to a minimum. GPS would allow players to be monitored in matches and training to see if there any differences in their activity levels, so that adjustments could be made.

Although there has been quantification of load across whole seasons using GPS (Anderson et al., 2016; Malone et al., 2015; Ritchie et al., 2016) there hasn’t been any over a congested whole season only over congested periods (Jones et al., 2018; Kovacs et al., 2020). Thus, this study looks to investigate the effect of a congested season on the activity of professional football players. As most previous studies when looking at congestion have only looked at small sample sizes and not as a whole season. Furthermore, there has not been this congestion of a whole season due to the COVID-19 pandemic. So, to our knowledge there has not been a study to investigate the effect of COVID-19 and the subsequent congestion that was caused the following season after that. Therefore, this present study will look to follow on from the work of Jones et al. (2018) and Kovacs et al. (2020) which used GPS as a way of analysing the effect of congestion on football players and to determine if there is an effect as suggested by the studies. This study will also use similar methods to Djaoui et al. (2014) by using separate periods of the season and comparing those periods with previous years to see if there has been any significant difference in each period and as whole season.

Research aims

Thus, the purpose of this study is to ascertain whether there has been an effect of a congested season on the activity of professional football players. Using a specific protocol that allows comparisons to be made with previous seasons to see if there have been any significant differences. This allowing us to answer the specific research aims to determine whether there is an effect on elite football players match activity due to a more congested season compared to previous seasons. Therefore, we will determine:

1. If there has been a greater total distance (TD) and high-speed distance (HSD) placed on the players in the congested season compared to previous
2. If there are any significant differences in individual positions match activity in the congested season compared to previous
3. If there has been an increase in the frequency of injuries in the congested season compared to previous.

CHAPTER III: METHODS

Activity pattern measurements

The validity and reliability of GPS system have been previously reported (Coutts & Duffield, 2010; Varley et al., 2012). GPS technology requires a receiver to be worn by each athlete, which draws from signals sent from 27 satellites equipped with atomic clocks in orbit of the earth but at least three earth orbiting satellite are needed to determine positional information and calculate movement speeds, distances and pathways (Larsson et al., 2003). But due to units including an accelerometer they will be referred to as MEMS, as previously stated before. Participants wore a MEMS unit (SPI HPU, GPSports,15Hz, Canberra, Australia) for the 2018/19 and 2019/20 seasons. For the 2020/21 season players wore (Playertek, Catapult, 10Hz, Leeds, UK). The accelerometer for each GPS unit is 100 and 400Hz, respectively. Two metrics have been identified for use in this present study TD; HSD which is the amount distance time spent at or greater than 18kph, as from he data stored from all three years include HSD and TD.

Participants

Participants will be from anonymised Global Positioning system (GPS) data provided by a team in the English Football League One Ethical approval was giving by the research ethics and advisory group at the University of Kent (Ethics Reference: 12_20_21). The data only included past MEMS data from competitive matches played by chosen team First Team players. The players included would have competed in from either 2018/19, 2019/20 or 2020/21 seasons. For the purpose of this study for player to be included in an evaluation of a match, the MEMS data must represent at least half of highest output for the metric during that match (i.e., the highest reading for total distance were 15000m, for a player to also be used they must have attained 7500m). The study included 65 players in total who met the above criteria (see table 3.1 for the breakdown of number of players).

TABLE 3.1. Breakdown of number of players in each position

Position	Overall Number of players	TD total number of players	HSD total number of players
DEF 2020/21	8	8	8
MID 2020/21	10	10	10
ATT 2020/21	7	7	7
Total 2020/21	**25**	**25**	**25**
DEF 2019/20	6	6	6
MID 2019/20	8	8	7
ATT 2019/20	8	8	7
Total 2019/20	**22**	**22**	**20**
DEF 2018/19	5	5	5
MID 2018/19	9	9	9

ATT 2018/19	4	4	4
Total 2018/19	**18**	**18**	**18**

Note abbreviations in the table are as follows total distance (TD) and high-speed distance (HSD)

Periodic analysis of MEMS data

This study used a data analysis method to look at 3 different periods of this season and compare those same periods with previous seasons. The first period evaluated were September as that is the first full month of a season. The next period was between December and the first week of January. This period is notoriously busy and will be a good indicator for any changes in activity profiles. The last period will be the 7th February – 7th March. This is due to this being the last month of the 2019/20 season due to COVID-19 Pandemic which cut the season short. Therefore, the last month where all three seasons can be compared at similar period. The metrics to be looked at include HSD, TD. Each period from one season was compared its counterpart from a different season, using the metrics provided by the MEMS data.

The justification for the periodic analysis of the MEMS data was due to there being a change in research question. Has the initial researched required access to first team players, so data could be collected throughout the season but due to COVID 19 contact with first team players was not possible. Therefore, the research was changed and historical first team data was used for the research. Due to the time contrariant with the change in research and that there were missing data sets, the best possible way to conduct the research was using 3 different periods across the season as described above and not all matches of the seasons.

Injury data

Injury data from the 2020/21 and 2019/20 was used to analyse if there has been an increased frequency for injuries. This will analyse the number of days missed and matches missed due to injury. However, as both seasons played a varied number of matches 55 for 2020/21 and 43 in 2019/20, the days missed and matches missed will be divided by the number of matches played to get a rate of days or matches missed per injury.

Analysis

Statistical test was performed in SPSS using a (IBM, New York, USA). A one way ANOVA will be performed on all the metrics for each individual period, the totals across the season (Totals are given has the mean values when each participant values for each period are added together, for that season), each period for positions and totals across the season for positions (Totals are given has the mean values when each participant values that play that particular position for each period are added together for that season). The key variables to be analysed were TD and HSD. Injury data was reported as descriptive.

Chapter IV: RESULTS

Differences in periods

For TD in periods 1 and 2 there were no significant difference between 2020/21 and 2019/20 (P= 0.64; P= 0.94, respectively). During period 3 again there was no significant difference between 2020/21 and 2019/20 (P= 1.00) but there was a significant difference in the 2018/19 season with the 2020/21 season (P <0.01) and the 2019/20 season (P= 0.02). See table 4.1 and Fig 4.1.

For HSD in periods 1 and 2 there were no significant difference between 2020/21 and 2019/20 (P= 0.08; P= 0.89, respectively). During period 3 again there was no significant difference between 2020/21 and 2019/20 (P= 0.09). This was the same for between 2018/19 and 2019/20 (P= 1.00) but there was a significant difference in the 2018/19 season with the 2020/21 season (P <0.01). See table 4.2 and Fig 4.1

Differences across the whole season

As a whole season across all three periods there was no significant differences for TD or HSD between 2020/21 and 2019/20 season (P = 0.88 and P = 0.28, respectively). Although 2020/21 was higher than 2019/20 in both instances, see table 4.1 and 4.2.

Table 4.1. Differences in Total distance over the three periods and in total

Variable	Period			Total
	1	2	3	
Total distance 2020/21(m)	11852 ± 1600 (19)	12058 ± 1706 (19)	11021 ± 1753* (15)	24784 ± 10111 (25)
Total distance 2019/20 (m)	11621 ± 1368 (18)	12006 ± 2217 (13)	10557 ± 1641$^{\#}$ (16)	24280 ± 11860 (22)
Total distance 2018/19 (m)			8304 ± 1849$^{*\#}$ (18)	

Values are mean ± SD. * denotes significant difference between 2020/21 and 2018/19 in the same period. # Denotes significant difference between 2019/20 and 2018/19for in the same period. () denotes number of participants.

Table 4.2. Differences in High-speed distance over the three periods and in total

Variable	Period			Total
	1	2	3	
High speed distance 2020/21 (m)	1015.41 ± 195.52 (19)	942.62 ± 233.95 (19)	944.40 ± 222.59* (15)	2055 ± 905 (25)
High speed distance 2019/20 (m)	890.90 ± 216.39 (18)	926.98 ± 283.07 (13)	766.31 ± 191.86 (15)	1885 ± 890 (21)
High speed distance 2018/19 (m)			737.04 ± 228.17* (18)	

Values are mean ± SD. * Denotes significant difference between 2020/21 and 2018/19 in the same period. () denotes number of participants.

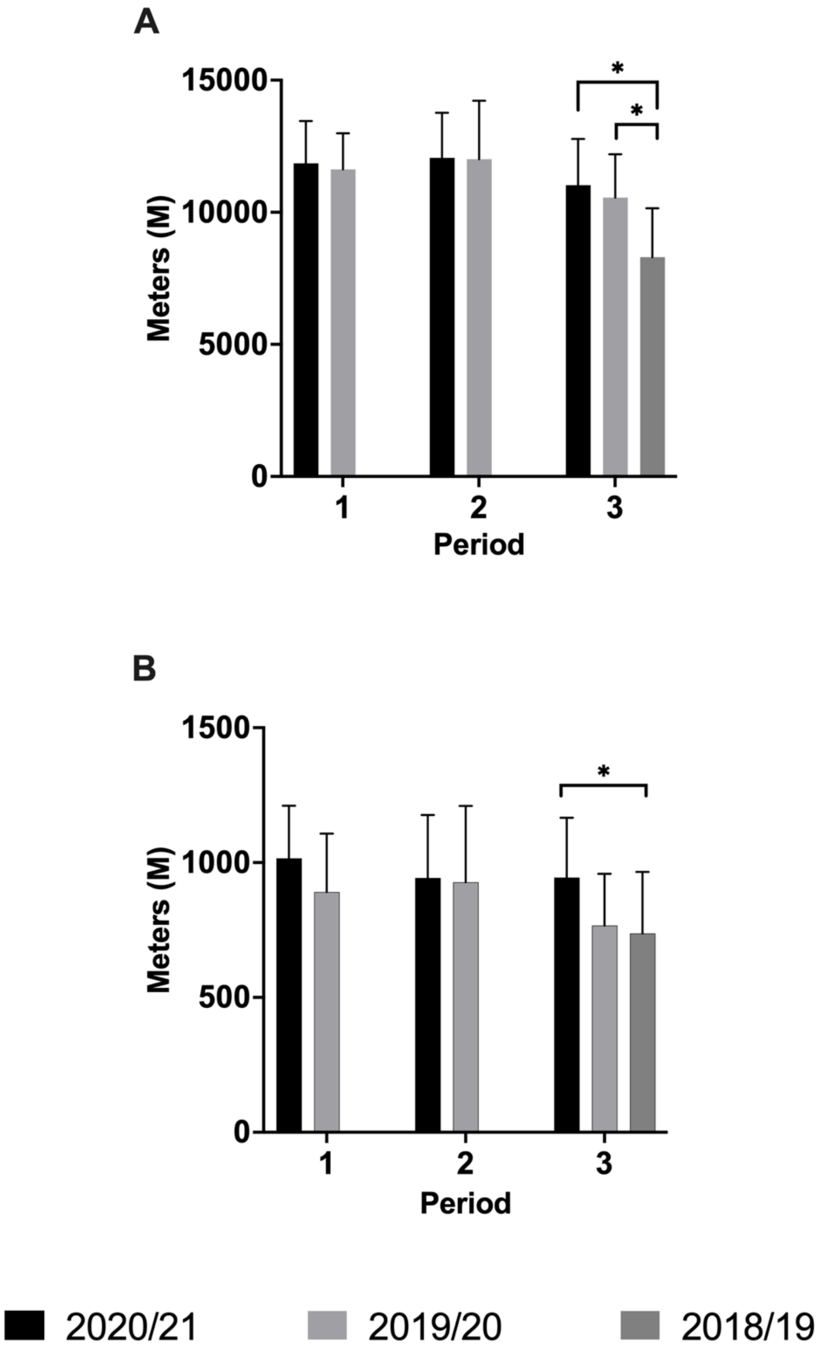

Fig 1. Mean ± SD showing (A) TD and (B) HSD. * Indicates significant difference between the years for that period.

Differences between the same positions

There were no significant differences for TD between 2020/21 and 2019/20 seasons for any of the same positions in period 1 (DEF P= 1.00; MID P= 1.00; ATT P= 1.00) and 2 (DEF P= 1.00; MID P= 1.00; ATT P= 1.00). In period 3 there was a significant difference in MID between 2020/21 and 2018/19 (P= 0.02), all other positions were not significant different when compared with similar positions in different seasons. See table 4.3 and fig 4.2.

There were no significant differences for HSD between 2020/21 and 2019/20 seasons for any of the same positions in period 1 (DEF P= 1.00; MID P= 1.00; ATT P= 1.00) and 2 (DEF P= 1.00; MID P= 1.00; ATT P= 1.00). In period 3 all positions were not significant different when compared with similar positions in different seasons. See table 4.4 and fig 4.2.

There were no significant differences when looking at all three periods as a whole season positional metrics between the 2020/21 and 2019/20 seasons. For TD and HSD when comparing the same position total between the two seasons all values were P= 1.00 (see table 4.3 and 4.4).

Table 4.3. Differences Total distance for different positions for each period and in total.

Position	Total Distance in each Period (m)			Total (m)
	1	2	3	
DEF 2020/21	12294 ± 595 (6)	12610 ± 744 (6)	11379 ± 1835 (5)	25790 ± 12000 (8)
MID 2020/21	12556 ± 1376 (7)	11828 ± 2297 (7)	11674 ± 1568 (5)*	22906 ± 8767 (10)
ATT 2020/21	10587 ± 1933 (6)	11775 ± 1749 (6)	10011 ± 1722 (5)	26319 ± 10756 (7)
DEF 2019/20	12002 ± 1404 (6)	12502 ± 661 (5)	11677 ± 437 (5)	32151 ± 9075 (6)
MID 2019/20	12035 ± 1473 (7)	13280 ± 2919 (4)	9827 ± 2081 (6)	24541 ± 12337 (8)
ATT 2019/20	10584 ± 611 (5)	12037 ± 1895 (4)	10313 ± 1431 (5)	24549 ± 10845 (8)
DEF 2018/19			9120 ± 225 (5)	
MID 2018/19			7476 ± 1970 (9)*	
ATT 2018/19			9148 ± 2199 (4)	

Values are mean ± SD. () Denotes number of players used for that period in that position. * Denotes significant difference between 2020/21 and 2018/19 when comparing the same position in the same period. Note no significant difference between 2020/21 and 2019/20 for same position when compared with a different season in any period and as a whole across the three periods.

Table 4.4. Differences High speed distance for different positions for each period and in total.

Position	Period			Total
	1	2	3	
DEF 2020/21	950.86 ± 157.89 (6)	927.81 ± 177.85 (6)	793.37 ± 171.41 (5)	1904.86 ± 1007.20 (8)
MID 2020/21	1082.29 ± 231.05 (7)	935.98 ± 321.01 (7)	1087.53 ± 241.83 (5)	1956.57 ± 857.60 (10)
ATT 2020/21	1001.91 ± 192.75 (6)	965.16 ± 202.00 (6)	952.30 ± 172.62 (5)	2366.27 ± 912.06 (7)
DEF 2019/20	838.67 ± 286.44 (6)	863.53 ± 153.046 (5)	685.85 ± 133.49 (5)	2128.82 ± 542.15 (6)
MID 2019/20	926.15 ± 202.50 (7)	1178.28 ± 172.43 (4)	756.30 ± 193.39 (6)	1966.74 ± 1091.46 (7)
ATT 2019/20	904.22 ± 168.68 (5)	755.00 ± 359.44 (4)	881.89 ± 238.50 (4)	1581.23 ± 909.65 (7)
DEF 2018/19			626.45 ± 135.39 (5)	
MID 2018/19			721.09 ± 243.50 (9)	
ATT 2018/19			911.18 ± 225.59 (4)	

Values are mean ± SD. () Denotes number of players used for that period in that position. Note no significant difference between any of the seasons for all positions when compared with similar positions in different seasons for any period or as a whole across the three periods.

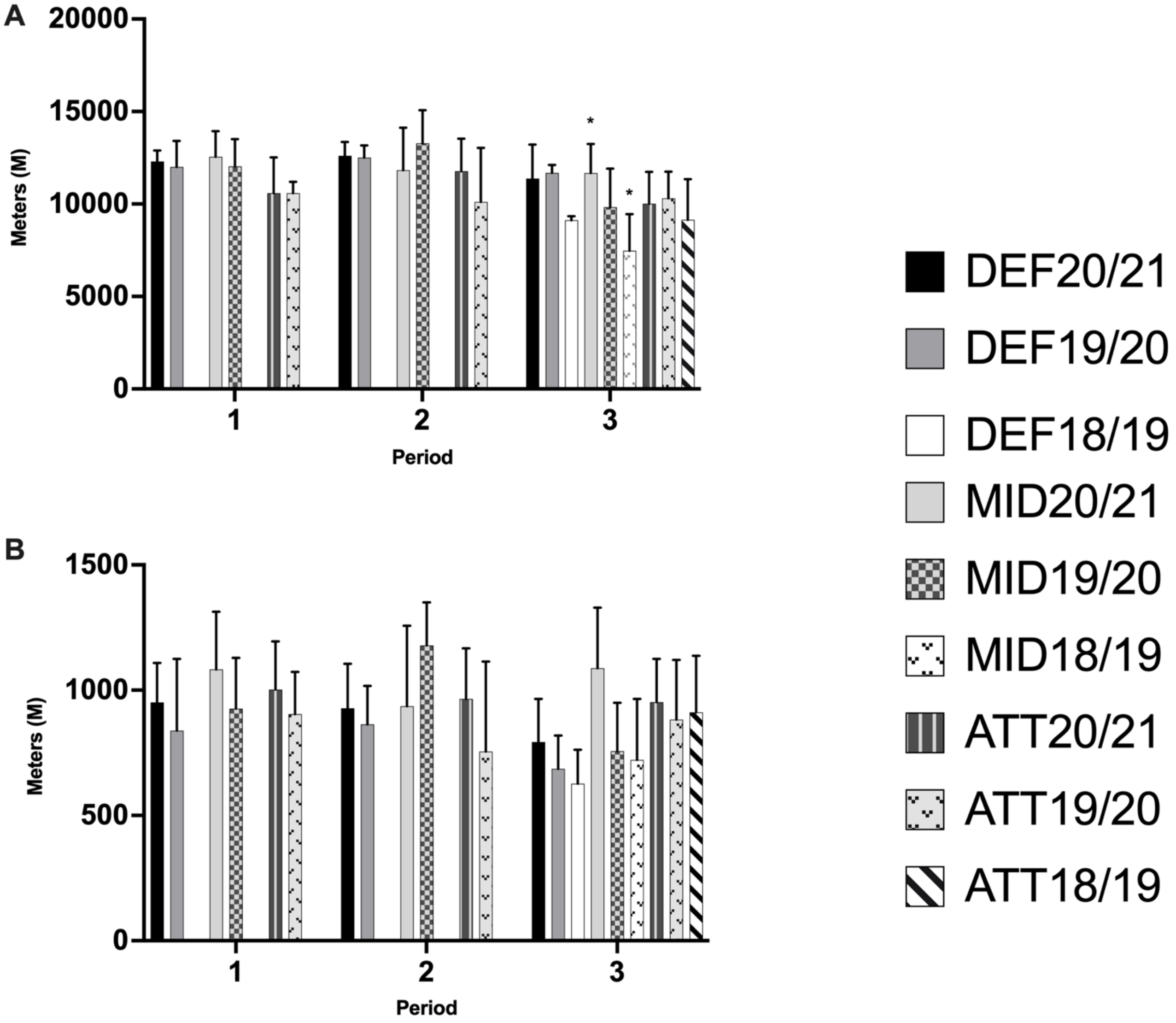

Fig 2. Values are mean ± SD showing (A) TD and (B) HSD. * denotes significant difference between 2020/21 and 2018/19 for same position in the same period.

Differences in Injuries

There was a higher rate of days missed of 5.19 in 2020/21 than 2019/20, thus showing a longer number of days missed per injury. This was similar for rate of games missed, where 2020/21 was higher than 2019/20 by 0.96, therefore almost an extra game was missed per injury in 2020/21 (see table 4.5).

Table 4.5. Differences in injuries

Injury year (Number of games played)	Days missed	Rate of days missed (rate = days missed/ number of game)	Games missed	Rate of games missed (rate = games missed/ number of game)
2020/21 (55)	746	13.56	156	2.84
2019/20 (43)	360	8.37	81	1.88

Chapter V: DISCUSSIONS

This study demonstrates that there was no significant difference for TD and HSD between the seasons, during the selected periods of the season or as a whole season across all three periods. This was similar when comparing the positions across different seasons. Where between the same positions in different seasons generally there was no significant distance for TD and HSD, during the periods or as a whole season across all three periods. This study therefore suggests that a congested season will have no significant impact on the players. On the other hand, there was an increase in the frequency of injuries from the 2020/21 season compared to the 2019/20 season. There was an increased number of days missed per injury and an extra match missed per injury in the congested season compared with the non congested season.

Congested match periods occur frequently in elite football (Dupont et al., 2010). Although congested match periods occur there has not been a congested season comparable the 2020/21 season before. Therefore, comparing to studies that have researched congested periods, would be the most effective in seeing if the results from those studies are comparable to the results of this current study. The results of the TD and HSD in this study are in line with those of Djaoui et al. (2014); Odetoyinbo et al. (2008); Rey et al. (2010); Varley et al. (2018), that they were largely unaffected by the congested season compared to different seasons. The present study did not show significant variation between any of periods or as a whole season across the three periods for TD apart for period three (See table 4.1 and fig

4.1). Where the 2018/19 season was significantly different to the 2020/21 (P < 0.01) and 2019/20 (P= 0.02) season in period 3. Although the significant difference may only come due that in the 2018/19 season in period three only five matches were played, compared to 7 matches played in the other two seasons in the same period. In contrast to previous studies and this current study, Kovacs et al. (2020) found elite youth football players produced low physical performance outputs during a fixture congestion across 3 matches. Although compared to the previous research the players had 72h of recovery between matches which they did not in Kovacs et al. (2020) thus, not allowing sufficient recovery for players to maintain physical performance outputs. In addition, Jones et al. (2018) reported a small but significant effect of within match patterns of total distance, low intensity distance, and sprint distance across the FCSen. The three FCSen were groups according to the number of days between successive matches. The first group comprised of players completing a single match performed in a weekly microcycle with no additional match performed within four days of this match. The second group encompassed data from the second match of a two match weekly micro cycle whereby two matches are performed with less than 4 days between matches. The third group used data from the third match of a three-game weekly mircocycle where matches were performed with less than 4 days between each match. However, Jones et al. (2018) was only able to find the small differences in TD as the results were looked at in 15 min epochs and not in halves or full match as previous studies have.

The results of HSD in this study were a parallel to that of TD. The present study did not show significant variation between any of periods or as a whole season across the three periods for HSD apart for period three (See table 4.2 and fig 4.1). Where the 2018/19 season was significantly different to the 2020/21 season (P < 0.01), again this is likely to be because of the disparity in the number of matches as mentioned before. Although, 2020/21 HSD had the fewer matches than 2018/19 HSD the mean in period 3 was higher for 2020/21 (see fig.1 and table 4.2.). This could be due to that performance during match-play is related to the physical activity completed by the opponent teams as well as their competitive level, (Rampinini et al., 2007b), high-speed activity completed by players during match-play is highly variable between matches. The observation that this variability is affected by factors such as playing position and having possession of the ball (Gregson et al., 2010) are all factors that could affect the variation HID. However, as a whole HSD was largely unaffected by the congested season. HSD being unaffected by congestion is common is previous studies as it is in this present study (Carling et al., 2012; Djaoui et al., 2014; Kovacs et al., 2020; Odetoyinbo et al., 2008; Rey et al., 2010; Varley et al., 2018). Djaoui et al. (2014) suggested that the above results may be achieved by implementation of light technical sessions along with fitness training sessions mainly developing: prevention agility and short sprinting training. Additionally, the strategy of rotation of players', the different tactics used in matches and the training in-between matches (essentially tactical and small-sided games) could also be an explanation of the observed results (Carling et al., 2012; Djaoui et al., 2014). The mentioned strategies were used by the team in this current study, as there key to maintain performance was using the amount of HSD covered to similar levels every week by maintain the 'sweet spot' in the acute:chronic workload ratio. The acute:chronic workload ratio was developed by Gabbert (2016), where acute TL accounted for one week training and represented analogous to state of fatigue, whist chronic training accounted for the rolling average for the most recent 3 – 6 weeks of training and represented an analogous to a state of fitness. By comparing the two it provides an index of athlete’s preparedness. Furthermore, Gabbert (2016) concluded in terms of injury risk that a ratio of 0.8 – 1.3 could be considered the training ‘sweet spot’ and anything ≥1.5 would be in the danger zone for injury. Hence this theory would be applied by manipulating training sessions to make sure acute:chronic workload ratio was maintained at the ‘sweet spot’ so the athletes were as prepared as they could be for the match and if they were outside the ‘sweet spot’ would be able to give advice accordingly.

A great benefit of GPS devices for a sport such as football is that it allows for activity profiles to be created for individual players, positions and whole teams. Over the years numerous time motion analysis and GPS analysis have been used to determine the physical profile of football players (Casamichana et al., 2012; Di Salvo et al., 2007; Mohr et al., 2003; Krustrup et al., 2003; Krustrup et al., 2005; Suarez-Arrones et al., 2014). From the research it is understood that a typical total distance covered during a match is 10 – 13km most of this distance is covered by walking and low-intensity running, hence making the high-intensity exercise periods important in terms of energy production. Thus, the amount of high-intensity exercise separates top-class players from players of a lower standard (Bangsbo et al., 2006). Additionally, an important fact of activity profiles is allowing understanding of workload imposed on certain positions during matches to be able to develop sport specific training protocol (Di Salvo et al., 2007). Therefore, it has been generally recognised that midfielders cover greater distances in a game than defenders and forwards (Di Salvo et al.,2007; Mohr et al., 2003; Suarez-Arrones et al., 2014).

The present study did not show significant variation between any of the same position for any periods or as a whole season across the three periods for TD apart for MID in period three (See table 4.3 and fig 4.2). Where the MID 2018/19 was significantly different to the MID 2020/21 (P = 0.02). Furthermore, you would expect MID 2018/19 to have the greater mean due to having played fewer matches in period three and with more players (9 players) in that period compared to the MID 2020/21 (5 players). However, it was the MID 2020/21 that had the higher mean than MID 2018/19 (11674 ± 1568m and 7476 ± 1970m, respectively). The differences in most cases are likely due with the specific tactical roles in the playing formation (Djaoui et al., 2014). For example, the MID 2018/19 might have been more defensive minded and ridged so not much running outside of the roles whist in the MID 2020/21 may have had more license to roam and get more forward, thus more distance covered. Nevertheless, the results showed that in general the same positions were not affected by a congested season

The previous research had suggested that the greatest volume of work at high intensity is carried out by attacking players (Mohr et al., 2003). Therefore, it could be assumed if these attacking players were to have a more congested season and they produces the greatest volume of at high intensity. That the work would decrease as has they wouldn't have enough recovery to keep producing those high volumes. However, this was not the case in this study as there was no significant difference in the attack or any of the same position for any period or as a whole season across the three periods (See table 4.4 and fig 4.2). Once again, agreeing with the common notion that HSD is not affected by congestion as none of the same positions were different.

In this present study, there was a difference in the amount games and days missed due to injuries. There were 746 days missed in 2020/21 season which had 55 matches compared to 360 days missed in 2019/20 season which had 43 matches before COVID19 stopped the season. There was a higher rate of days missed of 5 days per injury in 2020/21 than 2019/20 season, thus showing a longer number of days missed per injury (see table 4.5). An extra 5 days injured can have huge difference in the number of matches missed and that there were likely more muscle injuries due to the longer length of injuries. In terms of matches missed due to injury there were 156 matches missed in the 2020/21 season compared to 81 in the 2019/20 seasons. There was almost a rate of an extra game missed per injury in the 2020/21 season than 2019/20. These results are in line with Dupont et al. (2010) where a sporadic fixture congestion was associated with significantly higher incidences of injury. Although more research is needed in terms of the specific type of injuries, to give a more concise look on if it’s associated with congestion or not.

A metric that was not used during this study, that may have made a difference to the outcome of this study was Body Load (BL). The reasoning behind the exclusion of BL was due to the football club changing MEMS units during the period analysed. Therefore, how BL would be calculated from the two MEMS units would be different and couldn’t be compared to each other. Although this exclusion may have made a difference to the results of this study as Zanetti et al. (2018) investigated two elite youth football teams during an international tournament, where they were required to play in a congested period 5 matches over 3 days. These matches were compared with 5 matches of the two teams that were not congested. The comparison observed higher values for metabolic power (which has been suggested as a reliable marker of locomotor load where acceleration- and velocity-based running are accounted for (Rampinini et al., 2015), suggested that players were able to maintain the load they produced more during the congested period than the non-congested period. The findings of Zanetti et al. (2018) disagree with the research of Kovacs et al. (2020). Kovacs et al. (2020) found elite youth football players produced lower physical performance outputs (total distance, Low speed running distance and body load) during a fixture congestion across 3 matches in 3 days. Although Zanetti et al. (2018) had a greater match play physical demand than Kovacs et al. (2020) they were very similar in style of a tournament. The difference in the findings may be due to Zanetti et al. (2018) focusing on two teams from single club whereas Kovacs et al. (2020) quantified his performance output across all teams playing in the tournament. Furthermore, focusing on one team as in the study by Zanetti et al. (2018), the players' response to match activity profiles in the congested schedule could be due to pacing strategy, (consciously or subconsciously) to be able to maintain physical effort (Carling et al., 2012). Using the same strategy will be more consistent in one club than will be from multiple clubs at different levels.

The level of opponents may affect the amount of BL faced in a particular match. Playing against a higher-level team may increase competitiveness and motivation to apply more work in a particular match thus increasing BL and playing against a lower-level team may have the opposite effect (Zanetti et al., 2018). Thus, this may be truer when playing in an international tournament where all the competition is high, as was the case in Zanetti et al. (2018). When playing in a league it is more of a balance as there will be teams the same level, higher level and lower level. Therefore, throughout a league season the BL needs to be maintained for every game despite the level of competition. To hopefully maintain a high level of performance throughout the season. This could be achieved my monitoring and programming performance in training to mimic match conditions. Moreover, with more games closely together it could be assumed the load would be increased. Seemingly if this was the case, it would have an effect of the results of the study.

Limitations/Future research

There are a few limitations with this present study that need to be discussed and acted upon if future research is to happen. From this study were missing data that could have altered the results of the study. This would therefore change how the results would be interpreted and the findings of the current study may be different if access to full data sets. For example, TD was used as to evaluate which players would be included in study for each match. However, for the 2018/19 the data was missing for TD until 29th January, meaning only the last period analysed could be used for that season. Meaning comparison from the other two periods could not be made with the different years and the total for that season could not be used. The extra information that could have been provided by the missing data could have been very useful in further reiterating the results of this study or may have changed the results of the study. Therefore, if this study was to be repeated full data sets must be accessible, so that a better understanding of the results can be achieved when compared more to a season that was a full normal season.

In research of the current study is that there was no access to more metrics that were used across all three seasons. Although the metrics used were key metrics, it would have been interesting to use some more, especially BL, acceleration and deceleration. As they have been studied in many previous studies, therefore would have made good comparisons for this present study. The addition of more metrics would have been useful in confirming the results of this study or bringing about different or new interpretation of this present study. For instance, if more acceleration and deceleration were completed in the congested season it would further suggest that load was increased by congestion. Thus, in future studies more metrics should be used to allow for a more in depth look at the results of the study.

Furthermore, there is no indication of where the team was positioned in the league from the data analysed or the level competition faced. For example, the team may have been middle table near the end of the season and had nothing much to play for or playing the top teams of the league so needing to put more effort in the matches. Hence both could have affected the results in some way. Rampinini et al. (2007b) demonstrated that performance during match-play is related to the physical activity completed by the opponent teams as well as their competitive level, and this should be taken into account especially when evaluating the effects of training intervention on match running performance. Furthermore, Zanetti et al. (2018) stated there is possible influence of the quality of the opponent on their findings on running performance. That the higher-level opponents in the congested period compared to the non-congested period cannot be ruled out as a possible contextual factor that potentially impacted performance. Therefore, if the research was completed again, the teams faced and position in the league during the periods should be contextualised to give an understanding of where the team is at and team faced are at.

Additionally, in the present study is there was no input of recover strategies between the matches. Although there was mention of trying to maintain acute:chronic work ratio, there was no mention of any specific strategies that was used between the matches to help keep players optimum or prevent injury. For example, as there was an increase in frequency of injuries, without any knowledge of recover strategy in between the matches, there is no assumptions the increased injuries are not due to the type of recovery and training occurring in between the matches. Moreover, Carling et al. (2012) showed that injury rates are unaffected by fixture congestion when there is an effective recovery strategy in place. Therefore, future research should look to include a recovery strategy for in between matches to mitigate injuries occurring due to the work done in between matches. Although it must be taken into consideration that it would be difficult to get a professional team to implement a recovery strategy if they do not already have one if so, it may be a better choice to select a team that already has recovery strategies in place.

In the current study there not being more information on the injury data, limited the amount of analysis that could have been completed on the injury data, therefore gaining a better understanding on how injury was affected in the congested season compared to the other season. This included the specific types of injuries not being noted down correctly and not having access to individual injury reports. Thus, having greater access to the injury reports and history is vital for future studies, to allow a better understanding of how congestion affects injuries. The types of injuries from contact to non contact, would give a better understanding of if the injuries were more associated with the fixture congestion or not. For example, Carling et al. (2012) was able to conclude that the injuries in that study were due to match play with an opponent as they had access to whether the injuries were contact or non-contact. Furthermore, having the information on contact or noncontact injuries would be useful to be able to link injuries with the load from the congested season. For example. If there had been more non-contact injuries in the congested season compared to the non congested season, an assumption could be made that the cause would be due to the increased load.

Conclusions

In conclusion, there was no affect for TD or HSD, and this is in line with previous research. Furthermore, the study showed that there was again no significant difference for TD and HSD, between the same positions in the different seasons. Finally, the injury rates demonstrated that there was an increase in the number of days and matches missed from injuries in the congested 2020/21 season than the 2019/20 season. Considering the research hypothesis, this current study in part disagrees with the hypothesis that there was a greater load placed on the players, as the metrics TD and HSD were not affected. Although, the greater load was supported by the increase in the rate of days and matches missed per injury. This may have been strengthened if other metrics such as BL were measured during the study. Therefore, the current study can only suggest that there is no significant difference the activity profiles of football players as TD and HSD are not affected by congestion of a whole season. Thus, more research is needed to evaluate the outcomes of this study as it is the first to examine the effect of a congested season on football players.

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