A comparison of the physical load in match play and small-sided games in trained football players

by

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Abstract

The internal and external demands of football have been the subject of increasing attention over the past 30 years. Global positioning systems (GPS) have become widely used by sports teams to quantify training and non-competitive match demands. Although GPS technology has been used in football for some time, its sensitivity in determining training and match demands has been debated. The recent integration of accelerometers and GPS may therefore provide a more detailed analysis through quantifying all actions as a total mechanical stress.
Therefore, the aim of this investigation was to compare the internal and external demands of youth football players in four playing positions during small-sided games (SSGs) played with different player numbers in comparison to 11-a-side match play (MP).

Forty trained sub elite youth football players classified into four positional roles; central defender (CD), wide defender (WD), central midfielder (CM) and forward (FW); participated in the study (Mean ± SD age 17.00 ± 0.60 yrs, stature 179.88 ± 6.15 cm, mass 73.93 ± 5.85 kg). Players were analysed during three different conditioned small-sided games (2 vs. 2, 3 vs. 3, and 4 vs. 4) in which two ball touches were allowed per possession. In addition, six friendly matches were also completed. Internal demands were measured via heart rate (HR), whereas external demands were measured by tri-axial accelerometry. Variables recorded were total distance covered per min, distance covered in different speed zones per min (0-6.0, 6.1-8.0, 8.1-12.0, 12.1-15.0, 15.1-18.0, and >18.1 $km \cdot h^{-1}$), distance covered in different acceleration and deceleration zones per min (0 to ± 1, ± 1 to 2, ± 2 to 3, ± >3 $m \cdot s^{-2}$), repeated high-intensity efforts, work:rest ratio, tri-axial accumulated player load per min and the relative contribution from the X, Y and Z vectors per min.

When conditions were compared, significant main effects were found for accumulated player load per min ($F = 21.91$; $p<0.001$, $\eta^2 = 0.38$); contributions from the individual X ($F = 27.40$; $p<0.001$, $\eta^2 = 0.43$), Y ($F = 14.50$; $p<0.001$, $\eta^2 = 0.29$) and Z ($F = 19.28$; $p<0.001$, $\eta^2 = 0.35$) vectors per min; distance covered at 6.1-8.0 ($F = 29.93$; $p<0.001$, $\eta^2 = 0.45$) and 8.1-12.0 $km \cdot h^{-1}$ per min ($F = 7.06$; $p = 0.001$, $\eta^2 = 0.16$); and distance covered at 1 to 2 ($F = 5.78$; $p = 0.003$, $\eta^2 = 0.14$), 2 to 3 ($F = 12.32$; $p<0.001$, $\eta^2 = 0.26$) and -2 to -3 $m \cdot s^{-2}$ per min ($F = 14.32$; $p<0.001$, $\eta^2 = 0.29$) in which all SSGs elicited

significantly greater values than MP for each variable. In contrast, significant main effects were found for distance covered per min at 15.1-18.0 ($F = 25.01$; $p<0.001$, $\eta^2 = 0.41$) and >18.1 km·h^{-1} ($F = 96.18$; $p<0.001$, $\eta^2 = 0.73$) in which MP elicited significantly greater values than SSGs for each variable.

When positional role were compared, significant main effects were found for total distance covered per min ($F = 8.80$; $p<0.001$, $\eta^2 = 0.42$) and distance covered at 1 to 2 m·s^{-2} per min ($F = 8.54$; $p<0.001$, $\eta^2 = 0.42$) in which CM reported significantly greater values than the other positional roles. A significant main effect was also found for distance covered at >18.1 km·h^{-1} ($F = 6.66$; $p = 0.001$, $\eta^2 = 0.36$) in which FW reported significantly greater values than the other positional roles. A significant interaction was found for distance covered at >18.1 km·h^{-1} ($F = 4.31$; $p = 0.002$, $\eta^2 = 0.26$) in which FW reported significantly greater values than CD (8.74 ± 4.41 vs. 4.96 ± 1.82 m.min^{-1}, respectively, $p = 0.017$) and CM (8.74 ± 4.41 vs. 3.89 ± 1.43 m.min^{-1}, respectively, $p = 0.001$) during MP.

Based on the accelerometry data in the present study, it is likely that the physical demands of football and more specifically SSGs have been underestimated when determined using more traditional time-motion analysis methods and GPS technology. The findings of the present study demonstrate that the PL and acceleration / deceleration patterns observed during SSGs are greater than those observed in friendly MP. Therefore, the SSGs employed may offer a ‘density’ type-training stimulus through imposing relative demands on acceleration and deceleration in excess of those experienced during MP.

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Glossary of abbreviations

Accumulated player load per min	**PLacc.min^{-1}**
Analysis of variance	**ANOVA**
Arbitrary units	**AU**
Blood lactate concentration	**BLa**
Central defender	**CD**
Central midfielder	**CM**
Coefficient of variance	**CV**
Creatine phosphate	**PCr**
Distance covered	**DC**
Distance covered per min	**DC.min^{-1}**
English Premier League	**EPL**
External load	**EL**
Forward	**FW**
g force units	**g**
Global Positioning System	**GPS**
Heart rate	**HR**
Hertz	**Hz**
High-intensity running	**HIR**
High-speed running	**HSR**
Horizontal dilution of precision	**HDOP**
Interinstrument intraclass reliability	**ICC**
Intermediate-speed running	**ISR**
Internal load	**IL**
Low-speed running	**LSR**
Match play	**MP**
Max-speed running	**MSR**
Maximal oxygen uptake	**$\dot{V}O_{2max}$**
Maximum heart rate	**HR_{max}**
Muscle lactate concentration	**MLa**
Oxygen uptake	**$\dot{V}O_2$**
Percent of heart rate maximum	**%HR_{max}**
Physical load in the X axes per min	**X.min^{-1}**

Physical load in the Y axes per min	**$Y.min^{-1}$**
Physical load in the Z axes per min	**$Z.min^{-1}$**
Player load	**PL**
Semi-automatic multiple-camera system	**SAMCS**
Small-sided game	**SSG**
Standard error of the estimate	**SEE**
Time-motion analysis	**TMA**
Total distance covered	**TDC**
Total distance covered per min	**$TDC.min^{-1}$**
Typical error	**TE**
Vertical dilution of precision	**VDOP**
Very high-speed running	**VHSR**
Wide defender	**WD**
Wide midfielder	**WM**
Work rate profile	**WRP**

1. Literature review

1.1 Introduction

Since the foundation of the Football Association in 1863, football has become widely acknowledged for being one of the world's highest participated sports evidenced by the 250 million direct participants worldwide (Taylor, 2008; Giulianotti and Robertson, 2004). Both males and females play football on all continents, from children to adults, with different levels of expertise (Reilly, 1997; Stølen, Chamari, Castagna and Wisløff, 2005). Official matches are 90 min in duration, played by two teams of 11 players (three substitutions), and consisting of two 45 min halves, separated by a 15 min break. Successful performance in this sport requires development of several factors including technical, tactical, physical, physiological and mental skills (Stølen et al., 2005). Understanding the physical loads imposed on football players during competitive match play (MP) must be quantified in order to develop sport- and position-specific training protocols (Di Salvo et al., 2007). As such, in recent decades, there has been a remarkable expansion of sport science both as an academic discipline and as a field of applied practice (Williams, 2013). It is this development that has ensued to the myriad of research regarding match performance and the subsequent incorporation of science into training planning and nutritional strategies (Bangsbo, 2014). Currently, changes in both performance and physiological response during MP and training have been explored, with the focus on individual differences in the internal physical stress to which players are exposed (Bangsbo, 2014). There is however, a dearth of research that has elucidated the external physical stress imposed on players of different positional roles during MP. In addition, there is a lack of research to date that has compared such data to those typically experienced during commonly used small-sided training games (SSG) prompting the need to explore this further. Therefore the aims of the study are to measure the acute physiological and external demands per positional role of friendly MP and three different SSG formats (2-, 3-, and 4-a-side).

1.2 Time-motion analysis of football

1.2.1 Distance covered

The total distance covered (TDC) during MP has frequently been reported in the literature. Research using video-based time-motion analysis (TMA) and semi-automatic multiple-camera systems (SAMCS) have reported that outfield players cover on average 9-12 km during MP (Reilly and Thomas, 1976; Ekblom, 1986; Bangsbo, Norregaard and Thorsø, 1991; Bangsbo, 1994b; Mohr, Krustrup and Bangsbo, 2003; Di Salvo et al., 2007), whereas goalkeepers cover on average 4-6 km (Di Salvo, Benito, Calderón, Di Salvo and Pigozzi, 2008). It appears that midfield (MF) players cover the greatest distance as they act as links between defence and attack (Bangsbo, 1994b; Rienzi, Drust, Reilly, Carter and Martin, 2000; Di Salvo et al., 2007). Using a SAMCS, Di Salvo et al. (2007) found that MF covered the greatest distance (12 km), followed by FW (11.3 km) and CD (10.6 km).

It should be noted however, that large between-system differences have been reported for different match analysis systems when determining the TDC for outfield players. Moreover, video-based TMA, 1 Hz GPS, 5 Hz GPS and SAMCS reported total distance values of 9.51 ± 0.74, 9.52 ± 0.89, 10.72 ± 0.70 and 10.83 ± 0.77 km, respectively (Randers et al., 2010). Therefore, comparing data using different match-analysis systems should be done with caution. Indeed, GPS is less time-consuming than SAMCS and provides a more practical measure of work rate during training sessions and non-competitive matches. It should be noted however, that limitations for the use of GPS units exist which will be discussed in chapter 1.4. These limitations should be taken into consideration when implemented as an analysis tool in team sports such as football (Aughey, 2011).

1.2.2 Work rate profile

Football MP is characterised as an intermittent sport in which players have been found to perform approximately 1000-1460 acyclical and unpredictable changes in activity (Reilly, 1997; Krustrup, Mohr, Ellingsgaard and Bangsbo, 2005; Iaia, Rampinini and Bangsbo, 2009). This equates to a change in activity every 4 s with each activity lasting on average 5-6 s (Stølen et al., 2005; Reilly and Thomas, 1976). In one of the earliest studies using video-based TMA in football, Reilly and Thomas (1976) noted the percentages of activity for TDC by English 1st division (modern Premiership League) players during MP. They found that player activity consisted of 24 % walking, 36 % jogging, 20 % cruising (striding), 11 % sprinting, 7 % moving backwards and 2 % moving in possession of the ball. In contrast, research analysing elite Italian League players using computerised TMA revealed that the player activity consisted of 42 % walking, 30 % jogging, 8.7 % high-speed running (HSR), 3.7 % sprinting and 1.4 % backwards running (Mohr et al., 2003). A possible reason explaining the differences observed is that different match analysis systems were employed by the aforementioned studies. Computerised methods are more sensitive to distance measurements at high-speeds as it is not based on an analysts subjective estimation of movement speeds and instead uses pre-determined speed zones. Nevertheless, it has been estimated that approximately 80-90 % of match performance is spent in low to moderate-intensity activity whereas the remaining 10-20 % are high-intensity activities, suggesting MP relies predominately on aerobic metabolism (Reilly and Thomas, 1976; Mohr et al., 2003; Bangsbo, 1994a).

Analysis of the distances covered in pre-defined velocity bands enables greater understanding of the position-specific physical requirements. Central defenders generally cover less total, HSR and sprint distance then all other positions, as they are limited to defensive duties (Bradley et al., 2009a; Di Salvo et al., 2009). In contrary, central and wide midfielders typically cover the greatest total distance at low and moderate speeds, than other positions (Bradley et al., 2009a). Midfield positions are often required to act as links between defence and attack resulting in constant movement, resulting in larger distances being covered (Bangsbo, 1994). Further central midfielders have reported a greater percentage of total sprint efforts that are of short distances (0-5 m) compared to other positions (Di Salvo, et al., 2010). This suggests that it may be more important for central positions to be able to maximally accelerate than reaching a high-speed. The greatest distance at HSR is commonly undertaken by positions that have offensive duties, such as forwards, wide and central midfields and wide defenders (Bradley, Di Mascio, Peart, Olsen and Sheldon, 2009b; Di Salvo et al., 2009). Previous research by Di Salvo et al. (2009) found that the proportion of explosive leading sprints was related to playing position with forwards, wide midfielders and defenders reporting greater the distances and efforts. More recent research has reported longitudinal changes with maximal running speed increasing substantially from 2006-2007 to 2012-2013 possibly due to an increase in passing tempo (Barnes, Archer, Hogg, Bush and Bradley, 2014). Therefore, if players are producing shorter more explosive sprints but attaining higher maximal running speeds, then the acceleration capacity of players has developed, which may increase the occurrence of injury, supporting the need for appropriate pre-conditioning exercises (Barnes et al., 2014).

In recent years, researchers have used MP activity information to develop various SSG formats as a method to simultaneously improve player’s fitness, tactical thinking, and specific dynamics of the game (Hill-Haas, Dawson, Impellizzeri and Coutts, 2011). The recent application of GPS technology has enabled sport scientists to measure the activity profile of players during various SSG formats in order to optimise training prescription and periodisation. Although the internal load (IL) of MP and various training games has been researched extensively (Dellal et al., 2012b), the external load (EL) imposed on players as a result of the activities remains to be fully elucidated. With regards to EL, research has focused primarily on time-motion metrics such as TDC and the distance covered or time spent in different speed categories. This research has underestimated the true physical demands of football as it has omitted the mechanically stressful activities such as accelerations / decelerations (Osgnach, Poser, Bernardini, Rinaldo and di Prampero, 2010). Players of different positional roles undeniably experience different activity demands during MP. For example, CD and WD are substantially more engaged in jumping and heading, whereas CD make more tackles (Bangsbo, 1994b). Modern systems such as GPS allow biofeedback to accompany traditional feedback through the addition of a heart rate monitor and a triaxial accelerometer enabling the physical demands of non-distance contributing activities to be quantified. Such information will enable scientists and coaches when planning position-specific training and nutritional strategies (Bangsbo et al., 2006).

1.2.3 Influence of playing standard

Research has observed different activity profiles between teams of different performance levels with the amount of high-intensity efforts separating elite players from players at a lower standard. Although there was no difference in the TDC by Danish 1st and 2nd division players, Bangsbo et al. (1991) reported that 1st division players performed a greater percentage of time in moderate- and high-speed running, and sprint-running. Similarly, Mohr et al. (2003) observed that elite international players covered 28 % and 58 % more HSR and sprinting distance, respectively, than professional players at a lower standard. In contrast, greater distances at high-intensity running have been reported by players at a lower compared to higher competitive standard (Bradley et al., 2013). The differences observed in the aforementioned studies could be a result of the evolution of the technical demands of football. Moreover, the technical characteristics of modern lower league football may require players to tax their physical capacity to a greater extent than players at a higher standard (Bradley et al., 2013).

Differences have also been found to exist between teams of a similar standard. For example, using SAMCS, Dellal et al. (2011b) found that English Premier League (EPL) players perform a greater total distance whilst running than Spanish La Liga (SLL) players. Further data revealed that central attacking players in SLL cover the greatest distance in HSR when their team was in possession, whereas this was the case for WM in the EPL. A possible reason for the differences observed is that the EPL is characterised as forthright, fast and physical (Rienzi et al., 2000). This suggests that position-specific high-intensity training should be bespoke to the individual tactical role and the specific demands of the league in which the player performs.

Alongside activity profiles, maximal oxygen uptake ($\dot{V}O_2max$) values also differ between teams of different performance levels. Al-Hazzaa et al. (2001) reported $\dot{V}O_2max$ values for elite Saudi Arabian players of 56.8 ± 4.8 $mL.kg.min^{-1}$, whereas $\dot{V}O_2max$ values of 66.4 ± 7.6 and 59.4 ± 6.2 $mL.kg.min^{-1}$ were reported from Spanish First Division (Casajús, 2001) and EPL players (Strudwick, Reilly and Doran, 2002), respectively. The differences in $\dot{V}O_2max$ are positively related to match performance. Helgerud, Engen, Wisløff and Hoff (2001) observed that enhanced $\dot{V}O_2$ max improved performance evidenced by increases in the TDC, enhanced work intensity, and increased frequency of sprints and involvements of the ball during MP.

Although $\dot{V}O_2max$ values reported in the literature differ across nationality and similar competitive levels, $\dot{V}O_2$ max may not make a distinction between average and excellent players despite the importance of oxygen uptake ($\dot{V}O_2$) in maintaining work rate (Reilly, Bangsbo and Franks, 2000; Tønnessen, Hem, Leirstein, Haugen and Seiler, 2013). It is suggested that the differences in performance standard could also be attributed to improvements in anaerobic threshold and running economy enabling athletes to perform at a higher percentage of $\dot{V}O_2$ max (Helgerud et al., 2001).

1.2.4 Physical demands of football

The physical demands of modern football require an increased work rate, a higher frequency of competition, and as a consequence, players are required to work harder than in previous years (Carling, Bloomfield, Nelsen and Reilly, 2008). Research has found that players cover a greater total distance as well as a greater distance at high-speeds in the current decade in comparison with data from the last decade (Bradley et al., 2009a, 2011). The rise in tempo is likely a direct result of rule changes such as penalising of time-wasting and permitting the use of only three substitutes (Reilly, 2005). As such, detailed knowledge regarding the demands of modern performance requirements and the subsequent physical demands are required to enable coaches to design optimal training programs to meet the modern demands. Similarly, analysing training sessions throughout the competitive season can ensure that players are being appropriately loaded whilst avoiding plateaus in performance or overtraining / undertraining.

Unfortunately, TMA methods such as video-based TMA and SAMCS require a series of fixed cameras at the club stadia, creating operational problems for use in training environments, as the majority of teams train on an open field (Harley, Lovell, Barnes, Portas and Weston, 2011). More recent TMA methods such as GPS enable multiple-player tracking with instantaneous feedback. Osgnach et al. (2010) proposed using video analysis for official competitions, and GPS analysis for training. However, when 5 Hz GPS (Minimax, Catapult Innovations, Australia) and SAMCS (Prozone®, England) systems were compared for measuring sprint performance ($>7.0\ m\cdot s^{-1}$) during MP, Harley et al. (2011) reported moderate differences (40 %), thus emphasising the need for caution when using the two systems during training and MP. Therefore, using the same TMA system during training and MP would yield more reliable data. Unfortunately, the use of GPS technology during competitive matches is restricted, limiting its use to friendly games. To date, research has focused primarily on traditional TMA data acquired from MP and has compared these values with the demands of various SSG formats. As previously mentioned, this research has underestimated the physical demands when basing EL solely on kinematic parameters. A large physiological demand is imposed on players during accelerations / decelerations and during non-distance contributing activities such as jumping, change of direction and contact with other players. Recent integrations of accelerometers and GPS provide a practical method to measure the discrete activities experienced during MP and SSGs in training. Small-sided games are commonly used training modalities, yet the understanding of how to maximise their function is not complete (Owen, Wong, Paul and Dellal, 2014). Research is therefore required to elucidate the external load imposed on players during MP and SSGs. Information from this study aims to help coaches when structuring weekly training and conditioning programs.

1.3 Physiological demands of football

1.3.1 Aerobic energy production and contribution in football

1.3.1.1 Maximal oxygen consumption

Because of the games duration, in combination the intermittent nature as previously mentioned, football is primarily dependent upon aerobic metabolism (Stølen et al., 2005). To determine the aerobic energy contribution in football MP, research has attempted to measure $\dot{V}O_2$ (Ogushi, Ohashi, Nagahama, Isokawa and Suzuki, 1993), however, the importance of this measure is heavily debated. Ogushi et al. (1993) used Douglas bags to measure the $\dot{V}O_2$ of two student football players in 3 min periods and found average $\dot{V}O_{2max}$ values of 35 and 38 $mL.kg.min^{-1}$ in the first half and 29 and 30 $mL.kg.min^{-1}$ in the second half. Unfortunately, the sample size was limited and the playing standard of participants was not stated making the results difficult to extrapolate to professional football players. Furthermore, it is likely that values measured are underestimated, since the cumbersome equipment used would most likely have inhibited performance by reducing the involvement in duels, tackles and other energy demanding activities frequently observed in matches (Stølen et al., 2005).

Previous research has reported $\dot{V}O_{2max}$ values between 50 and 75 $mL.kg.min^{-1}$ in male professional soccer players and it has been suggested that 60 $mL.kg.min^{-1}$ is the minimum requirement to compete at elite status (Reilly et al., 2000; Hoff, Wisløff, Engen, Kemi and Helgerud, 2002; Dellal, Hill-Haas, Lago-Penas and Chamari, 2011a). In a recent study by Tønnessen, Hem, Leirstein, Haugen and Seiler (2013) $\dot{V}O_{2max}$ did not distinguish soccer players from different standards of play ranging from national team to second division and juniors. Differences in positional role were reported with MF reporting a high relative uptake than defenders and forwards, while goalkeepers had the poorest $\dot{V}O_{2max}$ values. Therefore, $\dot{V}O_{2max}$ is not a clearly distinguishing variable separating players of different standards and does not correlate with performance.

Despite technological advances in portable oxygen analysers, their use during official games is forbidden and incompatible with competitive situations. Furthermore, data obtained through direct measurements of $\dot{V}O_2$ can represent objective information regarding the energy expenditure of the game; thus, this method is only applicable in training situations. The difficulty of determining $\dot{V}O_2$ during football MP makes it necessary to use other physiological variables for the determination or estimation of the physical workload. Consequently, portable heart rate monitors have been used to measure the cardiovascular response to training due to the strong positive correlation between heart rate (HR) and $\dot{V}O_2$ established in laboratory treadmill tests by Bangsbo (1994b) and later validated by Esposito et al. (2004).

1.3.1.2 Heart rate

Heart rate monitoring has been employed extensively in football as it represents a non-invasive method to monitor the physiological response to unofficial MP (Edwards and Clark, 2006) and training sessions such as SSGs (Aroso, Rebelo and Gomes-Pereira, 2004; Owen, Twist and Ford, 2004; Dellal et al., 2011a). Mean HR has been reported to be between 165 and 175 beats.min^{-1} during both competitive and friendly MP (Thatcher and Batterham, 2004; Edwards and Clark, 2006).

According to the HR-$\dot{V}O_2$ relationship it has been found that the average intensity of elite adult players is 75 % $\dot{V}O_2$max during MP based on $\dot{V}O_2$max values obtained during football-specific exercises (Esposito et al., 2004; Stølen et al., 2005). However, the validity of HR as a measure of IL of football MP is questionable as research suggests that the effectiveness of HR during high-intensity intermittent exercise is reduced. For example, intensity during activities such as sprinting, jumping and tackling may be underestimated as the exercise bouts may not be long enough to elevate HR levels with a large proportion of the required energy supplied through anaerobic metabolism (Achten and Jeukendrup, 2003; Borresen and Lambert, 2008). Furthermore, it is possible that HR measured during MP is an overestimation, due to factors such as dehydration, hyperthermia and mental stress elevating HR whilst not affecting $\dot{V}O_2$ (González-Alonso, Mora-Rodríguez, Below and Coyle, 1997; González et al., 1999; Bangsbo et al., 2006). González-Alonso et al. (1997) found that hydration status can influence HR by up to 8 %. The use of GPS systems with integrated accelerometers during MP and training can provide a measure for the high-intensity actions that HR monitors fail to measure, thereby providing a better indication of football-specific actions (Scott et al., 2013). The combination of TMA, HR and accelerometer data will give coaches a more complete profile of the physical and physiological demands experienced in MP and training modalities.

1.3.2 Anaerobic energy production and contribution in football

Although aerobic metabolism dominates energy delivery during football MP, the most pivotal actions are executed by means of anaerobic metabolism (Wragg, Maxwell and Doust, 2000; Faude, Koch and Meyer, 2012). Faude et al. (2012) observed that linear sprinting is the most dominant action when scoring goals. Further, the majority of diagonal and arc movements are performed in forward directions with midfielders and strikers performing more than defenders suggesting that they are important directions in order to manipulate and create space or to evade a marker and be in a position to receive a pass from a teammate (Bloomfield, Polman and O'Donoghue, 2007). In addition, elite football players perform 150-250 brief intense actions during a game comprising of 30-40 short-sprints, jumps and tackles (Mohr et al., 2003), in addition to frequent contesting of possession (Reilly, 2007). It is the anaerobic energy release through the utilisation of fast glycolysis that is required to perform the high-intensity actions that will dictate crucial match outcomes (Karlsson, Nordesjö, Jorfeldt and Saltin, 1972). Furthermore, the high-intensity anaerobic activity has been reported to distinguish between different standards of players (Mohr et al., 2003), higher- and lower-levels of competition (Bangsbo, 1994b), training status (Krustrup et al., 2005), the tactical role of players within a team (Rampinini, Coutts, Castagna, Sassi and Impellizzeri, 2007a) and dictate crucial match outcomes and thus, the overall success of a team (Di Salvo et al., 2009).

1.3.2.1 Creatine Phosphate

Although not studied directly, the intense exercise bouts during MP leads to an increased rate of creatine phosphate (PCr) breakdown, which is resynthesised during lower intensity periods of exercise (Bangsbo, 1994a). If several successive intense exercise bouts occur, PCr levels may deplete to <30 % of resting values (Bangsbo, Iaia and Krustrup, 2007). Analysis of PCr levels in biopsies acquired after bouts of intense exercise have provided values approximately 75 % of the level measured at rest (Krustrup et al., 2006). Because the rate of muscle PCr resynthesis has been reported to be 0.5 $mmol.kg^{-1}d.w.s^{-1}$ after exercise and differs between individuals, it is likely that reported values are underestimated. For example, biopsies were taken 15-30 s following match activities in which PCr resynthesis would have occurred. Using the values for resynthesis rates of PCr and the measured PCr values in the aforementioned study, it can be estimated that PCr concentrations during the game would have been approximately 60 % of resting levels (Bangsbo et al., 2007). Unfortunately, PCr testing is limited as taking biopsies following bouts of high-intensity training and matches is impractical. Measuring blood lactate concentration (BLa) is a more practical measure of metabolic stress as the blood can be obtained immediately at the start and the end of halftime, as well as after a game (Krustrup et al., 2006; Bangsbo et al., 2007).

1.3.2.2 Blood lactate concentration

Blood lactate concentration has been utilised extensively with average values ranging between 2-10 mM for football MP (Ekblom, 1986; Krustrup et al., 2006). Methodological aspects such as the number of measures and the point when blood is collected have been questioned (Dellal et al., 2012c). Although Pyne, Boston, Martin and Logan (2000) validated blood sampling 3 min post exercise using a portable analyser, Krustrup et al. (2006) concluded that the correlation between BLa and muscle lactate concentration (MLa) is not high. As a result, values observed are unlikely to reflect the overall physical demands before the collection, as it is not a direct collection from the muscle. In contract, BLa during continuous-exercise reflect well, the MLa concentrations (Bangsbo et al., 2006). The differences between intermittent and continuous exercise are thought to be caused by different turnover rates of MLa and BLa during the two types of exercise, with lactate clearance being significantly higher in muscle than in the blood during intermittent exercise (Bangsbo, Johansen, Graham and Saltin, 1993). This is because the enhanced blood flow during intense-exercise results in an increase in lactate efflux (Bangsbo et al., 1993).

Therefore, during intermittent-exercise experienced in football, BLa can appear high despite MLa concentrations being low. This relationship appears to be influenced by the activities performed immediately prior to sampling. Bangsbo et al. (1991) observed a significant correlation between the amounts of HSR and BLa during MP. As such, the high BLa frequently observed in football may not represent a high lactate production in a single action during a game, but rather an accumulated response to several high-intensity activities (Ekblom, 1986; Bangsbo et al., 2006; Krustrup et al., 2006). This response should therefore be taken into account when interpreting BLa as a measure of MLa concentrations (Bangsbo et al., 2007). Nevertheless, based on the findings of high BLa and moderate MLa concentrations by Krustrup et al. (2006), it is suggested that the rate of glycolysis is high for short-periods during MP. Given the limitations of PCr and BLa as a measure of physiological load in addition to the impractical and intrusive nature of biopsy and BLa collection, HR is more frequently employed to determine the IL of friendly MP and SSGs as they evoke more favourable testing conditions.

1.4 Time-motion analyses techniques

Time-motion analysis has been employed to quantify the physical demands of football MP (Rienzi et al., 2000). Time-motion analysis is the method of determining the work rate profile (WRP) of different positional roles in terms of the TDC by players (Reilly and Thomas, 1976), and the distribution of match-time amongst different activities (Bangsbo et al., 1991).

1.4.1 Notational analysis

The first studies using TMA were used to determine the individual distances covered by players, as this index provides information regarding the physiological load imposed during football MP (Reilly and Thomas, 1976). Some of the earliest investigations used subjective methods such as scale drawings of a pitch (Zelenka, Seliger and Ondrej, 1967) or hand notation in combination with an audio tape recorder (Knowles and Brooke, 1974; Reilly and Thomas, 1976) to calculate the TDC by players during MP. However, when inter-observer reliability was determined for TDC per min and frequency of sprints, reliability coefficients were 0.61 and 0.98, respectively (Knowles and Brooke, 1974). It appears that notational analysis may be suitable for measuring the frequency of match activities such as jumping, heading and sprinting (Reilly and Thomas, 1976), but is limited in providing speed and distance information due to both the skill and speed required of the analyst and the inability of re-analysing the match (Spencer, Bishop, Dawson and Goodman, 2005).

1.4.2 Video recordings

Methods advanced to using video recordings (Bangsbo et al., 1991; Ali and Farrally, 1991a); and trigonometric via computerised techniques (Ohashi, Togari, Isokawa and Suzuki, 1988) allowing post-match re-analysis, thus enabling the analyst to pause, review and slow down the film. To determine the speed, distance and duration using manual video analysis, players stride lengths were determined post-match by filming the player performing movements such as jogging, striding, sprinting and jogging backwards (Reilly and Thomas, 1976). When analysing MP, movements were coded based on the analyst's subjective estimation of the stride length enabling time and distance covered (DC) for each movement to be determined (Reilly and Thomas, 1976). Alternatively, the analyst determined the frequency, DC and duration spent in each movement category by measuring the time it took a player to pass certain reference points on the field (Bangsbo et al., 1991; Mohr et al., 2003). Using the stride length method of analysis, inter-observer reliability for TDC during MP had a correlation coefficient of 0.998 (Withers, Maricic, Wasilewski and Kelly, 1982). However, striding and sprinting produced lower correlation coefficients of 0.745 and 0.815, respectively, due to observer disagreements on the classification of discrete work intervals. The results suggest that the ability to differentiate between various high-speed movements is challenging and subsequently, a limitation for manual video analysis.

Alongside inter-observer reliability, intra-observer reliability has been used to assess the field reference point technique in football referees with measures of TDC reporting a coefficient of variation (CV) of 1 %, while variations in walking, low-speed, high-speed and backwards running were 2, 5, 3 and 3 %, respectively (Krustrup and Bangsbo, 2001). These results suggest that the reliability of manual video analysis is less compromised when using a single observer, as interpretations of movement classifications can differ amongst separate observers. Using modern GPS devices, sport scientists are able to pre-determine the velocity required for each speed zone prior to training and MP, thereby eliminating inter-observer disagreements. Previous research has generalised speed groups to simplify comparisons across studies. These groups commonly consist of low-intensity activity (walking and jogging), high-intensity running (activity greater than or equal to running) and very high-intensity running (activity faster than running). However, it is difficult to make assertions of MP and training activities as different speed zones have been used in the literature. Moreover, high-intensity running (HIR) has been defined as movement speeds greater or equal to 14.4 $km \cdot h^{-1}$ (Bradley et al., 2009b) 19.1 $km \cdot h^{-1}$ (Di Salvo et al., 2007) and 19.8 $km \cdot h^{-1}$ (Bradley et al., 2009a). Furthermore, the term “intensity” is suggested to be incorrect as it implies that the player is moving at an individualised intensity (Abt and Lovell, 2009). To prevent any inappropriate assumptions regarding the relative intensity of activity for each player, the term “intensity” has been replaced with the term “speed” (Gregson, Drust, Atkinson and Di Salvo, 2010). Therefore, the term speed will be used, where appropriate, when discussing previous studies that have used to term intensity.

1.4.3 Global Positioning System

Data collecting using the methods outlined were at the time, convenient, inexpensive and reliable. Unfortunately, the validity of these methods has rarely been reported, mainly due to the lack of a criterion measure at the time. Furthermore, the methods were challenging, as the systems were complex and time-consuming, as data had to be coded, analysed and interpreted. Recent technological advances have meant that more sophisticated systems such as GPS (Larsson, 2003) and SAMCS (Di Salvo, Collins, McNeill and Cardinale, 2006) are being used to determine the WRP of football players during MP. These systems enable simultaneous analysis of all players to be completed in a relatively short-period, and provide a valuable pool of data informing and influencing the daily practices of coaches (Carling et al., 2008). Appropriate use of these systems provides more detailed understanding of the position-specific WRP of football players and their specific fitness requirements, the intensities of discrete activities during MP, and the occurrence of a reduced work rate among players (Bloomfield et al., 2007).

A growing body of literature has examined the use of GPS for MP and training analysis and has subsequently been employed by elite clubs. Unfortunately, usage of any system in which players are equipped with electronic devices is currently prohibited at professional level and is restricted to training sessions, friendly MP and youth competition. Despite their limitations and restricted use, the comprehensive, accurate and automated examination of player movement acquired through TMA has been used to make objective decisions for structuring conditioning elements of training and match preparation (Edgecomb and Norton, 2006; Jennings, Cormack, Coutts, Boyd and Aughey, 2010). It should be noted that football is a rapidly evolving sport and it is therefore essential to perform continuous research in order to assess and re-evaluate knowledge regarding the demands of the modern game.

Global Positioning System is a satellite-based positional system developed by U.S. military in the 1970s and calculates ground position firstly by measuring the times between atomic clocks within groups of satellites and a ground receiver (Wolf, Hallmark, Oliveira, Guensler and Sarasua, 1999). Travel times can be used to calculate the distances to the satellites before calculating the position of the ground receiver through triangulation (Aughey, 2011; Wolf et al., 1999). Recent developments in portable GPS units has enabled wider technological applications, including sport, thereby presenting sport scientists and coaches additional means for understanding the demands of physical activity (Cummins, Orr, O'Connor and West, 2013).

Since its first use in 1997 for athletic tracking during walking, running and cycling (Schutz and Chambaz, 1997), GPS has been used extensively in team sports such as football (Dellal, Drust and Lago-Penas, 2012a, 2012b; Scott et al., 2013), Australian football league (Edgecomb and Norton, 2006), Rugby League (McLellan, Lovell and Gass, 2011), Rugby Union (Cunniffe, Proctor, Baker and Davies, 2009), cricket (Petersen, Pyne, Dawson, Kellett and Portus, 2011) and hockey (Gabbett, 2010) for comprehensive analysis of player performance during both non-competitive and competitive MP and training. Global Positioning System devices allow kinematic variables such as distance and velocity to be measured, thereby measuring relevant information about an athlete's position, time, speed and direction granting instantaneous quantification of movement during training and MP (Beanland, Main, Aisbett, Gastin and Netto, 2014).

1.4.3.1 Validity and Reliability of Global Positioning System

A plethora of data exists on the validity of current GPS software estimation of TDC and movement speed. The data that does exist however makes it difficult to state the validity of GPS due to the variety of exercise tasks, GPS devices, sample rates and statistical methods employed by the research (Aughey, 2011). The gold-standard criterion method used to investigate GPS validity for distance is to measure a course with a trundle wheel (MacLeod, Morris, Nevill and Sunderland, 2009; Portas, Harley, Barnes and Rush, 2010) or tape measure (Coutts and Duffield, 2010) and, for speed, the use of timing gates at the start and finish (Barberó-Álvarez, Coutts, Granda, Barberó-Álvarez and Castagna, 2010). A summary of the findings and methods used to assess the validity of GPS for measuring distance is presented in Table 1.

The first commercially available GPS device capable of withstanding the heat, moisture and impact experienced in team sports became available in 2003 (Edgecomb and Norton, 2006). When the 1 Hz GPS device (GPSport Systems, Australia) was validated against a computer-based tracking system (Trakperformance, SportsTec Pty Ltd, Australia) for distance measurement via comparison with a calibrated trundle wheel, a systematic overestimation of approximately 5 % of distance existed by GPS (Edgecomb and Norton, 2006). The aforementioned study used non-differential GPS receivers, which in contrast to differential receivers; do not require a stationary receiver to compare its position with that given by the satellites, sending correctional information to the roving receiver (Townshead, Worringham and Stewart, 2008). For the purpose of this study, only studies using non-differential GPS receivers will be included for analyses, as the present study will only be using these systems.

Global Positioning Systems have advanced to sampling rates of 5, 10, or 15 Hz with research suggesting that higher frequency rates provide greater validity of distance measurement (Jennings et al., 2010; Coutts and Duffield, 2010; Duffield, Reid, Baker and Spratford, 2010; Castellano, Casamichana, Calleja-González, Román and Ostojic, 2011). When comparing the accuracy of distance measurement between a 1 and a 5 Hz GPS device (Minimax, Catapult Innovations, Australia), the standard error of the estimate (SEE) for actual distance in a standing-start 10 m sprint was 32.4 % and 30.9 %, respectively (Jennings et al., 2010). However, 10 Hz (Minimax, Catapult Innovations, Australia) exhibited a SEE of 10.9 % over a 15 m sprint (Castellano et al.,

2011) evidencing that the sampling rate may be limiting the accuracy of distance measurements (Cummins et al., 2013). It should be noted however, that Jennings et al. (2010) observed a reduction in the SEE by 2/3 when comparing sprinting 40 m and 10 m indicating that the validity of GPS measured distance improves as the duration of the task increases. Unfortunately, sprint distance in football rarely exceeds 20 m making the application of these results questionable (Carling et al., 2008; Stølen et al., 2005).

In addition to the TDC, the velocity of the task performed influences the validity of distance measured by the GPS. Portas, Rush, Barnes and Batterham (2007) observed the greatest GPS distance error during running at 6 $m \cdot s^{-1}$ and lowest during walking at 1.8 $m \cdot s^{-1}$ on straight paths using a 1 Hz GPS device. Similarly, Gray, Jenkins, Andrews, Taaffe and Glover (2010) showed that despite 1 Hz GPS (GPSports, Australia) providing a valid measure of TDC during both 200 m linear and non-linear running patterns, the validity and reliability was reduced when quantifying non-linear movements, particularly those at higher-running velocities. Given that many team sport athletes train and compete at movements greater than 3 $m \cdot s^{-1}$ and over curved, non-linear paths, manufacturers have developed more accurate GPS systems that sample at 5, 10 and 15 Hz.

When cricket specific locomotor patterns and distances were compared against criterion measures using 5 Hz GPS units (Minimax, Catapult Innovations, Australia), the SEE of distance for walking to striding ranged from 2 and 4 % and sprinting ranged from 5 and 24 % (Petersen, Pyne, Portus and Dawson, 2009). It should be noted however, that the validity improved from 24 to 16 % in one Minimax unit as sprint distance increased from 20 to 40 m. Additionally, recent research by Hurst and Sinclair (2013) determined the validity and reliability of a 5 Hz GPS system (Minimax, Catapult Innovations, Australia) for measuring non-linear cycling distance and velocity in comparison to a calibrated trundle wheel and cycle computer. They found that the distance measured by 5 Hz GPS was not significantly affected by velocity. Furthermore, both GPS derived distance and velocities were found to be valid and reliable when compared to criterion values. These results suggest that 5 Hz GPS are valid for measuring the non-linear, higher-velocity activities than those used in previous studies. However, the distances measured were >1500 m which is considerably greater than the distance covered at high-speed in football MP, making the application of these results to football questionable.

When 10 Hz (Minimax, Catapult Innovations, Australia) and 15 Hz (GPSport Systems, Australia) GPS units were compared, Johnston, Watsford, Kelly, Pine and Spurrs (2013) concluded that the 10 Hz GPS units measured movement demands with greater validity and inter-unit reliability than the 15 Hz units, however both 10 Hz and 15 Hz units provided improved measures of movement demands in comparison to 1 Hz and 5 Hz GPS units. The greater validity and inter-unit reliability observed in the 10 Hz compared to the 15 Hz GPS units may have been a result of the method used in the 15 Hz GPS units to enable higher sampling rates (Aughey, 2011). For example, previous research using the accelerometer to assist in measuring speed and distance travelled revealed low validity (Waldron, Worsfold, Twist and Lamb, 2011). Therefore, the higher the sampling rate, the more valid distance acquired from GPS becomes (Aughey, 2011; Cummins et al., 2013). However, if there is an error associated with each sampling point, the more sampling points increases the potential for error (GPSports, 2013).

Although the majority of performance in football is spent in low- to moderate-intensity, it is imperative that when measuring distance at high-intensities, GPS systems are accurate. Furthermore, critical movements to successful performance in football require the ability to maximally accelerate, decelerate and change direction at speed over short distances (Dobson and Keogh, 2007). Given that GPS works most effectively when movements are linear or with few directional changes, high sampling rates are required if GPS is to be a valid tool for establishing a WRP in football players (Witte and Wilson, 2004). Furthermore, it is unlikely that using 1 Hz GPS can detect anything other than the TDC by players (Aughey, 2011).

To the author's knowledge, three studies have published information on the validity of GPS for the measurement of accelerations / decelerations (Varley, Fairweather and Aughey, 2012; Akenhead, French, Thompson and Hayes, 2013; Rawstorn, Maddison, Ali, Foskett and Gant, 2014). When football players sprinted maximally over 10 m whilst towing a custom built monorail with two 10 Hz GPS units (Minimax, Catapult Innovations, Australia) secured to a sliding platform, Akenhead et al. (2013) reported that the SEE increased from 0.12 ± 0.02 $m \cdot s^{-1}$ during accelerations of 0 to 0.99 $m \cdot s^{-2}$ to 0.32 ± 0.06 $m \cdot s^{-1}$ during accelerations >4 $m \cdot s^{-2}$, respectively. Therefore, during accelerations of >4 $m \cdot s^{-2}$, accuracy is compromised when using 10 Hz GPS. It should be noted however, that elite football players have been found to rarely achieve a threshold of >4 $m \cdot s^{-2}$ evidenced by a low number of efforts (~13) (Bradley et al., 2009b). Osgnach et al. (2010) also confirmed this finding and found that the majority of distance (3821 ± 335 m) was covered at -1 to 0 $m \cdot s^{-2}$ with the least DC at >3 $m \cdot s^{-2}$ (180 ± 67 $m \cdot s^{-2}$).

In agreement with Akenhead et al. (2013), Varley et al. (2012) found that 5 Hz and 10 Hz GPS were acceptable for measuring instantaneous, linear acceleration and deceleration. However, football is more complex, and evokes frequent bouts of high-intensity multi-directional movement. When Rawston, Maddison, Ali, Foskett and Gant (2014) determined the validity of 5 Hz GPS for the measurement of rapid directional change, it was found that GPS underestimated movement distance and suggested that GPS technology is unlikely to record the most critical movements during MP.

Furthermore, software updates can have a substantial impact on the different metrics measured during football. In a recent study by Buchheit et al. (2014) it was found that software updates led to large and small decreases in the occurrence of accelerations and decelerations, respectively. Therefore, the effect of changes in hardware (e.g., new GPS units) and/or software (e.g., update) and the validity of the provided equations should be considered when using these systems with further research warranted.

As mentioned previously for validity, sample rate, velocity, duration of the task, and the type of task each affects the reliability of GPS (Aughey, 2011). It is important to test both the intra-reliability of the GPS system itself, through multiple-analysis of the same match, and the reliability of data by examining within-subject error across several games. Unfortunately these measures have rarely been achieved in the literature (Drust, Atkinson and Reilly, 2007). Research has shown that reliability decreases when changes of direction occur (Gray et al., 2010; Portas et al., 2010) and when velocity increases (Petersen et al., 2009; Gray et al., 2010; Jennings et al., 2010). Jennings et al. (2010) observed a larger CV during short, high-intensity efforts and suggested that GPS sampling at 1 Hz is inappropriate to assess running efforts. Given the typical length (10-20 m) of high-velocity movements in team sports, the efficacy of 1 Hz GPS to measure brief, high-intensity sprints and slow- and fast- accelerations over distances of less than 20 m is questionable.

Coutts and Duffield (2010) assessed three different 1 Hz GPS models from the same manufacturer (SPI 10; SPI Elite; WiSPI; GPSports Systems, Australia) during a circuit designed to replicate team sports. They compared TDC, low-speed activity distance (<4 $m \cdot s^{-1}$), HSR distance (>4 $m \cdot s^{-1}$), and very high-speed running (VHSR) distance (>5.5 $m \cdot s^{-1}$) between two devices of the same model and between different models over six laps of the circuit course. It was found that intra-model analysis has acceptable reliability for measuring TDC (CV = 4.0-7.2 %). However, the reliability decreased as movement velocity increased to >4 $m \cdot s^{-1}$ (CV = 11.2-32.4 %) and >5.5 $m \cdot s^{-1}$ (CV = 11.5-30.4 %). This trend was similar for inter-model analysis with TDC (CV = 2.4 %) presenting the highest levels of reliability followed by low-speed activity distance (CV = 3.9 %), HSR distance and VHSR distance (CV = 17.3 %). Therefore, data collected via different models will vary significantly making comparisons difficult. It is suggested that the reliability may be increased if devices were allocated to specific individuals.

Portas et al. (2010) provide the only research available that have analysed the reliability of GPS for football-specific activities in addition to linear and multi-directional courses. Using GPS devices (Minimax, Catapult Innovations, Australia) it was found that football-specific trials were comparable for 1 Hz and 5 Hz in which typical error (TE) ranged from 2.0 to 4.9 % and 2.2 to 4.5 %, respectively. Similarly, linear motion was also comparable for 1 Hz and 5 Hz in which TE ranged from 4.4 to 4.5 % and 4.6 and 5.3 %, respectively. However, multi-direction motion resulted in a loss of reliability as course complexity increased. Moreover, 1 Hz ranged from 3.1 to 7.7 % whereas 5 Hz ranged from 3.4 to 6.1 %. These results suggest that both 1 Hz and 5 Hz GPS are capable of quantifying distance in football. However, they have threshold limits, beyond which reliability becomes compromised.

Global Positioning Systems have questionable reliability and validity in measuring distance, especially at high speeds over short distances, such as those experienced in team sports (Jennings et al., 2010) and omits skill (passing, jumping, kicking and marking) and contact (tackling and blocking) based activities that occur up to 173 times during MP (Boyd, Ball and Aughey, 2011). Failure to adequately account for these activities may greatly underestimate the physical demands of modern football. Although several studies have shown GPS to be both valid and reliable for monitoring distance and velocity, these systems still have some limitations for use in team sports, due to the high-speed, short distance and non-linear activity involved. As such, a combination of

GPS with accelerometry technology may provide a more robust and comprehensive analysis of the demands of football (Neville, Wixted, Rowlands and James, 2010).

Table 1. Summary of validity studies on global positioning system

Study	GPS Device	Task	Criterion Measure	Variable assessed	Validity
Edgecomb and Norton, 2006	SPI-10 (1 Hz)	Movement around an oval (125-1386 m)	Trundle wheel	Distance	**SEE (%):** + 4.8 ± 7.2
MacLeod et al., 2009	SPI Elite (1 Hz)	Hockey-movement based circuit (8.50 to 6818 m) Speeds: walk to sprint (5.50-13.20 km·h^{-1})	Timing gates	Distance Mean speed	**Mean difference ± limits of agreement:** 2.5 ± 15.8 m for total distance on 6818 m track 0.0 ± 0.9 km·h^{-1} for mean speed **Pearson's correlation:** r ≥ 0.99 for mean speeds and distance
Petersen et al., 2009	SPI-10 (1 Hz) SPI Pro (5 Hz) MinimaxX (5 Hz)	Cricket-movement based circuit (20-8800m). 20, 30 and 40 m linear sprints Speeds: Walk to sprint	Timing gates	Distance	**Pearson's correlation:** r = 0.99 (p<0.001) **SEE (%) for walk to stride (1 to 5 m·s^{-1}):** SPI-10: S 1.7 to 3.8 **SEE (%) for sprinting (>5 m·s^{-1}):** SPI 10: S 5.3 to 23.8

Barberó-Álvarez et al., 2010	SPI Elite (1 Hz)	Repeated sprints (7 x 30 m)	Timing gates	Peak speed	**Pearson's correlation**: -0.93 ($p<0.001$)
Coutts and Duffield, 2010	SPI-10 (1 Hz) SPI-Elite (1 Hz) WiSPI (1 Hz)	Team-sport movement based circuit (128.50 m) Speed: walk to sprint	Timing gates	Distance	**Bias (%):** SPI-10: -4.1 ± 4.6 SPI-Elite: -2.0 ± 3.7 WiSPI: +0.7 ± 0.6
Duffield et al., 2010	SPI Elite (1 Hz) MinimaxX v2.0 (5 Hz)	Court-based movement drills (12 to 37 m) Speed: jog to fast run	VICON motion analysis system	Distance Mean speed Peak speed	**Distance SEE:** not reported Calculated from reported data ≈ 7 to 31%
Gray et al., 2010	SPI-Elite (1 Hz)	Linear and non-linear 200 m courses. Speed: 1.60 to 8.00 $m.s^{-1}$	Theodolite	Distance	**Linear course:** **Bias (95% limits of agreement):** +2.0 % (5.25 to -1.23) **Multidirectional course:** **Bias (95% limits of agreement):** -6.0 % (2.0 to -13.4)
Jennings et al., 2010	MinimaxX v2.5 (1 Hz) MinimaxX v2.5 (5 Hz)	Linear and non-linear team-sport movement based circuit	Timing gates	Distance	**SEE (%):** **Linear:**

					1 Hz: 9.6 ± 2.0 to 32.4 ± 6.9 5 Hz: 9.8 ± 2.0 to 30.9 ± 5.8 **Multidirectional:** 1 Hz: 9.0 ± 2.3 to 12.7 ± 3.0 5 Hz: 8.9 ± 2.3 to 11.7 ± 3.0 **Team-sport movement based circuit:** 1 Hz: 3.6 ± 0.6 5 Hz: 3.8 ± 0.6

Castellano et al., 2011	MinimaxX v4.0 (10 Hz)	15 and 30 m linear sprints	Timing gates	Distance	**SEM (%)** 15 m: 1.9 30 m: 5.1 **Bias (%)** 15 m: -11.9 % 30 m: -6.5 % **95 % confidence interval** 15 m: 12.9 to 13.6 m 30 m: 28.4 to 27.7 m
Portas et al., 2010	MinimaxX v2.5 (1 Hz) MinimaxX v2.5 (5 Hz)	Linear and non-linear soccer-movement based circuit (37.50 to 197 m)	Timing gates	Distance	**Pearson's correlation:** r = 0.99 for both 1 Hz and 5 Hz **Mean SEE (%)** **1 Hz:** Walk: 1.8 to 4.2 Run 2.4 to 6.8 Soccer specific: 1.3 to 3.0 **5 Hz** Walk 2.2 to 4.4

					Run: 2.2 to 3.6 Soccer specific: 1.5 to 2.2

Waldron et al., 2011	SPI Pro (5 Hz)	10, 20 and 30 m linear sprints Moving 10 m sprints	Timing gates	Distance Mean speed	**Distance (CV)** 5.0 to 8.09 % **Mean speed (CV):** 6.61 to 9.81 %
Hurst and Sinclair, 2013	MinimaxX v2.0 (5 Hz)	Three laps of a 1591.60 m non-linear cycling course Speed: 10 to 30 km·h^{-1}	Digital cycling computer	Distance Velocity	**Pearson's correlation:** Distance: no significant differences (p>0.05). 10 km·h^{-1} = 0.997 20 km·h^{-1} = 0.539 30 km·h^{-1} = 0.955
Johnston et al., 2013	MinimaxX v2.5 (5 Hz)	10 laps of a 130.50 m team sport simulation circuit Speed: walk to sprint	Timing gates	Distance Peak speed	t-test between GPS data and criterion measure for total distance and peak speed (p>0.05)
Varley et al., 2012	MinimaxX v2.0 (5 Hz) MinimaxX v4.0 (10 Hz)	Linear Speeds: constant speed, acceleration and deceleration s^{-2}) to 8	50 Hz Laser	Instantaneous velocity	**Constant velocity (CV %)** **1-3 m·s^{-1}** 5 Hz: 11.1 ± 0.58 (r = 0.91) 10 Hz: 8.3 ± 0.27 (r = 0.96) **3-5 m·s^{-1}**

					5 Hz: 10.6 ± 0.59 (r = 0.77) 10 Hz: 4.3 ± 0.15 (r = 0.95) **5-8 m·s^{-1}** 5 Hz: 3.6 ± 0.26 (r = 0.28) 10 Hz: 3.1 ± 0.13 (r = 0.92) **Acceleration (CV %)** **1-3 m·s^{-1}** 5 Hz: 14.9 ± 1.16 (r = 0.90) 10 Hz: 5.9 ± 0.23 (r = 0.98) **3-5 m·s^{-1}** 5 Hz: 9.5 ± 0.79 (r = 0.82) 10 Hz: 4.9 ± 0.21 (r = 0.98) **5-8 m·s^{-1}** 5 Hz: 7.1 ± 0.87 (r = 0.50) 10 Hz 3.6 ± 0.18 (r = 0.92) **Deceleration -85 m·s^{-1} (CV %)** 5 Hz: 33.2 ± 1.64 (r = 0.83)

					10 Hz: 11.3 ± 0.44 (r = 0.98)
Akenhead et al., 2013	MinimaxX v4.0 (10 Hz)	10 m linear accelerations (0 to >4 $m \cdot s^{-2}$)	2000 Hz laser	Instantaneous velocity	**SEE ± 95 % CI** Increased from 0.12 ± 0.02 $m \cdot s^{-1}$ during accelerations of 0 to 0.99 $m \cdot s^{-2}$ to 0.32 ± 0.06 $m \cdot s^{-1}$ during accelerations > 4 $m \cdot s^{-2}$. **TE** Increased from 0.05 ± 0.01 to 0.12 ± 0.01 $m \cdot s^{-1}$ during accelerations of 0 to 0.99 $m \cdot s^{-2}$ and > 4 $m \cdot s^{-2}$ respectively.
Rawstorn et al., 2014	SPI Pro X (5 Hz)	Loughborough Intermittent Shuttle-running Test movement pattern on curvilinear and shuttle running tracks (13200 m)	Reference	Distance	Total distance was over and underestimated during curvilinear (2.61 ± 0.8 %) and shuttle (−3.17 ± 2.46 %) trials, respectively.

1.4.4 Accelerometers

Accelerometers are highly responsive motion sensors used to measure the frequency and magnitude of movement (Krasnoff et al., 2008). The earliest devices were developed in the 1960's (Cavagna, Saibene and Margaria, 1961) and were first designed with a single motion sensor (uni-axial) to measure acceleration in one vector (vertical) (Montoye et al., 1983). More recent triaxial designs measure movement in three planes (anterior-posterior, medial-lateral and caudal-cranial) and were developed to measure multi-directional body movement, thus improving energy expenditure estimations (Bouten, Westerterp, Verduin and Janssen, 1994). Accelerometers measure kinetic energy, which is converted into electrical energy and translated by the device as acceleration measurement data (Boyd et al., 2011). More recent GPS units also include triaxial accelerometers to quantify physical activity and acceleration in three planes.

Accelerometers may offer a measurement system that avoids some of the limitations outlined previously with HR and TMA, including a higher sample rate compared with GPS (100 vs. 15 Hz), the ability to analyse multiple-players both indoors (Montgomery, Pyne and Minahan, 2010) and outdoors (Akenhead, Hayes, Thompson and French, 2012), reduced labour, and the inclusion of both skill and contact (Venter, Opperman and Opperman, 2011) based aspects of team sports that contribute to player demands (Boyd et al., 2011). The relationship between accelerometers and other measures such as HR (Coe and Pivarnik, 2001), energy expenditure (Puyau, Adolph, Vohra, Zakeri and Butte, 2004) and $\dot{V}O_2$ (Kozey, Lyden, Howe, Staudenmayer and Freedson, 2010) have previously been examined. This preliminary work inspired researchers to explore the application of accelerometers in the sporting population.

Early research into team sports using accelerometers have investigated the activity demands of basketball (Coe and Pivarnik, 2001; Montgomery et al., 2010), gait patterns in football (Tsivgoulis et al., 2009), and impacts from collisions in Rugby Union (Venter et al., 2011). Venter et al. (2011) used a scaling system to determine the intensity of collisions ranging from 5 G-force units (g) light impacts to >10 g severe impacts in under-19 rugby union MP. Results showed that back row forwards accumulated the highest total amount of impacts (683.4 g) whereas the front row forwards experienced the most severe impacts. Although there will be match to match variance, information regarding the number and intensity of impacts experienced by players of different positional roles can assist coaches when planning recovery sessions (Venter et al., 2011).

Recent research has become increasingly interested in other applications of accelerometers including player load (Casamichana, Castellano and Castagna, 2012; Aguiar, Bothelho, Gonçalves and Sampaio, 2013). Player load (PL) is a modified vector magnitude and is based upon the accelerations from the three planes at 100 Hz (Boyd et al., 2011). It is therefore, the collation of all forces imposed on an athlete, including acceleration / deceleration, related changes of direction and impacts from both the player-to-player collision and contact with the ground (foot strikes and falls). Player load is a relatively new indicator that provides a complete representation of the total body load experienced by football players and has been found to differentiate between SSGs and MP in basketball (Montgomery et al., 2010), and between positional roles in basketball (Montgomery et al., 2010) and netball (Cormack, Smith, Mooney, Young and O'Brien, 2013b). Therefore, PL may be useful to determine positional differences between SSGs and MP.

To date, research has predominately focused on the IL and the WRP experienced by players of different positions during MP and SSGs. This research has omitted the physical load during movements such as jumping, change of direction and acceleration / deceleration, collisions and possession contesting. Research is therefore required to examine the physical demands of these discrete activities during training sessions and MP to determine if players are being appropriately loaded. With regards to football, there has are two studies that have reported PL values for SSGs (Aguiar, Bothelho, Gonçalves and Sampaio, 2013) and PL values for both SSGs and friendly MP (Casamichana, Castellano and Castagna, 2012) using accelerometers. However, these studies have reported total PL from the summation of acceleration and deceleration movements in each anatomical plane (X: medial-lateral, Y: anterior-posterior, Z: caudal-cranial). Further research is therefore warranted to quantify the relative contributions of the individual vectors to total PL to provide an understanding of the movement patterns during MP and SSGs. Further, research investigating the differences in movement patterns between positional roles will assist coaches when planning strength and conditioning sessions.

Unfortunately, there is a lack of assessment of the validity and reliability of accelerometer data in the team sports environment. Previous assessments of the validity and reliability of accelerometers were limited to mechanical tests (Krasnoff et al., 2008; Van Hees, Slootmaker, De Groot, Van Mechelen and Van Lummel, 2009) and basic physical activity (Levine, Baukol and Westerterp, 2001; Fudge et al., 2007; Nichols, Morgan, Sarkin, Sallis and Calfas, 1999). To the researcher's knowledge, only five published articles exist that has examined the validity (Gabbett, Jenkins and Abernethy, 2010; Netto, Tran, Gastin and Aisbett, 2010; Beanland et al., 2014; Scott et al., 2013; Gastin, McLean, Breed and Spittle, 2014) and only one that has reported reliability results (Boyd et al., 2011) of accelerometry in a sporting environment.

1.4.4.1 Validity and reliability of accelerometers

The validation of accelerometers in physical activity is challenging, as a gold standard of measurement for comparison is currently unavailable. Therefore, research has inferred validity between accelerometry measures and physiological parameters such as energy expenditure (r = 0.99) and $\dot{V}O_2$ (r = 0.87) during low-intensity locomotion (Levine et al., 2001; Fudge et al., 2007). However, given that 10-20 % of football MP is high-intensity activities comprising of high-speed movements, it is imperative that modern accelerometers are able to accurately measure these activities (Bangsbo, 1994a).

With the recent application of wearable accelerometers, research is beginning to emerge assessing the validity of accelerometers to measure team sport-specific parameters, utilised as a tool for analysing performance (Gabbett et al., 2010; Netto et al., 2010; Scott et al., 2013; Gastin et al., 2014). Recent research by Gabbett et al. (2010) assessed the validity of a triaxial device (Minimax, Catapult Innovations, Australia) for detecting collisions in Rugby League training. The magnitude of each collision was categorised as mild, moderate or heavy. It was found that mild-collisions were the most difficult to detect (r = 0.89) compared to moderate (r = 0.97) and heavy (r = 0.99). It should be noted that relationships between the criterion measure (video) and the accelerometer detection were very high across all three magnitudes. Determining a mild-collision from one of non-significance appears difficult due to the broad category. For example, a mild-collision was defined as "contact made with player but able to continue forward progress / momentum out of tackle". However, it appears the Minimax accelerometer is a valid tool for detecting the frequency and magnitude of collisions in Rugby League training. In contrast, using the same algorithm developed for impact detection in the previous study, Gastin et al. (2014) found that out of the 352 tackles observed using video observation, only 78 % were correctly detected as tackles by the manufactures software. The tackle detection algorithm was therefore not suitable for tackle detection in American football suggesting that the underlying sensor requires sport and event-specific algorithms. To the researcher knowledge, there has been no research to date that has assessed accelerometer-derived collisions in football. It should be noted however that football players would mostly experience G-force values of between 5.00-6.99 based on the impact zone classification system by Owen, Venter, Toit and Kraak (2015). In contrary, Rugby union players can experience G-force values >10.0 which explains why research has focused primarily on collisions in rugby to prevent the occurrence of injuries.

Using the same accelerometer device as the study conducted by Gabbett et al. (2010) and Gastin et al. (2014), Casamichana et al. (2013) found that PL reported large to very large correlations with TDC (r = 0.70) during football training sessions. Similarly, Scott et al. (2013) also reported that PL was an acceptable measure of EL through moderate correlations with TDC (r = 0.93) and HR-based and rating of perceived exertion (RPE) based measures of IL (r = 0.71-0.84) during football training activities. It should be noted however, that as the contribution of anaerobic metabolism increases, HR measures may respond slowly to the short bouts of high-intensity activities (Achten and Jeukendrup, 2003), thus underestimating HR. Likewise, during field-based training, high-intensity activities are interspersed with a large volume of standing and low-speed movement when listening to the coach or awaiting to perform drills which may subsequently decrease perception of effort. Therefore, session RPE may underestimate the physiological load imposed by HSR and VHSR. It should be noted, however, that RPE is the only method that takes into consideration the psychological factors and its importance should therefore not be overlooked for monitoring training load and the prevention of overtraining. Nevertheless, PL may provide additional information for coaches and sport scientists that are not reflected in physiological and perceptual methods.

Using a different device (SPI Pro, GPSports Pty Ltd, Australia) from the previous studies, Netto et al. (2010) compared accelerometer data during cutting and running

tasks with a 24-camera high-speed motion analysis system (Eagle-4, Motion Analysis Corp, USA) from three markers (ankle, base of the spine and base of the neck). They found that accelerometer data was significantly higher in both the running and cutting tasks and that percentage CV values calculated for both accelerometer variables (vertical load and vector magnitude load) were well above acceptable limits (>34 %). Unfortunately, the device used in this study is different from the Minimax device used in previously mentioned studies (Gabbett et al., 2010; Scott et al., 2013; Gastin et al., 2014) and therefore the results cannot be extrapolated to the Minimax device.
Alongside validity, there is a general lack of research assessing the reliability of accelerometers, with all available research limited to mechanical tests (Nichols et al., 1999; Krasnoff et al., 2008; Van Hees et al., 2009; Boyd et al., 2011) basic physical activity (Nichols et al., 1999; Jakicic et al., 1999; Santa-Lozano et al., 2012) and sporting activity (Boyd et al., 2011).

When human participants were assessed during basic physical activity the Tritrac R3D accelerometer (Reining International, Wisconsin) was highly reliable between units (CV = 1.79 %; and interinstrument intraclass reliability (ICC) = 0.73 to 0.87 and for the same unit over multiple-trials conducted on separate days (ICC = 0.87 to 0.92) (Nichols et al., 1999). However, when inter-unit reliability of estimated energy expenditure was assessed, the error increased (CV = 3.57 %). Using a similar design, Jakicic et al. (1999) assessed the reliability of the Tritrac R3D accelerometer during five exercise modalities (walking, running, cycling, stepping and slideboard). They found that estimated energy expenditure, derived from the accelerometers showed high reliability for walking, running and slideboard. Results also suggest that as velocity increases, so does reliability, associated with a more consistent stride pattern with high running velocity. Unfortunately, the CV % was not reported in this investigation thus making it difficult to establish the magnitude of variation within- and between-units.

To the researcher’s knowledge there is only one study to date that has examined the within- and between-device reliability of accelerometers in a sporting context (Boyd et al., 2011). In the study conducted by Boyd et al. (2011), within- and between-device reliability for measuring PL was assessed by attaching eight accelerometers (Minimax, Catapult Innovations, Australia) to a hydraulic universal testing machine, which oscillated over two protocols (0.5 and 3.0 g). Results revealed that between-device reliability were CV 1.04 % for the 0.5 g trial and CV 1.02 % for the 3.0 g trial.

Similarly, within-device dynamic assessments were CV 0.91 % and CV 1.05 % for the 0.5 g and 3.0 g trial, respectively. The study also assessed the reliability of PL by instrumenting 10 players with two accelerometers during Australian football MP. The between-device reliability during MP was CV 1.9 % suggesting that Minimax accelerometers can be confidently applied to assess changes or differences in PL over multiple periods of activity, or between players.

Therefore, Minimax accelerometers can be confidently used as a reliable tool to measure physical activity in team sports across multiple-players and repeated activity bouts (Boyd et al., 2011). To date, extensive research has been employed to understand the physiological and technical demands of football. Research using modern TMA devices is required to further elucidate and compare the position-specific physiological and physical demands of MP and SSGs.

1.5 Small-sided games

Through detailed understanding of various field sports made possible through the implementation of TMA, coaches are now able to measure the physical activity profile of players in training. It is well documented that the greatest training benefits occur when the training stimulus evokes identical movement patterns and physiological demands of the sport (Müller, Benko, Raschner and Schwameder, 2000). With regards to football, a greater understanding of the physiological requirements of MP allow coaches to tailor training to adapt players to the physical, technical and tactical requirements observed in modern football matches (Aughey, 2011). Knowledge obtained through the application of TMA techniques in football has evolved coaching methods from solely using analytical (traditional) training methods such as aerobic interval training (Helgerud et al., 2001), in which fitness is the most important factor, to new approaches using SSGs in which the technical performance is of greater importance (Clemente, Martins and Mendes, 2014).

Small-sided games, also referred to as skill-based conditioning games (Gabbett, 2006) or game-based training (Gabbett, Jenkins and Abernethy, 2009) are modified games played on reduced pitch areas, often using modified rules, and involve a smaller number of players than traditional football MP (Hill-Haas et al., 2011). Endurance training carried out in this fashion allows additional development of the tactical and technical skills similar to situations experienced during MP in addition to improving motivation levels (Helgerud et al., 2001). Therefore, training can be implemented in a more football-specific way. Furthermore, the use of SSGs to develop physical fitness has been shown to be effective among football players by fulfilling the wide range of fitness requirements without compromising skill performance and decision making (Aguiar et al., 2013). In response to the growing popularity of SSGs, a comprehensive understanding of the stimulus imposed on players during these drills is essential to optimise the training adaptation (Gaudino, Alberti and Iaia, 2014). As with MP, research examining the physical demands of SSGs has focused primarily on traditional time-motion metrics in addition to the physiological and technical responses. Research has also omitted the discrete high-intensity activities that may occur more frequently during SSGs than MP due to the increased technical demands (Little and Williams, 2006, 2007; Owen et al., 2004; Dellal et al., 2008; Rampinini et al., 2007b; Mallo and Navarro, 2008).

1.5.1 Physiological responses of small-sided games

The favourable physiological responses stimulated by SSGs fulfil its application within football as a conditioning stimulus capable of improving aerobic endurance and anaerobic capacity irrespective of status (amateur vs. professional) or age (youth vs. adult) (Hill-Haas, Coutts, Dawson and Rowsell, 2010; Owen et al., 2014). Moreover, studies have demonstrated that the intensity of SSGs can be manipulated to elicit different physical, technical and tactical responses, including, the number of players (Little and Williams, 2007), the dimension and shape of the pitch (Owen et al., 2004), the duration of exercise and rest periods (Dellal et al., 2008), rules of the game (Little and Williams, 2006), coach encouragement (Rampinini et al., 2007b), or the inclusion of goal keepers (Mallo and Navarro, 2008).

Research has identified that SSGs, with a small number of players, bigger field dimensions, touch limitations, coach encouragement and no goalkeepers increase the HR and BLa response (Clemente et al., 2014). Dellal et al. (2011a) observed maximum heart rate (HR_{max}) values of 85-90 %, and BLa values of 2.8-5 mmol·L^{-1} during 2 vs. 2, 3 vs. 3 and 4 vs. 4 SSGs. These results are similar to HR_{max} values of 80-90 % and BLa values of 4-6 mmol·L^{-1} reported during MP (Dellal et al., 2012b; Bangsbo et al., 1991).

Furthermore, recent studies have reported that when compared to MP, SSGs (3 vs. 3, 5 vs. 5 and 7 vs. 7) played on small dimensions are sufficient for the development of aerobic capacity in football players, possibly through increases in low- and moderate-speed movement (Gabbett and Mulvey, 2008; Casamichana et al., 2012). In contrary, SSGs played as 1 vs. 1 and 2 vs. 2 are played at higher-intensities through eliciting significantly greater acceleration / deceleration loads than generic running drills which subsequently tax the anaerobic energy system (Ade, Harley and Bradley, 2014). Therefore if the development of the aerobic system is of importance, SSGs should be played on larger pitch dimensions (Casamichana and Castellano, 2010; Hill-Haas et al., 2011). In contrary, if the development of the anaerobic system is of importance, SSGs should be played on smaller pitch dimensions with fewer players (Ade, Harley and Bradley, 2014).

The evolution of TMA to modern GPS systems permit valid and reliable estimates of the EL experienced by multiple players during SSGs (Casamichana and Castellano, 2010; Castellano, Casamichana and Dellal, 2013; Dellal et al., 2011c). Using GPS systems, research has focused primarily on the HSR demands of SSGs, as this is believed to be a discriminator between successful and unsuccessful teams (Rampinini et al., 2009).

1.5.2 Time-motion analysis of small-sided games

1.5.2.1 High-speed running demands of small-sided games

Using GPS analysis, Gabbett and Mulvey (2008) and Casamichana et al. (2012) reported that SSGs (3 vs. 3, 5 vs. 5 and 7 vs. 7) evoke the majority of the features occurring in MP, but were insufficient to reproduce the high-intensity and repeated-sprint demands of high-level competitive situations. Casamichana et al. (2012) observed more sprints per hour of play during friendly MP, with greater mean durations and distances, greater maximum durations and distance, and a greater frequency per hour of play for sprints of 10-40 and >40 m. More recently, when comparing SSGs (4 vs. 4) and large-sided games (9 vs. 9 to 11 vs. 11), Owen et al. (2014) reported that in comparison to large-sided games, SSGs induced significantly less repeated high-intensity efforts (4.40 vs. 0.88 m, respectively), HIR (39 vs. 7 m, respectively) and sprint distance (11 vs. 0 m, respectively).

The results obtained from the aforementioned studies are important as elite male football is characterised by the amount of high-intensity activities performed by the players (Dellal et al., 2011b) and to be successful at this level requires multiple high-speed runs with an excellent capacity to recover (Dupont, Akakpo and Berthoin, 2004). The findings are attributed to the lack of space to accelerate to reach the highest velocities when playing SSGs. In addition, greater distance is covered when playing 11 vs. 11 during MP or in training, as there is a greater distance between players. Players will therefore be able to cover greater distances at higher speeds in order to apply pressure to the opposition or when moving to an area to receive passes (Corvino, Tessitore, Minganti and Sibila, 2014). Indeed, high-speed exercises differentiate standards of play (Mohr et al., 2003), the tactical role of the players (Di Salvo et al., 2009) and are related to the success of a team (Rampinini et al., 2007a). It is therefore, essential that the ability to perform these activities be developed effectively as they are sensitive to the effects of training (Hopkins, Hawley and Burke, 1999). Conversely, Dellal et al. (2012b) revealed that compared to MP, TDC per min of play, HIR activities, total number of duels, lost ball possessions, and HR were significantly greater within SSGs (4 vs. 4) for all playing positions. In contrast, BLa, percentage of successful passes, number of ball possessions, and RPE values were lower in SSGs compared to MP. It is believed that players performing more HIR and sprinting during SSGs compared to MP in this particular study is a result of the larger playing fields used (30 x 20 vs. 100 x 60 m, respectively) rather than a physical or technical component (Dellal et al., 2012b).

Although the SSGs drills used by Gabbett and Mulvey (2008), Casamichana et al. (2012) and Owen et al. (2014) failed to stimulate the high-speed actions performed during MP, the results from Dellal et al. (2012b) suggest that the HSR demands of MP can be successfully developed through SSGs played on larger field dimensions. It should be noted that the in the study by Dellal et al. (2012b), GPS and SAMCS were used for the SSGs and MP, respectively. The limitations of comparing the results from these two systems have already been outlined and further research using the same system during both SSGs and MP is required. Nevertheless, adopting a relative pitch ratio of 1:75 m^2 per player for different SSGs (2 vs. 2, 3 vs. 3 and 4 vs. 4) may stimulate similar high-speed efforts to those experienced in MP.

Recent research has found that between the 2006-2007 and 2012-2013 EPL seasons, the absolute number of both explosive and leading sprints increased (Barnes et al., 2014). Therefore, if players are producing shorter more explosive sprints but attaining higher maximal running speeds, then the acceleration capacity of the players has developed. It should be noted however, that the discrete high-intensity demands as a result of accelerating / decelerating have largely been omitted, possibly due to sensitivity issues of GPS systems for measuring acceleration / deceleration (Dellal et al., 2011c). Studies are beginning to emerge quantifying the acceleration / deceleration demands of SSGs (Ade, Harley and Bradley, 2014; Gaudino et al., 2014).

1.5.2.2 Acceleration demands of small-sided games

When studying the physical demands of MP, previous research has categorised gross locomotion using several speed zones (Mohr et al., 2003; Di salvo et al., 2009; Bradley et al., 2011). Unfortunately, this method fails to include accelerations and decelerations despite the fact that maximal accelerations can occur even at low absolute speeds (Varley et al., 2012; Akenhead et al., 2013). This is important, as accelerating is more energetically demanding than movement at a constant velocity (Osgnach et al., 2010). In addition, decelerations occur as frequently as accelerations in football MP (Osgnach et al., 2010) and have been found to induce significant mechanical stress on the body through the eccentric muscle actions required to decelerate (Thompson, Nicholas and Williams, 1999). Detailed analysis is required regarding these essential elements of football as a substantial metabolic load is imposed on players every time acceleration is elevated. To the researcher's knowledge, five studies have examined both the acceleration and deceleration demands of football MP (Osgnach et al., 2010; Akenhead et al., 2013; Varley and Aughey, 2013) and SSGs (Ade, Harley and Bradley, 2014; Gaudino et al., 2014).

Using multiple-camera analysis (SICS®, Bassano del Grappa, Italy), Osgnach et al. (2010) revealed that players cover the greatest distance in low deceleration (from -1 to 0 $m{\cdot}s^{-2}$) and low acceleration (from 0 to 1 $m{\cdot}s^{-2}$) with reported values of 35 and 32.8 % of TDC, respectively. Unfortunately, the use of multiple-camera analysis systems at training facilities is impractical prompting the application of small and unobtrusive GPS systems with built in accelerometers. Using a 5 Hz GPS, Varley and Aughey (2013) identified that players undertook 8-fold the number of max accelerations (>2.78 $m{\cdot}s^{-2}$)

than sprints per game (65 ± 21 vs. 8 ± 5, respectively) with 98 % of maximal accelerations occurring from a starting velocity lower than what is considered high-speed running. The results from this study highlight the importance of quantifying metabolic and physically demanding discrete movements such as accelerations and decelerations that are not measured by traditional methods of TMA like those used by Osgnach et al. (2010). Unfortunately, the research quantifying the EL of SSGs has adopted a similar approach to studies that have quantified the EL of MP in that the use of speed based categories have been employed. As previously mentioned, this approach may underestimate the demands of SSGs especially considering SSGs are typically not large enough to evoke maximal speeds but may evoke maximal accelerations (Gaudino et al., 2014).

With regards to SSGs, using different formats (5 vs. 5, 7 vs. 7 and 10 vs. 10); Gaudino et al. (2014) reported that the TDC, HSR distance (>14.4 $km \cdot h^{-1}$) as well as absolute maximum velocity, maximum acceleration and maximum deceleration increased with pitch size. On the contrary, the number of moderate-accelerations and decelerations (± 2-3 $m \cdot s^{-2}$) and the total number of changes in velocity were greater as the pitch size decreased. Similarly, Ade, Harley and Bradley (2014) found that 1 vs. 1 and 2 vs. 2 SSGs evoked significantly greater acceleration and deceleration loads than generic running drills. Using SSGs may develop the acceleration capability of players, however, they may also increase injury propensity through increased eccentric muscle actions to decelerate movement (Freckleton and Pizzari, 2013). Furthermore, the majority of injuries during football tournaments (80 %) are caused by contact with another player (Junge and Dvorak, 2013). The reduced pitch dimensions used during SSGs encourage players to frequently come into contact with one another and perform duels, thereby further increasing the propensity of injury.

Therefore, it appears that the physical demands of SSGs are more demanding than previously estimated in studies that examined running speed alone with greater differences observed when SSGs are played on smaller pitch sizes. To the researcher's knowledge there is no research to date that has determined the position-specific acceleration and deceleration demands of MP using accelerometers. Similarly, there has been no research that compared the acceleration / deceleration demands of MP with SSGs.

In addition to the acceleration and deceleration demands of MP and SSGs, recent research has become interested in the physical demands based on PL measures to provide sport scientists with a greater understanding of the EL accrued during training.

1.5.3 Player load responses during small-sided games

There have only been three studies using accelerometers to determine PL in football players (Casamichana et al., 2012; Scott et al., 2013; Aguiar et al., 2013). Scott et al. (2013) revealed that PL provided moderate, significant correlations with HR and RPE-based methods. Given that HR monitors respond slowly to short bursts of HSR and VHSR, thus underestimating IL (Achten and Jeukendrup, 2003); the internal total load may not reflect the high-intensity actions. It should be noted that using speed to assess the physiological demands of football may be limited, as it is based on the assumption that increased movement speed imposes greater exertion (Bloomfield et al., 2007). In addition, high-intensity activities also include jumps, turns, physical contacts and unorthodox movements which may be classified under low-speed activity, despite evoking high physiological load (Reilly and Bowen, 1984). Research is therefore, required to measure the physical demands of these movements using modern systems such as accelerometers. There is a dearth of research that has analysed the aforementioned high-intensity activities within football. Key information on these activity and movement demands in addition to the number and intensity of physical contacts and collisions can be quantified by PL and impact measures. There are two studies that have reported total accumulated PL values for SSGs (Aguiar et al., 2013) and accumulated PL per min (PLacc.min^{-1}) values for both SSGs and friendly MP (Casamichana et al., 2012) using accelerometers.

Aguiar et al. (2013) reported total accumulated PL values during various SSG formats (2 vs. 2, 3 vs. 3, 4 vs. 4 and 5 vs. 5). Total accumulated PL values increased with the number of players until 4 vs. 4 (95.18 ± 17.54 AU); with a significant decrease in 5 vs. 5 (86.43 ± 14.47 AU). In addition, PLacc.min^{-1} followed a similar fashion and increased with the number of players until the 4 vs. 4 (15.88 ± 2.93 AU); with a significant decrease in the 5 vs. 5 (14.22 ± 2.41 AU). Similar results were reported in Casamichana et al. (2012) study comparing the physical demands of friendly MP and SSGs. They observed higher PLacc.min^{-1} values during SSGs (15.8 ± 2.7 AU) compared to friendly MP (13.5 ± 1.5 AU). Unfortunately, the SSG values were mean values taken from three different SSG formats (3 vs. 3, 5 vs. 5 and 7 vs. 7) and therefore the PL responses to each individual SSG is unknown. It should be noted that all the studies examining PL during football MP and SSGs have reported PL as a single arbitrary unit. Further research is therefore required to quantify the contribution from each individual planar axes to determine where the majority of movement is accumulated during MP and SSGs. Research investigating the PL experienced by positional demand would also be useful for practitioners when designing training sessions and recovery regimes according to position-specific requirements.

1.6 Training and match play demands for late adolescent football players

There is a severe lack of research examining late adolescent football players. The MP and SSG demands have previously been described with studies reporting the TDC by players in an array of defined speed zones (Castagna, D'Ottavio and Abt, 2003; Buchheit, Delhomel and Ahmaidi, 2008; Buchheit, Mendez-Villanueva, Simpson and Bourdan, 2010). Given the innate differences in the capabilities between youth and senior football players, it would be inappropriate to use the same speed zones commonly applied in the literature to senior players to a youth player. For example, sprint performance is positively related to the age of players (Mujika, Spencer, Santisteban, Gioriena and Bishop, 2009), possibly due to the differences in thigh muscularity (Hoshikawa et al., 2009). Understanding the MP demands of youth football could have practical implications for training prescription, talent identification and the quantification of player training loads (Harley et al., 2010). The principle of specificity justifies the use of SSGs in training, because it is assumed that performance improves more when training simulates the physiological demands and movement patterns of competitive football MP. It is unknown however, what the physical demands of SSGs are, and whether they pose an injury risk to football players. The findings of this study aim to provide crucial information to sport scientists and coaches for the design and promotion for the use of various SSGs as part of a structured weekly training and conditioning program. In addition, the findings may also provide information on the potential for SSGs to lead to undertraining or overtraining in both youth and adult players thus optimising the physical preparation and reducing the incidence of injury.

1.7 Hypothesis

The hypotheses for this study were that:

1. Small-sided games will evoke a greater internal physiological load than match play.
2. Small-sided games will evoke a greater external load than match play.

The null hypothesis for this study states that the SSGs employed will not evoke greater internal physiological and external load than match play.

2. Methods

2.1 Participants

Forty trained youth male football players (age 17.00 ± 0.60 years, height 179.88 ± 6.15 cm, body mass 73.93 ± 5.85 kg), representing both English and Portuguese youth academy football teams volunteered to participate in this study. The players were classified to their playing positional role: CD, WD, CM and FW. Goal keepers were excluded from the study as they: (1) did not participate in the same training program as the remainder of the squad; and (2) research has observed a reduction in tempo of SSGs with the inclusion of goal keepers (Mallo and Navarro, 2008). Participants had 3-4 training sessions per week plus 1 match. To participate in the study it was required that all participants: read and understood the participant information sheet (appendix A and B), received parental consent (if required) (appendix C), signed an informed consent form (appendix D) to give written informed consent and completed a physical activity readiness questionnaire (appendix E). A risk assessment was also completed prior to testing to identify any potential hazards (appendix F and G). Written and informed consent was gained in accordance with procedures outlined in the declaration of Helsinki. The experimental protocol was approved by the University of Central Lancashire Ethical Committee.

2.2 Instrumentation

Participants height was recorded using a stadiometer to the nearest cm (Seca 220 Height Gauge Stadiometer, Seca, Town, Germany), whilst body mass was measured using digital scales to the nearest kg (Seca 882W Digital Scales, Seca, Town, Germany). Internal training intensity was determined using HR monitors (Polar Team System, Polar, Finland) during each SSG and friendly match. External training intensity and load were determined using positional GPS at 5 Hz and accelerometer data at 100 Hz (Minimax 2.0 GPS device, Catapult Innovations, Australia). The Minimax accelerometer was calibrated in accordance to the manufacturers instructions (appendix H). The players wore neoprene harnesses that enabled the devices to be fitted between the upper scapulae, at approximately the T3-4 junction. Following recording, the data was downloaded to proprietary software (Catapult Sprint software, version 5.0). Horizontal dilution of precision (HDOP) indicates accuracy of GPS in a horizontal plane. Vertical dilution of precision (VDOP) however, indicates accuracy of GPS in a vertical plane (Catapult Sports). During these trials, the CV for HDOP and VDOP were 5.82 and 5.24 %, respectively.

2.3 Procedures

2.3.1 Small-sided games

Prior to the commencement of the SSGs and friendly matches, the coach conducted a 20 min standardised warm up consisting of low-intensity running, striding and stretching. The SSGs were implemented in a random order over the duration of the study (14th may – 18 weeks). The specific training drill structures (Table 1) were chosen in accordance to previous research conducted by Dellal et al. (2011a; 2012b) and Rampinini et al. (2007b) and were used as aerobic high intensity training drills (Bangsbo, Mohr, Poulson, Perez-Gomez and Krustrup, 2006). Small-sided games played as 2 vs. 2, 3 vs. 3 and 4 vs. 4, without goalkeepers, with the aim to maintain possession of the ball for as long as possible whilst only allowing 2 touches per player possession were analysed. Players were not told to assume specific positional roles and instead were free to play the SSGs as they desired. Ball touches were kept to 2 touches maximum based on data determined in MP and the technical ability of the players (Dellal et al., 2011b). All SSGs had 3 min of active recovery between bouts. To avoid long game stoppages resulting in a loss of tempo, balls were available around the pitch areas for immediate availability with coaches situated outside the playing area, with the instruction to maintain collective possession for the longest. In all drill structures, participants were allowed to hydrate ad libitum. To increase exercise intensity, coaches were told to provide encouragement as it has been suggested (Hoff et al., 2002) and validated (Rampinini et al., 2007b) that coach encouragement increases the exercise intensity during SSGs. To isolate the effect of number of players per se on exercise intensity, the playing area per player was kept constant (Rampinini et al., 2007b).

Table 2. Characteristics of SSGs

	Observations	Game duration (min)	Duration of recovery (min)	Pitch area (m)	Pitch total area (m^2)	Pitch ratio per player (m^2)
2 vs. 2	10	4x2	3	20x15	300	1:75
3 vs. 3	7	4x3	3	25x18	450	1:75
4 vs. 4	5	4x4	3	30x20	600	1:75

2.3.2 Friendly matches

Players were also analysed during six 11-a-side friendly matches on the same surface area (100 x 60 m). The extra time in each half was excluded from the analysis and therefore, the only activities during the 90 min were analysed. Individual player data acquired from friendly MP was included for analysis provided they met the following criteria: (1) the player completed the full duration of the game; (2) they did not suffer an injury during the game; and (3) they played the same position throughout the game.

2.3.3 Physiological responses

Heart rate was measured continuously throughout the SSGs and friendly matches recording at a sampling frequency of 5 s using short-range radio telemetry which was recorded and logged by the GPS units. The data was subsequently uploaded to a computer and analysed using the software package *Logan plus* (*Catapult innovations*). Both mean HR and percent of estimated HR maximum were analysed. As the participants were aerobically trained athletes, the equation proposed by Whyte, George, Shave, Middleton and Nevill (2008) was used to determine HR_{max}.

2.3.4 Time-motion characteristics

External training load, movement demands and PL were determined via positional GPS and accelerometer data. Immediately prior to the warm up, several players from each positional role were fitted with a GPS unit and Polar HR belt and monitor.

The variables used to compare the physical demands of SSGs and MP was as follows: (a) the total distance covered per min ($TDC.min^{-1}$) and (b) the distance covered per min ($DC.min^{-1}$) and percentage of time (%T) spent in each of the speed zones: 0-6.0, 6.1-

8.0, 8.1-12.0, 12.1-15.0, 15.1-18.0, and >18.1 $km \cdot h^{-1}$. Speed zones have been criticised for being poor indicators of individual physiological stress load, as chosen movement speeds zones in previous TMA studies are the same for players at different performance levels (Aslan et al., 2012). Therefore the speed zones were chosen in accordance to previous research that has examined the movement speed zones in youth football players (Aslan et al., 2012).

Physical response was also studied by means of three global indicators of workload. Firstly, the work:rest ratio, defined as the DC by the player at a speed >4 $km \cdot h^{-1}$ (period of activity or work) divided by the DC at a speed of 0-3.9 $km \cdot h^{-1}$ (period of recovery or rest) was measured, as in the study by Casamichana et al. (2012). Secondly, accelerometry was used to determine the $DC.min^{-1}$ and %T spent in each of the acceleration / deceleration zones: 0 to ± 1, ± 1 to 2, ± 2 to 3, ± >3 $m \cdot s^{-2}$ in accordance with previous research (Osgnach et al., 2010; Akenhead et al., 2013).

Thirdly, accelerometry was used to quantify player's accumulated PL and the contribution from the individual X, Y and Z vectors. To avoid bias because of the duration differences between each of the SSGs and MP, the values were normalised for each min of play, as in the study of Montgomery et al. (2010) and Casamichana et al. (2012). Player load was calculated using the following formula:

$$\text{Player load} = \begin{matrix} ((aca_{t=i+1} - ach_{t=1})^2 \\ +(act_{t=i+1} - act_{t=1})^2 \\ +(acv_{t=i+1} - acv_{t=1})^2), \end{matrix}$$

where aca is the acceleration along the anterior-posterior or horizontal axes, act is the acceleration along the medial-lateral or transverse axes, acv is the acceleration along the caudal-cranial or vertical axes, i is the current time, and t is time. In line with previous research (Casamichana et al., 2012), the number of repeated high-intensity efforts (RHIE) was measured. A series of RHIE occurs when a player makes at least 3 efforts at a speed of 13 $km \cdot h^{-1}$ and with a 21 s recovery between them. To enable comparisons to be made between SSGs and MP, the frequencies of RHIE were expressed relative to 1 hour of play.

2.4 Statistical analysis

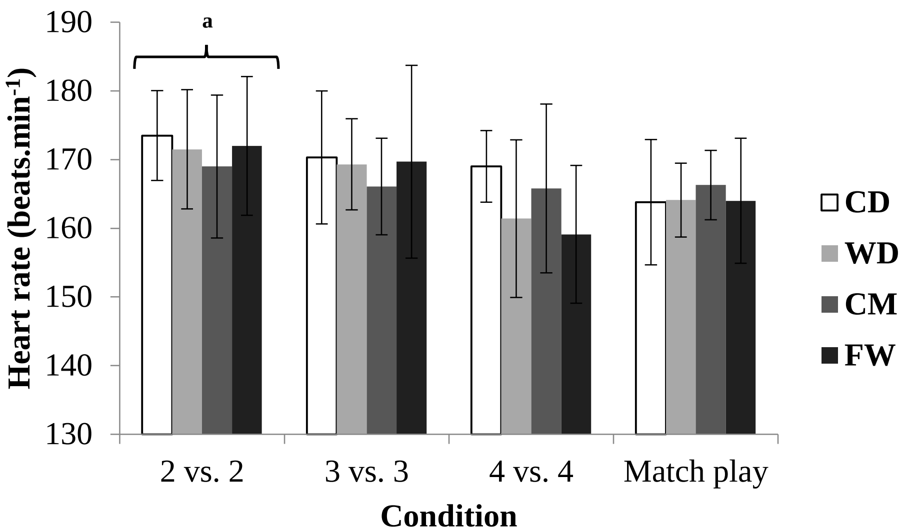
Statistical analysis was performed using SPSS Statistical software (SPSS 20.0, SPSS Inc., Chicago). A 4x4 analysis of variance (ANOVA) with repeated measures was used to compare the HR, TMA and PL demands of each positional role between SSGs and MP. Significant main effects of each factor were followed up with *post hoc* Bonferroni-corrected multiple comparisons. Effect sizes (ES) were calculated and the magnitude of the effect classified as trivial (<0.2), small (>0.2-0.6), moderate (>0.6-1.2), large (>1.2-2.0), and vary large (>2.0-4.0) (Batterham and Hopkins, 2006). Statistical significance was accepted when $p \leq 0.05$. All values were reported as mean ± standard deviation (SD) unless otherwise stated.

3. Results

The results section will be structured so that the first section (3.1) will state the internal physiological response whereas the following sections (3.2-3.6) will state the external responses to SSGs to match play.

3.1 Heart rate

Statistical analysis revealed a significant trivial main effect for mean HR $F(3, 108) = 5.73$; $p = 0.001$, $\eta^2 = 0.14$. Post hoc tests revealed a significantly greater mean HR for 2 vs. 2 than 4 vs. 4 (172 ± 8.86 vs. 164 ± 10.48 $beats.min^{-1}$, respectively, $p = 0.014$, CI = 1.11, 14.24) and for 2 vs. 2 than MP (172 ± 8.86 vs. 165 ± 7.20 $beats.min^{-1}$, respectively, $p = 0.002$, CI = 2.06, 11.84). In contrast, a non-significant main effect was found for positional role $F(3, 36) = 1.20$; $p<0.05$, $\eta^2 = 0.09$. A non-significant interaction $F(9, 108) = 0.76$; $p>0.05$, $\eta^2 = 0.06$ were found when positional roles were analysed by SSGs and MP. Mean HR responses during each condition for each positional role are shown in figure 1, and as can be seen mean HR decreased for each positional role with an increase in number of players until MP. Table 2 and 3 show the mean HR and estimated mean % estimated HR_{max} differences between conditions and positional roles, respectively.



Values mean ± SD; Post-hoc significant differences: Significantly greater heart rate for [a] 2 vs. 2 than 4 vs. 4 (p=0.014) and for 2 vs. 2 than MP (p=0.002).

Figure 1. Mean ± SD heart rate ($beats.min^{-1}$) during small-sided games and match play

Table 3. Mean ± SD values for heart rate (beats.min^{-1}) and % estimated heart rate maximum per condition

		Mean heart rate (beats.min^{-1})	% estimated HR_{max}
MP	CD	164 ± 9.11	85.05 ± 4.68
	WD	164 ± 5.36	85.18 ± 2.77
	CM	166 ± 5.06	86.30 ± 2.64
	FW	164 ± 9.09	85.13 ± 4.72
	Total (n = 40)	**165 ± 7.20**	**85.41 ± 3.72**
2 vs. 2	CD	174 ± 6.54	90.08 ± 3.35
	WD	172 ± 8.70	89.02 ± 4.40
	CM	169 ± 10.41	87.70 ± 5.47
	FW	172 ± 10.10	89.28 ± 5.30
	Total (n = 40)	**172 ± 8.86[a]**	**89.02 ± 4.60**
3 vs. 3	CD	170 ± 9.68	88.42 ± 5.06
	WD	169 ± 6.63	87.88 ± 3.42
	CM	166 ± 7.03	86.19 ± 3.66
	FW	170 ± 14.05	88.08 ± 7.25
	Total (n = 40)	**169 ± 9.56**	**87.65 ± 4.96**
4 vs. 4	CD	169 ± 5.21	87.75 ± 2.65
	WD	161 ± 11.49	83.78 ± 6.03
	CM	166 ± 12.30	86.03 ± 6.30
	FW	159 ± 10.04	82.58 ± 5.19
	Total (n = 40)	**164 ± 10.49**	**85.04 ± 5.43**

Values mean ± SD; Post-hoc significant differences: [a] Significantly greater heart rate for 2 vs. 2 than 4 vs. 4 (p=0.014) and for 2 vs. 2 than MP (p=0.002).

3.2 Distance covered

3.2.1 Total distance covered per min

Statistical analysis revealed a non-significant main effect for mean TDC.min^{-1} $F(3, 108) = 0.61$; $p>0.05$, $\eta^2 = 0.02$. In contrast, a significant small main effect was found when data were analysed by positional role $F(3, 36) = 8.80$; $p<0.001$, $\eta^2 = 0.42$. Post hoc tests revealed a significantly greater mean TDC.min^{-1} by CM than CD (102.96 ± 12.65 vs. 89.34 ± 11.65 m.min^{-1}, respectively, $p<0.001$, CI = 6.01, 21.24), CM than WD (102.96 ± 12.65 vs. 93.47 ± 12.16 m.min^{-1}, respectively, p = 0.008, CI = 1.88, 17.11), and CM than FW (102.96 ± 12.65 vs. 94.42 ± 17.41 m.min^{-1}, respectively, p = 0.021, CI = 0.93, 16.16). In contrast, no significant interactions $F(9, 108) = 0.36$; $p>0.05$, $\eta^2 = 0.03$ were found when positional roles were analysed by SSGs and MP. Table 4-7 show the mean kinematic and temporal differences between conditions and positional roles, respectively.

3.2.2 Work:rest ratio

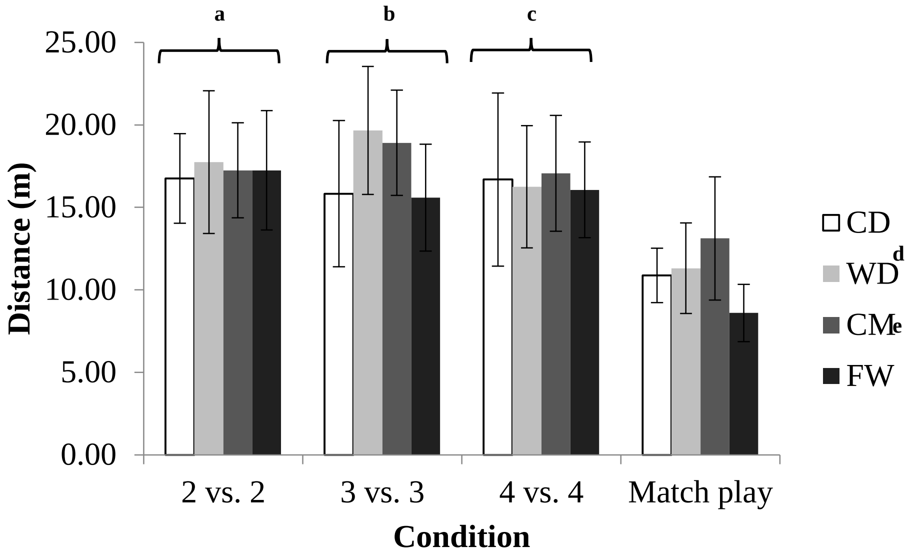
Statistical analysis revealed a non-significant main effect for mean work:rest ratio F(3, 108) = 2.25; p>0.05, η^2 = 0.06. In contrast, a significant small main effect was found when data were analysed by positional role F(3, 36) = 9.66; p<0.001, η^2 = 0.45. Post hoc tests revealed a significantly greater mean work:rest ratio by CM than CD (2.12 ± 0.55 vs. 1.50 ± 0.39, respectively, p<0.001, CI = 0.30, 0.96) and CM than WD (2.12 ± 0.55 vs. 1.72 ± 0.53, respectively, p = 0.011, CI = 0.07, 0.73). In contrast, no significant interactions F(9, 108) = 0.28; p>0.05, η^2 = 0.02 were found when positional roles were analysed by SSGs and MP. Table 4-7 show the mean kinematic and temporal differences between conditions and positional roles, respectively.

3.3 Distance covered in different speed zones

3.3.1 Distance covered in the low-speed boundary

3.3.1.2 Distance covered at 6.1-8.0 km·h^{-1}

Statistical analysis revealed a significant small main effect for mean DC.min^{-1} at 6.1-8.0 km·h^{-1} F(3, 108) = 29.23; p<0.001, η^2 = 0.45. Post hoc tests revealed a significantly greater mean DC.min^{-1} at 6.1-8.0 km·h^{-1} for 2 vs. 2 than MP (17.25 ± 3.33 vs. 10.98 ± 2.99 m.min^{-1}, respectively, p<0.001, CI = 4.40, 8.15), 3 vs. 3 than MP (17.50 ± 4.02 vs. 10.98 ± 2.99 m.min^{-1}, respectively, p<0.001, CI = 4.37, 8.67), and 4 vs. 4 than MP (16.52 ± 3.80 vs. 10.98 ± 2.99 m.min^{-1}, respectively, p<0.001, CI = 3.47, 7.61). Similarly, a significant small main effect was found for positional role F(3, 36) = 4.77; p = 0.007, η^2 = 0.28. Post hoc tests revealed significantly greater mean DC.min^{-1} at 6.1-8.0 km·h^{-1} by WD than FW (16.25 ± 4.74 vs. 14.38 ± 4.46 m.min^{-1}, respectively, p = 0.050, CI = 0.001, 3.74) and by CM than FW (16.59 ± 3.87 vs. 14.38 ± 4.46 m.min^{-1}, respectively, p = 0.013, CI = 0.35, 4.08). In contrast, no significant interactions F(9, 108) = 1.01; p>0.05, η^2 = 0.08 were found when positional roles were analysed by SSGs and MP. Mean DC.min^{-1} at 6.1-8.0 km·h^{-1} during each condition for each positional role are shown in figure 2, and as can be seen the mean values during each SSG were greater than MP for each positional role. Table 4-7 show the mean kinematic and temporal differences between conditions and positional roles, respectively.



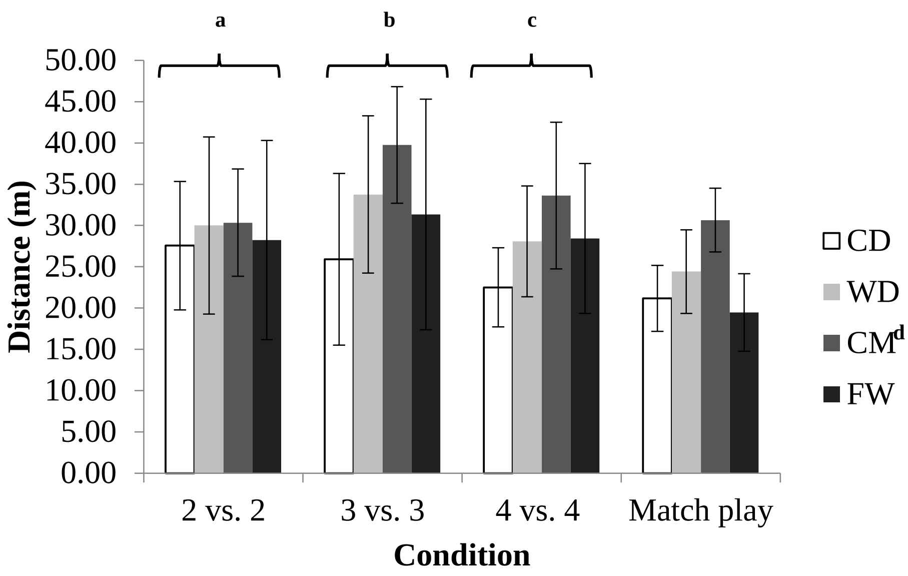
Significantly greater DC.min^{-1} at 6.1-8.0 km·h^{-1} for [a] 2 vs. 2 than MP (p<0.001), [b] 3 vs. 3 than MP (p<0.001), and [c] 4 vs. 4 than MP (p<0.001). Significantly greater DC.min^{-1} at 6.1-8.0 km·h^{-1} by [d] WD than FW (p=0.050) and [e] CM than FW (p=0.013).

Figure 2. Mean + SD distance covered per min (m) at 6.1-8.0 km·h^{-1} during small-sided games and match play

3.3.2 Distance covered in the moderate-speed boundary

3.3.2.1 Distance covered at 8.1-12.0 km·h^{-1}

A significant trivial main effect for mean DC.min^{-1} at 8.1-12.0 km·h^{-1} $F(2.43, 87.32) = 7.06$; $p = 0.001$, $\eta^2 = 0.16$ was found. Post hoc tests revealed a significantly greater mean DC.min^{-1} at 8.1-12.0 km·h^{-1} for 2 vs. 2 than MP (29.03 ± 9.24 vs. 23.92 ± 6.07 m.min^{-1}, respectively, p = 0.025, CI = 0.44, 9.77), 3 vs. 3 than MP (32.69 ± 11.30 vs. 23.92 ± 6.07 m.min^{-1}, respectively p<0.001, CI = 3.94, 13.59), and 4 vs. 4 than MP (28.16 ± 8.31 vs. 23.92 ± 6.07 m.min^{-1}, respectively, p = 0.034, CI = 0.21, 8.26). Similarly, a significant small main effect was found for positional role $F(3, 36) = 10.54$; $p<0.001$, $\eta^2 = 0.47$. Post hoc tests revealed significantly greater mean DC.min^{-1} at 8.1-12.0 km·h^{-1} by CM than CD (33.59 ± 7.59 vs. 24.29 ± 7.39 m.min^{-1}, respectively, p<0.001, CI = 4.51, 14.10) and CM than FW (33.59 ± 7.59 vs. 26.87 ± 11.10 m.min^{-1}, respectively, p = 0.002, CI = 1.93, 11.52). In contrast, no significant interactions $F(7.28, 87.32) = 0.80$; $p>0.05$, $\eta^2 = 0.06$ were found when positional roles were analysed by SSGs and MP. Mean DC.min^{-1} at 8.1-12.0 km·h^{-1} during each condition for each positional role are shown in figure 3, and can be seen, excluding the values by CM during 2 vs. 2 SSGs, mean values were greater across all SSGs for each positional role in comparison to MP. Table 4-7 show the mean kinematic and temporal differences between conditions and positional roles, respectively.



Significantly greater DC.min^{-1} at 8.1-12.0 km·h^{-1} for [a] 2 vs. 2 than MP (p=0.025), [b] 3 vs. 3 than MP (p<0.001), and [c] 4 vs. 4 than MP (p=0.034). Significantly greater DC.min^{-1} at 8.1-12.0 km·h^{-1} by [d] CM than CD (p<0.001) and CM than FW (p=0.002).

Figure 3. Mean ± SD distance covered per min (m) at 8.1-12.0 km·h^{-1} during small-sided games and match play

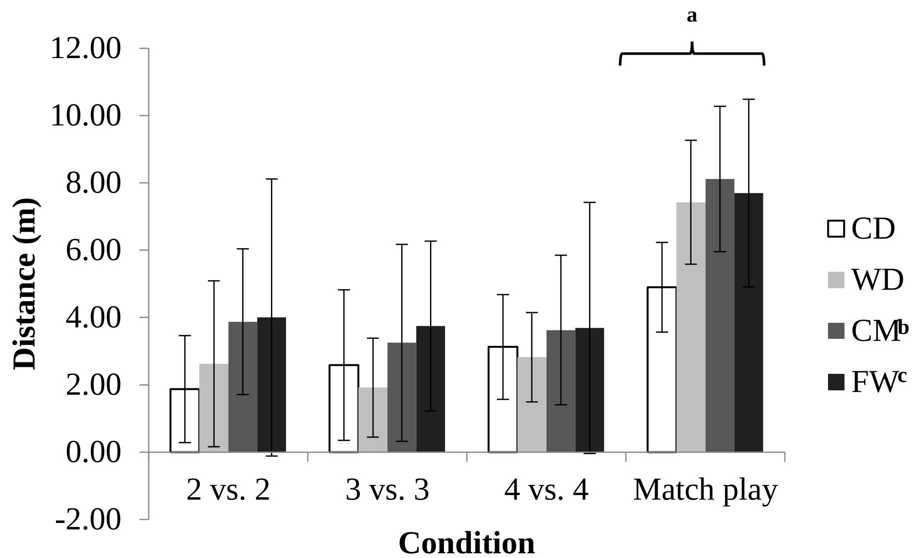
3.3.2.2 Distance covered at 12.1-15.0 km·h^{-1}

Statistical analysis revealed a non-significant main effect for mean DC.min^{-1} at 12.1-15.0 km·h^{-1} $F(3, 108) = 2.68$; $p>0.05$, $\eta^2 = 0.07$ was found. In contrast, a significant small main effect was found for positional role $F(3, 36) = 12.25$; $p<0.001$, $\eta^2 = 0.51$. Post hoc tests revealed significantly greater mean DC.min^{-1} at 12.1-15.0 km·h^{-1} by CM than CD (14.73 ± 5.60 vs. 8.77 ± 4.10 m.min^{-1}, respectively, p<0.001, CI = 3.16, 8.77), CM than WD (14.73 ± 5.60 vs. 10.97 ± 4.60 m.min^{-1}, respectively, p<0.001, CI = 0.95, 6.57), and FW than CD (12.20 ± 6.56 vs. 8.77 ± 4.10 m.min^{-1}, respectively, p = 0.010, CI = 0.63, 6.24). Additionally, no significant interactions $F(9, 108) = 1.42$; $p>0.05$, $\eta^2 = 0.11$ were found when positional roles were analysed by SSGs and MP. Table 4-7 show the mean kinematic and temporal differences between conditions and positional roles, respectively.

3.3.3 Distance covered in the high-speed boundary

3.3.3.1 Distance covered at 15.1-18.0 km·h^{-1}

A significant small main effect for mean DC.min^{-1} at 15.1-18.0 km·h^{-1} $F(3, 108) = 25.01$; $p<0.001$, $\eta^2 = 0.41$. Post hoc tests revealed a significantly greater mean DC.min^{-1} at 15.1-18.0 km·h^{-1} for MP than 2 vs. 2 (7.03 ± 2.38 vs. 3.09 ± 2.79 m.min^{-1}, respectively, $p<0.001$, CI = 2.21, 5.67), MP than 3 vs. 3 (7.03 ± 2.38 vs. 2.88 ± 2.37 m.min^{-1}, respectively, $p<0.001$, CI = 2.93, 5.39), and MP than 4 vs. 4 (7.03 ± 2.38 vs. 3.32 ± 2.33 m.min^{-1}, respectively, $p<0.001$, CI = 2.15, 5.28). Similarly, a significant small main effect was found for positional role $F(3, 36) = 5.85$; $p = 0.002$, $\eta^2 = 0.33$. Post hoc tests revealed a significantly greater mean DC.min^{-1} at 15.1-18.0 km·h^{-1} by CM than CD (4.72 ± 3.04 vs. 3.12 ± 2.00 m.min^{-1}, respectively, $p = 0.011$, CI = 0.27, 2.92) and FW than CD (4.79 ± 3.65 vs. 3.12 ± 2.00 m.min^{-1}, respectively, $p = 0.007$, CI = 0.34, 2.98). In contrast, no significant interactions $F(9, 108) = 0.71$; $p>0.05$, $\eta^2 = 0.06$ were found when positional roles were analysed by SSGs and MP. Mean DC.min^{-1} at 15.1-18.0 km·h^{-1} during each condition for each positional role are shown in figure 4, and as can be seen mean values were greater for MP for each positional role in comparison to all SSGs. Table 4-7 show the mean kinematic and temporal differences between conditions and positional roles, respectively.

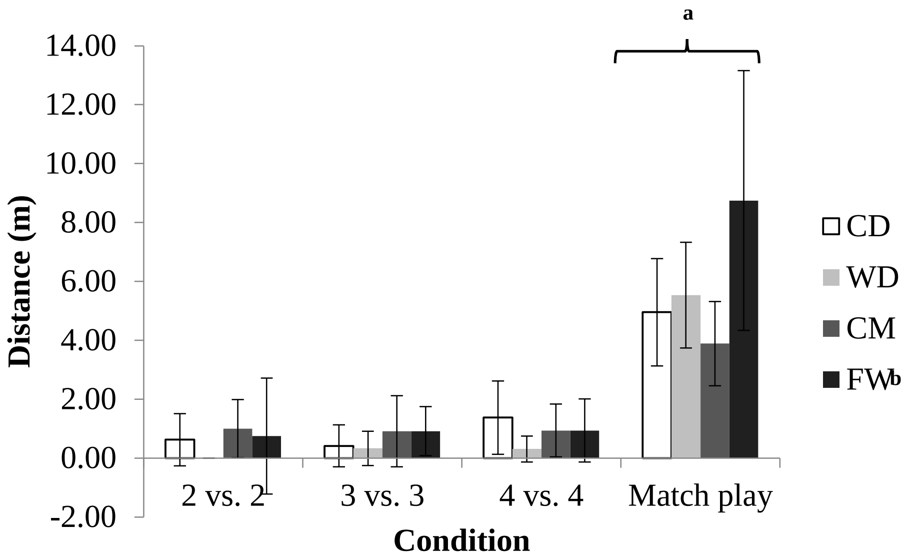


Significantly greater DC.min^{-1} at 15.1-18 km·h^{-1} for [a] MP than 2 vs. 2 ($p<0.001$), MP than 3 vs. 3 ($p<0.001$), and MP than 4 vs. 4 ($p<0.001$). Significantly greater DC.min^{-1} at 15.1-18.0 km·h^{-1} by [b] CM than CD ($p=0.011$) and [c] FW than CD ($p=0.007$).

Figure 4. Mean ± SD distance covered per min (m) at 15.1-18.0 km·h^{-1} during small-sided games and match play

3.3.3.2 Distance covered at >18.1 km·h^{-1}

Statistical analysis revealed a significant moderate main effect for mean DC.min^{-1} at >18.1 km·h^{-1} $F(1.64, 58.98) = 96.18$; $p<0.001$, $\eta^2 = 0.73$. Post hoc tests revealed a significantly greater mean DC.min^{-1} at >18.1 km·h^{-1} for MP than 2 vs. 2 (5.78 ± 3.14 vs. 0.59 ± 1.20 m.min^{-1}, respectively, $p<0.001$, CI = 3.78, 6.60), MP than 3 vs. 3 (5.78 ± 3.14 vs. 0.65 ± 0.87 m.min^{-1}, respectively, $p<0.001$, CI = 3.92, 6.35), and MP than 4 vs. 4 (5.78 ± 3.14 vs. 0.89 ± 1.00 m.min^{-1}, respectively, $p<0.001$, CI = 3.62, 6.16). Similarly, a significant small main effect was found for positional role $F(3, 36) = 6.66$; $p = 0.001$, $\eta^2 = 0.36$. Post hoc tests revealed significantly greater mean DC.min^{-1} at >18.1 km·h^{-1} by FW than CD (2.84 ± 4.21 vs. 1.84 ± 2.20 m.min^{-1}, respectively, $p = 0.023$, CI = 0.10, 1.89), FW than WD (2.84 ± 4.21 vs. 1.54 ± 2.51 m.min^{-1}, respectively, $p = 0.002$, CI = 0.40, 2.19), and FW than CM (2.84 ± 4.21 vs. 1.69 ± 1.70 m.min^{-1}, respectively, $p = 0.006$, CI = 0.26, 2.05). A significant small interaction $F(4.92, 58.98) = 4.31$; $p = 0.002$, $\eta^2 = 0.26$ was found when positional roles were analysed by SSGs and MP. To investigate the effect of condition separately for each positional role, a one-way ANOVA was performed. A non-significant main effect was found for mean DC.min^{-1} at >18.1 km·h^{-1} and 2 vs. 2 $F(3, 39) = 1.28$; $p>0.05$, 3 vs. 3 $F(3, 39) = 1.32$; $p>0.05$, and 4 vs. 4 $F(3, 39) = 1.91$; $p>0.05$. In contrary, a significant main effect was found for mean DC.min^{-1} at >18.1 km·h^{-1} for MP $F(3, 39) = 6.22$; $p = 0.002$. Post hoc tests revealed that for MP significantly greater mean DC.min^{-1} at >18.1 km·h^{-1} was performed by FW than CD (8.74 ± 4.41 vs. 4.96 ± 1.82 m.min^{-1}, respectively, $p = 0.017$, CI = 0.48, 7.09) and FW than CM (8.74 ± 4.41 vs. 3.89 ± 1.43 m.min^{-1}, respectively, $p = 0.001$, CI = 1.54, 8.16). Mean DC.min^{-1} at >18.0 km·h^{-1} during each condition for each positional role are shown in figure 5, and as can be seen mean values were greater for MP for each positional role in comparison to all SSGs. Table 4-7 show the mean kinematic and temporal differences between conditions and positional roles, respectively.



Significantly greater DC.min^{-1} at >18.1 km·h^{-1} for [a] MP than 2 vs. 2 (p<0.001), MP than 3 vs. 3 (p<0.001), and MP than 4 vs. 4 (p<0.001). Significantly greater DC.min^{-1} at >18.1 km·h^{-1} by [b] FW than CD (p=0.023), FW than WD (p=0.002), and FW than CM (p=0.006).

Figure 5. Mean ± SD distance covered per min (m) at >18.0 km·h^{-1} during small-sided games and match play. N.B. Gap in 2 vs. 2 condition for wide defenders indicates no distance covered at >18.1 km·h^{-1}

3.3.7 Repeated high-intensity efforts

Statistical analysis revealed a non-significant main effect for mean RHIE $F(3, 108) = 1.61$; $p>0.05$, $\eta^2 = 0.04$. In contrary, a significant small main effect was found for positional role $F(3, 36) = 4.75$; $p = 0.010$, $\eta^2 = 0.28$. Post hoc tests revealed significantly greater mean RHIE by CM than CD (10.09 ± 8.34 vs. 4.68 ± 4.76, respectively, p = 0.013, CI = 0.82, 10.00), and CM than WD (10.09 ± 8.34 vs. 5.42 ± 4.98, respectively, p = 0.044, CI = 0.09, 9.27). A non-significant interaction $F(9, 108) = 0.78$; $p>0.05$, $\eta^2 = 0.06$ was found when positional roles were analysed by SSGs and MP. Table 4-7 show the mean kinematic and temporal differences between conditions and positional roles, respectively.

Table 4. Mean ± SD values for total distance covered (m), distance covered in pre-defined speed zones (m), number of repeated high-intensity efforts and work:rest ratio per condition

		Work:rest ratio	TDC.min^{-1} (m.min^{-1})	DC.min^{-1} at 6.1-8.0 km·h^{-1} (m.min^{-1})	DC.min^{-1} at 8.1-12.0 km·h^{-1} (m.min^{-1})	DC.min^{-1} at 12.1-15.0 km·h^{-1} (m.min^{-1})	DC.min^{-1} at 15.1-18.0 km·h^{-1} (m.min^{-1})	DC.min^{-1} at >18 km·h^{-1} (m.min^{-1})	RHIE
MP	CD	1.33 ± 0.25	86.99 ± 9.76	10.88 ± 1.66	21.18 ± 4.00	9.62 ± 2.98	4.90 ± 1.33	4.96 ± 1.82	4.47 ± 2.96
	WD	1.59 ± 0.32	95.01 ± 9.47	11.31 ± 2.74	24.41 ± 5.07	12.88 ± 2.14	7.42 ± 1.84	5.53 ± 1.80	9.53 ± 2.83
	CM	2.19 ± 0.72	104.36 ± 11.81	13.12 ± 3.73	30.64 ± 3.86	18.19 ± 4.68	8.11 ± 2.16	3.89 ± 1.43	12.73 ± 4.45
	FW	1.65 ± 0.66	94.31 ± 13.58	8.60 ± 1.74	19.47 ± 4.69	11.18 ± 3.44	7.70 ± 2.79	8.74 ± 4.41*	9.60 ± 5.85
	Total (n=40)	**1.69 ± 0.60**	**95.17 ± 12.51**	**10.98 ± 2.99**	**23.92 ± 6.07**	**12.97 ± 4.65**	**7.03 ± 2.38[d]**	**5.78 ± 3.14[e]**	**9.08 ± 5.03**
2 vs. 2	CD	1.62 ± 0.55	93.38 ± 15.32	16.75 ± 2.71	27.56 ± 7.78	10.38 ± 5.47	1.88 ± 1.59	0.63 ± 0.88	7.50 ± 6.12
	WD	1.93 ± 0.80	95.25 ± 18.96	17.75 ± 4.32	30.00 ± 10.72	12.25 ± 6.87	2.63 ± 2.46	0.00 ± 0.00	3.50 ± 4.12
	CM	2.23 ± 0.67	99.75 ± 11.77	17.25 ± 2.87	30.33 ± 6.50	11.63 ± 4.97	3.88 ± 2.16	1.00 ± 0.99	8.25 ± 10.28
	FW	2.05 ± 0.67	96.63 ± 22.08	17.25 ± 3.62	28.22 ± 12.07	14.00 ± 8.20	4.00 ± 4.12	0.75 ± 1.97	9.00 ± 11.07
	Total (n=40)	**1.96 ± 0.68**	**96.25 ± 16.95**	**17.25 ± 3.33[b]**	**29.03 ± 9.24[c]**	**12.07 ± 6.38**	**3.09 ± 2.79**	**0.59 ± 1.20**	**7.06 ± 8.36**
3 vs. 3	CD	1.57 ± 4.20	88.42 ± 13.58	15.83 ± 4.43	25.92 ± 10.40	7.50 ± 4.25	2.58 ± 2.24	0.42 ± 0.71	3.00 ± 4.83
	WD	1.70 ± 0.45	94.67 ± 10.27	19.67 ± 3.87	33.75 ± 9.53	10.00 ± 3.79	1.92 ± 1.47	0.33 ± 0.58	4.50 ± 5.50
	CM	2.15 ± 0.46	107.92 ± 11.87	18.92 ± 3.19	39.75 ± 7.06	16.92 ± 5.46	3.25 ± 2.93	0.92 ± 1.21	11.50 ± 10.55
	FW	1.83 ± 0.75	94.17 ± 19.91	15.58 ± 3.24	31.33 ± 13.98	13.25 ± 7.05	3.75 ± 2.52	0.92 ± 0.83	7.00 ± 7.89
	Total (n=40)	**1.82 ± 0.56**	**96.29 ± 15.59**	**17.50 ± 4.02[b]**	**32.69 ± 11.30[c]**	**11.92 ± 6.22**	**2.88 ± 2.37**	**0.65 ± 0.87**	**6.50 ± 7.94**
4 vs. 4	CD	1.47 ± 0.25	88.56 ± 6.93	16.69 ± 5.25	22.50 ± 4.80	7.57 ± 3.00	3.13 ± 1.56	1.38 ± 1.24	3.75 ± 3.95
	WD	1.68 ± 0.43	88.94 ± 7.45	16.25 ± 3.70	28.07 ± 6.72	8.75 ± 3.64	2.82 ± 1.33	0.31 ± 0.44	4.13 ± 5.14
	CM	1.92 ± 0.40	99.81 ± 14.91	17.07 ± 3.51	33.63 ± 8.90	12.19 ± 4.82	3.63 ± 2.22	0.94 ± 0.90	7.88 ± 6.72
	FW	1.68 ± 0.44	92.56 ± 15.36	16.06 ± 2.90	28.44 ± 9.09	10.38 ± 6.91	3.69 ± 3.73	0.94 ± 1.07	7.88 ± 10.82
	Total (n=40)	**1.69 ± 0.41**	**92.47 ± 12.27**	**16.52 ± 3.80[b]**	**28.16 ± 8.31[c]**	**9.72 ± 4.96**	**3.32 ± 2.33**	**0.89 ± 1.00**	**5.91 ± 7.15**

Values mean ± SD; Interaction effects: * Significantly greater DC.min^{-1} at >18.1 km·h^{-1} by FW than CD (p=0.017) and FW than CM (p=0.001). Post-hoc significant differences: [a] Significantly greater DC.min^{-1} at 0-6.0 km·h^{-1} for 4 vs. 4 than 2 vs. 2 (p=0.024), 4 vs. 4 than 3 vs. 3 (p=0.016) and MP than 3 vs. 3 (p=0.019); [b] Significantly greater DC.min^{-1} at 6.1-8.0 km·h^{-1} for 2 vs. 2 than MP (p<0.001), 3 vs. 3 than MP (p<0.001), and 4 vs. 4 than MP (p<0.001); [c] Significantly greater DC.min^{-1} at 8.1-12.0 km·h^{-1} for 2 vs. 2 than MP (p=0.025), 3 vs. 3 than MP (p<0.001), and 4 vs. 4 than MP (p=0.034); [d] Significantly greater DC.min^{-1} at 15.1-18 km·h^{-1} for MP than 2 vs. 2 (p<0.001), MP than 3 vs. 3 (p<0.001), and MP than 4 vs. 4 (p<0.001); [e] Significantly greater DC.min^{-1} at >18.1 km·h^{-1} for MP than 2 vs. 2 (p<0.001), MP than 3 vs. 3 (p<0.001), and MP than 4 vs. 4 (p<0.001). NB. N=10 per positional role.

Table 5. Mean ± SD values for total distance covered (m) and the percentage of time covered in each speed zone (%) per condition

		TDC.min^{-1} (m.min^{-1})	TDC at 6.1-8.0 km·h^{-1} (%)	TDC at 8.1-12.0 km·h^{-1} (%)	TDC at 12.1-15.0 km·h^{-1} (%)	TDC at 15.1-18.0 km·h^{-1} (%)	TDC at >18.1 km·h^{-1} (%)
MP	CD	86.99 ± 9.76	9.00 ± 1.15	12.70 ± 2.31	4.70 ± 1.34	1.70 ± 0.48	1.40 ± 0.70
	WD	95.01 ± 9.47	10.60 ± 12.07	15.70 ± 2.21	6.20 ± 0.63	2.70 ± 0.67	1.60 ± 0.52
	CM	104.36 ± 11.81	11.50 ± 3.10	19.10 ± 3.70	8.90 ± 2.47	3.40 ± 0.70	1.50 ± 0.53
	FW	94.31 ± 13.58	6.90 ± 1.10	13.10 ± 3.25	5.20 ± 1.93	3.20 ± 1.23	3.60 ± 1.84
	Total (n=40)	**95.17 ± 12.51**	**9.50 ± 2.63**	**15.15 ± 3.83**	**6.25 ± 2.34**	**2.75 ± 1.03**	**2.03 ± 1.37**
2 vs. 2	CD	93.38 ± 15.32	13.80 ± 1.93	18.90 ± 4.95	4.80 ± 2.49	0.80 ± 0.79	0.20 ± 0.42
	WD	95.25 ± 18.96	14.70 ± 3.27	20.30 ± 7.47	5.70 ± 3.33	1.30 ± 1.34	0.00 ± 0.00
	CM	99.75 ± 11.77	14.30 ± 1.89	20.00 ± 3.86	5.40 ± 2.27	1.40 ± 0.84	0.40 ± 0.52
	FW	96.63 ± 22.08	13.10 ± 3.54	20.50 ± 8.34	7.10 ± 4.33	1.80 ± 1.93	0.30 ± 0.67
	Total (n=40)	**96.25 ± 16.95**	**13.98 ± 2.72**	**19.93 ± 6.20**	**5.75 ± 3.20**	**1.33 ± 1.31**	**0.23 ± 0.48**
3 vs. 3	CD	88.42 ± 13.58	13.00 ± 2.31	16.00 ± 4.81	3.40 ± 1.78	1.20 ± 0.92	0.00 ± 0.00
	WD	94.67 ± 10.27	15.90 ± 2.81	20.00 ± 6.34	4.60 ± 1.71	0.80 ± 0.63	0.10 ± 0.32
	CM	107.92 ± 11.87	14.30 ± 2.98	22.00 ± 4.78	7.50 ± 2.55	1.40 ± 0.84	0.40 ± 0.52
	FW	94.17 ± 19.91	12.70 ± 3.16	19.10 ± 8.46	6.70 ± 3.62	1.70 ± 1.16	0.60 ± 0.52
	Total (n=40)	**96.29 ± 15.59**	**12.70 ± 3.16**	**19.10 ± 8.46**	**6.70 ± 3.62**	**1.70 ± 1.16**	**0.60 ± 0.52**
4 vs. 4	CD	88.56 ± 6.93	12.50 ± 4.03	15.70 ± 1.83	4.00 ± 1.70	2.00 ± 1.33	0.80 ± 0.92
	WD	88.94 ± 7.45	13.40 ± 3.75	17.70 ± 4.85	4.30 ± 2.16	1.30 ± 1.06	0.10 ± 0.32
	CM	99.81 ± 14.91	14.30 ± 3.20	20.90 ± 5.26	5.80 ± 2.49	1.50 ± 0.97	0.30 ± 0.40
	FW	92.56 ± 15.36	12.40 ± 2.46	17.00 ± 4.97	5.00 ± 3.30	1.60 ± 1.65	0.40 ± 0.52
	Total (n=40)	**92.47 ± 12.27**	**13.15 ± 3.37**	**17.83 ± 4.70**	**4.78 ± 2.49**	**1.60 ± 1.26**	**0.40 ± 0.67**

Values mean ± SD. NB. N=10 per positional role.

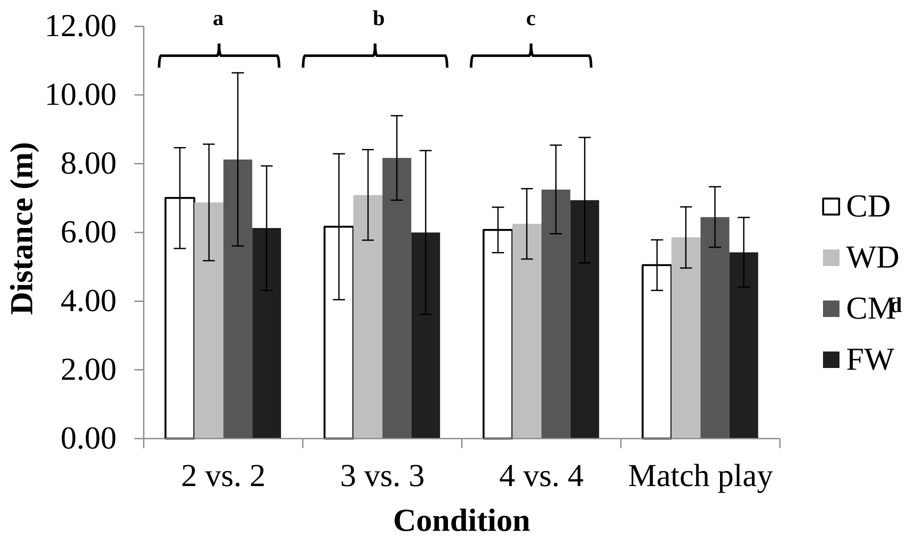
3.4 Distance covered in different acceleration / deceleration zones

3.4.1 Distance covered at low acceleration

Statistical analysis revealed a non-significant main effect for mean $DC.min^{-1}$ at 0 to 1 $m \cdot s^{-2}$ $F(2.20, 79.06) = 1.87$; $p>0.05$, $\eta^2 = 0.05$. In contrast, a significant small main effect was found for positional role $F(3, 36) = 5.85$; $p = 0.002$, $\eta^2 = 0.33$. Post hoc tests revealed significantly greater mean $DC.min^{-1}$ at 0 to 1 $m \cdot s^{-2}$ by CM than CD (51.77 ± 8.45 vs. 45.10 ± 7.59 $m.min^{-2}$, respectively, p = 0.001, CI = 2.10, 11.23). A non-significant interaction $F(6.59, 79.06) = 1.08$; $p>0.05$, $\eta^2 = 0.08$ was found when positional roles were analysed by SSGs and MP.

3.4.2 Distance covered at moderate acceleration

Statistical analysis revealed a significant trivial main effect for mean $DC.min^{-1}$ at 1 to 2 $m \cdot s^{-2}$ $F(2.29, 82.33) = 5.78$; $p = 0.003$, $\eta^2 = 0.14$. Post hoc tests revealed a significantly greater mean $DC.min^{-1}$ at 1 to 2 $m \cdot s^{-2}$ for 2 vs. 2 than MP (7.03 ± 1.98 vs. 5.69 ± 1.00 $m.min^{-2}$, respectively, p = 0.002, CI = 0.40, 2.28), 3 vs. 3 than MP (6.85 ± 1.97 vs. 5.69 ± 1.00 $m.min^{-2}$, respectively, p = 0.002, CI = 0.36, 1.97), and 4 vs. 4 than MP (6.63 ± 1.32 vs. 5.69 ± 1.00 $m.min^{-2}$, respectively, p = 0.007, CI = 0.20, 1.68). Similarly, a significant small main effect was found for positional role $F(3, 36) = 8.54$; $p<0.001$, $\eta^2 = 0.42$. Post hoc tests revealed significantly greater mean $DC.min^{-1}$ at 1 to 2 $m \cdot s^{-2}$ by CM than CD (7.50 ± 1.70 vs. 6.07 ± 1.50 $m.min^{-2}$, respectively, p<0.001, CI = 0.53, 2.32), CM than WD (7.50 ± 1.70 vs. 6.52 ± 1.32 $m.min^{-2}$, respectively, p = 0.025, CI = 0.09, 1.87), and CM than FW (7.50 ± 1.70 vs. 6.12 ± 1.84 $m.min^{-2}$, respectively, p = 0.001, CI = 0.48, 2.27). A non-significant interaction $F(6.86, 82.33) = 0.81$; $p>0.05$, $\eta^2 = 0.06$ was found when positional roles were analysed by SSGs and MP. Mean $DC.min^{-1}$ at 1 to 2 $m \cdot s^{-2}$ during each condition for each positional role are shown in figure 6, and as can be seen mean values were greater during SSGs for each positional role in comparison to MP. Table 8-11 show the mean kinematic and temporal differences between conditions and positional roles, respectively.

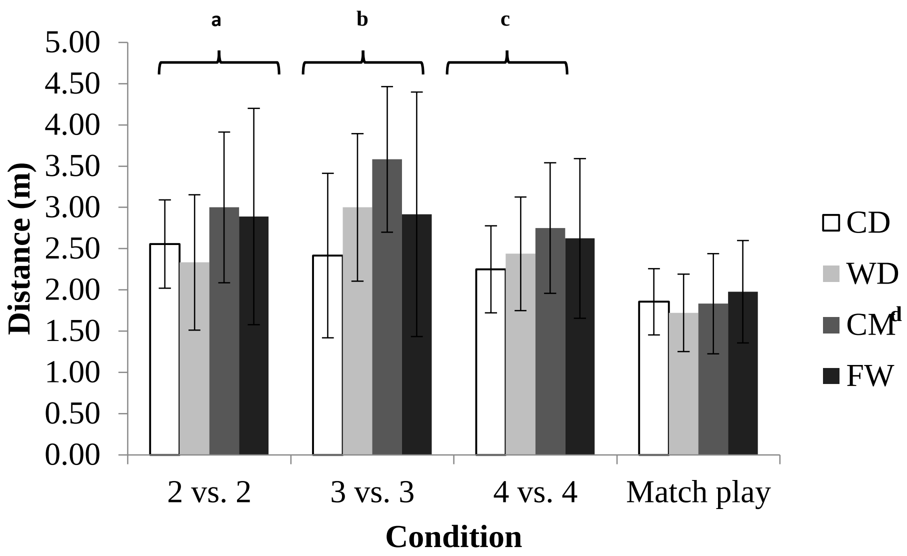


Significantly greater DC.min^{-1} at [a] 1 to 2 m·s^{-2} for 2 vs. 2 than MP (p=0.002), [b] 3 vs. 3 than MP (p=0.002), and [c] 4 vs. 4 than MP (p=0.007). Significantly greater mean distance covered at 1 to 2 m·s^{-2} by [d] CM than CD (p<0.001), CM than WD (p=0.025), and CM than FW (p=0.001).

Figure 6. Mean ± SD distance covered per min (m) at 1 to 2 m·s^{-2} during small-sided games and match play

3.4.3 Distance covered at high acceleration

Statistical analysis revealed a significant small main effect for mean DC.min^{-1} at 2 to 3 m·s^{-2} F(2.39, 86.12) = 12.32; p<0.001, η^2 = 0.26. Post hoc tests revealed a significantly greater mean DC.min^{-1} at 2 to 3 m·s^{-2} for 2 vs. 2 than MP (2.69 ± 0.94 vs. 1.85 ± 0.52 m.min^{-2}, respectively, p<0.001, CI = 0.34, 1.36), 3 vs. 3 than MP (2.98 ± 1.13 vs. 1.85 ± 0.52 m.min^{-2}, respectively, p<0.001, CI = 0.57, 1.69), and 4 vs. 4 than MP (2.52 ± 0.76 vs. 1.85 ± 0.52 m.min^{-2}, respectively, p<0.001, CI = 0.32, 1.03). Similarly, a significant small main effect was found for positional role F(3, 36) = 3.21; p = 0.035, η^2 = 0.21. Post hoc tests revealed significantly greater mean DC.min^{-1} at 2 to 3 m·s^{-2} by CM than CD (2.79 ± 1.00 vs. 2.27 ± 0.68 m.min^{-2}, respectively, p = 0.046, CI = 0.01, 1.04). A non-significant interaction F(7.18, 86.12) = 0.72; p>0.05, η^2 = 0.06 was found when positional roles were analysed by SSGs and MP. Mean DC.min^{-1} at 2 to 3 m·s^{-2} during each condition for each positional role are shown in figure 7, and as can be seen mean values were greater during SSGs for each positional role in comparison to MP. Table 8-11 show the mean kinematic and temporal differences between conditions and positional roles, respectively.

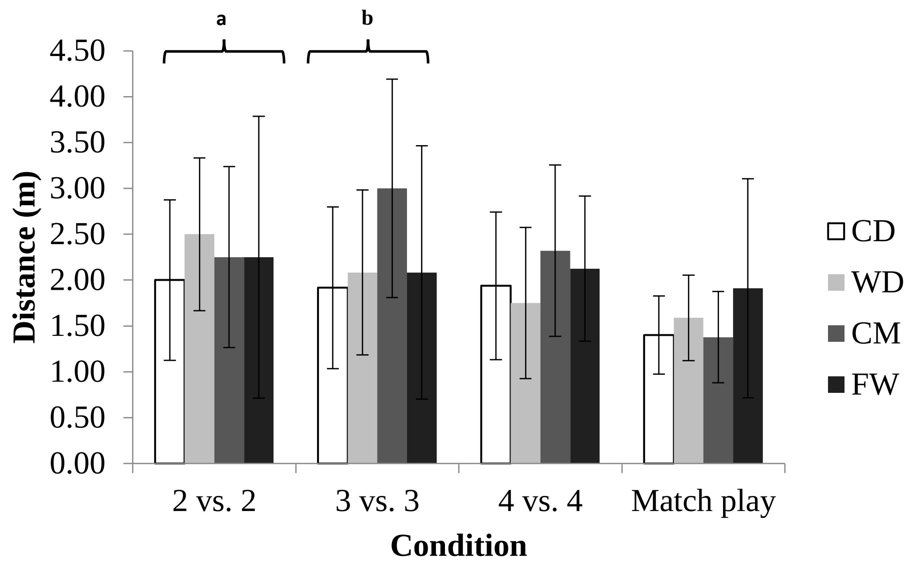


Significantly greater DC.min^{-1} at 2 to 3 m·s^{-2} for [a] 2 vs. 2 than MP (p<0.001), [b] 3 vs. 3 than match play (p<0.001), and [c] 4 vs. 4 than MP (p<0.001). Significantly greater mean distance covered at 2 to 3 m·s^{-2} by [d] CM than CD (p=0.046).

Figure 7. Mean ± SD distance covered per min (m) at 2 to 3 m·s^{-2} during small-sided games and match play

3.4.4 Distance covered at max acceleration

Statistical analysis revealed a significant trivial main effect for mean DC.min^{-1} at >3 m·s^{-2} $F(2.22, 79.88) = 4.23$; $p = 0.015$, $\eta^2 = 0.11$. Post hoc tests revealed a significantly greater mean DC.min^{-1} at >3 m·s^{-2} for 2 vs. 2 than MP (2.25 ± 1.07 vs. 1.57 ± 0.72 m.min^{-2}, respectively, p = 0.011, CI = 0.12, 1.24) and 3 vs. 3 than MP (2.27 ± 1.15 vs. 1.57 ± 0.72 m.min^{-2}, respectively, p = 0.004, CI = 0.18, 1.22). In contrast, a non-significant main effect was found for positional role $F(3, 36) = 1.98$; $p>0.05$, $\eta^2 = 0.14$. A non-significant interaction $F(6.66, 79.88) = 0.92$; $p>0.05$, $\eta^2 = 0.07$ was found when positional roles were analysed by SSGs and MP. Mean DC.min^{-1} at >3 m·s^{-2} during each condition for each positional role are shown in figure 8, and as can be seen mean values were greater during SSGs for each positional role in comparison to MP. Table 8-11 show the mean kinematic and temporal differences between conditions and positional roles, respectively.

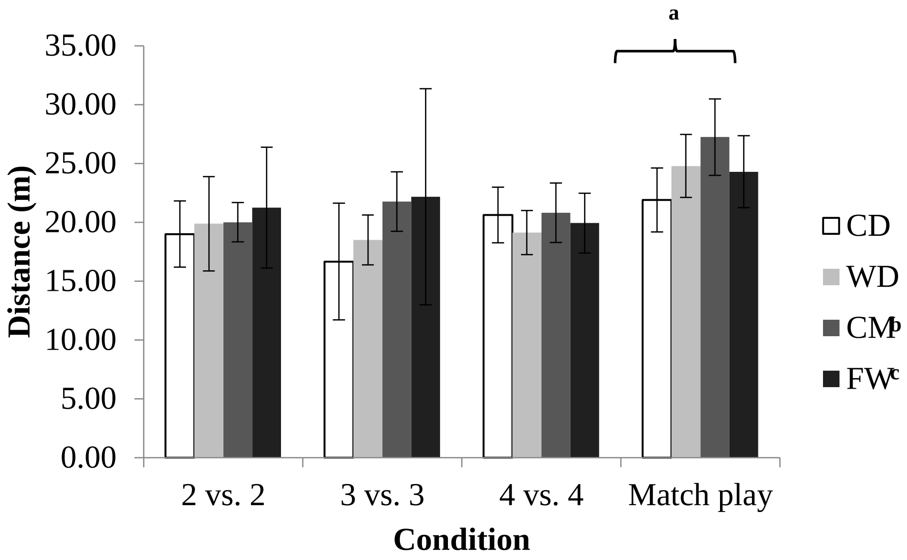


Significantly greater DC.min^{-1} at >3 m·s^{-2} for [a] 2 vs. 2 than MP (p=0.011) and [b] 3 vs. 3 than MP (p=0.004).

Figure 8. Mean ± SD distance covered per min (m) at >3 m·s^{-2} during small-sided games and match play

3.4.5 Distance covered at low deceleration

Statistical analysis revealed a significant small main effect for mean DC.min^{-1} at 0 to -1 m·s^{-2} $F(3, 108) = 14.37$; $p<0.001$, $\eta^2 = 0.29$. Post hoc tests revealed a significantly greater mean DC.min^{-1} at 0 to -1 m·s^{-2} for MP than 2 vs. 2 (24.55 ± 3.41 vs. 20.03 ± 3.60 m.min^{-2}, respectively, p<0.001, CI = 2.33, 6.71), MP than 3 vs. 3 (24.55 ± 3.41 vs. 19.77 ± 5.74 m.min^{-2}, respectively, p<0.001, CI = 1.97, 7.59), and MP than 4 vs. 4 (24.55 ± 3.41 vs. 20.13 ± 2.35 m.min^{-2}, respectively, p<0.001, CI = 2.61, 6.24). Similarly, a significant small main effect was found for positional role $F(3, 36) = 5.13$; $p = 0.005$, $\eta^2 = 0.30$. Post hoc tests revealed significantly greater mean DC.min^{-1} at 0 to -1 m·s^{-2} by CM than CD (22.45 ± 3.77 vs. 19.55 ± 3.80 m.min^{-2}, respectively, p = 0.007, CI = 0.61, 5.19) and FW than CD (21.91 ± 5.63 vs. 19.55 ± 3.80 m.min^{-2}, respectively, p = 0.040, CI = 0.08, 4.65). A non-significant interaction $F(9, 108) = 1.44$; $p>0.05$, $\eta^2 = 0.11$ was found when positional roles were analysed by SSGs and MP. Mean DC.min^{-1} at 0 to -1 m·s^{-2} during each condition for each positional role are shown in figure 9, and as can be seen mean values were greater during MP for each positional role in comparison to all SSGs. Table 8-11 show the mean kinematic and temporal differences between conditions and positional roles, respectively.

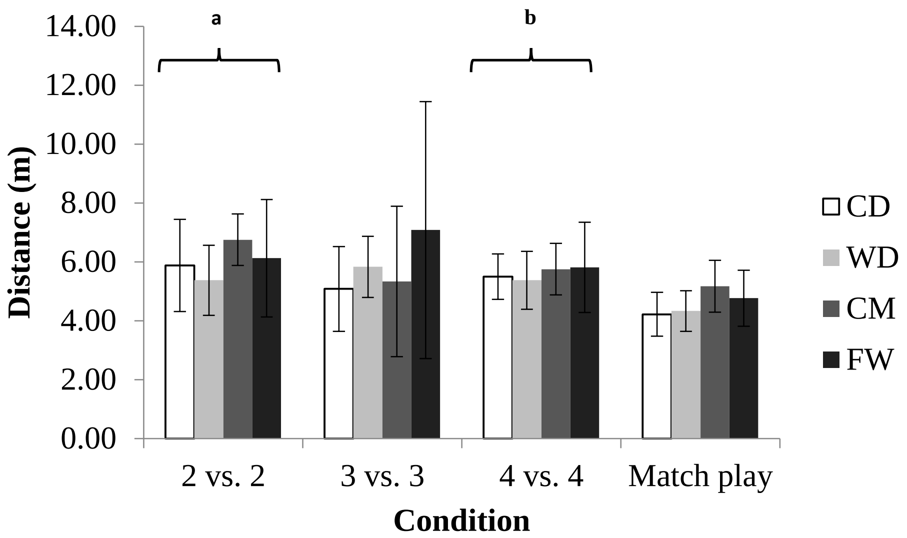


Significantly greater DC.min^{-1} at 0 to -1 m·s^{-2} for [a] MP than 2 vs. 2 (p<0.001), MP than 3 vs. 3 (p<0.001), and MP than 4 vs. 4 (p<0.001). Significantly greater mean distance covered at 0 to -1 m·s^{-2} by [b] CM than CD (p=0.007) and [c] FW than CD (p=0.040).

Figure 9. Mean ± SD distance covered per min (m) at 0 to -1 m·s^{-2} during small-sided games and match play

3.4.6 Distance covered at moderate deceleration

Statistical analysis revealed a significant trivial main effect for mean DC.min^{-1} at -1 to -2 m·s^{-2} $F(1.98, 71.18) = 5.59$; $p = 0.006$, $\eta^2 = 0.13$. Post hoc tests revealed a significantly greater mean DC.min^{-1} at -1 to -2 m·s^{-2} for 2 vs. 2 than MP (6.03 ± 1.49 vs. 4.62 ± 0.88 m.min^{-2}, respectively, p<0.001, CI = 0.64, 2.17) and 4 vs. 4 than MP (5.61 ± 1.05 vs. 4.62 ± 0.88 m.min^{-2}, respectively, p = 0.001, CI = 0.35, 1.62). In contrast, a non-significant main effect was found for positional role $F(3, 36) = 2.11$; $p>0.05$, $\eta^2 = 0.15$. A non-significant interaction $F(5.93, 71.18) = 0.91$; $p>0.05$, $\eta^2 = 0.07$ was found when positional roles were analysed by SSGs and MP. Mean DC.min^{-1} at -1 to -2 m·s^{-2} during each condition for each positional role are shown in figure 10, and as can be seen mean values were greater during all SSGs for each positional role in comparison to MP. Table 8-11 show the mean kinematic and temporal differences between conditions and positional roles, respectively.

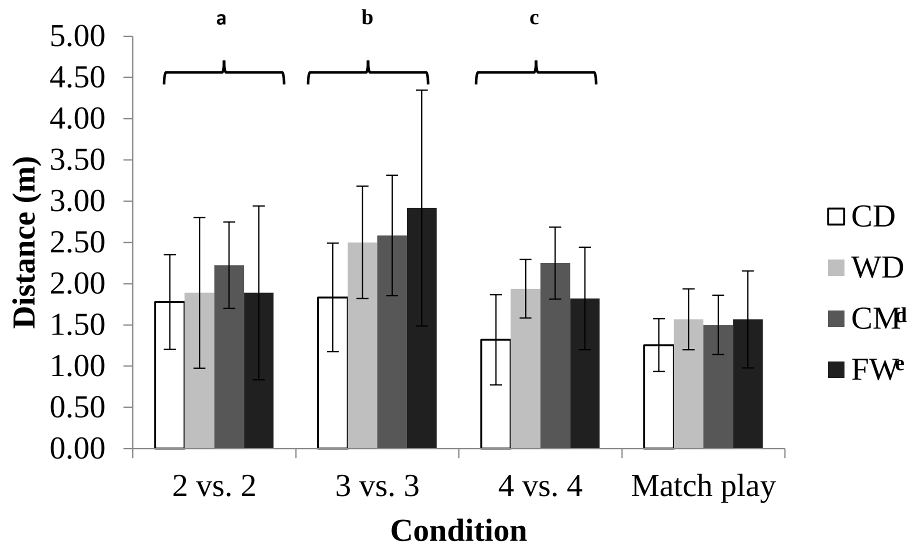


Significantly greater DC.min^{-1} at -1 to -2 m·s^{-2} for [a] 2 vs. 2 than MP (p<0.001) and [b] 4 vs. 4 than MP (p=0.001).

Figure 10. Mean ± SD distance covered per min (m) at -1 to -2 m·s^{-2} during small-sided games and match play

3.4.7 Distance covered at high deceleration

Statistical analysis revealed a significant small main effect for mean DC.min^{-1} at -2 to -3 m·s^{-2} $F(3, 108) = 14.32$; $p<0.001$, $\eta^2 = 0.29$. Post hoc tests revealed a significantly greater mean DC.min^{-1} at -2 to -3 m·s^{-2} for 3 vs. 3 than 2 vs. 2 (2.46 ± 0.98 vs. 1.94 ± 0.78 m.min^{-2}, respectively, p = 0.013, CI = 0.08, 0.95), 3 vs. 3 than 4 vs. 4 (2.46 ± 0.98 vs. 1.83 ± 0.59 m.min^{-2}, respectively, p = 0.004, CI = 0.16, 1.10), 3 vs. 3 than MP (2.46 ± 0.98 vs. 1.47 ± 0.42 m.min^{-2}, respectively, p<0.001, CI = 0.50, 1.47), 2 vs. 2 than MP (1.94 ± 0.78 vs. 1.47 ± 0.42 m.min^{-2}, respectively, p = 0.017, CI = 0.06, 0.87), and 4 vs. 4 than MP (1.83 ± 0.59 vs. 1.47 ± 0.42 m.min^{-2}, respectively, p = 0.014, CI = 0.05, 0.66). Similarly, a significant small main effect was found for positional role $F(3, 36) = 5.08$; $p = 0.005$, $\eta^2 = 0.30$. Post hoc tests revealed significantly greater mean DC.min^{-1} at -2 to -3 m·s^{-2} by FW than CD (2.05 ± 1.08 vs. 1.55 ± 0.58 m.min^{-2}, respectively, p = 0.026, CI = 0.04, 0.96) and CM than CD (2.14 ± 0.65 vs. 1.55 ± 0.58 m.min^{-2}, respectively, p = 0.006, CI = 0.13, 1.05). A non-significant interaction $F(9, 108) = 1.01$; $p>0.05$, $\eta^2 = 0.08$ was found when positional roles were analysed by SSGs and MP. Mean DC.min^{-1} at -2 to -3 m·s^{-2} during each condition for each positional role are shown in figure 11, and as can be seen mean values were greater during all SSGs for each positional role in comparison to MP. Table 8-11 show the mean kinematic and temporal differences between conditions and positional roles, respectively.



Significantly greater DC.min^{-1} at -2 to -3 m·s^{-2} for [a] 2 vs. 2 than MP (p=0.017), [b] 3 vs. 3 than 2 vs. 2 (p=0.013), 3 vs. 3 than 4 vs. 4 (p=0.004), 3 vs. 3 than MP (p<0.001), and [c] 4 vs. 4 than MP (p=0.014). Significantly greater mean distance covered at -2 to -3 m·s^{-2} by [d] CM than CD (p=0.006) and [e] FW than CD (p=0.026).

Figure 11. Mean ± SD distance covered per min (m) at -2 to -3 m·s^{-2} during small-sided games and match play

3.4.8 Distance covered at max deceleration

Statistical analysis revealed a non-significant main effect for mean DC.min^{-1} at >-3 m·s^{-2} $F(2.26, 81.24) = 1.78$; $p>0.05$, $\eta^2 = 0.05$ and positional role $F(3, 36) = 0.68$; $p>0.05$, $\eta^2 = 0.05$. A non-significant interaction $F(6.78, 81.24) = 0.51$; $p>0.05$, $\eta^2 = 0.04$ was found when positional roles were analysed by SSGs and MP. Table 8-11 show the mean kinematic and temporal differences between conditions and positional roles, respectively.

Table 6. Mean ± SD values for total distance covered and distance covered in pre-defined acceleration / deceleration zones per condition

		TDC.min^{-1} (m.min^{-1})	DC.min^{-1} at 0 to 1 m·s^{-2} (m.min^{-1})	DC.min^{-1} at 1 to 2 m·s^{-2} (m.min^{-1})	DC.min^{-1} at 2 to 3 m·s^{-2} (m.min^{-1})	DC.min^{-1} at >3 m·s^{-2} (m.min^{-1})	DC.min^{-1} at 0 to -1 m·s^{-2} (m.min^{-1})	DC.min^{-1} at -1 to -2 m·s^{-2} (m.min^{-1})	DC.min^{-1} at -2 to -3 m·s^{-2} (m.min^{-1})	DC.min^{-1} at >-3 m·s^{-2} (m.min^{-1})
MP	CD	86.99 ± 9.76	46.00 ± 5.93	5.05 ± 0.73	1.86 ± 0.40	1.40 ± 0.43	21.90 ± 2.72	4.22 ± 0.74	1.26 ± 0.32	0.89 ± 0.26
	WD	95.01 ± 9.47	51.23 ± 4.86	5.86 ± 0.89	1.72 ± 0.47	1.59 ± 0.47	24.78 ± 2.68	4.33 ± 0.69	1.57 ± 0.37	1.29 ± 0.43
	CM	104.36 ± 11.81	56.27 ± 7.07	6.45 ± 0.88	1.83 ± 0.61	1.38 ± 0.50	27.23 ± 3.25	5.18 ± 0.88	1.50 ± 0.36	1.32 ± 0.53
	FW	94.31 ± 13.58	50.69 ± 8.05	5.42 ± 1.01	1.98 ± 0.62	1.91 ± 1.19	24.29 ± 3.06	4.77 ± 0.95	1.57 ± 0.59	1.17 ± 0.45
	Total (n=40)	**95.17 ± 12.51**	**51.05 ± 7.32**	**5.69 ± 1.00**	**1.85 ± 0.52**	**1.57 ± 0.72**	**24.55 ± 3.41[d]**	**4.62 ± 0.88**	**1.47 ± 0.42**	**1.17 ± 0.45**
2 vs. 2	CD	93.38 ± 15.32	47.25 ± 6.69	7.00 ± 1.47	2.56 ± 0.54	2.00 ± 0.87	19.00 ± 2.81	5.88 ± 1.56	1.78 ± 0.57	1.38 ± 0.40
	WD	95.25 ± 18.96	48.88 ± 9.83	6.88 ± 1.69	2.33 ± 0.82	2.50 ± 0.83	19.88 ± 4.02	5.38 ± 1.19	1.89 ± 0.91	1.50 ± 0.99
	CM	99.75 ± 11.77	45.75 ± 11.12	8.13 ± 2.52	3.00 ± 0.91	2.25 ± 0.99	20.00 ± 1.67	6.75 ± 0.87	2.22 ± 0.52	1.50 ± 0.99
	FW	96.63 ± 22.08	48.63 ± 9.92	6.13 ± 1.81	2.89 ± 1.31	2.25 ± 1.54	21.25 ± 5.14	6.13 ± 1.99	1.89 ± 1.05	1.75 ± 1.05
	Total (n=40)	**96.25 ± 16.95**	**47.63 ± 9.25**	**7.03 ± 1.98[a]**	**2.69 ± 0.94[b]**	**2.25 ± 1.07[c]**	**20.03 ± 3.60**	**6.03 ± 1.49[e]**	**1.94 ± 0.78[f]**	**1.53 ± 0.87**
3 vs. 3	CD	88.42 ± 13.58	41.92 ± 11.93	6.17 ± 2.12	2.42 ± 1.00	1.92 ± 0.88	16.67 ± 4.95	5.08 ± 1.44	1.83 ± 0.66	1.33 ± 0.70
	WD	94.67 ± 10.27	47.92 ± 6.54	7.09 ± 1.32	3.00 ± 0.90	2.08 ± 0.90	18.50 ± 2.11	5.83 ± 1.04	2.50 ± 0.68	1.33 ± 0.43
	CM	107.92 ± 11.87	54.25 ± 5.58	8.17 ± 1.23	3.58 ± 0.88	3.00 ± 1.19	21.75 ± 2.53	5.33 ± 2.55	2.58 ± 0.73	1.50 ± 0.77
	FW	94.17 ± 19.91	43.17 ± 17.25	6.00 ± 2.38	2.92 ± 1.48	2.08 ± 1.38	22.17 ± 9.17	7.08 ± 4.36	2.92 ± 1.43	1.17 ± 0.98
	Total (n=40)	**96.29 ± 15.59**	**46.81 ± 11.94**	**6.85 ± 1.97[a]**	**2.98 ± 1.13[b]**	**2.27 ± 1.15[c]**	**19.77 ± 5.74**	**5.83 ± 2.69**	**2.46 ± 0.98[f]**	**1.33 ± 0.73**
4 vs. 4	CD	88.56 ± 6.93	45.25 ± 3.18	6.07 ± 0.66	2.25 ± 0.53	1.94 ± 0.80	20.63 ± 2.37	5.50 ± 0.77	1.32 ± 0.55	1.38 ± 0.57
	WD	88.94 ± 7.45	46.75 ± 3.56	6.25 ± 1.02	2.44 ± 0.69	1.75 ± 0.82	19.13 ± 1.87	5.38 ± 0.98	1.94 ± 0.35	1.07 ± 0.51
	CM	99.81 ± 14.91	50.82 ± 5.85	7.25 ± 1.29	2.75 ± 0.79	2.32 ± 0.93	20.81 ± 2.52	5.75 ± 0.87	2.25 ± 0.44	1.38 ± 0.57
	FW	92.56 ± 15.36	46.63 ± 7.30	6.94 ± 1.83	2.63 ± 0.97	2.13 ± 0.79	19.94 ± 2.54	5.81 ± 1.53	1.82 ± 0.62	1.25 ± 0.78
	Total (n=40)	**92.47 ± 12.27**	**47.36 ± 5.46**	**6.63 ± 1.32[a]**	**2.52 ± 0.76[b]**	**2.03 ± 0.83**	**20.13 ± 2.35**	**5.61 ± 1.05[e]**	**1.83 ± 0.59[f]**	**1.27 ± 0.61**

Values mean ± SD; Post-hoc significant differences: [a] Significantly greater DC.min^{-1} at 1 to 2 m·s^{-2} for 2 vs. 2 than MP (p=0.002), 3 vs. 3 than MP (p=0.002), and 4 vs. 4 than MP (p=0.007); [b] Significantly greater DC.min^{-1} at 2 to 3 m·s^{-2} for 2 vs. 2 than MP (p<0.001), 3 vs. 3 than match play (p<0.001), and 4 vs. 4 than MP (p<0.001); [c] Significantly greater DC.min^{-1} at >3 m·s^{-2} for 2 vs. 2 than MP (p=0.011) and 3 vs. 3 than MP (p=0.004); [d] Significantly greater DC.min^{-1} at 0 to -1 m·s^{-2} for MP than 2 vs. 2 (p<0.001), MP than 3 vs. 3 (p<0.001), and MP than 4 vs. 4 (p<0.001); [e] Significantly greater DC.min^{-1} at -1 to -2 m·s^{-2} for 2 vs. 2 than MP (p<0.001) and 4 vs. 4 than MP (p=0.001); [f] Significantly greater DC.min^{-1} at -2 to -3 m·s^{-2} for 3 vs. 3 than 2 vs. 2 (p=0.013), 3 vs. 3 than 4 vs. 4 (p=0.004), 2 vs. 2 than MP (p=0.017), 3 vs. 3 than MP (p<0.001), and 4 vs. 4 than MP (p=0.014). NB. N=10 per positional role.

Table 7. Mean ± SD values for total distance covered and the percentage of time covered in each acceleration / deceleration zones per condition

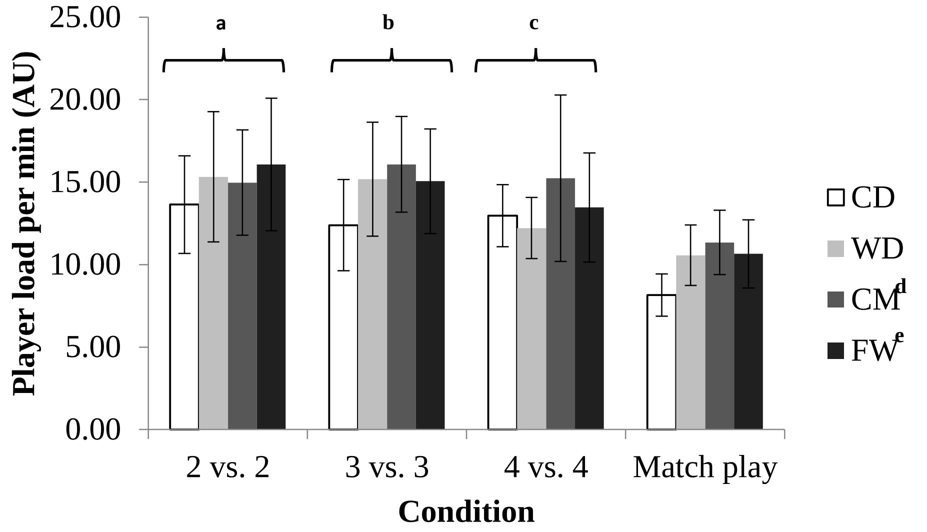
		TDC.min^{-1} (m)	TDC at 0 to 1 m·s^{-2} (%)	TDC at 1 to 2 m·s^{-2} (%)	TDC at 2 to 3 m·s^{-2} (%)	TDC at >3 m·s^{-2} (%)	TDC at 0 to -1 m·s^{-2} (%)	TDC at -1 to -2 m·s^{-2} (%)	TDC at -2 to -3 m·s^{-2} (%)	TDC at >-3 m·s^{-2} (%)
MP	CD	86.99 ± 9.76	63.10 ± 2.60	4.30 ± 0.82	1.50 ± 0.53	1.40 ± 0.52	24.10 ± 1.29	3.70 ± 0.48	1.00 ± 0.00	0.80 ± 0.42
	WD	95.01 ± 9.47	61.10 ± 2.13	4.60 ± 0.97	1.40 ± 0.52	1.50 ± 0.53	24.80 ± 1.32	3.60 ± 0.52	1.30 ± 0.48	1.20 ± 0.42
	CM	104.36 ± 11.81	61.00 ± 2.87	4.90 ± 0.99	1.70 ± 0.48	1.10 ± 0.32	24.60 ± 1.84	4.20 ± 0.79	1.00 ± 0.00	1.20 ± 0.42
	FW	94.31 ± 13.58	61.60 ± 2.12	4.10 ± 0.88	1.50 ± 0.53	1.20 ± 0.42	25.40 ± 1.90	3.40 ± 0.52	1.30 ± 0.48	1.10 ± 0.32
	Total (n=40)	**95.17 ± 12.51**	**61.70 ± 2.50**	**4.48 ± 0.93**	**1.53 ± 0.51**	**1.30 ± 0.46**	**24.73 ± 1.62**	**3.73 ± 0.64**	**1.15 ± 0.36**	**1.08 ± 0.42**
2 vs. 2	CD	93.38 ± 15.32	57.10 ± 2.08	6.60 ± 0.84	2.40 ± 0.52	1.70 ± 0.67	21.50 ± 0.97	6.40 ± 0.84	2.00 ± 0.47	1.70 ± 0.67
	WD	95.25 ± 18.96	58.00 ± 2.16	5.80 ± 1.14	2.00 ± 0.67	1.80 ± 0.63	22.10 ± 2.02	5.70 ± 0.48	2.30 ± 0.67	1.60 ± 1.17
	CM	99.75 ± 11.77	56.70 ± 2.26	6.50 ± 1.51	2.40 ± 0.52	1.80 ± 0.79	21.70 ± 1.64	6.20 ± 0.92	2.40 ± 0.52	2.20 ± 0.79
	FW	96.63 ± 22.08	57.30 ± 3.47	5.00 ± 0.82	2.60 ± 0.70	1.70 ± 0.95	23.20 ± 1.23	6.00 ± 0.82	2.00 ± 0.67	1.70 ± 0.95
	Total (n=40)	**96.25 ± 16.95**	**58.65 ± 2.87**	**6.00 ± 1.18**	**2.43 ± 0.68**	**1.98 ± 0.70**	**20.88 ± 2.04**	**5.90 ± 0.78**	**2.18 ± 0.71**	**1.63 ± 0.81**
3 vs. 3	CD	88.42 ± 13.58	60.10 ± 3.00	5.60 ± 0.97	2.20 ± 0.42	1.70 ± 0.48	20.90 ± 1.79	5.50 ± 0.71	1.90 ± 0.32	1.70 ± 0.82
	WD	94.67 ± 10.27	59.90 ± 0.42	5.80 ± 0.52	2.60 ± 1.87	1.90 ± 1.91	19.20 ± 0.42	6.20 ± 0.70	2.40 ± 0.53	1.70 ± 0.48
	CM	107.92 ± 11.87	56.00 ± 1.49	7.20 ± 1.14	2.60 ± 0.70	2.50 ± 0.71	21.20 ± 1.14	6.30 ± 0.48	2.40 ± 0.70	1.70 ± 0.82
	FW	94.17 ± 19.91	58.60 ± 2.59	5.40 ± 0.97	2.30 ± 0.82	1.80 ± 0.79	22.20 ± 2.20	5.60 ± 1.07	2.00 ± 0.94	1.40 ± 1.07
	Total (n=40)	**96.29 ± 15.59**	**58.65 ± 2.87**	**6.00 ± 1.18**	**2.43 ± 0.68**	**1.98 ± 0.70**	**20.88 ± 2.04**	**5.90 ± 0.78**	**2.18 ± 0.71**	**1.63 ± 0.81**
4 vs. 4	CD	88.56 ± 6.93	58.30 ± 2.06	6.30 ± 0.95	2.30 ± 0.48	1.50 ± 0.71	22.70 ± 1.34	5.70 ± 0.67	1.60 ± 0.52	1.40 ± 0.52
	WD	88.94 ± 7.45	60.20 ± 1.87	5.70 ± 1.25	2.10 ± 0.74	1.60 ± 0.70	21.60 ± 0.84	5.50 ± 0.85	2.00 ± 0.47	1.30 ± 0.48
	CM	99.81 ± 14.91	60.30 ± 1.64	5.60 ± 0.52	2.20 ± 0.42	2.00 ± 0.67	20.70 ± 1.49	5.40 ± 0.52	2.00 ± 0.47	1.80 ± 0.79
	FW	92.56 ± 15.36	59.10 ± 1.66	5.90 ± 0.88	2.20 ± 0.42	1.80 ± 0.63	22.10 ± 1.73	5.70 ± 0.67	1.80 ± 0.63	1.40 ± 0.70
	Total (n=40)	**92.47 ± 12.27**	**59.48 ± 1.93**	**5.88 ± 0.94**	**2.20 ± 0.52**	**1.73 ± 0.68**	**21.78 ± 1.53**	**5.58 ± 0.68**	**1.85 ± 0.53**	**1.48 ± 0.70**

Values mean ± SD. NB. N=10 per positional role.

3.5 Player load

3.5.1 Accumulated player load per min

Statistical analysis revealed a significant small main effect for mean PLacc.min^{-1} F(3, 108) = 21.91; p<0.001, η^2 = 0.38. Post hoc tests revealed a significantly greater mean PLacc.min^{-1} for 2 vs. 2 than MP (15.00 ± 3.53 vs. 10.18 ± 2.12 AU, respectively, p<0.001, CI = 3.02, 6.62), 3 vs. 3 than MP (14.68 ± 3.27 vs. 10.18 ± 2.12 AU, respectively, p<0.001, CI = 2.93, 6.06), and 4 vs. 4 than MP (13.47 ± 3.35 vs. 10.18 ± 2.12 AU, respectively, p<0.001, CI = 1.49, 5.09). Similarly, a significant small main effect was found for positional role F(3, 36) = 5.19; p = 0.004, η^2 = 0.30. Post hoc tests revealed a significantly greater PLacc.min^{-1} by CM than CD (14.41 ± 3.80 vs. 11.79 ± 3.11 AU, respectively, p = 0.004, CI = 0.68, 4.56) and FW than CD (13.81 ± 3.72 vs. 11.79 ± 3.11 AU, respectively, p = 0.037, CI = 0.08, 3.97). A non-significant interaction F(9, 108) = 0.80; p>0.05, η^2 = 0.06 was found when positional roles were analysed by SSGs and MP. Mean PLacc.min^{-1} during each condition for each positional role are shown in figure 12, and as can be seen mean values were greater during all SSGs for each positional role in comparison to MP. Table 12 and 13 show the mean differences between conditions and positional roles, respectively.



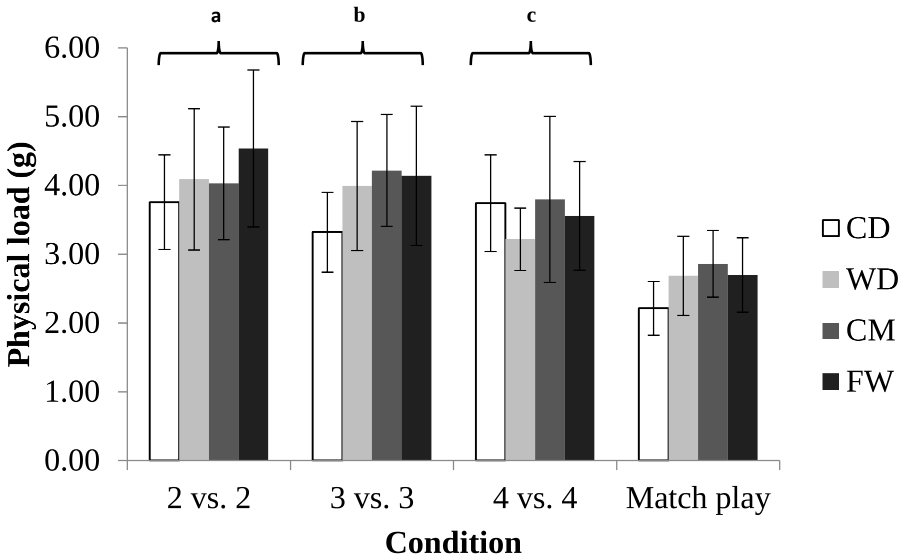
Significantly greater PLacc.min^{-1} for [a] 2 vs. 2 than MP (p<0.001), [b] 3 vs. 3 than MP (p<0.001), and [c] 4 vs. 4 than MP (p<0.001). Significantly greater PLacc.min^{-1} by [d] CM than CD (p=0.004) and [e] FW than CD (p=0.037).

Figure 12. Mean ± SD accumulated player load per min (AU) during small-sided games and match play

3.6 Contribution from each planar axes

3.6.1 Physical load in the X axes per min

Statistical analysis revealed a significant small main effect for mean physical load in the X axes per min ($X.min^{-1}$) $F(3, 108) = 27.40$; $p<0.001$, $\eta^2 = 0.43$. Post hoc tests revealed a significantly greater mean $X.min^{-1}$ for 2 vs. 2 than MP (4.10 ± 0.94 vs. 2.61 ± 0.54 g, respectively, p<0.001, CI = 1.02, 1.96), 3 vs. 3 than MP (3.92 ± 0.89 vs. 2.61 ± 0.54 g, respectively, p<0.001, CI = 0.87, 1.73), and 4 vs. 4 than MP (3.58 ± 0.83 vs. 2.61 ± 0.54 g, respectively, p<0.001, CI = 0.51, 1.42). Similarly, a significant small main effect was found for positional role $F(3, 36) = 3.26$; $p = 0.032$, $\eta^2 = 0.21$. However, post hoc tests revealed no significant differences between different positional roles. A non-significant interaction $F(9, 108) = 1.12$; $p>0.05$, $\eta^2 = 0.09$ was found when positional roles were analysed by SSGs and MP. Mean $X.min^{-1}$ during each condition for each positional role are shown in figure 13, and as can be seen mean values were greater during all SSGs for each positional role in comparison to MP. Table 12 and 13 show the mean differences between conditions and positional roles, respectively.

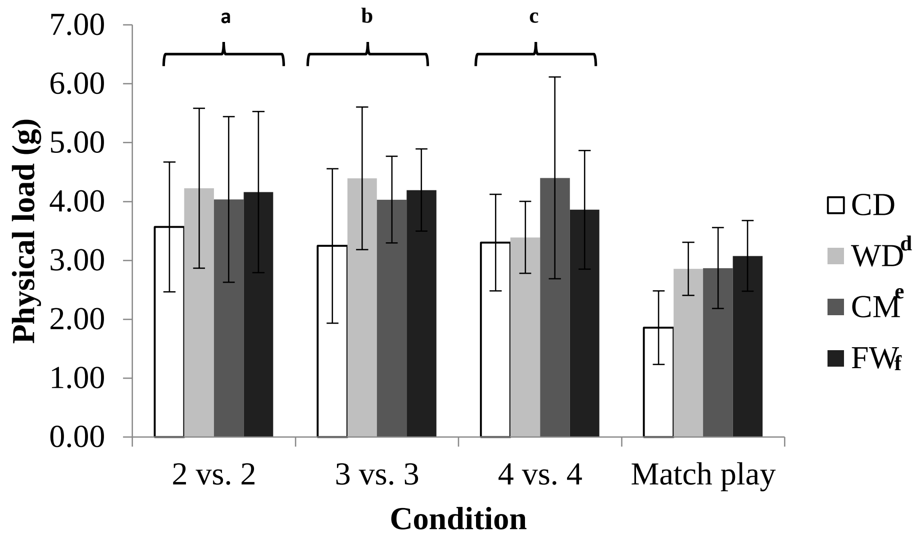


Significantly greater physical load in the X axes per min for [a] 2 vs. 2 than MP (p<0.001), [b] 3 vs. 3 than MP (p<0.001), and [c] 4 vs. 4 than MP (p<0.001).

Figure 13. Mean ± SD physical load in the X axes per min (g) during small-sided games and match play

3.6.2 Physical load in the Y axes per min

Statistical analysis revealed a significant small main effect for mean physical load in the Y axes per min (Y.min^{-1}) F(3, 108) = 14.50; p<0.001, η^2 = 0.29. Post hoc tests revealed a significantly greater mean Y.min^{-1} for 2 vs. 2 than MP (4.00 ± 1.29 vs. 2.66 ± 0.75 g, respectively, p<0.001, CI = 0.69, 1.98), 3 vs. 3 than MP (3.97 ± 1.08 vs. 2.66 ± 0.75 g, respectively, p<0.001, CI = 0.76, 1.84), and 4 vs. 4 than MP (3.74 ± 1.16 vs. 2.66 ± 0.75 g, respectively, p<0.001, CI = 0.48, 1.67). Similarly, a significant small main effect was found for positional role F(3, 36) = 5.85; p = 0.002, η^2 = 0.33. Post hoc tests revealed a significantly greater mean Y.min^{-1} by WD than CD (3.72 ± 1.14 vs. 2.99 ± 1.17 g, respectively, p = 0.024, CI = 0.07, 1.38), CM than CD (3.83 ± 1.31 vs. 2.99 ± 1.17 g, respectively p = 0.006, CI = 0.18, 1.50), and FW than CD (3.82 ± 1.04 vs. 2.99 ± 1.17 g, respectively, p = 0.007, CI = 0.17, 1.49). A non-significant interaction F(9, 108) = 0.76; p>0.05, η^2 = 0.06 was found when positional roles were analysed by SSGs and MP. Mean Y.min^{-1} during each condition for each positional role are shown in figure 14, and as can be seen mean values were greater during all SSGs for each positional role in comparison to MP. Table 12 and 13 show the mean differences between conditions and positional roles, respectively.

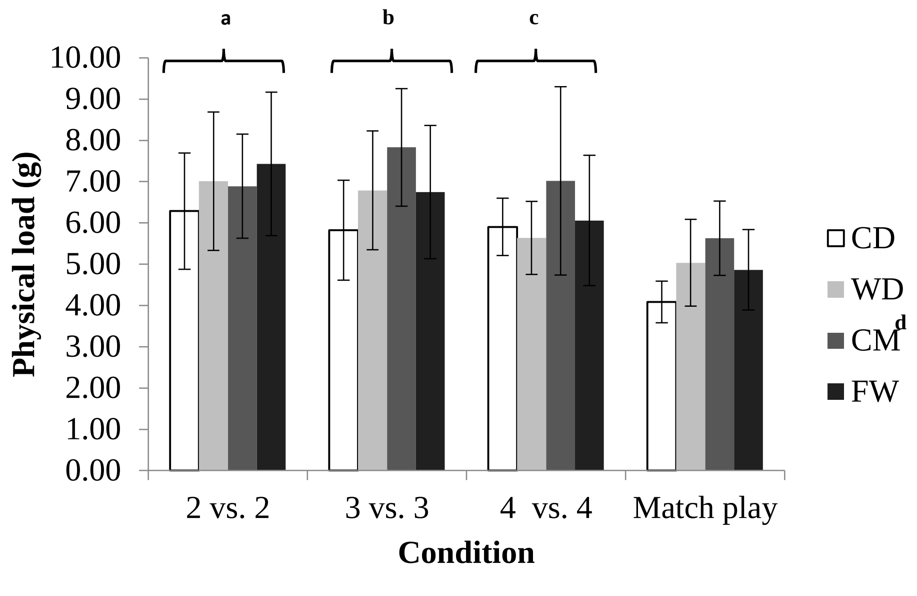


Significantly greater physical load in the Y axes per min for [a] 2 vs. 2 than MP (p<0.001), [b] 3 vs. 3 than MP (p<0.001), and [c] 4 vs. 4 than MP (p<0.001). Significantly greater physical load in the Y axes per min by [d] WD than CD (p=0.024), [e] CM than CD (p=0.006), and [f] FW than CD (p=0.007).

Figure 14. Mean ± SD physical load in the Y axes per min (g) during small-sided games and match play

3.6.3 Physical load in the Z axes per min

Statistical analysis revealed a significant small main effect for mean physical load in the Z axes ($Z.min^{-1}$) $F(3, 108) = 19.28$; $p<0.001$, $\eta^2 = 0.35$. Post hoc tests revealed a significantly greater mean $Z.min^{-1}$ for 2 vs. 2 than MP (6.90 ± 1.53 vs. 4.90 ± 1.01 g, respectively, $p<0.001$, CI = 1.18, 2.83), 3 vs. 3 than MP (6.80 ± 1.55 vs. 4.90 ± 1.01 g, respectively, $p<0.001$, CI = 1.17, 2.62), and 4 vs. 4 than MP (6.17 ± 1.53 vs. 4.90 ± 1.01 g, respectively, $p = 0.001$, CI = 0.42, 2.09). Similarly, a significant small main effect was found for positional role $F(3, 36) = 5.45$; $p = 0.003$, $\eta^2 = 0.31$. Post hoc tests revealed a significantly greater mean $Z.min^{-1}$ by CM than CD (6.84 ± 1.69 vs. 5.53 ± 1.31 g, respectively, $p = 0.002$, CI = 0.40, 2.23). In contrast, a non-significant interaction $F(9, 108) = 0.93$; $p>0.05$, $\eta^2 = 0.07$ was found when positional roles were analysed by SSGs and MP. Mean $Z.min^{-1}$ during each condition for each positional role are shown in figure 15, and as can be seen mean values were greater during all SSGs for each positional role in comparison to MP. Table 12 and 13 show the mean differences between conditions and positional roles, respectively.



Significantly greater physical load in the Z axes per min for [a] 2 vs. 2 than MP ($p<0.001$), [b] 3 vs. 3 than MP ($p<0.001$), and [c] 4 vs. 4 than MP ($p<0.001$). Significantly greater physical load in the Z axes per min by [d] CM than CD ($p=0.002$).

Figure 15. Mean ± SD physical load in the Z axes (g) per min during small-sided games

Table 8. Mean ± SD values for accumulated player load (AU) and the physical load in the X, Y and Z axes (g) per condition

		$PLacc.min^{-1}$ (AU)	**$X.min^{-1}$ (g)**	**$Y.min^{-1}$ (g)**	**$Z.min^{-1}$ (g)**
MP	CD	8.15 ± 1.28	2.21 ± 0.39	1.86 ± 0.62	4.09 ± 0.50
	WD	10.57 ± 1.84	2.69 ± 0.58	2.86 ± 0.45	5.03 ± 1.05
	CM	11.34 ± 1.95	2.86 ± 0.48	2.87 ± 0.69	5.63 ± 0.90
	FW	10.65 ± 2.06	2.70 ± 0.54	3.08 ± 0.60	4.86 ± 0.97
	Total (n = 40)	**10.18 ± 2.12**	**2.61 ± 0.54**	**2.66 ± 0.75**	**4.90 ± 1.01**
2 vs. 2	CD	13.64 ± 2.96	3.76 ± 0.69	3.57 ± 1.10	6.29 ± 1.41
	WD	15.32 ± 3.95	4.09 ± 1.03	4.23 ± 1.36	7.01 ± 1.68
	CM	14.98 ± 3.20	4.03 ± 0.82	4.04 ± 1.41	6.89 ± 1.26
	FW	16.08 ± 4.02	4.54 ± 1.14	4.16 ± 1.37	7.43 ± 1.74
	Total (n = 40)	**15.00 ± 3.53[a]**	**4.10 ± 3.94[b]**	**4.00 ± 1.29[c]**	**6.90 ± 1.53[d]**
3 vs. 3	CD	12.39 ± 2.76	3.32 ± 0.58	3.25 ± 1.31	5.83 ± 1.21
	WD	15.18 ± 3.45	3.99 ± 0.94	4.39 ± 1.21	6.79 ± 1.44
	CM	16.08 ± 2.90	4.22 ± 0.81	4.03 ± 0.74	7.83 ± 1.42
	FW	15.06 ± 3.17	4.14 ± 1.01	4.20 ± 0.70	6.75 ± 1.61
	Total (n = 40)	**14.68 ± 3.27[a]**	**3.92 ± 0.89[b]**	**3.97 ± 1.08[c]**	**6.80 ± 1.55[d]**
4 vs. 4	CD	12.97 ± 1.88	3.74 ± 0.70	3.30 ± 0.82	5.90 ± 0.70
	WD	12.22 ± 1.86	3.22 ± 0.45	3.39 ± 0.61	5.64 ± 0.88
	CM	15.23 ± 5.04	3.80 ± 1.21	4.40 ± 1.71	7.02 ± 2.28
	FW	13.46 ± 3.30	3.56 ± 0.79	3.86 ± 1.01	6.06 ± 1.58
	Total (n = 40)	**13.47 ± 3.35[a]**	**3.58 ± 0.83[b]**	**3.74 ± 1.16[c]**	**6.17 ± 1.53[d]**

Values mean ± SD. NB. N=10 per positional role; Post-hoc significant differences: [a] Significantly greater $PLacc.min^{-1}$ for 2 vs. 2 than MP ($p<0.001$), 3 vs. 3 than MP ($p<0.001$), and 4 vs. 4 than MP ($p<0.001$); [b] Significantly greater physical load in the X axes per min for 2 vs. 2 than MP ($p<0.001$), 3 vs. 3 than MP ($p<0.001$), and 4 vs. 4 than MP ($p<0.001$). [c] Significantly greater physical load in the Y axes per min for 2 vs. 2 than MP ($p<0.001$), 3 vs. 3 than MP ($p<0.001$), and 4 vs. 4 than MP ($p<0.001$); [d] Significantly greater physical load in the Z axes per min for 2 vs. 2 than MP ($p<0.001$), 3 vs. 3 than MP ($p<0.001$), and 4 vs. 4 than MP ($p<0.001$).

4. Discussion

As discussed in chapter one, the physiological and physical demands of various SSG modalities and MP have been researched extensively. However, research has failed to identify the discrete physically demanding movements, therefore underestimating the demands. It was therefore the purpose of this investigation to measure the physical demands per positional role of MP and three different SSG drills, and to determine whether the SSGs employed offer a functional training stimulus. To the researcher's knowledge, this is the only study that has used accelerometers to examine the position-specific load and acceleration / deceleration demands of MP and SSGs. Further, this study is the first to use accelerometers to examine the magnitude of three-dimensional movements.

The null hypothesis that SSGs would not evoke a greater internal physiological loads than match play was accepted, although heart rate was significantly greater during 2 vs. 2 than match play. Heart rate was expected to reduce as the number of players increased, however the lower heart rate found for 4 vs. 4 SSGs in comparison to match play was not expected. In contrary, the null hypothesis that SSGs would not evoke a greater external load than match play was rejected as SSGs elicited significantly greater player load than match play.

The key findings were that PL and the contribution from the individual X, Y and Z vectors were greater during SSGs than MP. Further, CM exhibited the greatest PL and individual contributions from the X, Y and Z vectors across conditions, whereas CD exhibited the lowest.

4.1 Heart rate

The use of SSGs as a football conditioning method to improve the aerobic capacity of players has been supported in the literature (Coutts et al., 2009; Dellal et al., 2011a, 2012b). Heart rate monitoring has been traditionally used during these drills as a method to quantify the physiological responses to SSGs. The results of the current study demonstrated that mean HR was significantly greater during the 2 vs. 2 SSGs than MP. Further, although not to a level of significance, HR was greater during 3 vs. 3 SSGs for all positional roles in comparison to MP with only CD reporting greater HR values in 4 vs. 4 SSGs than MP (figure 1). The findings of Owen, Wong, McKenna and Dellal (2011) are in agreement with the present study, in which higher HR responses occurred during SSGs (3 vs. 3) than LSGs (9 vs. 9). The differences between SSGs and LSGs/MP could be explained by the greater technical, physical and tactical demands imposed by SSGs both in offensive and defensive phases (Dellal et al., 2012b). Additionally, the period of recovery is shorter during SSGs, evidenced by a greater work-rest ratio in the current study (1.96 and 1.82 for 2 vs. 2 and 3 vs. 3, respectively), in comparison to MP (1.69) suggesting that the frequency of activities is greater for SSGs.

Williams and Owen (2007) found similar results to the present study in which HR reduced as player numbers increased from 2 vs. 2 to 3 vs. 3 (179 vs. 166 beats.min^{-1}, respectively), and from 3 vs. 3 to 4 vs. 4 (166 vs. 165 beats.min^{-1}, respectively) on different pitch dimensions (20x15, 25x20 and 30x25 m, respectively). The increases in pitch dimensions used as player number increased in the aforementioned study also resulted in greater relative pitch dimensions per player across the SSGs. Therefore, the reductions in intensity as pitch size increased may have been a result of the independent effects of increasing the number of players or the inability of the additional players to cover more of the available area (Hill-Haas et al., 2011). The current study controlled for pitch size by maintaining relative pitch dimensions of 1:75 m^2 for all SSGs to determine the effects of increasing player numbers on HR responses.

Using a similar methodology to the present study in which the relative pitch ratio per player was 1:75 m^2 for all SSG drills examined, amateur football players reported HR values of 92, 90 and 87 %HR_{max} for 2 vs. 2, 3 vs. 3 and 4 vs. 4 SSGs, respectively (Dellal et al., 2011). The present study observed slightly lower values of 89, 87 and 85 % estimated HR_{max} for 2 vs. 2, 3 vs. 3 and 4 vs. 4 SSGs, respectively. The study of Dellal et al. (2011) did not state the method used to determine HR_{max}. However, the present study used the predictive HR_{max} equation for male athletes proposed by Whyte et al. (2008) as endurance training decreases HR values thereby making this equation appropriate (Kostis et al., 1982). Nevertheless, there is a reduction in physiological response as the number of players increase in SSGs, which could possibly be a result of the decreasing interaction with members of the same team and opponents (Hill-Haas et al., 2009).

The 4 vs. 4 SSG modality used in the present study failed to elevate HR levels to those considered beneficial to stimulate cardiovascular development (Clemente et al., 2014). These results are contrary to Dellal et al. (2012b) who found that 4 vs. 4 SSGs evoked significantly greater mean HR responses than MP for all positional roles. The differences in results could be explained by the use of four support players in the study by Dellal et al. (2012b), which would have increased intensities through an increased technical demand in comparison to the present study that used no support players. Overall, a consensus across studies suggests that SSGs similar to those used in the present study (2 vs. 2 and 3 vs. 3) may be useful in training to improve aerobic fitness in football players through evoking greater HR responses than MP.

It should be noted that amateur football players have been found to be less technically proficient than professionals with the former displaying a greater amount of lost balls per possession (Hughes and Franks, 2005). This is important, as it has been indicated that a decrease in the percentage of successful passes during MP is correlated to the score of the game (Rampinini et al., 2009). Therefore, technical development is fundamental in the preparation of football players. Small sided games also appear to develop this aspect of training, and the two touch rule used in the present study has been suggested to develop amateur and youth players through a greater technical demand (Dellal et al., 2011a). Unfortunately, the present study failed to measure the technical demand of the SSGs employed prompting further research.

The greatest work-rate in football is imposed on CM who act as a link between defence and attack, thereby requiring a greater physiological response (Reilly and Thomas, 1976). Although a non-significant main effect was found for positional role, in line with previous research, CM reported greater mean HR values than other positional roles during MP, emphasising the importance for cardiovascular development for this positional role (Ali and Farrally, 1991b; Dellal et al., 2012b). However, during 2 vs. 2 and 3 vs. 3 SSGs, CM reported the lowest mean HR values in comparison to other positions. Similar results were reported by Dellal et al. (2012b) who found lower $\%HR_{max}$ values by central defensive midfielders than central defenders, wide defenders, wide midfielders and forwards during 4 vs. 4 SSGs. The differences in HR response between positional roles could be due to the duration of the SSGs (2 x 4 min and 3 x 4 min for 2 vs. 2 and 3 vs. 3, respectively), which may have been an insufficient time to allow cardiac adaptations for CM. Alternatively, CM completed a greater total distance at activities considered high intensity such as movement occurring at 15.1-18.0 $km \cdot h^{-1}$

and 2 to 3 $m \cdot s^{-2}$ (figure 4 and 7, respectively) which may not have been measured by HR. As discussed in chapter 1.3, using HR to monitor exercise response especially at high intensities has not been considered as the best indicator to examine the physical demands of SSGs. This is because during activities that occur rapidly and at high intensities a large proportion of the required energy is supplied through anaerobic metabolism and the duration of these activities are not long enough to elevate HR levels due to the time lag in the heart response to changes in exercise intensity (Achten and Jeukendrup, 2003; Borresen and Lambert, 2008). Therefore, it is important to link these physiological results with external measures to give a more accurate depiction of the physical demands.

4.2 Distance covered

Recent advances in time-motion analysis technology have enabled external load measures such as the total distance covered and distance covered in different speed zones to be objectively quantified during both training and MP. The present study found that there were no significant differences in $TD.min^{-1}$ between SSGs and MP. In contrast, Casamichana et al. (2012) found that semi-professional football players covered significantly greater $TD.min^{-1}$ during SSGs than MP. These conflicting results may be explained by the differences in methodologies used between studies. For example, results from 3 vs. 3, 5 vs. 5 and 7 vs. 7 played on a relative pitch size of 1:210 m^2 per player were combined and expressed as one $TD.min^{-1}$ value in the study by Casamichana et al. (2012). Indeed, larger pitch sizes increase the amount of total distance covered during SSGs when player numbers remain constant (Casamichana and Castellano, 2010). Therefore, the smaller absolute pitch sizes used in the present study may explain the differences in total distance covered between studies. Furthermore, youth players were used in the present study, whereas semi-professional players were used in the aforementioned study. Since physical capacities vary according to age and subsequent growth spurts, physical capabilities may have been limited in the youth players used in the present study (Philippaerts et al., 2006), thereby limiting the ability to cover greater distances.

In line with previous research CM in the present study covered the greatest total distance whilst CD covered the least total distance during MP (Di Salvo et al., 2006; Bradley et al., 2009b; Dellal et al., 2012b). Based on these values it is essential that CM cover a similar or greater total distance in training than other positional roles in order to prepare for the demands of MP. The SSGs used in the present study evoked relatively homogenous TD.min^{-1} across all conditions for each positional role suggesting the SSGs meet the demands of MP. Therefore, SSGs played on a relative pitch size of 1:75 m^2 with two touches may be a prudent choice for coaches aiming to prepare players for the demands of MP if distance travelled is of importance. However, making assumptions of the physical demands of MP and SSGs based solely on the total distance covered is imprudent, as how the distance was covered is of greater importance to fully understanding the physical demands.

4.3 Distance covered in different speed zones

As previously mentioned, based on values obtained during MP it is essential that CM develop their aerobic profile whereas WD and FW develop their anaerobic profile (Bangsbo, 1994a; Shepard, 1999). Central defenders covered the greatest distance at the lowest speeds (0-8.0 km·h^{-1}), than any other positional role during MP. However, at the greatest work-speeds (>15.1 km·h^{-1}), CD covered the least distance. These results are consistent with results from Di Salvo et al. (2009) and Rampinini, Sassi, Sassi and Impellizzeri (2004) who found that CD covered the least distance at high-speed activity during MP. Central midfield players, on the other hand, reported the greatest distances in faster running speeds (8.1-15.0 km·h^{-1}) during MP. Forwards covered the greatest distance in the fastest speeds (>15.1 km·h^{-1}) followed by WD then CM during MP in the present study. Research by Ekblom (1986) and Tumilty (1993) who found that CD cover the least distance at the fastest speeds during MP are in agreement with the current study. Furthermore, the finding that WD covered significantly greater distances at the fastest speeds compared to central positions is supported by Di salvo et al. (2009). The combined offensive and defensive duties explain the greater distances covered at the fastest speeds by external compared to central positions. The findings of Di Salvo et al. (2009) are in agreement with the present study that observed greater sprint distances completed by wide players. Unfortunately, there is limited information regarding the position-specific movement demands of SSGs, with even less research that has compared values with MP (Casamichana et al., 2012; Dellal et al., 2012b).

To date, research that has examined the position-specific demands of MP and SSGs have only examined the high-speed running demands of SSGs, or has combined values measured from different SSG drills together (Casamichana et al., 2012; Dellal et al., 2012b). The present research however, provides novel findings in that the total distance covered in several speed categories for different positional roles during both MP and various SSG drills were determined, thereby providing sport scientists and coaches with a greater understanding of the physical demands experienced by different positional roles. The SSGs used in the present study, evoked different movement responses for different positional roles.

Across all positional roles, the greatest distance performed at the lowest speeds (0-6.0 $km\cdot h^{-1}$) was found for MP, and the smallest distance was found for 3 vs. 3 SSG. A possible explanation for the results reported may be increased opportunity to rest during MP as a result of the larger absolute and relative pitch size. In contrast, the greatest distance performed at faster speeds (6.1-8.0 and 8.1-12.0 $km\cdot h^{-1}$, respectively) and, therefore, higher intensities were found in 3 vs. 3 SSGs, and the smallest distance found in MP. Therefore, SSGs are played at consistently faster speeds than MP and is a possible reason for the differences in physiological responses between the two conditions. The distance covered at 6.1-8.0 $km\cdot h^{-1}$ was greater for all positional roles for all SSGs in comparison to MP. Similarly, the distance covered at 8.1-12.0 $km\cdot h^{-1}$ was greater for all positional roles for all SSGs in comparison to MP except for CM during 2 vs. 2 SSGs in which similar results were found. A possible reason explaining this could be a difficulty reaching the speeds due to the pitch dimensions used, with less absolute space for CM to reach these speeds during 2 vs. 2 in comparison to 3 vs. 3 and 4 vs. 4 SSGs. Therefore, the SSGs used in the present study are useful for stimulating the moderate-speed (6.1-12.0 $km\cdot h^{-1}$) demands of MP, but are inappropriate for stimulating the high-speed running demands.

In general, larger game formats are associated with greater ranges of distance covered at speeds >15.1 $km\cdot h^{-1}$ (Dellal et al., 2012b; Hill-Haas et al., 2009). The SSGs used in the present study failed to replicate the high-speed running and sprint demands of MP. For example, the greatest distance at 15.1-18.0 $km\cdot h^{-1}$ were reported for MP and the smallest distance were reported for 3 vs. 3 SSGs. Similarly, the greatest distance at >18.1 $km\cdot h^{-1}$ were reported for MP and the smallest distance were reported for 2 vs. 2 SSGs. The 4 vs. 4 SSGs failed to evoke greater distances at >15.1-18.0 $km\cdot h^{-1}$ than MP which is in line with research by Hodgson, Akenhead and Thomas (2014) who reported no high-speed running distance for 4 vs. 4 SSGs in which no support players were used and the pitch size and duration were in accordance to the present study. On the other hand, Dellal et al. (2012b) reported greater values performed at high-speed running and sprinting during 4 vs. 4 SSGs than MP when playing on the same pitch dimensions as the aforementioned and the present study. A possible explanation for the differences reported could be due to the use of four supporting players used in the study of Dellal et al. (2012b) as previously mentioned, which would have increased game speed through an increased technical demand. Alternatively, the participants used in the present study may not have been able to sustain high-speed running due to maturity levels. In agreement with previous research, it is possible that the activity profiles of SSGs can be determined by the complex interaction of pitch size, number of players, opportunity for direct involvement of the ball and match style (Aguiar et al., 2012).

Forwards and WD reported the greatest distances at the fastest speeds during MP (>18.1 $km \cdot h^{-1}$) and it is therefore essential that these speeds are stimulated in training to elicit a training response. However, in accordance with previous research SSGs failed to stimulate these speeds due to the lack of absolute pitch size, thereby restricting the ability to reach high speeds. Therefore, if the development of high-speed running is important, coaches should use larger pitch sizes than those used in the present study such as those used by Dellal et al. (2012b). Despite the SSGs in the present study failing to provide a functional equivalent for the development of high speeds for all positional roles, SSGs may provide players with a stimulus to maintain moderate speeds and therefore evoke developments in the aerobic profile.

Further support can be found for the development of moderate-speed running by the greater number of repeated high-intensity efforts per hour observed during SSGs with the greatest values reported for 2 vs. 2 SSGs, and the smallest values reported for MP. These results conflict with those of Casamichana et al. (2012) who reported a greater number of repeated high-intensity efforts per hour during MP than SSGs (15.30 ± 6.10 vs. 7.50 ± 11.30). As previously mentioned, the methodology employed in the present study differ from Casamichana et al. (2012) and could be a possible explanation for the differences observed in RHIE. It should be noted that inconsistencies exist in the terminology used in the research to describe repeated high-intensity efforts. Moreover, repeated high-intensity efforts have also been termed "repeated-sprint ability" and researchers have used these terms interchangeably when making comparisons (Barberó-Álvarez, Boullose, Nakamura. Andrín, Weston, 2014). Furthermore, these studies have defined what constitutes repeated high-intensity efforts differently. For example, the present study, Spencer et al. (2005) and Casamichana et al. (2012) have all defined repeated high-intensity efforts as a player making at least 3 efforts at a speed >13 km·h^{-1} and with a <21 s recovery between them. On the other hand, Buchheit et al. (2010) defined repeated-sprint ability as a minimum of 2 consecutive sprints interspersed with a maximum of 60 s. Therefore, a consensus determining what defines a repeated high-intensity efforts is required before assertions are made regarding the demands of football.

Understanding the high-speed running demands of MP and training drills is important as the amount of high-speed running separates successful from unsuccessful and elite from non-elite teams (Bangsbo et al., 1991; Mohr et al., 2003). However, solely using high-speed running to determine the intensity of MP and SSGs may underestimate the physical demands of football. A growing body of research has included the acceleration and deceleration demands of football based on the premise that accelerations and decelerations evoke a greater energy cost and muscular demand, even when absolute speed is low (Osgnach et al., 2010; Thompson et al., 1999). Previous research may have omitted this information based on the uncertainty of GPS measurement for acceleration, particularly over short distances (Varley et al., 2012).

While the GPS measurement validity of running velocity is well established, there is scant research that has determined the validity of these systems when measuring rapid directional change (Rawstorn et al., 2014). As athletes may execute 550-730 turning movements during MP with greater values speculated for SSGs (Bloomfield et al., 2007; Carling et al., 2008), it is important to determine the validity of GPS for measuring these movements. Using the Loughborough Intermittent Shuttle-running protocol designed to simulate the activity patterns of MP (Nicholas, Nuttall and Williams, 2000), Rawstorn et al. (2014) reported that rapid directional change degrades GPS measurement accuracy with this effect independent of movement velocity. As GPS measurement validity is also reduced during sprinting and rapid acceleration, it appears GPS may not be appropriate for determining MP activity profiles as key aspects of MP may be misrepresented (Coutts and Duffield, 2010; Jennings et al., 2010; Varley et al., 2012). However, recent integrations of accelerometers sampling at 100 Hz have enabled researchers to more accurately measure the acceleration and deceleration demands of MP and SSGs (Gaudino et al., 2014).

4.4 Acceleration / deceleration

Despite extensive research quantifying the physical demands, there is still a dearth of load-related information of MP and SSGs. Notably, little information is available regarding the crucial physical (acceleration and deceleration) components taxed within SSG drills. The unpredictable and multi-factorial nature of SSGs evokes a number of explosive actions and changes in velocity, thereby requiring a high complexity in the quantification of workload (Gaudino et al., 2014).

The importance of quantifying acceleration / deceleration is supported by recent findings showing that in professional players 18 % of the total distance covered during MP occurs whilst accelerating or decelerating at >1 $m \cdot s^{-2}$ (Akenhead et al., 2013). Nevertheless, it appears that alongside kinematic (i.e. movement speeds) and cardiovascular variables (i.e. HR), there is also a mechanical load component during accelerations and decelerations that should be taken into consideration when quantifying the total workload placed upon players. The present study revealed that in youth players the %TDC.min whilst accelerating or decelerating at >1 $m \cdot s^{-2}$ was 13 % during MP and 21, 22 and 20 % during 2 vs. 2, 3 vs. 3 and 4 vs. 4 SSGs, respectively. Therefore, SSGs may provide a 'density' type-training stimulus through imposing relative demands on accelerating and deceleration abilities in excess of those experienced during MP (Hodgson et al., 2014).

The greater distances reported in acceleration vs. deceleration for MP (69 vs. 31 %), 2 vs. 2 (67 vs. 32 %), 3 vs. 3 (69 vs. 31 %) and 4 vs. 4 (69 vs. 31 %) are in line with research by Akenhead et al. (2013) and Hodgson et al. (2014) who observed greater accelerations than decelerations during MP and 4 vs. 4 SSGs played on small pitch sizes, respectively. These results reflect the primary muscle actions involved in these movements. Moreover, acceleration is dependant upon propulsive forces achieved primarily through concentric muscle actions, whereas deceleration requires breaking forces produced by eccentric muscle action (Hodgson et al., 2014). As human skeletal muscle is stronger eccentrically, players are able to generate greater braking than propulsive forces, thereby slowing down faster and covering less distance as a consequence during deceleration movements. Failure of the working muscles to produce the required force at appropriate times may lead to compromised physical performance during change of direction and an increased risk of injury (Smith, Sizer and James, 2009), thus emphasising the importance to develop athletes for the acceleration and deceleration demands of MP. However, without an understanding of the position-specific acceleration and deceleration demands of MP, it is uncertain which positional roles require a stronger development and therefore a greater stimulus during training. The present research therefore, provides novel information regarding the position-specific acceleration and deceleration demands of MP and SSGs.

There exists limited match data using accelerometers to measure the position-specific acceleration / deceleration profiles to directly compare with. Therefore, findings are also compared with previous time-motion analysis research. Central players have been shown to complete more explosive sprints that wide players (Di Salvo et al., 2010), which could be explained by the congestion in those areas of the field. In contrary, using the same device to the present study, Varley and Aughey (2013) found that wide players reported the greatest number (90 ± 15) of maximal accelerations (>2.78 m·s^{-2}). The findings of the present study appear to conflict with the aforementioned studies with FW performing the greatest DC.min^{-1} at accelerations >3 m·s^{-2} with CM covering the least distance. Direct comparisons between the aforementioned studies are difficult due to the differences in playing formations adopted. Differences in playing formation have been found to influence different activity and therefore, different acceleration / deceleration profiles (Bradley et al., 2011). Further, factors including; playing standard and game score, would also affect positional activity profiles (Barron, Atkins, Edmundson and Fewtrell, 2014). It should also be noted that differences in methodology exist between studies with the present and Varley and Aughey (2013) studies using 5 Hz GPS (Minimax, Catapult Innovations, Australia) whereas Di Salvo et al. (2010) and Varley and Aughey (2013) used SAMCS (Prozone®, Leeds, UK) and 5 Hz GPS (SPI-Pro, GPSports, Australia), respectively. As alluded to in chapter 1, video-based time-motion analysis and GPS are incompatible (Harley et al., 2011).

The present study reported a significantly greater distance covered across all positional roles at 1 to 2 and ± 2 to 3 m·s^{-2} during all SSGs compared to MP whereas 2 vs. 2 and 4 vs. 4 and 2 vs. 2 and 3 vs. 3 reported significantly greater distance at -1 to -2 m·s^{-2} and >3 m·s^{-2}, respectively. Gaudino et al. (2014) reported similar values to the present study with the frequency of moderate-accelerations (1 to 2 m·s^{-2}) and decelerations (-1 to -2 m·s^{-2}) decreasing as the number of players increased from 5 vs. 5 to 10 vs. 10. However, this study did not find any differences in the frequency of high decelerations (-2 to -3 m·s^{-2}), high accelerations (2 to 3 m·s^{-2}) or max accelerations (>3 m·s^{-2}) across

5 vs. 5, 7 vs. 7 and 10 vs. 10 SSGs. It should be noted, that as the number of players increased, the relative area per player increased and it is therefore uncertain whether the number of players or pitch size per se was responsible for the results reported in the aforementioned study. In a study examining the effect of increasing pitch size whilst keeping the number of players constant, Hodgson et al. (2014) reported that 4 vs. 4 (+ goal keepers) SSGs played on a moderate pitch size (40x30 m) provide an optimal training stimulus in comparison to 4 vs. 4 SSGs played on small (30x20 m) and large (50x40 m) pitch areas. For example, a high frequency of technical actions in combination with a greater physical demand evidenced by a greater total distance covered in acceleration, deceleration and high-speed running were reported for medium pitch areas.

These findings of the current study concur with an emerging and growing body of evidence that including acceleration measures in time-motion analysis will permit a greater understanding of the physical demands of football SSGs and MP (Osgnach et al., 2010; Akenhead et al., 2013; Gaudino et al., 2013). Furthermore, previous omissions of acceleration parameters have underestimated the metabolic and neuromuscular demands of football. The results suggest, that when acceleration and deceleration measures are included in analysis, SSGs evoke greater external load in comparison to MP. In addition, between-position differences exist with CM and FW covering a greater total distance in more intense acceleration zones supporting the need for position-specific training. The SSGs used in the present study, specifically 2 vs. 2 and 3 vs. 3, may be suitable for stimulating the propulsive and braking forces that occur more frequently during MP for WD, CM and FW via a ‘density’ type stimulus (Hodgson et al., 2014). It should be noted however, that the SSGs used in the present study failed to stimulate high-speed running that contributes 10-20 % of MP (Reilly and Thomas, 1976; Mohr et al., 2003). Therefore, using SSGs similar to those used in the present study should be used if the aim is the development of acceleration and deceleration whilst simultaneously taxing the aerobic system, whereas SSGs played on larger field dimensions should be used if the aim is the development of high-speed running.

Episodes of physical contact such as tackling, bumping, blocking and contested situations when the ball is in dispute are also common in football (Dawson et al., 2004). Currently, using notational analysis, these activities can be counted and classified;

however, failing to quantify these forms of physical stresses may underestimate the external load. Recent applications of triaxial accelerometers have enabled research to quantify all accounts of external load in team sport (Montgomery et al., 2010). Findings from basketball have reported that PL was capable of differentiating loads between a competitive match, modified scrimmage games, and various training drills (Montgomery et al., 2010). Therefore PL was used in the present study to quantify all measures of external load during MP and SSGs.

4.5 Player load

The present study provides novel position-specific information regarding the PL responses of both MP and SSGs when a relative pitch size was used for each SSG drill. The novel findings of the present study were that PLacc.min^{-1} was greater in all SSGs for each positional role in comparison to MP, though the interaction was not to a level of significance. In addition, a significant main effect for condition was found with mean PLacc.min^{-1} decreasing as the number of players increased. Similarly, a significant main effect was found for positional role with CM reporting the greatest PLacc.min^{-1}.

Unfortunately, as with acceleration, there is limited research that has examined the PL responses to MP to make comparisons with. Previous research examining semi-professional players found that PLacc.min^{-1} was greater during SSGs (15.8 ± 2.7 AU) in comparison with MP (13.5 ± 1.5 AU), which is in line to the current study (Casamichana et al., 2012). The current study however provides more detailed information regarding the position-specific PL responses to both MP and SSGs, thereby improving the understanding of the total load imposed on football players. During MP, CM reported the greatest PLacc.min^{-1} values, whereas CD reported the lowest values. As PL quantifies the total external load experienced by players, including the discrete, non-distance contributing activities such as jumping and collisions, these results provide further evidence that CM indeed require greater work rate demands with CD requiring the least work rate (Di Salvo et al., 2007). A possible explanation for the greater PLacc.min^{-1} reported by CM during MP, could be due largely to the greater total distance covered by this positional role in comparison to other positional roles. Total distance covered has recently shown large to very large correlations with PL (r = 0.74) supporting this notion (Casamichana, Castellano, Calleja-Gonzalez, Román and Castagna, 2013).

As outlined in the previous paragraph, the SSG drills used in the present study evoked a greater PLacc.min^{-1} for all positional roles in comparison to MP. The findings of Casamichana et al. (2012) support the findings of the present study. However, it is difficult to make direct comparisons as this study reported a total PLacc.min^{-1} value when values from three different SSGs (3 vs. 3, 5 vs. 5 and 7 vs. 7) were combined. Therefore, the individual PLacc.min^{-1} responses for each SSG are unknown. It is common for several SSG drills to be employed in a single training session making the results of the study by Casamichana et al. (2012) practical for coaches using similar game formats. However, it is important to provide information and therefore a greater understanding of independent SSG drills to prevent the overtraining / undertraining of football players.

Across the SSG drills used in the present study, those with the fewest players reported the greatest PLacc.min^{-1} values with values decreasing with an increase in the number of players. Moreover, 2 vs. 2 SSGs reported the greatest values, which decreased linearly with an increase in the number of players with 4 vs. 4 SSGs reporting the lowest values. The results of Aguiar et al. (2013) are in contrary to the findings of the present study in which 2 vs. 2 SSGs reported a total PL value of 88.63 ± 20.37 AU that increased linearly with an increase in the number of players with 4 vs. 4 SSGs reporting a total PL value of 95.18 ± 17.54 AU. A possible reason for these findings could be attributed to the different methodology employed to the present study. For example, the duration of the SSGs employed was considerably greater than the present study with formal goals and goalkeepers used. In addition, a pitch ratio of 1:150 m^2 per player was used which would have been less restrictive than the pitch dimensions used in the present study which may have stimulated both a greater total distance covered and a greater distance covered at >18.1 km·h^{-1}. The present study therefore provides novel findings for possession based SSGs played on smaller pitch sizes with reduced game durations.

As mentioned previously, total distance covered has recently shown large to very large correlations with PL in football MP (Casamichana, Castellano, Calleja-Gonzalez, Román and Castagna, 2013). However, although distance may account for a high proportion of PL during SSGs, it should be noted that the total distance covered per min was homogenous across conditions. Therefore, the greater PLacc.min^{-1} values reported in SSGs may have been a result of the confinements of the pitch dimensions and the rules used in which the relationship between PLacc.min^{-1} and total distance covered per min is somewhat different than observed in MP where there is a greater opportunity to accumulate distance in high-speed running (Cormack et al., 2013b). Interestingly, SSGs evoked less DC.min^{-1} at >15.1 km·h^{-1} than MP and therefore the PL differences cannot be attributed to the distance covered in high-speed running. A possible explanation for the differences in PLacc.min^{-1} could be attributed to the higher intensity of acceleration and deceleration and discrete non-distance contributing activities such as duelling, tackling and blocking that also contribute to PL. Acceleration elicits a greater metabolic demand as well as a greater neural activation of the working muscles compared to constant speed running (Mero and Komi, 1986). The small pitch dimensions used in the present study would have limited the players ability to maintain a constant speed and would have evoked a greater number of changes in direction and thus, acceleration and decelerations in comparison to MP. Furthermore, the smaller relative pitch dimension per player is less during SSGs in comparison to MP (1:75 vs. 1:273 m^2), therefore increasing the frequency of contacts and duels, which contribute to PL. Therefore, it appears that the greater PLacc.min^{-1} reported for SSGs in the present study are likely due to the physical response to acceleration and deceleration activities in addition to the discrete, non-distance contributing activities.

As previously mentioned, all SSGs used in the present study evoked greater PLacc.min^{-1} for all positional roles in comparison to MP. The greatest PLacc.min^{-1} values during 2 vs. 2 SSGs were reported for FW with the lowest values for CD. During 3 vs. 3 and 4 vs. 4 SSGs, CM reported the greatest PLacc.min^{-1} with CD and WD reporting the lowest values for 3 vs. 3 and 4 vs. 4 SSGs, respectively. Therefore, similar to the acceleration and deceleration results in the previous section, SSGs may provide a ‘density’ type-training stimulus. Small-sided games played as 2 vs. 2 and 3 vs. 3 may be more appropriate for the development of all positional roles at the start of the training week when training intensity and volume is typically higher. On the other hand, SSGs played as 4 vs. 4 may be more appropriate closer to competition due to the reduction in intensity.

Player load now provides sport scientists with an objective measure of total external load, which include non-distance contributing activities that can be used to differentiate training and competition demands of team sports (Montogomery et al., 2010). However, quantifying the magnitude of accelerations / decelerations in each planar axes may provide an even greater understanding of the position-specific movement patterns. To the researcher's knowledge, there is no study to date that has quantified the contribution of PL from each planar axes.

4.6 Physical load in the individual X, Y and Z vectors

Alongside acceleration and deceleration profiles and PL, the present study provides position-specific information regarding the contribution of physical load from the individual X, Y and Z vectors using accelerometers for SSGs and MP, which has not previously been researched. The novel findings of the present study were that physical load in the X, Y and Z vectors were greater in all SSGs for all positional roles in comparison to MP, though the interaction was not to level of significance. In addition, a significant main effect for condition was found in each axes in which mean physical load in the X, Y and Z vectors decreased as the number of players increased. Similarly, a significant main effect was found for positional role was found in which CM reported the greatest physical load values in the X, Y and Z axes across all conditions with CD reporting the lowest values. To the authors knowledge this is the only study to date that has quantified the magnitude of movement in each individual planar axes in football.

The physical load in the X axes was relatively homogenous across positional roles during MP. Despite CM engaging in more moderate-intensity activity more frequently, and for longer durations than other position roles (Di salvo et al., 2007), Rienzi et al. (2000) and Bloomfield et al. (2007) identified that CD performed the greatest distance whilst moving laterally. Baroni, Wiest, Generosi, Vaz and Junior (2011) found that fatigue compromises the postural stability of football players. Moreover, 15 % medial-lateral displacement was observed pre- and post-fatigue inducing exercise. Therefore, the homogenous values observed across positions may be explained by the lateral movement demands for CD, whereas other positional roles may accumulate a greater medial-lateral displacement when passing or shooting following high-intensity activity. The SSGs used in the present study elicited a significantly greater physical load in the X axes in comparison to MP, which could possibly be explained by the frequency of high-intensity accelerations / decelerations which may affect medial-lateral displacement when performing technical activities. The results could also be a result of the smaller pitch dimensions eliciting rapid changes of direction or "shuffling" (lateral) movements during SSGs.

With regards to the physical load values in the Y (anterior-posterior) axes, FW reported the greatest values with CD reporting the lowest values, though not to a level of significance. A possible explanation for the differences could be that FW covered greater distances at 12.1-18 $km \cdot h^{-1}$ and ± >1 $m \cdot s^{-2}$. Movement at these high intensities would likely result in anterior-posterior changes of upper body position (i.e. forward and backward lean) and therefore a greater distance covered during high-intensity activities would increase the acceleration values in the Y axes. Cormack, Mooney, Morgan and McGuigan (2013a) observed an inverse relationship between anterior-posterior acceleration and high-speed running in a fatigued state and suggested that fewer anterior-posterior changes of upper body position could indicate a less $TDC.min^{-1}$ in high-speed running. This is supported by the significantly greater Y axes values reported during all SSGs than MP with values decreasing as the number of players increase. Furthermore, a greater distance covered at ± >1 $m \cdot s^{-2}$ was reported for 2 vs. 2 and 3 vs. 3 in comparison to 4 vs. 4 suggesting that a greater number of accelerations in the SSGs and therefore greater changes in upper body positions.

Central midfielders reported the greatest physical loads in the Z (caudal-cranial) axes with CD reporting the lowest values during MP, though again not to a level of significance. Although the data do not provide a definite conclusion to why CM report the greatest values, it is possible that accelerations measured in the vertical plane reflect PL accumulated from running and the associate vertical displacement. If, as previous work in netball, hockey and Australian football suggested players that run at a higher intensity (including high-speed running, accelerating / decelerating involving more rapid vertical displacement than slower speed running), this could account for the greater contribution from the vertical vector (Brewer, Dawson, Heasman, Stewart and Cormack, 2010; Hobara et al., 2010; Jennings, Cormack, Coutts and Aughey, 2012). This notion is supported by the significantly greater physical loads in the Z axes during SSGs in comparisons to MP. Indeed, results from the present study have demonstrated that although SSGs do not evoke high-speed running, they impose a large physical demand on players through a greater accumulation of accelerations and decelerations. Cormack et al. (2013a) found reductions in the Z-vector accelerometer in the fatigued state. Given that neuromuscular fatigue directly impairs the ability to sprint or accelerate / decelerate; this provides further support to the contribution of high intensity activities such as acceleration / deceleration and sprinting to Z-vector accelerometer.

4.7 Practical applications

Previous time-motion analysis studies reporting distance or time spent in certain speed zones have underestimated the external demands of MP and more importantly, SSGs. Practitioners should therefore assess the frequency and magnitude of accelerations / decelerations to provide a complete profile of external load. When these parameters are included in analysis, SSGs played on small pitch dimensions impose a significantly greater physical demand than previously thought based on the lack of distance covered at high-speed running. Therefore, eccentric conditioning drills are encouraged to prepare players for the demands of SSGs and MP.

Despite a greater understanding of the physical demands of training and MP, practitioners are now presented with similar challenges to those experienced when interpreting the wealth of information acquired from traditional time-motion analysis. To overcome the challenge of the time-consuming nature of time-motion analysis, a practical solution could be the amalgamation of time-motion analysis into a single objective measure of external load such as PL. However, until this method is refined, it is suggested that practitioners adopt a similar approach to Rugby League (Gastin et al., 2014), in which a combination of accelerometer data and video recording would produce more useful and practical information regarding a match or training session.

Practitioners are advised to develop position specific drills that mimic the physical, technical and tactical aspects of the game while simultaneously overloading the players. To achieve this it is recommended that during SSGs are played with goals (without goalkeepers) in which players assume their specific positional roles. It has been reported that SSGs played without goalkeepers increase the intensity of the games (Mallo and Navaro, 2008). Further, teams tend to increase their defensive organisation to better protect the goal during games without goalkeepers, making the offensive process more cautious (Mallo and Navaro, 2008). If however, the primary aim of a particular session is to overload players through increased acceleration / deceleration movement, then SSGs played in a similar format to those used in the present study is suggested.

4.8 Limitations

There are several limitations to the present study, which must be considered when interpreting the findings. For instance, the participants comprised of players from both English and Portuguese teams. Although the players were similar in performance standards, environmental and cultural factors may have affected the results. English football is characterised as forthright, fast and physical, whereas Portuguese football is characterised as creative, skill-full and possession orientated (Rienzi et al., 2000; Brown, 2002). Further, environmental factors such as temperature and humidity were not controlled which may have affected the physiological responses as previously discussed in chapter 1.3. This is accepted as a flaw in the study design and future studies should use participants from the same team.
It has been reported that high-speed running activity in an elite football team as a whole for a series of eight matches played reported a % CV values of 30 % (Carling, Le Gall and Dupont, 2011). Therefore, there are large match-to-match variances that should be taken into consideration when interpreting the findings. The variance in intense activity and player load between several small-sided games is currently unknown and is therefore considered a limitation of the present study.

The validity and reliability of the 5 Hz GPS system used in the present study has been reported. These systems are not as sensitive to the rapid, multi-directional actions that occur during match play and more frequently during small-sided games. More recent GPS units that sample at 10 and 15 Hz have been found to be more accurate for distance measurement during short, intense actions (Castellano et al., 2011; Akenhead et al., 2013).

The present study, as with many previous studies employing time-motion analysis, used arbitrary speed and acceleration zones thereby restricting the interpretation of relative physiological demands. However, given the complexity of movement patterns inherent in football, there is currently no consensus on how to establish individual limits from which to affirm relative intensities. Although the current study used speed zones proposed for young soccer players by Aslan et al. (2012), individual players from the same positional role may elicit different physiological responses when moving in the same speed zone.

The matches used in the present study were not official competitions, because the Football Association prohibits the use of any device worn by a player to monitor performance such as those used in the present study. It is only speculative, but the differences observed in the physiological and physical profiles might be even greater if SSGs were compared with competitive rather than friendly MP (Gabbett and Mulvey, 2008).

A further limitation was that players were analysed during different periods of the season. For example, some players were analysed prior to the commencement of the football season, whereas others were analysed at the end of the football season. Indeed, fatigue may have influenced the results of those at the end of the football; however, these players are expected to be match sharp. Recent research has demonstrated that in elite youth female football players, acceleration, sprint and change of direction performance degrades over the course of a season (Taylor, Portas, Wright, Hurst and Weston, 2012). In contrary, the players that were analysed prior to the football season would not have accumulated fatigue, but would be expected to be less match sharp. Unfortunately, time constraints meant that it was not possible to test players at the same time and therefore this should be taken into consideration when interpreting the results. Future research should collect all of the data at the same time to limit the effects of fatigue.

4.9 Directions for future research

Through investigation of an alternative measure to objectively quantify the external load of MP and SSGs, this thesis has highlighted further avenues for future research. As alluded to in the previous section, the current study examined players from both English and Portuguese teams. Despite this being the main limitation, future research may seek to establish whether there are differences in the physical responses to MP and SSGs between English and Portuguese players. Such information, would aid coaches when prescribing appropriate training programs to players that have recently transferred clubs. Unfortunately, this study was unable to make comparisons between players of different geographical locations due to the limited sample size.

The friendly matches and SSGs in this study were played on 3G surfaces, and currently to the author’s knowledge; the influence of playing surface on PL has not been investigated. Previous research using traditional time-motion analysis measures reported that the physical and technical demands of synthetic and grass surfaces are not significantly different (Andersson, Ekblom and Krustrup, 2008). However, as mentioned continuously throughout this thesis, traditional time-motion analysis systems underestimate total external load through omitting discrete actions such as accelerations / declarations. Therefore, future research should determine the total external load demands of football on different playing surfaces through accelerometer measures such as PL.

4.10 Conclusion

In conclusion, this study provides novel findings into the differences in PL generated from triaxial accelerometer between SSGs and MP for different positional roles. As a result, this technology may provide a practical and useful tool for assessing activity profile in football. Central midfielders reported the greatest PL values during MP providing further support for the considerably greater work-rate demands for this positional role. Small-sided games evoked considerably greater PL and acceleration / deceleration values for all positional roles in comparison to MP, suggesting that previous time-motion analysis research using traditional constant-speed zones have underestimated the demands of football. Whilst the relative contribution of the X, Y and Z vectors to PL does not appear practically different between positional rules during MP, the greater values reported in SSGs suggest that these games may provide a 'density' type-training stimulus through imposing relative demands on acceleration and deceleration abilities in excess of those experienced during MP.

5. References

Abt, G. and Lovell, R. (2009) The use of individualized speed and intensity thresholds for determining the distance run at high-intensity in professional soccer. *Journal of Sports Sciences*, 27(9), 893-898.

Achten, J. and Jeukendrup, A.E. (2003) Heart rate monitoring: applications and limitations. *Sports Medicine*, 33(7), 517-538.

Ade, J.D., Harley, J.A. and Bradley, P.S. (2014) Physiological response, time-motion characteristics, and reproducibility of various speed-endurance drills in youth soccer players: small-sided games versus generic running. *International Journal of Sports Physiology and Performance*, 9, 471-479.

Aguiar, M.V.D., Bothelho, G.M.A., Gonçalves, B.S.V. and Sampaio, J.E. (2013) Physiological responses and activity profiles of football small-sided games. *Journal of Strength and Conditioning Research*, 27(5), 1287-1294.

Akenhead, R., Hayes, P.R., Thompson, K.G. and French, D. (2012) Diminutions of acceleration and deceleration output during professional football match-play. *Journal of Science and Medicine in Sport*, 16(6), 556-561.

Akenhead, R., French, D., Thompson, K.G. and Hayes, P.R. (2013) The acceleration dependent validity and reliability of 10Hz GPS. *Journal of Science and Medicine in Sport*, 17(5), 562-566.

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

Ali, A. and Farrally, M. (1991a) A computer-video aided time motion analysis technique for match analysis. *The Journal of Sports Medicine and Physical Fitness*, 31(1), 82-88.

Ali, A. and Farrally, M. (1991b) Recording soccer players' heart rates during matches. *Journal of Sport Sciences*, 9(2), 183-189.

Andersson, H., Ekblom, B. and Krustrup, P. (2008) Elite football on artificial turf versus natural grass: movement patterns, technical standards, and player impressions. *Journal of Sports Sciences*, 26(2), 113-122.

Aroso, J., Rebelo, A.N. and Gomes-Pereira, J. (2004) Physiological impact of selected game-related exercises. *Journal of Sport Science*, 22, 522.

Aslan, A., Acikada, C., Güvenç, A., Gören, H., Hazir, T. and Özkara, A. (2012) Metabolic demands of match performance in young soccer players. *Journal of Sport Science and Medicine,* 11(4), 170-179.

Aughey, R.J. (2011) Applications of GPS technologies to field sports. *International Journal of Sports Physiology and Performance*, 6, 295-310.

Bangsbo, J., Nørregaard, L. and Thorsø, F. (1991) Activity profile of competition soccer. *Canadian Journal of Sport Sciences*, 16(2) 110-116.

Bangsbo, J., Johansen, L., Graham, T. and Saltin, B. (1993) Lactate and H^+ effluxes from human skeletal muscles during intense, dynamic exercise. *Journal of Physiology*, 462, 115-133.

Bangsbo, J. (1994a) Energy demands in competitive soccer. *Journal of Sport Sciences*, 12, S5-S12.

Bangsbo, J. (1994b). The physiology of soccer--with special reference to intense intermittent exercise. *Acta Physiologica Scandinavica*, 619, 1-155.

Bangsbo, J., Mohr, M. and Krustrup, P. (2006) Physical and metabolic demands of training and match-play in the elite football player. *Journal of Sport Sciences*, 24(7), 665-674.

Bangsbo, J., Mohr, M., Poulsen, A., Perez-Gomez, J. and Krustrup, P. 2006. Training and testing the elite athlete. *Journal of Exercise Science and Fitness*, 4(1), 1-14.

Bangsbo, J., Iaia, F.M. and Krustrup, P. (2007) Metabolic response and fatigue in soccer. *International Journal of Sports Physiology and Performance*, 2(2), 111-127.

Bangsbo, J. (2014) Physiological demands of football. *Sport Science Exchange*, 27(125), 1-6.

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

Barberó-Álvarez, J.C., Boullose, D., Nakamura, F.Y., Andrín, G., Weston, M. (2014) Repeated Acceleration Ability (RAA): A New Concept with Reference to Top-Level Field and Assistant Soccer Referees. *Asian Journal of Sports Medicine*, 5(1), 63-66.

Barnes, C., Archer, D.T., Hogg, B., Bush, M. and Bradley, P.S. (2014) The evolution of physical and technical performance parameters in the English Premier League. *International Journal of Sports Medicine*, 35(13), 1-6.

Baroni, B.M., Wiest, M.J., Generosi, R.A., Vaz, M.A. and Junior, E.C.P.L. (2011) Effect of muscle fatigue on posture control in soccer players during the short-pass movement. *Brazilian Journal of Kinanthropometry and Human Performance*, 13(5), 348-353.

Barron, D.J., Atkins, S., Edmundson, C. and Fewtrell, D. (2014) Accelerometer derived load according to playing position in competitive youth soccer. *International Journal of Performance Analysis in Sport*. 14, 734-743.

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

Beanland, E., Main, L.C., Aisbett, B., Gastin, P. and Netto, K. (2014) Validation of GPS and accelerometer technology in swimming. *Journal of Science and Medicine in Sport*, 17(2), 234-238.

Bloomfield, J., Polman, R. and O'Donoghue, P. (2007) Physical demands of different positions in FA Premier League soccer. *Journal of Sport Science and Medicine*, 6(1), 63-70.

Borresen, J. and Lambert, M.I. (2008) Autonomic control of heart rate during and after exercise: measurements and implications for monitoring training status. *Sports Medicine*, 38(8), 633-646.

Bouten, C.V., Westerterp, K.R., Verduin, M. and Janssen, J.D. (1994) Assessment of energy expenditure for physical activity using a tri-axial accelerometer. *Medicine and Science in Sports Exercise*, 26(12), 1516-1523.

Boyd, L.J., Ball, K. and Aughey, R.J. (2011) The reliability of MinimaxX accelerometers for measuring physical activity in Australian football. *International Journal of Sports Physiology and Performance*, 6(3), 311-321.

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

Bradley, P.S., Di Mascio, M., Peart, D., Olsen, P. and Sheldon, B. (2009b) High-intensity activity profiles of elite soccer players at different performance levels. *Journal of Strength and Conditioning Research*, 24(9), 2343-2351.

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

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

Brewer, C., Dawson, B., Heasman, J., Stewart, G. and Cormack, S. (2010) Movement pattern comparisons in elite (AFL) and sub-elite (WAFL) Australian football games using GPS. *Journal of Science and Medicine in Sport*, 13(6), 618-623.

Buchheit, M., Delhomel, G. and Ahmaidi, S. (2008) Time-motion analysis of elite young French soccer players. *Coaching Sport Science*, 3(2), 21.

Buchheit, M., Mendez-Villanueva, A., Simpson, B.M. and Bourdon, P.C. (2010) Match running performance and fitness in youth soccer. *International Journal of Sports Medicine*, 31(11), 818-825.

Buchheit, M., Al Haddad, H., Simpson, B.M., Palazzi, D., Bourdon, P.C., Di Salvo, V., Mendez-Villanueva, A. (2014) Monitoring accelerations with GPS in football: time to slow down? *International Journal of Sports Physiology and Performance*, 9(3), 442-445.

Carling, C., Bloomfield, J., Nelsen, L. and Reilly, T. (2008) The role of motion analysis in elite soccer: contemporary performance measurement techniques and work rate data. *Sports Medicine*, 38(10), 839-862.

Carling, C., Le Gall, F., Dupont, G. (2011) Are physical performance and injury risk in a professional soccer team in match play affected over a prolonged period of fixture congestion? *International Journal of Sports Medicine*, 33(1), 36-42.

Casajús, J.A. (2001) Seasonal variation in fitness variables in professional soccer players. *Journal of Sports Medicine and Physical Fitness*, 41(4), 463-467.

Casamichana, D. and Castellano, J. (2010) Time-motion, heart rate, perceptual and motor behaviour demands in small-sides soccer games: effects of pitch size. *Journal of Sports Sciences*, 28(14), 1615-1623.

Casamichana, D., Castellano, J. and Castagna, C. (2012) Comparing the physical demands of friendly matches and small sided games in semiprofessional soccer players. *Journal of Strength and Conditioning Research*, 26(3), 837-843.

Casamichana, D., Castellano, J., Calleja-Gonzalez, J., San Román, J. and Castagna, C. (2013) Relationship between indicators of training load in soccer players. *Journal of Strength and Conditioning Research*, 27(2), 369-374.

Castagna, C., D'Ottavio, S. and Abt, G. (2003) Activity profile of young soccer players during actual match play. *Journal of Strength and Conditioning Research*, 17(4), 775-780.

Castellano, J., Casamichana, D., Calleja-González, J., San Román, J. and Ostojic S.M. (2011) Reliability and accuracy of 10 Hz GPS devices for short-distance exercise. *Journal of Sport Science and Medicine*, 10(1), 233-234.

Castellano, J., Casamichana, D. and Dellal, A. (2013) Influence of game format and number of players on heart rate responses and physical demands in small-sided soccer games. *Journal of Strength and Conditioning Research*, 27(5), 1295-1303.

Cavagna, G., Saibene, F. and Margaria, R. (1961) A three-directional accelerometer for analyzing body movements. *Journal of Applied Physiology*, 16, 191.

Clemente, F.M., Martins, F.M.L. and Mendes, R.S. (2014) Developing aerobic and anaerobic fitness using small-sided soccer games: methodological proposals. *Strength and Conditioning*, 36(3), 76-87.

Coe, D. and Pivarnik, J.M. (2001) Validation of the CSA accelerometer in adolescent boys during basketball practice. *Pediatric Exercise Science*, 13(4), 373-379.

Cormack, S.J., Mooney, M.G., Morgan, W. and McGuigan, M.R. (2013) Influence of neuromuscular fatigue on accelerometer load in elite Australian football players. *International Journal of Sports Physiology and Performance*, 8(4), 373-378.

Cormack, S., Smith, R., Mooney, M., Young, W. and O'Brien, B. (2013) Accelerometer load as a measure of activity profile in different standards of Netball match play. *International Journal of Sports Physiology and Performance*, 9(2), 283-291.

Corvino, M., Tessitore, A., Minganti, C. and Sibila, M. (2014) Effect of court dimensions on players' external and internal load during small-sided handball Games. *Journal of Sport Science and Medicine*, 13(2), 297-303.

Coutts, A.J. and Duffield, R. (2010) Validity and reliability of GPS devices for measuring movement demands of team sports. *Journal of Science and Medical Sport*, 13(1), 133-135.

Cummins, C., Orr, R., O'Connor, H. and West, C. (2013) Global Positioning Systems (GPS) and microtechnology sensors in team sports: a systematic review. *Sports Medicine*, 43(10), 1025-1042.

Cunniffe, B., Proctor, W., Baker, J.S. and Davies, B. (2009) An evaluation of the physiological demands of elite rugby union using Global Positioning System tracking software. *Journal of Strength and Conditioning Research*, 23(4), 1195-1203.

Dawson, B., Hopkinson, R., Appleby, B., Stewart, G. and Roberts, C. (2004) Player movement patterns and game activities in the Australian Football League. *Journal of Science and Medicine in Sport*, 7(3), 278-291.

Dellal, A., Chamari, K., Pintus, A., Girard, O., Cotte, T. and Keller, D. (2008) Heart rate responses during small-sided games and short intermittent running training in elite soccer players: a comparative study. *Journal of Strength and Conditioning Research*, 22(5), 1449-1457.

Dellal, A., Hill-Haas, S., Lago-Penas, C. and Chamari, K. (2011a). Small-sided games in soccer: amateur vs. professional players' physiological responses, physical, and technical activities. *Journal of Strength and Conditioning Research*, 25(9), 2371-2381.

Dellal, A., Chamari, C., Wong, D.P., Ahmaidi, S., Keller, D., Barros, R.M.L., Bisciotti, G.N. and Carling, C. (2011b) Comparison of the physical and technical performance in

European professional soccer match-play: The FA Premier League and LIGA. *European Journal of Sport Science*, 11(1), 51-59.

Dellal, A., Chamari, K., Owen, A. L., Wong, P.L., Lago-Penas, C. and Hill-Haas, S. (2011c) Influence of technical instructions on the physiological and physical demands of small-sided soccer games. *European Journal of Sport Science*, 11 (5) 341-346.

Dellal, A., Drust, B. and Lago-Penas, C. (2012a) Variation of activity demands of small-sided soccer games. *International Journal of Sport Medicine*, 33(5), 370-375.

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

Dellal, A., Da Silva, C.D., Hill-Haas, S., Wong, D.P., Natali, A.J., De Lima, J.R.P., Bara Filho, M.G.B., Marins, J.J.C.B., Garcia, E.S. and Karim, C. (2012c) Heart rate monitoring in soccer: interest and limits during competitive match play and training, practical application. *The Journal of Strength and Conditioning Research*, 26(10), 2890-2906.

Di Salvo, V., Collins, A., McNeill, B. and Cardinale, M. (2006) Validation of Prozone ®: A new video-based performance analysis system. *International Journal of Performance Analysis in Sport*, 6(1), 108-119.

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

Di Salvo, V., Benito, P.J., Calderón, F.J., Di Salvo, M. and Pigozzi, F. (2008) Activity profile of elite goalkeepers during football match-play. *The Journal of Sports Medicine and Physical Fitness*, 48(4), 443-446.

Di Salvo, V., Gregson, W., Atkinson, G., Tordoff, P. and Drust, B. (2009) Analysis of high intensity activity in Premier League soccer. *International Journal of Sports Medicine*, 30(3), 205-212.

Di Salvo, V., Barron, R., González-Haro, C., Gormasz, C., Pigozzi, F. and Bachl, N. (2010) Sprinting analysis of elite soccer players during European Champions League and UEFA Cup matches. *Journal of Sports Sciences*, 28(14), 1-6.

Dobson, B.P. and Keogh, J.W.L. (2007) Methodological issues for the application of time-motion analysis research. *Strength and Conditioning Journal*, 29(2), 48-55.

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

Duffield, R., Reid, M., Baker, J. and Spratford, W. (2010) Accuracy and reliability of GPS devices for measurement of movement patterns in confined spaces for court-based sports. *Journal of Science and Medicine in Sport*, 13(5), 523-525.

Dupont, G., Akakpo, K. and Berthoin, S. (2004) The effect of in-season, high-intensity interval training in soccer players. *Journal of Strength and Conditioning Research*, 18(3), 584-589.

Edgecomb, S.J. and Norton, K.I. (2006) Comparison of global positioning and computer-based tracking systems for measuring player movement distance during Australian football. *Journal of Science and Medicine in Sport*, 9(1-2), 25-32.

Edwards, A.M. and Clark, N.A. (2006) Thermoregulatory observations in soccer match-play: professional and recreational level applications using an intestinal pill system to measure core temperature. *British Journal of Sports Medicine*, 40(2), 133-138.

Ekblom, B. (1986) Applied physiology of soccer. *Sports Medicine*, 3(1), 50-60.

Esposito, F., Impellizzeri, F.M., Margonato, V., Vanni, R., Pizzini, G. and Veicsteinas, A. (2004) Validity of heart rate as an indicator of aerobic demand during soccer activities in amateur soccer players. *European Journal of Applied Physiology*, 93(1-2), 167-172.

Faude, O., Koch, T. and Meyer, T. (2012) Straight sprinting is the most frequent action in goal situations in professional football. *Journal of Sport Sciences*, 30(7), 625-631.

Freckleton, G. and Pizzari, T. (2013) Risk factors for hamstring muscle strain injury in sport: a systematic review and meta-analysis. *British Journal of Sports Medicine*, 47(6), 351-358.

Fudge, B.W., Wilson, J., Easton, C., Irwin, L., Clark, J., Haddow, O., Kayser, B. and Pitsiladis, Y.P. (2007) Estimation of oxygen uptake during fast running using accelerometry and heart rate. *Medicine & Science in Sports & Exercise*, 39(1), 192-198.

Gabbett, T.J. (2006) Skill-based conditioning games as an alternative to traditional conditioning for rugby league players. *Journal of Strength Conditioning Research*, 20(2), 309-315.

Gabbett, T.J. and Mulvey, M.J. (2008) Time-motion analysis of small-sided training games and competition in elite women soccer players. *Journal of Strength and Conditioning Research*, 22(2), 543-552.

Gabbett, T., Jenkins, D. and Abernethy, B. (2009) Game-based training for improving skill and physical fitness in team sport athletes. *International Journal of Sports Science and Coaching*, 4(2), 273-283.

Gabbett, T.J. (2010) GPS analysis of elite women's field hockey training and competition. *Journal of Strength and Conditioning Research*, 24(5), 1321-1324.

Gabbett, T., Jenkins, D. and Abernethy, B. (2010) Physical collisions and injury during professional rugby league skills training. *Journal of Science and Medicine in Sport*, 13(6), 578-583.

Gastin, P.B., McLean, O.C., Breed, R.V. and Spittle, M. (2014) Tackle and impact detection in elite Australian football using wearable microsensor technology. *Journal of Sport Sciences*, 32(10), 947-953.

Gaudino, P., Iaia, F.M., Alberti, G., Strudwick, A.J., Atkinson, G. and Gregson, W. (2013) Monitoring training in elite soccer players: systematic bias between running speed and metabolic power data. *International Journal of Sports Medicine*, 34(11), 963-968.

Gaudino, P., Alberti, G. and Iaia, F.M. (2014) Estimated metabolic and mechanical demands during different small-sided games in elite soccer players. *Human Movement Science*, 36, 123-133.

Giulianotti, R. and Robertson, R. (2004) The globalization of football: a study in the glocalization of the 'serious life'. *The British Journal of Sociology*, 55(4), 545-568.

González-Alonso, J., Mora-Rodríguez, R., Below, P.R. and Coyle, E.F. (1997) Dehydration markedly impairs cardiovascular function in hyperthermic endurance athletes during exercise. *Journal of Applied Physiology*, 82(4), 1229-1236.

González-Alonso, J., Teller, C., Andersen, S.L., Jensen, F.B., Hyldig, T. and Nielsen, B. (1999) Influence of body temperature on the development of fatigue during prolonged exercise in the heat. *Journal of Applied Physiology*, 86(3), 1032-1039.

GPSports. (2013) *Understanding GPS Tracking.* [online] Available at: < http://www.gpsports.com/support/FAQ_GPS_Tracking.pdf> [Accessed 11 April 2014].

Gray, A.J., Jenkins, D., Andrews, M.H., Taaffe, D.R. and Glover, M.L. (2010) Validity and reliability of GPS for measuring distance travelled in field-based team sports. *Journal of Sports Sciences*. 28(12), 1319-1325.

Gregson, W., Drust, B., Atkinson, G. and Salvo, V.D. (2010) Match-to-match variability of high-speed activities in Premier League Soccer. *International Journal of Sports Medicine*, 31(4), 237-242.

Harley, J.A., Barnes, C.A., Portas, M., Lovell, R., Barrett, S., Paul, D. and Weston, M. (2010) Motion analysis of match-play in elite U12 to U16 age-group soccer players. *Journal of Sport Science*, 28(13), 1391-1397.

Harley, J.A., Lovell, R.J., Barnes, C.A., Portas, M.D. and Weston, M. (2011). The interchangeability of Global Positioning System and semiautomated video-based performance data during elite soccer match play. *Journal of Strength and Conditioning Research*, 25(8), 2334-2336.

Helgerud, J., Engen, L.C., Wisløff, U. and Hoff, J. (2001) Aerobic endurance training improves soccer performance. *Medicine and Science in Sport and Exercise*, 33(11), 1925-1931.

Hill-Haas S.V., Coutts A.J., Dawson B.T. and Rowsell G.J. (2010) Time-motion characteristics and physiological responses of small-sided games in elite youth players: the influence of player number and rule changes. *Journal of Strength and Conditioning Research*, 24(8), 2149-2156.

Hill-Haas, S.V., Dawson, B., Impellizzeri, F.M. and Coutts, A.J. (2011) Physiology of small-sided games training in football: a systematic review. *Sports Medicine*, 41(3), 199-220.

Hobara, H., Inoue, K., Gomi, K., Sakamoto, M., Muraoka, T., Iso, S. and Kanosue, K. (2010) Continuous change in spring-mass characteristics during a 400 m sprint. *Journal of Science and Medicine in Sport*, 13(2), 256-261.

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

Hoff, J., Wisløff, U., Engen, L.C., Kemi, O.J. and Helgerud, J. (2002) Soccer specific aerobic endurance training. *British Journal of Sport Medicine*, 36(3), 218-221.

Hopkins, W.G., Hawley, J.A. and Burke, L.M. (1999) Design and analysis of research on sport performance enhancement. *Medicine and Science in Sport and Exercise*, 31(3), 472-485.

Hoshikawa, Y., Iida, T., Muramatsu, M., Nakajima, Y., Fukunaga, T. and Kanehisa, H. (2009) Differences in thigh muscularity and dynamic torque between junior and senior soccer players. *Journal of Sport Sciences*, 27(2), 129-138.

Hughes, M. and Franks, I. (2005) Analysis of passing sequences, shots and goals in soccer. *Journal of Sport Science*, 23(5), 509-514.

Hurst, H.T. and Sinclair, J. (2013) Validity and reliability of 5 Hz GPS for measurement of non-linear cycling distance and velocity. *International Journal of Sports Science and Engineering*, 7(1), 11-16.

Iaia, F.M., Rampinini, E. and Bangsbo, J. (2009) High-intensity training in football. *International Journal of Sports Physiology and Performance*, 4(3), 291-306.

Jakicic, J.M., Winters, C., Lagally, K., Ho, J., Robertson, R.J. and Wing, R.R. (1999) The accuracy of the TriTrac-R3D accelerometer to estimate energy expenditure. *Medicine and Science in Sport and Exercise*, 31(5), 747-754.

Jennings, D., Cormack, S., Coutts, A.J., Boyd, L. and Aughey, R.J. (2010) The validity and reliability of GPS units for measuring distance in team sport specific running patterns. *International Journal of Sports Physiology and* Performance, 5(3), 328-341.

Jennings, D., Cormack, S., Coutts, A.J., Boyd, L. and Aughey, R.J. (2012) International field hockey players perform more high-speed running than national-level counterparts. *Journal of Strength and Conditioning Research*, 26(4), 947-952.

Johnston, R.J., Watsford, M.L., Kelly, S.J., Pine, M.J. and Spurrs, R.W. (2013) Validity and interunit reliability of 10 Hz and 15 Hz GPS units for assessing athlete movement demands. *Journal of Strength and Conditioning Research*, 28(6), 1649-1655.

Junge, A. and Dvorak, J. (2013) Injury surveillance in the World Football Tournaments 1998–2012. *British Journal of Sports Medicine*, 47(12), 782-788.

Karlsson, J., Nordesjö, L.O., Jorfeldt, L. and Saltin, B. (1972) Muscle lactate, ATP, and CP levels during exercise after physical training in man. *Journal of Applied Physiology*, 33(2), 199-203.

Knowles, J.E. and Brooke, J.D. (1974) A movement analysis of player behaviour in soccer match performance. *In Proceedings: 8th conference on The British Society of Sport Psychology*, University of Salford, 246-256.

Kostis, J.B., Moreyra, A.E., Amendo, M.T., Pietro, J., Cosgrove, N. and Kuo, P.T. (1982) The effect of age on heart rate in subjects free of heart disease. Studies by ambulatory electrocardiography and maximal exercise stress test. *Circulation* 65(1), 141-145.

Kozey, S.L., Lyden, K., Howe, C.A., Staudenmayer, J.W. and Freedson, P.S. (2010) Accelerometer output and MET values of common physical activities. *Medicine in Sport and Exercise Science*, 42(9), 1776-1784.

Krasnoff, J.B., Kohn, M.A., Choy, F.K., Doyle, J., Johansen, K. and Painter, P.L. (2008) Interunit and intraunit reliability of the RT3 triaxial accelerometer. *Journal of Physical Activity and Health*, 5(4), 527-538.

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

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

Krustrup, P., Mohr, M., Steensberg, A., Bencke, J., Kjaer, M. and Bangsbo, J. (2006) Muscle and blood metabolites during a soccer game: implications for sprint performance. *Medicine and Science in Sport and Exercise*, 38(6), 1165-1174.

Larsson, P. (2003) Global Positioning System and sport-specific testing. *Sports Medicine*, 33(15), 1093-1101.

Levine, J.A., Baukol, P.A. and Westerterp K.R. (2001) Validation of the Tracmor triaxial accelerometer system for walking. *Medicine and Science in Sport and Exercise*, 33(9), 1593-1597.

Little, T. and Williams, A.G. (2006) Suitability of soccer training drills for endurance training. *Journal of Strength and Conditioning Research*, 20(2), 316-319.

Little, T. and Williams, A.G. (2007) Measures of exercise intensity during soccer training drills with professional soccer players. *Journal of Strength and Conditioning*, 21(2), 367-371.

MacLeod, H., Morris, J., Nevill, A. and Sunderland, C. (2009) The validity of a non-differential Global Positioning System for assessing player movement patterns in field hockey. *Journal of Sport Sciences*, 27(2), 121-128.

Mallo, J. and Navarro, E. (2008) Physical load imposed on soccer players during small-sided training games. *The Journal of Sports Medicine and Physical Fitness*, 48(2), 166-171.

McLellan, C.P., Lovell, D.I. and Gass, G.C. (2011) Performance analysis of elite Rugby League match play using Global Positioning Systems. *Journal of Strength and Conditioning Research*, 25(6), 1703-1710.

Mero, A. and Komi, P.V. (1986) Force-, EMG-, and elasticity-velocity relationships at submaximal, maximal and supramaximal running speeds in sprinters. *European Journal of Applied Physiology and Occupational Physiology*, 55(5), 553-561.

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

Montgomery, P.G., Pyne, D.B. and Minahan, C.L. (2010) The physical and physiological demands of basketball training and competition. *International Journal of Sports Physiology and Performance*, 5(1), 75-86.

Montoye, H.J., Washburn, R., Servais, S., Ertl, A., Webster, J.G. and Nagle, F.J. (1983) Estimation of energy expenditure by a portable accelerometer. *Medicine and Science in Sport and Exercise*, 15(5), 403-407.

Mujika, I., Spencer, M., Santisteban, J., Goiriena, J.J. and Bishop, D. (2009) Age-related differences in repeated-sprint ability in highly trained youth football players. *Journal of Sport Science*, 27(14), 1581-1590.

Müller, E., Benko, U., Raschner, C. and Schwameder, H. (2000) Specific fitness training and testing in competitive sports. *Medicine and Science in Sports and Exercise*, 32(1), 216-220.

Netto, K., Tran, J., Gastin, P. and Aisbett, B. (2010) Validity of GPS housed accelerometer data in running and cutting. *Journal of Science and Medicine in Sport*, 13(6), *Conference paper*, Deakin University.

Neville, J., Wixted, A., Rowlands, D. and James, D. (2010) Accelerometers: an underutilized resource in sports monitoring. *In Proceedings: 6th International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP)*, Brisbane, Australia, 287-290.

Nichols, J.F., Morgan, C.G., Sarkin, J.A., Sallis, J.F. and Calfas, K.J. (1999) Validity, reliability, and calibration of the Tritrac accelerometer as a measure of physical activity. *Medicine and Science in Sport and Exercise*, 31(6), 908-912.

Nicholas, C.W., Nuttall, F.E. and Williams, C. (2000) The Loughborough Intermittent Shuttle Test: A field test that simulates the activity pattern of soccer. *Journal of Sports Sciences*, 18, 97-104.

Ogushi, T., Ohashi, J., Nagahama, H., Isokawa, M. and Suzuki, S. (1993) Work intensity during soccer match-play. In: *Science and Football II*, 1st Edition. Reilly, T., Clarys, J. and Stibbe, A. (Editors), Spon Press, London.

Ohashi, J., Togari, H., Isokawa, M. and Suzuki, S. (1988) Measuring movement speeds and distance covered during soccer match-play. In: *Science and Football*, 1st Edition. Reilly, T., Lees, A., Davids, K. and Murphy, W.J. (Editors), Spon Press, London.

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

Owen, A., Twist, C. and Ford, P. (2004) Small-sided games: the physiological and technical effect of altering pitch size and player numbers. *Insight*, 2(7), 50-53.

Owen, A.L., Wong, D.P., Paul, D. and Dellal, A. (2014) Physical and technical comparisons between various-sided games within professional soccer. *International Journal of Sports Medicine*, 35(4), 286-292.

Owen, S.M., Venter, R.E., du Toit, S. and Kraak, W.J. (2015) Acceleratory match-play demands of a Super Rugby team over a competitive season**.** *Journal of Sport Sciences*, 1-9.

Petersen, C., Pyne, D., Portus, M. and Dawson, B. (2009) Validity and reliability of GPS units to monitor cricket-specific movement patterns. *International Journal of Sports Physiology and Performance*, 4(3), 381-393.

Petersen, C.J., Pyne, D.B., Dawson, B.T., Kellett, A.D. and Portus, M.R. (2011) Comparison of training and game demands of national level cricketers. *Journal of Strength and Conditioning Research*, 25(5), 1306-1311.

Philippaerts, R.M., Vaeyens, R., Janssens, M., Van Renterghem, B., Matthys, D., Craen, R., Bourgois, J., Vrijens, J., Beunen, G. and Malina, R.M. (2006) The relationship between peak height velocity and physical performance in youth soccer players. *Journal of Sport Sciences*, 24(3), 221-230.

Portas, M.D., Rush, C.J., Barnes, C.A. and Batterham, A.M. (2007) Method comparison of linear distance and velocity measurements with global positioning satellite (GPS) and the timing gate techniques. *Journal of Sport Science and Medicine*, 6(10), 7-8.

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

Puyau, M.R., Adolph, A.L., Vohra, F.A., Zakeri, I. and Butte, N.F. (2004) Prediction of activity energy expenditure using accelerometers in children. *Medicine and Science in Sport and Exercise*, 36(9), 1625-1631.

Pyne, D.B., Boston, T., Martin, D.T. and Logan, A. (2000) Evaluation of the Lactate Pro blood lactate analyser. *European Journal of Applied Physiology*, 82(1-2), 112-116.

Rampinini, E., Sassi, A., Sassi, R. and Impellizzeri, F.M. (2004) Variables influencing fatigue in soccer performance. *International Congress on Sport Rehabilitation and Traumatology. The rehabilitation of sports muscular and tendon injuries*, Milan, Italy.

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

Rampinini, E., Impellizzeri, F.M., Castagna, C., Abt, G., Chamari, K., Sassi, A. and Marcora, S.M. (2007b) Factors influencing physiological responses to small-sided soccer games. *Journal of Sport Sciences*, 25(6), 659-666.

Randers, M.B., Mujika, I., Hewitt, A., Santisteban, J., Bischoff, R., Solano, R., Zubillaga, A., Peltola, E., Krustrup, P. and Mohr, M. (2010) Application of four different football match analysis systems: A comparative study. *Journal of Sport Sciences*, 28(2), 171-182.

Rawstorn, J.C., Maddison, R., Ali, A., Foskett, A. and Gant, N. (2014) Rapid directional change degrades GPS distance measurement validity during intermittent intensity running. *PLoS ONE*, 9(4), 1-6.

Reilly, T. and Thomas, V. (1976) A motion analysis of work-rate in different positional roles in professional football match-play. *Journal of Human Movement Studies,* 2, 87-97.

Reilly, T. and Bowen, T. (1984) Exertional costs of changes in directional modes of running. *Perceptual and Motor Skills*, 58, 149-150.

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

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

Reilly, T. (2005) An ergonomics model of the soccer training process. *Journal of Sport Sciences*, 23(6), 561-572.

Reilly, T. (2007) *The Science of Training – Soccer: A Scientific Approach to Developing Strength, Speed and Endurance*. 1st Edition. Routledge, London.

Rienzi, E., Drust, B., Reilly, T., Carter, J.E. and Martin, A. (2000) Investigation of anthropometric and work-rate profiles of elite South American international soccer players. *Journal of Sports Medicine and Physical Fitness,* 40(2), 162-169.

Santa-Lozano, A., Torres-Luque, G., Marín, P.J., Ruiz, J.R., Lucia, A. and Garatachea, N. (2012) Intermonitor variability of GT3X accelerometer. *International Journal of Sports Medicine*, 33(12), 994-999.

Schutz, Y. and Chambaz, A. (1997) Could a satellite-based navigation system (GPS) be used to assess the physical activity of individuals on earth? *European Journal of Clinical Nutrition*, 51(5), 338-339.

Scott, B.R., Lockie, R.G., Knight, T.J., Clark, A.C., Xanne, A.K. and Janse de Jonge, X.A. (2013) A comparison of methods to quantify the in-season training load of professional soccer players. *International Journal of Sports Physiology and Performance,* 8(2), 195-202.

Shepard, R.J. (1999) Biology and medicine of soccer: an update. *Journal of Sport Sciences*, 17(10), 757-786.

Smith, M.P., Sizer, P.S. and James, C.R. (2009) Effects of fatigue on frontal plane knee motion, muscle activity, and ground reaction forces in men and women during landing. *Journal of Sport Science and Medicine,* 8, 419-427.

Spencer, M., Bishop, D., Dawson, B., and Goodman, C. (2005) Physiological and metabolic responses of repeated-sprint activities: specific to field-based team sports. *Sports Medicine,* 35(12), 1025-1044.

Stølen, T., Chamari, K., Castagna, C. and Wisløff, U. (2005) Physiology of soccer: an update. *Sports Medicine*, 35(6), 501-536.

Strudwick, A., Reilly, T. and Doran, D. (2002) Anthropometric and fitness characteristics of elite players in two football codes. *Journal of Sports Medicine and Physical Fitness*, 42(2), 239-242.

Taylor, M. (2008) *The Association Game: A History of British Football.* 1st Edition. Routledge, Edinburgh.

Taylor, J.M., Portas, M.D., Wright, M,D., Hurst, C. and Weston, M. (2012) Within-Season Variation of Fitness in Elite Youth Female Soccer Players. *Journal of Athletic Enhancement*, 1(2), 1-5.

Thatcher, R. and Batterham, A.M. (2004) Development and validation of a sport-specific exercise protocol for elite youth soccer players. *Journal of Sports Medicine and Physical Fitness*, 44(1), 15-22.

Thompson, D., Nicholas, C.W. and Williams, C. (1999) Muscular soreness following prolonged intermittent high-intensity shuttle running. *Journal of Sport Sciences*, 17(5), 387-395.

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

Townshead, A.D., Worringham, C.J. and Stewart, I.B. (2008) Assessment of speed and position during human locomotion using nondifferential GPS. *Medicine and Science in Sports and Exercise*, 40(1), 124-132.

Tsivgoulis, S.D., Papagelopoulos, P.J., Efstathopoulos, N., Papadakis, N.C., Kampanis, N.A., Christakis, D.G. and Katonis, P.G. (2009) Accelerometry for evaluation of gait pattern in healthy soccer athletes. *The Journal of International Medical Research,* 37(6), 1692-1700.

Tumilty, D. (1993) Physiological characteristics of elite soccer players. *Sports Medicine*, 16(2), 80-96.

Van Hees, V.T., Slootmaker, S.M., De Groot, G., Van Mechelen, W. and Van Lummel, R.C. (2009) Reproducibility of a tri-axial seismic accelerometer (DynaPort). *Medicine and Science in Sport and Exercise*, 41(4), 810-817.

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

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

Venter, R.E., Opperman, E. and Opperman, S. (2011) The use of Global Positioning System (GPS) tracking devices to assess movement demands and impacts in Under-19 Rugby Union match play. *African Journal for Physical, Health Education, Recreation and Dance,* 17(1), 1-8.

Waldron, M., Worsfold, P., Twist, C. and Lamb, K. (2011) Concurrent validity and test-retest reliability of a Global Positioning System (GPS) and timing gates to assess sprint performance variables. *Journal of Sports Sciences*, 29(15), 1613-1619.

Whyte, G.P., George, K., Shave, R., Middleton, N. and Nevill, A.M. (2008) Training induced changes in maximum heart rate. *International Journal of Sports Medicine*, 29(2), 129-133.

Williams, M. (2013) *Science and Soccer: Developing Elite Player*. 3rd Edition, Routledge, New York.

Withers, R.T., Maricic, Z., Wasilewski, S. and Kelly, L. (1982) Match analysis of Australian professional soccer players. *Journal of Human Movement Studies*, 8(4), 159-176.

Witte, T.H. and Wilson, A.M. (2004) Accuracy of non-differential GPS for the determination of speed over ground. *Journal of Biomechanics*, 37(12), 1891-1898.

Wolf, J., Hallmark, S., Oliveira, M., Guensler, R. and Sarasua, W. (1999) Accuracy issues with route choice data collection by using Global Positioning System. *Transportation Research Record*, 1660(1), 66-74.

Wragg, C.B., Maxwell, N.S. and Doust, J.H. (2000) Evaluation of the reliability and validity of a soccer-specific field test of repeated sprint ability. *European Journal of Applied Physiology*, 83(1), 77-83.

Zelenka, V., Seliger, V. and Ondrej, O. (1967) Specific function testing of young football players. *Journal of Sports Medicine and Physical Fitness*. 7(3), 143-147.

6. Appendices

Appendix A. **Participant information sheet for English youth players**

Participant information sheet: English youth players

You are being invited to volunteer in a research study. Before making your decision, it is important that you read the information presented, and ask **any** questions regarding the investigation. Please take your time to decide and do not feel obliged to take part. Thank you.

Study Title:	A comparison of the physical load in match play and small-sided games in trained football players.
Investigator:	**Mathew Beenham**
Supervisors:	**Howard Hurst, David Barron, Steve Atkins.**

What is the purpose of the study?

To determine: (1) the amount of player load experienced by players of different positional roles during match play and (2) the amount of player load experienced by players of different positional roles during small sided games.

Why have I been chosen?

You have been chosen based on your experience playing football.

What will be involved?

If you agree to participate in the study, you will be required to provide parental consent before you can continue. In addition, you will also be required to: (1) complete a PAR-Q form to ensure that it is safe for you to exercise and (2) sign an informed consent form to confirm your understanding of the investigation.

In this study, you will be required to attend your Football training sessions as normal at Myerscough College. You will be required to partake in 3 different small-sided games: 2 v 2, 3 v 3, and 4 v 4 and one 11 v 11 match. It is anticipated that training sessions will take approximately 1 hour.

On the first day of testing, measurements will be recorded including age, height and weight.

On the testing days, a warm up and cool down will be provided to ensure optimal performance and to prevent injury. The structures of the small sided games are shown in the table below.

	Game duration (min)	Duration of recovery between SSG (min)	Pitch area (m)	Pitch total area (m^2)	Pitch ratio per player (m^2)
2 v 2	4 x 2	3	20 x 15	300	1:75
3 v 3	4 x 3	3	25 x 18	450	1:75
4 v 4	4 x 4	3	30 x 20	600	1:75

You will be required to maintain your normal diet and water intake.

You are free to withdraw from the study at any time up to the point of testing.

There are no lifestyle restrictions from taking part in this study.

If there is anything that you are unsure of, or if you have any questions, feel free to ask.

If you would like to participate, please complete the informed consent form.

What are the risks of taking part?

Risk(s) involved in taking part in this study include:

1. Potential discomfort may be brought about by the effort required to participate in high intensity exercise associated with small sided games and football matches.

Do you have to take part?

No, this study it is entirely voluntary. You can withdraw from the study at any point without prejudice and without compromising their position on the football team. Any data collected up to and including the point of withdrawal will be used in the study unless requested to be removed by yourself.

Confidentiality

All the information and results collected during the study will be kept confidential. In addition, you will be assigned an identification number which will be referred to when analysing and discussing the results collected and in any future publication of results.

What will happen to the results?

The information and results that you provide will be used to write reports and may be seen publicly.

What if something goes wrong?

In the event that you feel distressed by participating in the study, please contact Director of Research Dr David Elphinstone at Myerscough College on 01995 642309 or Dr John Minten at the University of Central Lancashire at 01772 894901.

Who is organising and funding the research

Mathew Beenham, in collaboration with Department of Sport at Myerscough College and The University of Central Lancashire.

Who may I contact for further information?

If you would like more information about the research before you decide whether or not you would be willing to take part, please contact:

Mathew Beenham

Research department of sport

Myerscough College

Bilsborrow

Preston

PR3 0RY

mbeenham@myerscough.ac.uk

07792748719

Or alternatively, contact Mathew Beenham's research supervisor: Dr Howard Hurst, Senior lecturer in Sport Science, Darwin Building 223, University of central Lancashire, PR1 2QS. HTHurst@uclan.ac.uk.

Thankyou for your interest in this research

Appendix B. Participant information sheet for Portuguese youth players

Participant information sheet: Portuguese youth players

You are being invited to volunteer in a research study. Before making your decision, it is important that you read the information presented, and ask **any** questions regarding the investigation. Please take your time to decide and do not feel obliged to take part. Thank you.

Study Title:	A comparison of the physical load in match play and small-sided games in trained football players.
Investigator:	**Mathew Beenham**
Supervisors:	**Howard Hurst, David Barron, Steve Atkins.**

What is the purpose of the study?

To determine: (1) the amount of player load experienced by players of different positional roles during match play and (2) the amount of player load experienced by players of different positional roles during small sided games.

Why have I been chosen?

You have been chosen based on your experience playing professional football.

What will be involved?

If you agree to participate in the study, you will be required to: (1) complete a PAR-Q form to ensure that it is safe for you to exercise and (2) sign an informed consent form to confirm your understanding of the investigation.

In this study, you will be required to attend your Football training sessions as normal at Associação Académica de Coimbra. You will be required to partake in 3 different small-sided games: 2 v 2, 3 v 3, and 4 v 4 and one 11 v 11 match. It is anticipated that training sessions will take approximately 1 hour.

On the first day of testing, measurements will be recorded including age, height and weight.

On the testing days, a warm up and cool down will be provided to ensure optimal performance and to prevent injury. The structures of the small sided games are shown in the table below.

	Game duration (min)	Duration of recovery between SSG (min)	Pitch area (m)	Pitch total area (m^2)	Pitch ratio per player (m^2)
2 v 2	4 x 2	3	20 x 15	300	1:75
3 v 3	4 x 3	3	25 x 18	450	1:75
4 v 4	4 x 4	3	30 x 20	600	1:75

You will be required to maintain your normal diet and water intake.

You are free to withdraw from the study at any time up to the point of testing.

There are no lifestyle restrictions from taking part in this study.

If there is anything that you are unsure of, or if you have any questions, feel free to ask.

If you would like to participate, please complete the informed consent form.

What are the risks of taking part?

Risk(s) involved in taking part in this study include:

1. Potential discomfort may be brought about by the effort required to participate in high intensity exercise associated with small sided games and football matches.

Do you have to take part?

No, this study it is entirely voluntary. You can withdraw from the study at any point without prejudice and without compromising their position on the football team. Any data collected up to and including the point of withdrawal will be used in the study unless requested to be removed by yourself.

Confidentiality

All the information and results collected during the study will be kept confidential. In addition, you will be assigned an identification number which will be referred to when analysing and discussing the results collected and in any future publication of results.

What will happen to the results?

The information and results that you provide will be used to write reports and may be seen publicly.

What if something goes wrong?

In the event that you feel distressed by participating in the study, please contact Director of Research Dr David Elphinstone at Myerscough College on 01995 642309 or Dr John Minten at the University of Central Lancashire at 01772 894901.

Who is organising and funding the research

Mathew Beenham, in collaboration with Department of Sport at Myerscough College and The University of Central Lancashire.

Who may I contact for further information?

If you would like more information about the research before you decide whether or not you would be willing to take part, please contact:

Mathew Beenham

Research department of sport

Myerscough College

Bilsborrow

Preston

PR3 0RY

mbeenham@myerscough.ac.uk

07792748719

Or alternatively, contact Mathew Beenham's research supervisor: Dr Howard Hurst, Senior lecturer in Sport Science, Darwin Building 223, University of central Lancashire, PR1 2QS. HTHurst@uclan.ac.uk.

Thankyou for your interest in this research

Appendix C. Parental consent form

Parental Permission for Children Participation in Research

Title:

A comparison of the physical load in match play and small-sided games in trained football players.

Introduction

The purpose of this form is to provide you (as the parent or guardian of a prospective research study participant) information that may affect your decision as to whether or not to let your child participate in this research study. The person performing the research will describe the study to you and answer all your questions. Read the information below and ask any questions you might have before deciding whether or not to give your permission for your child to take part. If you decide to let your child be involved in this study, this form will be used to record your permission.

Purpose of the Study

If you agree, your child will be asked to participate in a research study about comparing the physical load in match play and small-sided games between elite professional and sub-elite amateur football players. The purpose of this study is determine: (1) the amount of player load (collation of all forces imposed on an athlete) experienced during match play and (2) If players are experiencing similar loading during training.

What is my child going to be asked to do?

If you allow your child to participate in this study, they will be asked to:

- Attend and participate in their normal football training sessions and games at Myerscough College.
- Wear GPS units and heart rate monitors worn around the chest to monitor physical activity.

This study will take 1-2 months, aiming to conduct 10 tests in training sessions and 1tests in match, and consisting of approximately 40 participants of other people in this study.

What are the risks involved in this study?

There are no foreseeable risks to participating in this study.

What are the possible benefits of this study?

The possible benefits of participation are knowledge regarding how much force your child is experiencing during matches and whether or not they are receiving similar forces during training. This could help reduce the chances of injury occurring in matches and training.

Does my child have to participate?

No, your child's participation in this study is voluntary. Your child may decline to participate or to withdraw from participation at any time up to the point of testing. Withdrawal or refusing to participate will not affect their relationship with Myerscough College in anyway. You can agree to allow your child to be in the study now and change your mind later without any penalty.

What if my child does not want to participate?

In addition to your permission, your child must agree to participate in the study. If you child does not want to participate they will not be included in the study and there will be no penalty. If your child initially agrees to be in the study they can change their mind later without any penalty.

Will there be any compensation?

Neither you nor your child will receive any type of payment participating in this study.

How will your child's privacy and confidentiality be protected if s/he participates in this research study?

Your child's privacy and the confidentiality of his/her data will be protected and will only be viewed by myself and my supervisors. Your child's names will be replaced with a number so that their details cannot be traced back.

If it becomes necessary for the Institutional Review Board to review the study records, information that can be linked to your child will be protected to the extent permitted by law. Your child's research records will not be released without your consent unless required by law or a court order. The data resulting from your child's participation may be made available to other researchers in the future for research purposes not detailed within this consent form. In these cases, the data will contain no identifying information that could associate it with your child, or with your child's participation in any study.

Photographs may be taken of the testing procedures for writing up the project and for possible publication. However, all identifiable features of your child will be obscured to ensure anonymity. If you agree to this you will be asked to initial statement 7 on the consent form.

Whom to contact with questions about the study?

Prior, during or after your participation you can contact the researcher Mathew Beenham at 07792748719 or send an email to mbeenham@myerscough.ac.uk for any questions or if you feel that you have been harmed. This study has been reviewed and approved by The University Institutional Review Board.

What if something goes wrong?

In the event that you feel distressed by participating in the study, please contact Director of Research Dr David Elphinstone at Myerscough College on 01995 642309 or Dr John Minten at the University of Central Lancashire at 01772 894901.

Signature

You are making a decision about allowing your child to participate in this study. Your signature below indicates that you have read the information provided above and have decided to allow them to participate in the study. If you later decide that you wish to withdraw your permission for your child to participate in the study you may discontinue his or her participation at any time. You will be given a copy of this document.

____
Printed Name of Child

___________________________________ __________________
Signature of Parent(s) or Legal Guardian Date

___________________________________ __________________

Signature of Investigator Date

Appendix D. Participant informed consent form

Participant Consent Forms

'A comparison of the physical load in match play and small-sided games in trained football players.'

Name of research: Mathew Beenham

Please tick the box if you agree to the statement:

1. I have read the attached information sheet and discussed the project with the investigator. ☐

2. The nature, demands and the risks associated with the project have been explained to me. ☐

3. I knowingly accept the risks involved and feel confident that I can undertake the requirements of the test without undue strain. ☐

4. As such I agree to participate in the above named study. ☐

5. I understand that I may withdraw my consent and discontinue participation at any time up to the point of testing without having to give an explanation. ☐

6. I understand that my name and personal details will be kept confidential. ☐

7. I understand that photographs of testing may be taken and that all identifiable features will be obscured. As such I give consent to having my photograph taken. ☐

______________________	__________	______________________
Name of participant	Date	Signature
______________________	__________	______________________
Researcher	Date	Signature

Appendix E. Physical activity readiness questionnaire.

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO		
☐	☐	1.	**Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	2.	**Do you feel pain in your chest when you do physical activity?**
☐	☐	3.	**In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	4.	**Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	5.	**Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	6.	**Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	7.	**Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ________________________________

SIGNATURE ________________________________ DATE ________________

SIGNATURE OF PARENT or GUARDIAN (for participants under the age of majority) ________________________________ WITNESS ________________

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

1:12

continued on other side...

Appendix F. Risk assessment for English youth player testing

Assessment Undertaken By: **(Investigator)**	**Assessment Verified By:** **(Technician or other competent person)**
Name: Mathew Beenham	Name: Dr Howard Hurst
Signed:	Signed:
Date: 13/05/14	Date*: 13/05/14
Note: Risk Assessment is valid for* ***one year* *from the date given above. Risk Assessments for activities lasting longer than one year should be reviewed annually.*	
Countersigned by Head of School or Chair of H&S Committee:	
Date:	
Risk Assessment For:	
Activity: A comparison of the physical load in match play and small-sided games in trained football players.	
Location of Activity: Myerscough College in Preston, England and Associação Académica de Coimbra in Portugal.	

List of significant/ potential hazards	List groups of people who are at risk	Level of risk (high, medium, low)	List the action/safety precautions needed
Risks to personal safety	Investigator and subject	Low	Participant has read attached safety guidelines.
Normal emergency situations (e.g. fire)	Investigator and subject	Low	Participant will familiarise themselves with fire drill and any other relevant emergency procedures at the activity location.
Use of electrical equipment	Investigator and subject	Low	Only PAT tested electrical equipment will be used. Any trailing cables etc will be taped down.
Demands of training and playing competition football	Subject	Medium	Prior to engaging in testing, subjects will complete a physical activity readiness questionnaire (PAR-Q) to notify to investigator of anything that could potentially harm the subject. Throughout testing, subjects will be constantly observed and monitored. A first aider will also be present throughout the test to aid any health problems that may arise.
Faulty equipment	Investigator and subject	Low	Prior to testing, all equipment will be checked to ensure that they are safe to use.
Unfamiliarity with the testing protocols	Subject	Low	All subjects will be briefed prior to testing and will also have an opportunity to ask questions regarding the investigation.
Weather extremes	Subject	Low/medium	Groundsman, coach or referee can call off game/training in extreme weather
Pitch quality	Subject	Low/medium	Groundsman, coach or referee checks the pitch prior to training/ games.
Dehydration	Subject	Medium	Water bottles will be placed around the training/match area for immediate access.
Physical injuries	Subject	Medium	Players will perform a standardised warm up and cool down prior to training directed by the coaching staff. A first aider will be present throughout testing. Players are required to wear shin pads.

Appendix G. Overseas risk assessment for Portuguese youth player testing

OVERSEAS TRAVEL RISK ASSESSMENT FORM	uclan University of Central Lancashire

Risk Assessment For
Service / School:
Location of Activity: Portugal
Activity: Mathew Beenham, John Fry, Howard Hurst and David Barron overseas travel to Académica de Coimbra in Coimbra, Portugal by air travel transport. Dates in Coimbra will be 19th-23rd May 2014 with the intention of conducting research. **REF:**

Assessment Undertaken By
Name: Steve Atkins
Date: 13/05/2014
Signed by Dean of School / equivalent or nominee:
Date: 13/05/14

Assessment Reviewed
Name:
Date:
This section to be used if this risk assessment is to be used for further identical trips

List significant hazards here:	**List groups of people at risk:**	**List existing controls, or refer to safety procedures etc.**	**For risks, which are not adequately controlled, list actions needed.**	**Remaining level of risk: high, med or low**
Personal 'fitness' to travel – disabilities, pre-existing medical conditions, country specific diseases, etc *(e.g. Malaria, Typhoid, Hepatitis A, Diphtheria, Yellow Fever).*	Mathew Beenham, John Fry, Howard Hurst, David Barron	Procedural Guidance for H&S During Overseas Travel Traveller advised to see their GP and seek medical advice on their fitness to travel and vaccinations required for travel to Portugal	Ensure staff receive required vaccinations and health surveillance as appropriate via University Occupational Health Provider / GP	Low

		Regular travellers overseas to have medical examinations; Traveller must have had necessary vaccinations and purchased anti-malarial drugs prior to travel (where necessary); No member of staff or student is permitted to travel on University business against advice of their GP. Travel advice from FCO Travel health advice from NHS Fitfortravel Traveller to declare any relevant pre-existing medical condition or disability that could be potentially worsened by the proposed overseas travel/activity; If travelling to an EU country, travellers should obtain a European Health Insurance Card (EHIC) before leaving the UK. Specific safety advice from FCO to be included where relevant	Consult FCO: Your Trip Advice Consult AonProtect Personal Accident & Travel Assistance Consult FCO: Disabled Travellers	
Air travel to Portugal *Long haul flight - DVT / Dehydration*	Mathew Beenham, Howard Hurst, John Fry and David Barron	Procedural Guidance for H&S During Overseas Travel Traveller advised to follow all DVT / dehydration precautions advised by aircraft cabin crew. Procedural Guidance on Travel Related Deep Vein Thrombosis (DVT).		Low

		Specific safety advice from FCO to be included where relevant		
Accommodation *Fire, personal security*	Mathew Beenham, Howard Hurst, John Fry and David Barron	Procedural Guidance for H&S During Overseas Travel AonProtect Personal Accident & Travel Assistance University approved hotel. Previous experience of accommodation; Local security arrangements. Travellers advised to read the evacuation procedures in the accommodation and ensure they are familiar with the appropriate escape route from their rooms and how to raise the alarm should you see smoke or fire. Remember to lock your door at night and when you go out during the day, as you would at home. Obtain suitable electrical adapter for the local voltage/plug type. Specific safety advice from FCO to be included where relevant		Low
General safety issues at locations being visited *Fire, personal security*	Mathew Beenham, Howard Hurst, John Fry and David Barron	Premises / site / activity safety procedures / instructions to be followed at all times; Any safety equipment provided by staff at premises must be used as directed Attendees to familiarise	Any activities that are undertaken as an addition to those outlined before the trip begun, must be assessed prior to them starting.	Low

		themselves with the location of fire escape routes; <u>University</u> & premises accident reporting procedures.		
Weather Possible extremes of hot cold or wet. *Hot – heatstroke, sunburn* *Cold – hypothermia*.	Mathew Beenham, Howard Hurst, John Fry and David Barron	<u>Research expected weather conditions prior to travel.</u> <u>For hot climates:</u> Drink lots of water at regular intervals throughout the day (3 litres per day). Take re-hydration sachets to replace lost salts. Wear a hat with a brim wide enough to shade your face. Wear loose-fitting clothes made of breathable fabrics such as linen or cotton. Light colours are reflective and therefore cooler than dark colours. Pack a variety of clothing in case of sudden weather changes. Protect yourself from sun and insects. Wear long-sleeved shirt and long skirt or trousers. High alcohol consumption to be avoided. Exposure to extreme midday heat will be minimised. First aid kits available from University Occupational Health. <u>For cold climates:</u>		Low

		Always wear warm, windproof and waterproof clothing including that that covers the ears. Dress in loose-fitting multiple layers to trap air and create an insulating effect. Add or take off a layer as needed. Protect extremities (such as fingers, toes, nose, and ear lobes). Wear warm socks and robust, waterproof shoes/boots. Avoid prolonged exposure and shelter from high winds. Always take a change of dry clothing. Avoid drinking alcohol when it is very cold. Specific safety advice from FCO to be included where relevant		
Transportation *Potential breakdown / accident, vehicle* *stationary for significant periods of time in areas without food or water.*	Mathew Beenham, Howard Hurst, John Fry and David Barron	Procedural Guidance for H&S During Overseas Travel AonProtect Personal Accident & Travel Assistance Use hotel or other recommended taxi companies. Always pre-book taxes. Water and food will be carried on all lengthy trips in case of such scenarios. Any train safety information provided to be followed at all times.	FCO - Driving abroad safety advice.	Low

		Ensure train sleeping compartment doors are locked when occupied. Hired vehicles - Assess vehicle suitability for basic safety features e.g. working brakes – many hire vehicles do not meet the standards of the UK. Roads may be in a poor state of repair, use recommended local guides/drivers where appropriate. Specific safety advice from FCO to be included where relevant		
Manual handling (luggage) *Injuries arising from incorrect lifting techniques*	Mathew Beenham, Howard Hurst, John Fry and David Barron	Information provision; Maintain good posture when lifting or lowering equipment, avoid twisting or bending to reduce the chance of back injury	Manual handling training available through SHE Section.	Low
Medical emergency	Mathew Beenham, Howard Hurst, John Fry and David Barron	Ensure University medical and emergency insurance policy details are up to date at easily accessible. AonProtect Personal Accident & Travel Assistance Check availability of prescribed medication. Specific safety advice from FCO to be included where relevant		Low
Food Poisoning	Mathew Beenham, Howard Hurst, John Fry and David Barron	Procedural Guidance for H&S During Overseas Travel Only drink water from bottled sources and avoid food prepared		Low

		by unlicensed vendors at all times. Carry Imodium or similar medication and rehydration sachets. Specific safety advice from FCO to be included where relevant		
Terrain - walking and trek-based activities *Slips, falls and trips*	Mathew Beenham, Howard Hurst, John Fry and David Barron	Suitable footwear will be worn – staff/students are given a full briefing session and an equipment list prior to the trip commencing. Work will not be undertaken in poor light conditions where the ground is uneven. Trip instructors/guides have assessed the locations for activities on previous visits. Procedural Guidance for Field Trips & Field Work Activities		Low
Terrorism, personal security / safety	Mathew Beenham, Howard Hurst, John Fry and David Barron	Procedural Guidance for H&S During Overseas Travel Check FCO website and AonProtect Personal Accident & Travel Assistance website prior to travel to ensure there are no restrictions - no member of staff/student permitted to travel to a country against advice from FCO. **Out of Hours:** Security (24-hour security lodge) holds a cascade list of senior staff within the University: (+44) 01772 892068.	Travellers strongly advised to research the county / specific area which they are visiting e.g. personal safety, areas to avoid, local customs, legislation, etc. FCO: Your Trip Advice Tailored Travel Briefings available via AonProtect Personal Accident & Travel Assistance for travel to higher risk counties Any activities that are undertaken as an addition to those outlined before the trip begun must be risk	Low

		Personal attack alarms available from Security; Ensure mobile phones will operate within the country being visited; Traveller to register with FCO LOCATE scheme Travellers should remain vigilant in all public places and take sensible precautions for personal safety and avoid public gatherings and demonstrations, which have the potential to turn violent. Only take with you the cash you will need for the day and leave valuables in a hotel safe / safety deposit box. Accident Reporting Procedures; Specific safety advice from FCO to be included where relevant	assessed prior to commencement.	

Working in an isolated area *Difficulty in summoning help*	Mathew Beenham, Howard Hurst, John Fry and David Barron	Details of the site and schedule will be left at the accommodation. Lone working should be avoided in remote or areas where summoning help is difficult. Mobile phones to contact emergency services. All party members will inform other party members as to their whereabouts and their expected time of return. Lone Worker Guidance for all Employees.		Low
Document Control *Loss of passports, visas, insurance details, etc*	Mathew Beenham, Howard Hurst, John Fry and David Barron	Travellers advised to take photocopies of all important travel documents keeping them separate from originals; There is a requirement in many countries to carry your passport or a copy with you at all times. UCLan accident emergency insurance and procedure.	Assistance from relevant Consulate.	Low
Additional specific risks related to your travel, work or intended leisure activities with inherent risks which are not covered above.	Mathew Beenham, Howard Hurst, John Fry and David Barron			Low

Sources of information to assist you complete your travel risk assessment:

UK Foreign & Commonwealth Office Country Specific Safety Advice: http://www.fco.gov.uk/en/travel-and-living-abroad

AonProtect Personal Accident & Travel Assistance – red24 https://www.red24.com/affiliate/aonprotect/ – 4 digit passcode is 7797

The University's accident and insurance policy through the use of **red24** a leading global security company, gives you access to essential security and health advice for over 230 countries and territories worldwide. The specific information provided by red24 is far more comprehensive and detailed than that provided by the FCO which may prove vital particularly with travel to higher risk destinations.

Red24 will also email travellers a security briefing tailored to your travel itinerary when travelling to a high-risk region, covering the risks, preventative measures and important contacts you require to help you remain safe while travelling abroad.

Please note: The services of red24 **must not** be used for the booking of flights, accommodation, etc. the University's Travel Office must always be the first point of contact.

The Foreign and Commonwealth Office LOCATE Scheme

The Foreign and Commonwealth Office's Online Registration module supports the registration of citizens living or visiting abroad. It allows individuals to register and manage their own travel details via the Internet both prior to and during a period abroad. This information can be used by FCO to alert citizens to relevant travel concerns as well as contact citizens in the event of an emergency.

Advice on completion of this form can be requested from your SHE Adviser or contact the SHE Section: Ext 2067.

Appendix H. Minimax calibration

To begin the calibration process, turn on the minimaxx and insert into a calibration cradle. Prior to commencing the calibration process, LoganPlus must be set to ‘Rowing’ in the sports selection section on the ‘Settings’ tab. Ensure that LoganPlus has been restarted after this prior to continuing.

Connect the cradle to your PC and click on the ‘Diagnostics’ tab in LoganPlus.

Click the ‘Cable Connect’ button and wait a few seconds for the data stream to appear. Now you should be able to move the minimaxx device and see the corresponding accelerometer, gyroscope and magnetometer traces respond accordingly.

Accelerometers

Click the ‘Auto’ checkbox in the ‘Accelerometer Calibration’ section to begin the accelerometer calibration. Position the calibration cradle on each of it’s six flat faces, each time waiting for the word ‘Stable’ to appear on the left side of the trace. Click the ‘Auto’ box to uncheck and save the calibration values.

Gyroscopes

Orient the calibration cradle to the roll axis.

Click the first ‘Set Zero’ box (over the text) and when the ‘Degrees’ value changes to ‘0’ rotate the calibration cradle by 90 degrees so that the cradle edge is no aligned to the straight edge. Now click the ‘Set Gain 90’ box (over the text) to set the calibration.

Now repeat the process for the pitch and roll axis.

Magnetometers

Click the checkbox marked ‘Auto’ next to the magnetometer trace on the Diagnostic page.

Ensure the minimaxX device is not near a magnetic source (TV, speakers, monitors etc.).

Rotate the minimaxX in its calibration cradle with your hand through all angles. Continue to do this until the magnetometer graphs show a consistent response and the values in the ‘Normal’ and ‘Reverse’ columns stop changing. Click the ‘Auto’ checkbox again and uncheck it and save the calibration data.

Completion

Check the values that have been set for the minimaxx calibration. The values should be similar but not necessarily identical to those shown in the table below.

	Accelerometer		**Gyroscope**		**Magnetometer**	
Axis	**+G**	**-G**	Zero	Gain	+B	-B
Forward	2315	1755	2027.4	0.7132	2073	1756
Side	1778	2325	2026.1	0.7158	2276	1974
Up	2310	1763	2007.8	0.7475	2256	1934

Disconnect the minimaxx from the calibration cradle and turn off.

Appendix I. Mean ± SD values for heart rate (beats.min^{-1}) and % estimated heart rate maximum per positional role

		Mean heart rate (beats.min^{-1})	% estimated HR_{max}
CD	MP	164 ± 9.11	85.05 ± 4.68
	2 vs. 2	174 ± 6.54	90.08 ± 3.35
	3 vs. 3	170 ± 9.68	88.42 ± 5.06
	4 vs. 4	169 ± 5.21	87.75 ± 2.65
	Total (n = 10)	**169 ± 8.33**	**87.83 ± 4.31**
WD	MP	164 ± 5.36	85.18 ± 2.77
	2 vs. 2	172 ± 8.70	89.02 ± 4.40
	3 vs. 3	169 ± 6.63	87.88 ± 3.42
	4 vs. 4	161 ± 11.49	83.78 ± 6.03
	Total (n = 10)	**167 ± 9.02**	**86.46 ± 4.67**
CM	MP	166 ± 5.06	86.30 ± 2.64
	2 vs. 2	169 ± 10.41	87.70 ± 5.47
	3 vs. 3	166 ± 7.03	86.19 ± 3.66
	4 vs. 4	166 ± 12.30	86.03 ± 6.30
	Total (n = 10)	**167 ± 8.88**	**86.56 ± 4.61**
FW	MP	164 ± 9.09	85.13 ± 4.72
	2 vs. 2	172 ± 10.10	89.28 ± 5.30
	3 vs. 3	170 ± 14.05	88.08 ± 7.25
	4 vs. 4	159 ± 10.04	82.58 ± 5.19
	Total (n = 10)	**166 ± 11.72**	**86.27 ± 6.08**

Appendix J. Distance covered at 0-6.0 km·h^{-1}

A significant trivial main effect for mean DC.min^{-1} at 0-6.0 km·h^{-1} $F(2.20, 79.14) = 7.19$; $p = 0.001$, $\eta^2 = 0.17$ was found. Post hoc tests revealed a significantly greater mean DC.min^{-1} at 0-6.0 km·h^{-1} for 4 vs. 4 than 2 vs. 2 (33.85 ± 5.09 vs. 30.50 ± 5.83 m.min^{-1}, respectively, p = 0.024, CI = 0.30, 6.39), MP than 2 vs. 2 (34.25 ± 4.38 vs. 30.50 ± 5.83 m.min^{-1}, respectively, p = 0.004, CI = 0.91, 6.58), 4 vs. 4 than 3 vs. 3 (33.85 ± 5.09 vs. 29.40 ± 7.86 m.min^{-1}, respectively, p = 0.016, CI = 0.61, 8.29) and MP than 3 vs. 3 (34.25 ± 4.38 vs. 29.40 ± 7.86 m.min^{-1}, respectively, p = 0.019, CI = 0.56, 9.14). Similarly, a significant small main effect was found for positional role $F(3, 36) = 4.07$; $p = 0.014$, $\eta^2 = 0.25$. Post hoc tests revealed a significantly greater mean DC.min^{-1} at 0-6.0 km·h^{-1} by CD than WD (34.61 ± 5.34 vs. 30.87 ± 5.52 m.min^{-1}, respectively, p = 0.040, CI = 0.11, 7.37) and by CD than CM (34.61 ± 5.34 vs. 30.51 ± 5.12 m.min^{-1}, respectively, p = 0.019, CI = 0.47, 7.73). In contrast, a no significant interactions $F(6.60, 79.14) = 1.25$; $p>0.05$, $\eta^2 = 0.10$ were found when positional roles were analysed by SSGs and MP. Table 4-7 show the mean kinematic and temporal differences between conditions and positional roles, respectively.

Appendix K. Mean ± SD values for total distance covered (m) and distance covered (m), number of repeated high-intensity efforts and work:rest ratio per condition

		TDC.min^{-1} (m.min^{-1})	**DC.min^{-1} at 0-6.0 km·h^{-1} (m.min^{-1})**
MP	CD	86.99 ± 9.76	35.45 ± 1.93
	WD	95.01 ± 9.47	33.47 ± 4.34
	CM	104.36 ± 11.81	30.40 ± 3.52
	FW	94.31 ± 13.58	37.67 ± 4.07
	Total (n=40)	**95.17 ± 12.51**	**34.25 ± 4.38[a]**
2 vs. 2	CD	93.38 ± 15.32	33.25 ± 4.94
	WD	95.25 ± 18.96	28.50 ± 6.26
	CM	99.75 ± 11.77	32.00 ± 3.87
	FW	96.63 ± 22.08	28.25 ± 6.90
	Total (n=40)	**96.25 ± 16.95**	**30.50 ± 5.83**
3 vs. 3	CD	88.42 ± 13.58	32.17 ± 8.02
	WD	94.67 ± 10.27	28.75 ± 5.96
	CM	107.92 ± 11.87	27.75 ± 6.87
	FW	94.17 ± 19.91	28.92 ± 10.41
	Total (n=40)	**96.29 ± 15.59**	**29.40 ± 7.86**
4 vs. 4	CD	88.56 ± 6.93	37.57 ± 3.49
	WD	88.94 ± 7.45	32.75 ± 4.01
	CM	99.81 ± 14.91	31.88 ± 5.11
	FW	92.56 ± 15.36	33.19 ± 6.05
	Total (n=40)	**92.47 ± 12.27**	**33.85 ± 5.09[a]**

Appendix L. Mean ± SD values for total distance covered (m) and the percentage of time covered at 0-6.0 km·h^{-1} (%) per condition

		TDC.min^{-1} (m.min^{-1})	TDC at 0-6.0 km·h^{-1} (%)
MP	CD	86.99 ± 9.76	70.40 ± 3.98
	WD	95.01 ± 9.47	62.90 ± 4.31
	CM	104.36 ± 11.81	55.40 ± 7.17
	FW	94.31 ± 13.58	68.90 ± 6.67
	Total (n=40)	**95.17 ± 12.51**	**64.40 ± 8.11**
2 vs. 2	CD	93.38 ± 15.32	61.20 ± 8.65
	WD	95.25 ± 18.96	57.40 ± 13.83
	CM	99.75 ± 11.77	58.30 ± 7.09
	FW	96.63 ± 22.08	56.90 ± 14.81
	Total (n=40)	**96.25 ± 16.95**	**58.45 ± 11.25**
3 vs. 3	CD	88.42 ± 13.58	66.40 ± 8.67
	WD	94.67 ± 10.27	58.40 ± 9.62
	CM	107.92 ± 11.87	54.10 ± 7.87
	FW	94.17 ± 19.91	59.20 ± 14.85
	Total (n=40)	**96.29 ± 15.59**	**59.20 ± 14.85**
4 vs. 4	CD	88.56 ± 6.93	64.80 ± 3.33
	WD	88.94 ± 7.45	63.00 ± 6.60
	CM	99.81 ± 14.91	56.80 ± 10.05
	FW	92.56 ± 15.36	63.50 ± 9.58
	Total (n=40)	**92.47 ± 12.27**	**62.03 ± 8.18**

Appendix M. Mean ± SD values for total distance covered (m), distance covered in pre-defined speed zones (m), number of repeated high-intensity efforts and work:rest ratio per positional role

		Work:rest ratio	**TDC.min^{-1} (m.min^{-1})**	**DC.min^{-1} at 0-6.0 km·h^{-1} (m.min^{-1})**	**DC.min^{-1} at 6.1-8.0 km·h^{-1} (m.min^{-1})**	**DC.min^{-1} at 8.1-12.0 km·h^{-1} (m.min^{-1})**	**DC.min^{-1} at 12.1-15.0 km·h^{-1} (m.min^{-1})**	**DC.min^{-1} at 15.1-18.0 km·h^{-1} (m.min^{-1})**	**DC.min^{-1} at >18 km·h^{-1} (m.min^{-1})**	**RHIE**
CD	MP	1.33 ± 0.25	86.99 ± 9.76	35.45 ± 1.93	10.88 ± 1.66	21.18 ± 4.00	9.62 ± 2.98	4.90 ± 1.33	4.96 ± 1.82	4.47 ± 2.96
	2 vs. 2	1.62 ± 0.55	93.38 ± 15.32	33.25 ± 4.94	16.75 ± 2.71	27.56 ± 7.78	10.38 ± 5.47	1.88 ± 1.59	0.63 ± 0.88	7.50 ± 6.12
	3 vs. 3	1.57 ± 4.20	88.42 ± 13.58	32.17 ± 8.02	15.83 ± 4.43	25.92 ± 10.40	7.50 ± 4.25	2.58 ± 2.24	0.42 ± 0.71	3.00 ± 4.83
	4 vs. 4	1.47 ± 0.25	88.56 ± 6.93	37.57 ± 3.49	16.69 ± 5.25	22.50 ± 4.80	7.57 ± 3.00	3.13 ± 1.56	1.38 ± 1.24	3.75 ± 3.95
	Total (n=10)	**1.50 ± 0.39**	**89.34 ± 11.65**	**34.61 ± 5.34[c]**	**15.04 ± 4.39**	**24.29 ± 7.39**	**8.77 ± 4.10**	**3.12 ± 2.00**	**1.84 ± 2.20**	**4.68 ± 4.76**
WD	MP	1.59 ± 0.32	95.01 ± 9.47	33.47 ± 4.34	11.31 ± 2.74	24.41 ± 5.07	12.88 ± 2.14	7.42 ± 1.84	5.53 ± 1.80	9.53 ± 2.83
	2 vs. 2	1.93 ± 0.80	95.25 ± 18.96	28.50 ± 6.26	17.75 ± 4.32	30.00 ± 10.72	12.25 ± 6.87	2.63 ± 2.46	0.00 ± 0.00	3.50 ± 4.12
	3 vs. 3	1.70 ± 0.45	94.67 ± 10.27	28.75 ± 5.96	19.67 ± 3.87	33.75 ± 9.53	10.00 ± 3.79	1.92 ± 1.47	0.33 ± 0.58	4.50 ± 5.50
	4 vs. 4	1.68 ± 0.43	88.94 ± 7.45	32.75 ± 4.01	16.25 ± 3.70	28.07 ± 6.72	8.75 ± 3.64	2.82 ± 1.33	0.31 ± 0.44	4.13 ± 5.14
	Total (n=10)	**1.72 ± 0.53**	**93.47 ± 12.16**	**30.87 ± 5.52**	**16.25 ± 4.74[d]**	**29.06 ± 8.69**	**10.97 ± 4.60**	**3.70 ± 2.82**	**1.54 ± 2.51**	**5.42 ± 4.98**
CM	MP	2.19 ± 0.72	104.36 ± 11.81	30.40 ± 3.52	13.12 ± 3.73	30.64 ± 3.86	18.19 ± 4.68	8.11 ± 2.16	3.89 ± 1.43	12.73 ± 4.45
	2 vs. 2	2.23 ± 0.67	99.75 ± 11.77	32.00 ± 3.87	17.25 ± 2.87	30.33 ± 6.50	11.63 ± 4.97	3.88 ± 2.16	1.00 ± 0.99	8.25 ± 10.28
	3 vs. 3	2.15 ± 0.46	107.92 ± 11.87	27.75 ± 6.87	18.92 ± 3.19	39.75 ± 7.06	16.92 ± 5.46	3.25 ± 2.93	0.92 ± 1.21	11.50 ± 10.55
	4 vs. 4	1.92 ± 0.40	99.81 ± 14.91	31.88 ± 5.11	17.07 ± 3.51	33.63 ± 8.90	12.19 ± 4.82	3.63 ± 2.22	0.94 ± 0.90	7.88 ± 6.72
	Total (n=10)	**2.12 ± 0.55[a]**	**102.96 ± 12.65[b]**	**30.51 ± 5.12**	**16.59 ± 3.87[d]**	**33.59 ± 7.59[e]**	**14.73 ± 5.60[f]**	**4.72 ± 3.04[g]**	**1.69 ± 1.70**	**10.09 ± 8.34[i]**
FW	MP	1.65 ± 0.66	94.31 ± 13.58	37.67 ± 4.07	8.60 ± 1.74	19.47 ± 4.69	11.18 ± 3.44	7.70 ± 2.79	8.74 ± 4.41	9.60 ± 5.85
	2 vs. 2	2.05 ± 0.67	96.63 ± 22.08	28.25 ± 6.90	17.25 ± 3.62	28.22 ± 12.07	14.00 ± 8.20	4.00 ± 4.12	0.75 ± 1.97	9.00 ± 11.07
	3 vs. 3	1.83 ± 0.75	94.17 ± 19.91	28.92 ± 10.41	15.58 ± 3.24	31.33 ± 13.98	13.25 ± 7.05	3.75 ± 2.52	0.92 ± 0.83	7.00 ± 7.89
	4 vs. 4	1.68 ± 0.44	92.56 ± 15.36	33.19 ± 6.05	16.06 ± 2.90	28.44 ± 9.09	10.38 ± 6.91	3.69 ± 3.73	0.94 ± 1.07	7.88 ± 10.82
	Total (n=10)	**1.80 ± 0.64**	**94.42 ± 17.41**	**32.01 ± 7.93**	**14.38 ± 4.46**	**26.87 ± 11.10**	**12.20 ± 6.56[f]**	**4.79 ± 3.65[g]**	**2.84 ± 4.21[h]**	**8.37 ± 8.86**

Values mean ± SD; Post-hoc significant differences: [a] Significantly greater work:rest ratio by CM than CD ($p<0.001$) and CM than WD ($p=0.11$) [b] Significantly greater TDC.min^{-1} by CM than CD ($p<0.001$), CM than WD ($p=0.008$), and CM than FW ($p=0.021$); [c] Significantly greater mean work:rest ratio by CM than CD ($p <0.001$) and CM than WD ($p = 0.11$); [d] Significantly greater DC.min^{-1} at 0-6.0 km·h^{-1} by CD than WD ($p=0.040$) and CD than CM ($p=0.019$); [e] Significantly greater DC.min^{-1} at 6.1-8.0 km·h^{-1} by WD than FW ($p=0.050$) and CM than FW ($p=0.013$); [f] Significantly greater DC.min^{-1} at 8.1-12.0 km·h^{-1} by CM than CD ($p<0.001$) and CM than FW ($p=0.002$); [g] Significantly greater DC.min^{-1} at 12.1-15 km·h^{-1} by CM than CD ($p<0.001$), CM than WD ($p=0.004$) and FW than CD ($p=0.010$); [h] Significantly greater DC.min^{-1} at 15.1-18.0 km·h^{-1} by CM than CD ($p=0.011$) and FW than CD ($p=0.007$); [i] Significantly greater DC.min^{-1} at >18.1 km·h^{-1} by FW than CD ($p=0.023$), FW than WD ($p=0.002$), and FW than CM ($p=0.006$); [i] Significantly greater RHIE by CM than CD ($p=0.013$) and CM than WD ($p=0.044$). NB. N=10 players per positional role completed each condition.

Appendix N. Mean ± SD values for total distance covered (m) and the percentage of time covered in each speed zone (%) per positional role

		TDC.min^{-1} (m.min^{-1})	TDC at 0-6.0 km·h^{-1} (%)	TDC at 6.1-8.0 km·h^{-1} (%)	TDC at 8.1-12.0 km·h^{-1} (%)	TDC at 12.1-15.0 km·h^{-1} (%)	TDC at 15.1-18.0 km·h^{-1} (%)	TDC at >18.1 km·h^{-1} (%)
CD	MP	86.99 ± 9.76	70.40 ± 3.98	9.00 ± 1.15	12.70 ± 2.31	4.70 ± 1.34	1.70 ± 0.48	1.40 ± 0.70
	2 vs. 2	93.38 ± 15.32	61.20 ± 8.65	13.80 ± 1.93	18.90 ± 4.95	4.80 ± 2.49	0.80 ± 0.79	0.20 ± 0.42
	3 vs. 3	88.42 ± 13.58	66.40 ± 8.67	13.00 ± 2.31	16.00 ± 4.81	3.40 ± 1.78	1.20 ± 0.92	0.00 ± 0.00
	4 vs. 4	88.56 ± 6.93	64.80 ± 3.33	12.50 ± 4.03	15.70 ± 1.83	4.00 ± 1.70	2.00 ± 1.33	0.80 ± 0.92
	Total (n=10)	**89.34 ± 11.65**	**65.70 ± 7.21**	**12.08 ± 3.10**	**15.83 ± 4.24**	**4.23 ± 1.89**	**1.43 ± 1.01**	**0.60 ± 0.81**
WD	MP	95.01 ± 9.47	62.90 ± 4.31	10.60 ± 12.07	15.70 ± 2.21	6.20 ± 0.63	2.70 ± 0.67	1.60 ± 0.52
	2 vs. 2	95.25 ± 18.96	57.40 ± 13.83	14.70 ± 3.27	20.30 ± 7.47	5.70 ± 3.33	1.30 ± 1.34	0.00 ± 0.00
	3 vs. 3	94.67 ± 10.27	58.40 ± 9.62	15.90 ± 2.81	20.00 ± 6.34	4.60 ± 1.71	0.80 ± 0.63	0.10 ± 0.32
	4 vs. 4	88.94 ± 7.45	63.00 ± 6.60	13.40 ± 3.75	17.70 ± 4.85	4.30 ± 2.16	1.30 ± 1.06	0.10 ± 0.32
	Total (n=10)	**93.47 ± 12.16**	**60.43 ± 9.30**	**13.65 ± 3.53**	**18.43 ± 5.68**	**5.20 ± 2.24**	**1.53 ± 1.18**	**0.45 ± 0.75**
CM	MP	104.36 ± 11.81	55.40 ± 7.17	11.50 ± 3.10	19.10 ± 3.70	8.90 ± 2.47	3.40 ± 0.70	1.50 ± 0.53
	2 vs. 2	99.75 ± 11.77	58.30 ± 7.09	14.30 ± 1.89	20.00 ± 3.86	5.40 ± 2.27	1.40 ± 0.84	0.40 ± 0.52
	3 vs. 3	107.92 ± 11.87	54.10 ± 7.87	14.30 ± 2.98	22.00 ± 4.78	7.50 ± 2.55	1.40 ± 0.84	0.40 ± 0.52
	4 vs. 4	99.81 ± 14.91	56.80 ± 10.05	14.30 ± 3.20	20.90 ± 5.26	5.80 ± 2.49	1.50 ± 0.97	0.30 ± 0.40
	Total (n=10)	**102.96 ± 12.65**[a]	**56.15 ± 7.97**	**13.60 ± 2.99**	**20.50 ± 4.41**	**6.90 ± 2.74**	**1.93 ± 1.19**	**0.65 ± 0.74**
FW	MP	94.31 ± 13.58	68.90 ± 6.67	6.90 ± 1.10	13.10 ± 3.25	5.20 ± 1.93	3.20 ± 1.23	3.60 ± 1.84
	2 vs. 2	96.63 ± 22.08	56.90 ± 14.81	13.10 ± 3.54	20.50 ± 8.34	7.10 ± 4.33	1.80 ± 1.93	0.30 ± 0.67
	3 vs. 3	94.17 ± 19.91	59.20 ± 14.85	12.70 ± 3.16	19.10 ± 8.46	6.70 ± 3.62	1.70 ± 1.16	0.60 ± 0.52
	4 vs. 4	92.56 ± 15.36	63.50 ± 9.58	12.40 ± 2.46	17.00 ± 4.97	5.00 ± 3.30	1.60 ± 1.65	0.40 ± 0.52
	Total (n=10)	**94.42 ± 17.41**	**62.13 ± 12.43**	**11.28 ± 3.67**	**17.43 ± 6.98**	**6.00 ± 3.40**	**2.08 ± 1.61**	**1.23 ± 1.72**

Values mean ± SD; Post-hoc significant differences: Significantly greater TDC.min^{-1} by CM than CD ($p<0.001$), CM than WD ($p=0.008$), and CM than FW ($p=0.021$). NB. N=10 players per positional role completed each condition.

Appendix O. Mean ± SD values for total distance covered and distance covered in pre-defined acceleration / deceleration zones per positional role

		$TDC.min^{-1}$ (m)	$DC.min^{-1}$ at 0 to 1 $m·s^{-2}$ ($m.min^{-1}$)	$DC.min^{-1}$ at 1 to 2 $m·s^{-2}$ ($m.min^{-1}$)	$DC.min^{-1}$ at 2 to 3 $m·s^{-2}$ ($m.min^{-1}$)	$DC.min^{-1}$ at >3 $m·s^{-2}$ ($m.min^{-1}$)	$DC.min^{-1}$ at 0 to -1 $m·s^{-2}$ ($m.min^{-1}$)	$DC.min^{-1}$ at -1 to -2 $m·s^{-2}$ ($m.min^{-1}$)	$DC.min^{-1}$ at -2 to -3 $m·s^{-2}$ ($m.min^{-1}$)	$DC.min^{-1}$ at >-3 $m·s^{-2}$ ($m.min^{-1}$)
CD	MP	86.99 ± 9.76	46.00 ± 5.93	5.05 ± 0.73	1.86 ± 0.40	1.40 ± 0.43	21.90 ± 2.72	4.22 ± 0.74	1.26 ± 0.32	0.89 ± 0.26
	2 vs. 2	93.38 ± 15.32	47.25 ± 6.69	7.00 ± 1.47	2.56 ± 0.54	2.00 ± 0.87	19.00 ± 2.81	5.88 ± 1.56	1.78 ± 0.57	1.38 ± 0.40
	3 vs. 3	88.42 ± 13.58	41.92 ± 11.93	6.17 ± 2.12	2.42 ± 1.00	1.92 ± 0.88	16.67 ± 4.95	5.08 ± 1.44	1.83 ± 0.66	1.33 ± 0.70
	4 vs. 4	88.56 ± 6.93	45.25 ± 3.18	6.07 ± 0.66	2.25 ± 0.53	1.94 ± 0.80	20.63 ± 2.37	5.50 ± 0.77	1.32 ± 0.55	1.38 ± 0.57
	Total (n=10)	**89.34 ± 11.65**	**45.10 ± 7.59**	**6.07 ± 1.50**	**2.27 ± 0.68**	**1.81 ± 0.78**	**19.55 ± 3.80**	**5.17 ± 1.30**	**1.55 ± 0.58**	**1.24 ± 0.53**
WD	MP	95.01 ± 9.47	51.23 ± 4.86	5.86 ± 0.89	1.72 ± 0.47	1.59 ± 0.47	24.78 ± 2.68	4.33 ± 0.69	1.57 ± 0.37	1.29 ± 0.43
	2 vs. 2	95.25 ± 18.96	48.88 ± 9.83	6.88 ± 1.69	2.33 ± 0.82	2.50 ± 0.83	19.88 ± 4.02	5.38 ± 1.19	1.89 ± 0.91	1.50 ± 0.99
	3 vs. 3	94.67 ± 10.27	47.92 ± 6.54	7.09 ± 1.32	3.00 ± 0.90	2.08 ± 0.90	18.50 ± 2.11	5.83 ± 1.04	2.50 ± 0.68	1.33 ± 0.43
	4 vs. 4	88.94 ± 7.45	46.75 ± 3.56	6.25 ± 1.02	2.44 ± 0.69	1.75 ± 0.82	19.13 ± 1.87	5.38 ± 0.98	1.94 ± 0.35	1.07 ± 0.51
	Total (n=10)	**93.47 ± 12.16**	**48.69 ± 6.58**	**6.52 ± 1.32**	**2.37 ± 0.84**	**1.98 ± 0.82**	**20.57 ± 3.67**	**5.23 ± 1.10**	**1.97 ± 0.69**	**1.30 ± 0.63**
CM	MP	104.36 ± 11.81	56.27 ± 7.07	6.45 ± 0.88	1.83 ± 0.61	1.38 ± 0.50	27.23 ± 3.25	5.18 ± 0.88	1.50 ± 0.36	1.32 ± 0.53
	2 vs. 2	99.75 ± 11.77	45.75 ± 11.12	8.13 ± 2.52	3.00 ± 0.91	2.25 ± 0.99	20.00 ± 1.67	6.75 ± 0.87	2.22 ± 0.52	1.50 ± 0.99
	3 vs. 3	107.92 ± 11.87	54.25 ± 5.58	8.17 ± 1.23	3.58 ± 0.88	3.00 ± 1.19	21.75 ± 2.53	5.33 ± 2.55	2.58 ± 0.73	1.50 ± 0.77
	4 vs. 4	99.81 ± 14.91	50.82 ± 5.85	7.25 ± 1.29	2.75 ± 0.79	2.32 ± 0.93	20.81 ± 2.52	5.75 ± 0.87	2.25 ± 0.44	1.38 ± 0.57
	Total (n=10)	**102.96 ± 12.65** [a]	**51.77 ± 8.45**[b]	**7.50 ± 1.70**[c]	**2.79 ± 1.00**	**2.24 ± 1.07**[d]	**22.45 ± 3.77**	**5.75 ± 1.56**[e]	**2.14 ± 0.65**	**1.42 ± 0.71**
FW	MP	94.31 ± 13.58	50.69 ± 8.05	5.42 ± 1.01	1.98 ± 0.62	1.91 ± 1.19	24.29 ± 3.06	4.77 ± 0.95	1.57 ± 0.59	1.17 ± 0.45
	2 vs. 2	96.63 ± 22.08	48.63 ± 9.92	6.13 ± 1.81	2.89 ± 1.31	2.25 ± 1.54	21.25 ± 5.14	6.13 ± 1.99	1.89 ± 1.05	1.75 ± 1.05
	3 vs. 3	94.17 ± 19.91	43.17 ± 17.25	6.00 ± 2.38	2.92 ± 1.48	2.08 ± 1.38	22.17 ± 9.17	7.08 ± 4.36	2.92 ± 1.43	1.17 ± 0.98
	4 vs. 4	92.56 ± 15.36	46.63 ± 7.30	6.94 ± 1.83	2.63 ± 0.97	2.13 ± 0.79	19.94 ± 2.54	5.81 ± 1.53	1.82 ± 0.62	1.25 ± 0.78
	Total (n=10)	**94.42 ± 17.41**	**47.28 ± 11.25**	**6.12 ± 1.84**	**2.60 ± 1.16**	**2.09 ± 1.21**[d]	**21.91 ± 5.63**	**5.95 ± 2.60**[e]	**2.05 ± 1.08**	**1.33 ± 0.85**

Values mean ± SD; Post-hoc significant differences: [a] Significantly greater $TDC.min^{-1}$ by CM than CD ($p<0.001$), CM than WD ($p=0.008$), and CM than FW ($p=0.021$); [b] Significantly greater mean $DC.min^{-1}$at 0 to 1 $m·s^{-2}$ by CM than CD ($p=0.001$); [c] Significantly greater mean distance covered at 1 to 2 $m·s^{-2}$ by CM than CD ($p<0.001$), CM than WD ($p=0.025$), and CM than FW ($p=0.001$); [d] Significantly greater mean distance covered at 2 to 3 $m·s^{-2}$ by CM than CD ($p=0.046$); [e] Significantly greater mean distance covered at 0 to -1 $m·s^{-2}$ by CM than CD ($p=0.007$) and FW than CD ($p=0.040$); [f] Significantly greater mean distance covered at -2 to -3 $m·s^{-2}$ by CM than CD ($p=0.006$) and FW than CD ($p=0.026$). NB. N=10 players per positional role completed each condition.

Appendix P. Mean ± SD values for total distance covered and the percentage of time covered in each acceleration / deceleration zone per positional role

		TDC.min^{-1} (m)	TDC at 0 to 1 m·s^{-2} (%)	TDC at 1 to 2 m·s^{-2} (%)	TDC at 2 to 3 m·s^{-2} (%)	TDC at >3 m·s^{-2} (%)	TDC at 0 to -1 m·s^{-2} (%)	TDC at -1 to -2 m·s^{-2} (%)	TDC at -2 to -3 m·s^{-2} (%)	TDC at >-3 m·s^{-2} (%)
CD	MP	86.99 ± 9.76	63.10 ± 2.60	4.30 ± 0.82	1.50 ± 0.53	1.40 ± 0.52	24.10 ± 1.29	3.70 ± 0.48	1.00 ± 0.00	0.80 ± 0.42
	2 vs. 2	93.38 ± 15.32	57.10 ± 2.08	6.60 ± 0.84	2.40 ± 0.52	1.70 ± 0.67	21.50 ± 0.97	6.40 ± 0.84	2.00 ± 0.47	1.70 ± 0.67
	3 vs. 3	88.42 ± 13.58	60.10 ± 3.00	5.60 ± 0.97	2.20 ± 0.42	1.70 ± 0.48	20.90 ± 1.79	5.50 ± 0.71	1.90 ± 0.32	1.70 ± 0.82
	4 vs. 4	88.56 ± 6.93	58.30 ± 2.06	6.30 ± 0.95	2.30 ± 0.48	1.50 ± 0.71	22.70 ± 1.34	5.70 ± 0.67	1.60 ± 0.52	1.40 ± 0.52
	Total (n=10)	**89.34 ± 11.65**	**59.72 ± 3.31**	**5.70 ± 1.24**	**2.10 ± 0.60**	**1.56 ± 0.60**	**22.30 ± 1.81**	**5.33 ± 1.21**	**1.63 ± 0.54**	**1.40 ± 0.71**
WD	MP	95.01 ± 9.47	61.10 ± 2.13	4.60 ± 0.97	1.40 ± 0.52	1.50 ± 0.53	24.80 ± 1.32	3.60 ± 0.52	1.30 ± 0.48	1.20 ± 0.42
	2 vs. 2	95.25 ± 18.96	58.00 ± 2.16	5.80 ± 1.14	2.00 ± 0.67	1.80 ± 0.63	22.10 ± 2.02	5.70 ± 0.48	2.30 ± 0.67	1.60 ± 1.17
	3 vs. 3	94.67 ± 10.27	59.90 ± 0.42	5.80 ± 0.52	2.60 ± 1.87	1.90 ± 1.91	19.20 ± 0.42	6.20 ± 0.70	2.40 ± 0.53	1.70 ± 0.48
	4 vs. 4	88.94 ± 7.45	60.20 ± 1.87	5.70 ± 1.25	2.10 ± 0.74	1.60 ± 0.70	21.60 ± 0.84	5.50 ± 0.85	2.00 ± 0.47	1.30 ± 0.48
	Total (n=10)	**93.47 ± 12.16**	**59.80 ± 2.37**	**5.48 ± 1.13**	**2.03 ± 0.77**	**1.70 ± 0.61**	**21.93 ± 2.53**	**5.25 ± 1.15**	**2.00 ± 0.72**	**1.45 ± 0.71**
CM	MP	104.36 ± 11.81	61.00 ± 2.87	4.90 ± 0.99	1.70 ± 0.48	1.10 ± 0.32	24.60 ± 1.84	4.20 ± 0.79	1.00 ± 0.00	1.20 ± 0.42
	2 vs. 2	99.75 ± 11.77	56.70 ± 2.26	6.50 ± 1.51	2.40 ± 0.52	1.80 ± 0.79	21.70 ± 1.64	6.20 ± 0.92	2.40 ± 0.52	2.20 ± 0.79
	3 vs. 3	107.92 ± 11.87	56.00 ± 1.49	7.20 ± 1.14	2.60 ± 0.70	2.50 ± 0.71	21.20 ± 1.14	6.30 ± 0.48	2.40 ± 0.70	1.70 ± 0.82
	4 vs. 4	99.81 ± 14.91	60.30 ± 1.64	5.60 ± 0.52	2.20 ± 0.42	2.00 ± 0.67	20.70 ± 1.49	5.40 ± 0.52	2.00 ± 0.47	1.80 ± 0.79
	Total (n=10)	**102.96 ± 12.65**	**58.50 ± 3.01**	**6.05 ± 1.38**	**2.23 ± 0.62**	**1.85 ± 0.80**	**22.05 ± 2.14**	**5.53 ± 1.09**	**1.95 ± 0.75**	**1.73 ± 0.78**
FW	MP	94.31 ± 13.58	61.60 ± 2.12	4.10 ± 0.88	1.50 ± 0.53	1.20 ± 0.42	25.40 ± 1.90	3.40 ± 0.52	1.30 ± 0.48	1.10 ± 0.32
	2 vs. 2	96.63 ± 22.08	57.30 ± 3.47	5.00 ± 0.82	2.60 ± 0.70	1.70 ± 0.95	23.20 ± 1.23	6.00 ± 0.82	2.00 ± 0.67	1.70 ± 0.95
	3 vs. 3	94.17 ± 19.91	58.60 ± 2.59	5.40 ± 0.97	2.30 ± 0.82	1.80 ± 0.79	22.20 ± 2.20	5.60 ± 1.07	2.00 ± 0.94	1.40 ± 1.07
	4 vs. 4	92.56 ± 15.36	59.10 ± 1.66	5.90 ± 0.88	2.20 ± 0.42	1.80 ± 0.63	22.10 ± 1.73	5.70 ± 0.67	1.80 ± 0.63	1.40 ± 0.70
	Total (n=10)	**94.42 ± 17.41**	**59.15 ± 2.91**	**5.10 ± 1.08**	**2.15 ± 0.74**	**1.63 ± 0.74**	**23.23 ± 2.19**	**5.18 ± 1.30**	**1.78 ± 0.73**	**1.40 ± 0.81**

Values mean ± SD; Post-hoc significant differences: Significantly greater TDC.min^{-1} by CM than CD ($p<0.001$), CM than WD ($p=0.008$), and CM than FW ($p=0.021$). NB. N=10 players per positional role completed each condition.

Appendix Q. Mean ± SD values for accumulated player load (AU) and the physical load in the X, Y and Z axes (g) per positional role

		PLacc.min^{-1} (AU)	X.min^{-1} (g)	Y.min^{-1} (g)	Z.min^{-1} (g)
CD	MP	8.15 ± 1.28	2.21 ± 0.39	1.86 ± 0.62	4.09 ± 0.50
	2 vs. 2	13.64 ± 2.96	3.76 ± 0.69	3.57 ± 1.10	6.29 ± 1.41
	3 vs. 3	12.39 ± 2.76	3.32 ± 0.58	3.25 ± 1.31	5.83 ± 1.21
	4 vs. 4	12.97 ± 1.88	3.74 ± 0.70	3.30 ± 0.82	5.90 ± 0.70
	Total (n = 10)	**11.79 ± 3.11**	**3.26 ± 0.86**	**2.99 ± 1.17**	**5.53 ± 1.31**
WD	MP	10.57 ± 1.84	2.69 ± 0.58	2.86 ± 0.45	5.03 ± 1.05
	2 vs. 2	15.32 ± 3.95	4.09 ± 1.03	4.23 ± 1.36	7.01 ± 1.68
	3 vs. 3	15.18 ± 3.45	3.99 ± 0.94	4.39 ± 1.21	6.79 ± 1.44
	4 vs. 4	12.22 ± 1.86	3.22 ± 0.45	3.39 ± 0.61	5.64 ± 0.88
	Total (n = 10)	**13.32 ± 3.48**	**3.49 ± 0.95**	**3.72 ± 1.14[b]**	**6.12 ± 1.50**
CM	MP	11.34 ± 1.95	2.86 ± 0.48	2.87 ± 0.69	5.63 ± 0.90
	2 vs. 2	14.98 ± 3.20	4.03 ± 0.82	4.04 ± 1.41	6.89 ± 1.26
	3 vs. 3	16.08 ± 2.90	4.22 ± 0.81	4.03 ± 0.74	7.83 ± 1.42
	4 vs. 4	15.23 ± 5.04	3.80 ± 1.21	4.40 ± 1.71	7.02 ± 2.28
	Total (n = 10)	**14.41 ± 3.80[a]**	**3.73 ± 0.99**	**3.83 ± 1.31[b]**	**6.84 ± 1.69[c]**
FW	MP	10.65 ± 2.06	2.70 ± 0.54	3.08 ± 0.60	4.86 ± 0.97
	2 vs. 2	16.08 ± 4.02	4.54 ± 1.14	4.16 ± 1.37	7.43 ± 1.74
	3 vs. 3	15.06 ± 3.17	4.14 ± 1.01	4.20 ± 0.70	6.75 ± 1.61
	4 vs. 4	13.46 ± 3.30	3.56 ± 0.79	3.86 ± 1.01	6.06 ± 1.58
	Total (n = 10)	**13.81 ± 3.72[a]**	**3.73 ± 1.11**	**3.82 ± 1.04[b]**	**6.27 ± 1.74**

Values mean ± SD; Post-hoc significant differences: [a] Significantly greater PLacc.min^{-1} by CM than CD (p=0.004) and FW than CD (p=0.037). [b] Significantly greater physical load in the Y axes per min by WD than CD (p=0.024), CM than CD (p=0.006), and FW than CD (p=0.007); [c] Significantly greater physical load in the Z axes per min by CM than CD (p=0.002).