Movement Profile Monitoring in Professional Football

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September 2013

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Contents

Abstract

Introduction: Professional football clubs utilise global positioning satellite (GPS) systems to monitor the players speed and distances covered during training sessions and motion camera tracking (MCT) systems in competitive matches. Collectively, the data provides the total external workload placed on a player. For this to be accurate the data has to be able to be used interchangeably. The GPS systems also have the ability to monitor the players workload in real-time, and also internal parameters such as heart rate and body forces.

Study 1: The study investigated the differences in GPS data from real-time to post session in an elite competitive football environment. Parameters for external workload and internal workload were compared. No difference was found between datasets for internal workload but significant differences ($P<0.05$) were found for external workload. Study 2: The study firstly aimed to quantify the differences between a GPS and MCT system in a competitive match environment. Secondly, it aimed to further quantify the accuracy at higher running velocities of the systems in a controlled environment by comparing velocity data to that obtained from timing gates. Significant differences were found for overall distance, and all the distances covered in the higher speed zones, between the systems in the competitive match environment. In the controlled environment, it was found the GPS significantly under recorded entries into the highest speed zone and MCT over recorded.

Conclusion: The real time monitoring of GPS for external parameters is not accurate and the data from the GPS and MCT systems cannot be used interchangeably. Both systems are inaccurate when tracking movement at higher velocities. Users of these systems should be aware of the limitations and limits of agreement between them. This is of particular importance if setting physical performance targets on a player with data from one system and monitoring with the other.

1.0 Introduction

Football is a team sport consisting of 10 outfield players and one goal keeper. Team managers are permitted to make up to three player substitutions in a match for tactical reasons or if a player is injured. Football matches are 90 minutes in duration with two periods of 45 minutes, separated by a 15 minute half time break. Typically, three minutes of injury time are added to each half. In some competitions the game is extended by 30 minutes (two periods of 15 minutes) of extra time if neither side has won the match within the initial 90 minute period.

1.1 The physiological demands of football

The physiological demands of football are multi dimensional. Players are required to repeatedly jog, run, sprint, accelerate, decelerate and jump *(Bangsbo & Michalsik, 2002)*. Football is characterized by long periods of low-level moderate intensity exercise fluctuating with random, intermittent, spontaneous and short intense activity *(Polman, Walsh, Bloomfield & Nesti, 2004).* This is in addition to the requirements of the football specific skills of passing, tackling, heading, shooting and controlling the ball (*Stolen, Chamari, Castagna & Wisloff, 2005)*. Players will also regularly engage in physical contact with the opposition. It is often required that the football specific skills are performed at the highest physical intensity. The combination of the multi-dimensional physical activity and football specific skills requires the players to have the physical qualities of a high level of aerobic and anaerobic endurance, agility, sprinting ability, jumping and kicking power *(Reilly, 1997).* However, the players generally do not excel in any one single physical component unlike athletes in other sports *(Hoff & Helgerud, 2004).*

Research into the analysis of movement in football has shown that players typically complete 1179 changes in activity across a 90 minute match *(Bangsbo, Norregand & Thorsoe, 1991).* More recently this has increased with studies reporting 1431 *(Rienzi et al., 2000)* and 1459 *(Krustup, Mohr, Ellingsgaard & Bangsbo, 2005)* activity patterns per match. This increase is due to the greater magnitude of speed and physical requirements in the modern game. This is highlighted in the English top division where players covered more distance in competitive matches post 1992 *(Strudwick & Reilly, 2001)*. Further motion analysis research has analysed the activity profiles and physical requirements of elite football providing data on the distance covered during a match, the amount and duration of high intensity running activity, positional requirements and player fatigue both within a game and across a season. Players will cover a distance ranging between 9 and 12 km in contemporary elite male competition with distances of up to 14 km reported *(Carling, Bloomfield, Nelson & Reilly, 2008)*. However even though overall distance is a good indicator of individual player work rate and energy expenditure the high intensity activity is a constant characteristic, of great importance and another measure of physical performance *(Carling, Bloomfield, Nelson & Reilly, 2008)*. High intensity movements are typically defined as sprinting (greater than 7.0 $m.s^{-1}$) and high speed running (greater than 5.5$m.s^{-1}$) *(Randers, Jensen & Krustrup, 2010)*. Throughout a match a player will run at high speed once every minute and sprint at maximum velocity every four (*Di Salvo, Baron, Tschan, et al., 2007*). Players sprint on average for four seconds covering a distance of 20 meters (*Stolen, Chamari, Castagna & Wisloff, 2005)*. Due to the short duration of the sprint distance the players acceleration, in order to reach the ball first or to pass an opponent, may be of greater importance than maximal speed. The players overall work rate and high intensity activity is reduced when competition commences in an environment with a higher ambient temperature *(Ekbloom, 1986)*. Additionally it has been shown that heat stress in a player impairs the ability to repeatedly perform anaerobic components of the game (*Mohr & Krustrup, 2013).*

The tactical requirements of the game demands different physical requirements for the different playing positions. For example, the midfield players generally cover the most distance *(Mohr, Krustrup & Bangsbo, 2003)* with wide midfields covering significantly more distance at high intensities than players in central midfield (*Zubillaga, Gorospel, Mendo , et al., 2007*). An analysis of high intensity activity over several seasons in the English premier league *(Di Salvo et al., 2009)* also showed that wide midfielders covered the most distance at a high intensity with the central defenders covering the least. Additionally it showed that high intensity activity decreased in the second half with the greatest decline in the wide midfielders and attackers. Interestingly it was found that teams finishing in the bottom five and middle ten league positions completed significantly more high intensity activity across the season than those which finished in the top five positions. This could be attributed to the teams with a higher success rate being in possession of the ball for longer periods of time. More recent research has also shown that high-intensity running is influenced by the score line as well as substitutions but not match importance (*Bradley & Noakes 2013).* Interestingly it has been shown that high intensity running is higher in the third tier of English professional football relative to the higher two tiers, even though the players were of a similar physical capacity *(Bradley et al, 2013).*

Aerobic power is commonly measured by maximal oxygen uptake and is referred to as VO_2max. The VO_2max in elite professional football players is usually within the range of 55 and 65 $ml \cdot kg \cdot min^{-1}$ *(Bangsbo, 1994, Al-Haaza et al,. 2001).* It is difficult to measure oxygen uptake during a match due to the equipment hindering regular play. However, research using heart rate monitors and a subsequent estimation of oxygen uptake has indicated that players operate at approximately 75% of their maximal oxygen uptake (*Bangsbo, 1994)*. It has been shown that professional elite players from higher ranked teams have a higher VO_2max than those in lower ranked teams *(Bangsbo & Michalsik, 2002)*. Additionally, when a player is running with possession of the ball the oxygen demands and perceived exertion are higher than when running without *(Reilly & Ball, 1984)* There were no reported significant differences in VO_2max between outfield players based on their position within the team *(Bangsbo & Michalsik, 2002)*.

The anaerobic component of the physical requirement is often determined by the concentration of lactate in the blood. Lactate levels as high as 14 $mmol \cdot L^{-1}$ have been recorded during a match with the average values of 6.8 $mmol \cdot L^{-1}$ in the first half and 2.5 $mmol \cdot L^{-1}$ in the second half (*Stolen, Chamari, Castagna & Wisloff, 2005)*. This reflects the reduced high intensity activity in the second period of the match.

1.2 Training design

Due to the multifaceted physical requirements in the game of football it is important that training is designed to cover both the aerobic and anaerobic components and also replicate match intensities so that the player is adequately prepared for competition. As an aid to do this top level professional football clubs are increasingly tracking the players movement profiles both in training and competition. This allows the sports science and fitness staff to quantify the longitudinal external workload placed upon a player aiding in periodization of the training. If a player is returning from injury the external workload can be increased gradually in an attempt to return the player to their pre-injury fitness level and to avoid the injury reoccurring. It has been shown that injury occurrence has a significant impact on a team's performance, making the prevention and management of injuries of high importance *(Hägglund, Martin, et al, 2013)*. If a younger player is promoted up through the ranks from the academy to the elite development squad through to the first team it is possible to determine if their physical performance is of a high enough standard for the demands of the higher level.

It is possible to illicit different physiological responses within football specific training by controlling the parameters involved. For example, one study investigated the physical responses in a small sided game (SSG) of decreasing the number of players per team from six per side through to two per side but maintaining the relative pitch size per player *(Hill-Haas, Dawson, Coutts & Rowsell, 2009)*. The results showed that players in the smaller game format spent more time at over 90% of their maximum heart rate (HR) and reported a higher level of perceived rate of exertion. However the average distance covered at a higher running velocity was greater in the larger sessions. This suggests that using smaller matches in training can develop the players aerobic and anaerobic capacity and the larger games can reproduce more high intensity running similar to competition. Furthermore it has been suggested that SSG, compared with interval running, are more highly recommended training drills for the coincident development of physical capacity and technical skills in young soccer players *(Radziminski et al, 2013)*. It is important to include a sport specific high intensity training load as it has been shown to lower the players risk of injury *(Verrall, Slavotinek & Barnes, 2005)*.

1.3 Team sport motion analysis systems

There are various systems available in order to track a players movement profile. Typically this is done by using global positioning satellite (GPS) system receivers in training and semi automated motion camera tracking (MCT) systems in competition.

There are three main companies who manufacture and supply team sport GPS monitoring systems to professional football clubs; Catapult (Canberra, Australia), GPSports (Fyshwick, Australia) and Statsports (Dundalk, Ireland). All 20 professional clubs in the English premier league clubs use a system from one of these three suppliers. There are two main companies who manufacture and install MCT at elite football club stadia; Prozone (Leeds, UK) and Amisco (Nice, France). All clubs in the English premier league have one of these two systems installed at their stadia.

The two types of systems offer various advantages and disadvantages. GPS systems allow monitoring of additional physiological parameters such as HR and an estimation of the gravitational forces placed on the player via an integrated accelerometer. Contemporary units also incorporate a gyroscope to measure twists and rotations although this functionality is yet to be utilised. Data is often streamed in real time (RT) allowing sports science staff to instantaneously quantify the players external work load during training. However, the players have to wear additional apparel to house the unit, on their back between the shoulders, which some find intrusive. The units typically weigh between 60 and 120g. They are often not permitted to be used in competition, although this could change. The GPS units can be prone to signal dropouts, if the unit is not receiving a signal from at least four satellites, compromising data integrity. Some systems overcome this be using data from the accelerometer as well as the GPS receiver to calculate movement data. The units can only be used outdoors although most units have an 'indoor' mode where the GPS functionality is not utilised but data is able to be logged from the HR and accelerometer. The GPS units demand a lot of power resulting in a short battery life, usually within the range of four to six hours for modern systems. This can be problematic if multiple training sessions are undertaken on the same day, as there may be time limitations restricting the opportunity to recharge the units between sessions.

Multiple studies have been undertaken to validate and test the reliability of various different GPS systems. Table 1.1 summarises the specification, functionality and validation research for systems from the three main team sport GPS manufacturers used in contemporary elite level professional football in the UK.

Table 1.1: GPS Systems Specification and Research. (SF: sampling frequency, ACC: Integrated accelerometer, *, the viper system is verbally quoted as 10Hz)

Manufacturer	System	SF (Hz)	HRM	ACC	RT	Validation research
GPSports	SPI Pro X II	15	Y	y	y	Not known
	SPI Pro	5	Y	n	Y	Petersen et al., 2009
	SPI Elite	1	n	n	n	MacLeod et al., 2009
						Barbero-Alvarez et al., 2010
						Coutts et al.,2010
						Duffield et al., 2010
						Gray et al., 2010,
Catapult	MinimaxX v2.0	1 & 5	y	y	y	Petersen et al., 2009
						Duffield et al., 2010
						Jennings et al 2010
						Portas et al., 2010
	MinimaxX v2.5	10	y	y	Y	Castellano et al. 2011
StatSports	Viper	10*	Y	y	y	Not known

Both 1 Hz and 5 Hz GPS systems have been shown to be a valid and accurate tool for field-based assessment of overall distance covered during linear and soccer specific motion when a 5% threshold is adopted (*Portas, Harley, Barnes & Rush, 2010)*. Systems with a greater sampling frequency are more accurate at measuring distance especially at higher velocities and over a longer duration *(Aughey, 2011)*. In a 10m standing start maximal sprint

a 1 Hz GPS system, the standard error of the estimate was 32.4% and 30.9% for a 5Hz system *(Jennings, Cormack, Coutts, Boyd & Aughey, 2010)*. The standard error was reduced by two thirds when the sprint length was increased to 40m. Similar results were obtained in another study where the standard error of the mean was 10.9% for a 10Hz system in a 15m sprint *(Castellano, Casamichana, Calleja-González, San Román & Ostojic, 2011)*. This was further reduced to 5.1% when the length of sprint was doubled from 15m to 30m. As players cover on average a distance of 20 meters (*Stolen, Chamari, Castagna & Wisloff, 2005)* when sprinting in competition it raises the question of the validity GPS systems to measure high intensity match performance in football.

Currently only one study *(Aughey & Falloon, 2010) has* validated the efficacy of RT GPS data using the 5Hz MinimaxX v2.0 system in two competitive Australian Rules football matches. The findings showed the RT data to be significantly different to the data downloaded from the units post match for overall distance and for distance covered in all of the speed zones. The discrepancy is potentially due transmission loss and the limited RT bandwidth available to transmit the data relative to the rate it is logged within the unit. This highlights that caution should be used when monitoring players in RT and basing any training benchmarks on post session data.

The main advantages of the MCT systems are that as well as physical movement profiles they also provide tactical data on the individual player and of the team. The fitness data can also be further quantified by being in possession of the ball both individually and as a team. The players do not have to wear additional kit but they can only be tracked in the stadium where the system is installed. A main disadvantage is that the data is not provided in RT. The MCT systems are substantially more expensive than GPS systems.

Prozone uses eight cameras installed in the corners of the stadium, with three in opposite corners and one in the other two corners. All cameras capture the entire playing surface with every area of the pitch covered by at least two cameras. All video feeds are fed back to a video server which also runs proprietary capture software. Automated tracking determines the movement profiles of each player from each camera and then subsequently combined into a single dataset. Player movement profiles are then confirmed by human monitoring post event to ensure a high quality of data. Prozone is calibrated for pitch coordinates upon installation of the system *(Di Salvo et al., 2006)*. The Amisco system also uses eight synchronised cameras located high in the corners of the stadium. The video feeds from these cameras are subsequently digitally encoded and the players angles and movements calculated *(Di Salvo et al., 2007)*. A systematic review into 38 studies which utilised the Amisco and Prozone systems concluded that they are valuable data collection tool to identify the physiological demands placed on players during competition *(Castellano, Alvarez-Pastor, & Bradley, 2014).*

Prozone has been shown to be highly correlated for average velocity (range approximately 7.5 to 25 $km \cdot h^{-1}$) for straight line runs over a distance of 60m (r=0.99) and curved runs over 50m (r=0.99) when compared with timing gate data *(Di Salvo et al., 2006)*. Further results from the same study show strong correlations for a maximal sprint over 15m (r=0.99) and a 20m sprint and turn (r=0.95). Even though this study has shown high correlations with average velocity it has not confirmed peak velocity or the accuracy of distance reported across various different speed zones. To the authors knowledge there is no published work validating the Amisco system.

In order to monitor the longitudinal external load on a player the movement profile data from the two different types of system, in training and in competition, has to be used collectively. In order that this global load is accurate the direction and level of agreement between the datasets from the two types of systems has to be confirmed. In a study comparing the MCT system Amisco with the 1Hz GPSport SPI Elite system and the Catapult 5Hz MinimaxX v2.0, it was found that the overall distance covered was higher for both of the GPS systems but lower distance was recorded when the players moved at a higher velocity *(Randers, et al., 2010)*. Similar results were found in a study comparing the MCT system Prozone with the Catapult 5 Hz MinimaxX v2.0 *(Harley, Lovell, Barnes, Portas & Westen, 2011)*. Prozone reported that the overall distance covered was lower but the distance covered sprinting was higher compared to GPS. Both of the studies found high correlations between the systems, for overall distance and distance covered at higher velocities, but both concluded that caution should be applied when using the data from the two systems interchangeably.

1.4 Movement profile parameters

The parameters which are measured by the two types of system include maximum velocity, the distance covered and time spent in various speed zones, entries made into each speed zone, overall distance and acceleration. The GPS systems also provide data on HR and time spent in different HR zones. The GPS systems with integrated accelerometers supply data on the accumulative stress on the player, usually in the form of proprietary index scores, such as bodyload (GPSports), player load (Catapult) and dynamic stress load (Statsports). Information on how the body load and dynamic stress load are calculated is not available. Player load is expressed as “the square root of the sum of the squared instantaneous rate of change in acceleration in each of the three vectors (X, Y and Z axis) and divided by 100” *(Boyd, Ball & Aughey, 2011)*. Player load has been shown to have a strong correlation (r=0.89) with overall distance as recorded by the GPS signal *(Boyd, Ball & Aughey, 2011)*. This parameter then provides another measurement to quantify training load especially if training is undertaken indoors and the GPS data is not available. The Viper system, from Statsports, also provides three metabolic parameters using a combination of the accelerometer and GPS movement data. These are equivalent metabolic distance (EMD), metabolic power (MP) and high metabolic load (HML). The MP is an estimate of the players energy expenditure. Many systems also supply a similar estimation based on the players HR but this is calculated through the movement data. The EMB is an estimate of the distance a player would have covered if they had run at a steady state. It attempts to quantify the metabolic impact on a player from the accelerations undertaken during a training session. The HML measures the distance covered during periods of high acceleration and combines it with the high intensity running distance. These parameters are currently still being researched and developed and as of yet here has been no published confirmation of their validity. However, they do provide sports science staff with extra parameters to quantify the external load on a player during SSG where overall distance and sprint distance can be low but the number of accelerations high.

1.5 Current Research

This study aims to address three main research questions.

1. How does the RT data compare to the subsequent downloaded post session data for a team sport GPS system?
2. Can the movement profile data from an MCT and GPS system be used interchangeably to provide the players comprehensive longitudinal training load?

3. How accurate are an MCT and GPS system at recording distance covered at maximal velocity over a distance typical of sprints in an elite game of football?

The predominant GPS (SPI Pro X II) and MCT (Prozone) systems used in the English premier league in the 2011-2012 football season will be used in this study. These systems have not been compared before in similar previous research. This also makes the current study of high interest to sports science staff operating in professional football and using these systems.

The first question is addressed in chapter two. It is of importance because if RT training load parameters are set based on post session data and differences between the two datasets exist than the desired training load may not be achieved in the specific session being monitored. This could then result in non-optimal conditioning of the player.

The second question is addressed in chapter three. The data from the two different types of system needs to be used interchangeably in order to accurately quantify longitudinal training load. This will then increase the probability of periodization resulting in players being in optimal physical condition at times of competition.

The third question is also investigated in chapter three. If high intensity conditioning drills are based from MCT competitive match data in order to replicate match intensity, the data provided from the MCT and GPS system needs to be valid and accurate. The accuracy of the two different types of system for the highest velocity running zone will be investigated in more detail than in previous research.

2.0 – The comparison of a team sport GPS motion tracking system data during real-time monitoring (1Hz) versus post-game (15Hz) in an elite competitive football environment

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2.1 Abstract

Team sports clubs monitor players speed and distance during training sessions with GPS systems to quantify the training load in real-time (RT) and post-session (PS). However no data of the relative validity of RT and PS data is available for all systems. This study aims to investigate the differences in RT and PS data in an elite competitive football environment and to calculate a correction factor (CF) if any exist.

In three Barclay's premier league reserve team fixtures, 10 outfield players wore GPS Sport SPI Pro X II units. Data for overall distance (OD), sprint distance (SD) (> 7m.s^{-1}), high speed distance (HS) (>5.5m.s^{-1}), maximum velocity (MV) time at > 85% HR_{max} (RZ) and the accelerometer data index score bodyload (BL), was compared from RT to PS.

RT was significantly lower compared to PS for: MV (m·s^{-1}) 7.9±0.7 to 8.5±0.7, D (m) 9350±1559 to 9650±1587, HS (m) 327±119 to 432±154, and SD (m) 65±45 to 104±60. RT was not significantly different to PS for: RZ(s) in RT compared to PS, 2898±1265 to 2959±1299 (p=0.068) and BL (AU) 206±61 to 209±62 (p=0.097) (All data mean±*s*). The RT parameters BL, MV, RZ, OD and HS had strong correlations with PS of 0.99, 0.82, 0.99, 0.99 and 0.80 respectively. SD had a moderate correlation of 0.79. A CF applied to all of the highly correlated variables resulted in no difference from RT to PS data.

It is recommended that the BL and RZ parameters are used when setting training load if basing the parameters from PS data. If MV, OD and HS are used then the relevant CF should be applied. No CF could be calculated for SD.

Abstract word count: 274

2.1 Introduction

Professional football (soccer) clubs and other team sports are increasingly utilising global positioning satellite (GPS) tracking systems to monitor players speed and distance during training sessions in order to quantify the training load placed on the players *(Aughey, 2011*, *Carling, Bloomfield, Nelson & Reilly, 2008)*. Modern GPS team sport tracking systems enable multiple players to be monitored in real-time (RT) as well as logging the data for it to be downloaded post-session (PS) *(Aughey, 2011*, *Aughey & Falloon, 2010)*).

Tracking the players' movements during training sessions enables coaching staff to monitor players during outside end stage rehabilitation, conditioning drills, full squad training and during reserve team and friendly fixtures ensuring that the session contains the correct pre-determined load on the player. This is increasingly important for those players returning from injury and those with a high history of injury, as sport specific high intensity training load has been shown to reduce the risk of injury occurrence *(Verrall, Slavotinek & Barnes, 2005)*. The subsequent downloading of the data PS allows for the complete logging of the longitudinal training load and for the session to be further split down into specific drills. This aids in the planning of the periodization of the squad training and in the design of subsequent sessions respectively.

The physiological demands of soccer are well documented (*Bangsbo, Mohr & Krustrup, 2006, Bradley, Di Mascio, Peart, Olsen & Sheldon, 2010, Drust, Atkinson, & Reilly*

2007, Mohr, Krustrup & Bangsbo, 2003) and require a high aerobic fitness component with intermittent and repeated bouts of sprinting which is highly anaerobic in nature. A greater distance covered anaerobically requires a longer recovery time and as such it is the most important area to monitor. It has been shown that GPS systems with a higher sampling frequency report a more accurate value in the higher speed zones but still have a large error margin *(Aughey, 2011).*

RT to PS data has been compared for a 5Hz GPS system *(Aughey & Falloon, 2010)* during two Australian Rules football matches and concluding that caution should be used when setting targets with PS data for RT monitoring. This was due to the large magnitude of error in the two data sets particularly at higher running velocities. To the authors knowledge this has been the only paper which has compared data RT to PS.

The aim of the current experiment is to investigate the differences in the data monitored RT to PS for a higher resolution GPS system in a competitive soccer match environment and to calculate a correction factor (CF) if any differences occur. It is hypothesised that RT will record lower overall distance and distances covered in the higher speed zones compared to the PS data.

2.2 Methods

2.2.1 Experimental Approach to the Problem

In order to compare the data monitored in RT to PS, 10 outfield players wore GPS units and heart rate (HR) monitor straps during three Barclay's premier league reserve team fixtures. During the three fixtures the players were monitored in RT and the variables measured were compared post-match to the PS downloaded data. The two highest speed zones for soccer are defined as sprint distance (SD) and high speed distance (HS) which is greater than 5.5m.s^{-1} and 7m.s^{-1} respectively (6,9). These two highest speed zones are collectively known as high intensity (HI) activity. The HI, HS and SD variables, alongside overall distance (OD) covered and maximum velocity (MV), are considered the external load (EL) on the player. The GPS units also incorporate a HR monitoring device and a tri-axel accelerometer to estimate the forces placed on a player. The time spent at > 85% HR_{max} is defined as being in the players red zone (RZ). The accelerometer data index score bodyload (BL) is based on cumulative impacts through the player based upon their own body weight *(GPSports, 2006).* The RZ and BL are considered the internal load (IL) on the player.

All variables, OD, HS, SD, HI, MV, RZ and BL which can be monitored in RT were compared to PS. A competitive match environment was used as a full sized pitch will illicit higher OD and HI distance and the competitive nature of session inducing more RZ time than a similar length training session.

2.2.2 Subjects

The players who participated in this study were all professional and had given written informed consent to the club to participate in competitive matches and training sessions whilst being monitored during these activities. Institutional ethical approval was also obtained.

Across the three competitive reserve team fixtures all 10 starting outfield players (n=18) were monitored. They consisted of a mix of first team (n=7) and elite development squad (n=11) professional soccer players. The average (mean ± S.D.) age was 22.1 ± 4.1 years old, body weight 79.9 ± 7.2 kg, height 181.6 ± 5.5 cm and a VO_2peak 59.5 ± 3.3 ml^{-1}·kg^{-1}·min^{-1}. VO_2peak was determined by a graded exercise test to exhaustion (1kph increment per minute until 16 kph followed by 1.4% grade increment per minute) on a treadmill

(Woodway) at the end of pre-season training of the UK 2011/12 soccer season. Breath analysis was conducted (Cortex Metalyzer 3B) and HR monitored (Activio) throughout the test. From this exhaustive test mean maximal heart rate was measured at 192 ± 9 beats per minute (BPM) and subsequently the players RZ threshold calculated to be 163 ± 7 BPM.

2.2.3 Equipment and logistics

The three reserve team fixtures took place in the autumn of 2011 at two different stadia. The GPS units were SPI Pro X II (GPSports, Fyshwick, Australia) units and RT monitoring using GPSport SPI RT software (version R2 2010) and wireless receiver. All GPS units were fully charged before each match. Prior to the first match at each stadium a RT channel scan was completed and the GPS units configured to the cleanest channel for each location. In both locations the RT receiver during the match, and pre-match scan, was 2m behind the home team technical area, on a 1.5m high tripod resulting in a clear line of site to the playing surface.

The subjects completed a 30 minute warm-up routine 40 minutes before kick off during which time the GPS units were turned on and placed in bra or vest style apparel designed to hold the unit securely in place on the back of the subject between the two scapula. The unit number matched the subjects shirt number and was placed with their match shirt alongside a polar (Polar Electro Oy, Kempele, Finland) T32 HRMstrap. All off the payers had extensive previous experience wearing the HRM and GPS units in training and match situations. RT monitoring was started immediately prior to the start of the match and stopped at the end of the match.

2.2.4 Data collection

A post-match RT report was created from the SPI RT software to generate the RT dataset and used for further analysis. Additionally, the HS and SD parameters for each subject were manually recorded as they are not automatically included in the RT report. The PS data was uploaded from the units using GPSport SPI EZY (version R1 2011.16 P10) software and then imported into teamAMS (version R1 2011.16 P10). All of the subjects speed and individual HR zones are uniformly set and applied to each subject in SPI RT and teamAMS software for the RT and PS data respectively. The PS data for each individual subject is split in order to capture the first and second half only so it is across the same time period as the RT data.

2.2.5 Statistical Analyses

Statistics analyses were calculated using SPSS Statistics for Windows Version 20 (Armonk, NY: IBM Corp.). Comparison between RT and PS was completed using a 2-tailed paired samples t-test with significance set at P<0.05. Correlations were tested by the Pearson correlation coefficient (r) with statistical significance set at P<0.01. The relationship between the mean and absolute difference between the 2 datasets was examined using Pearson's correlation coefficient. If r^2 was between 0 and 0.1 the data was considered homoscedastic. Heteroscedasticity was indicated if positive relations were observed and $r^2 > 0.1$. If heteroscedasticity was indicated logarithmic transformations of the data were then performed. Systematic bias (SB) and random error (RE) for the ratio LOA (rLOA) were then calculated.

2.3 Results

Comparisons between the data for all the variables are shown in table 2.1. The EL variables MV, OD, HS and SD were all found to be significantly different ($p<0.01$) The IL variables of BL and RZ were not different from RT to PS.

Table 2.1: Dependent sample t-tests for all variables

	RZ (s)	BL (AU)	OD (m)	HSD (m)	SD (m)	HI (m)	MV($m \cdot s^{-1}$)
RT	2898 ± 1265	206 ± 61	9350 ± 1587	327 ± 119	65 ± 45	392 ± 142	7.9 ± 0.7
PS	2955 ± 1299	209 ± 62	9650 ± 1587	432 ± 153	104 ± 60	537 ± 200	8.5 ± 0.7
t	1.89	1.72	13.53 **	6.38 **	5.72 **	7.28 **	7.15 **
df	29	29	29	29	29	29	29

**p<0.01, All data M±sd

Pearson's correlations (r) were calculated for all variables from RT to PS. The variables MV (r=0.821), RZ (r=0.992), OD (r=0.997), HS (r=0.806) and BL (r=0.988) are all highly correlated (r > 0.8) with SD (r=0.774) approaching a strong correlation.

To calculate the CF between the EL variables the PS value was divided by the RT value. The mean correction factor was then applied to the RT data. The corrected RT data (RTc) was then compared to the PS data as shown in table 2.2.

Table 2.2: Correction factor and dependent sample t-tests for all external variables

	OD (m)	HSD (m)	SD (m)	HI (m)	MV ($m \cdot s^{-1}$)
RT	9350 ± 1587	327 ± 119	65 ± 45	392 ± 142	7.9 ± 0.7
PS	9650 ± 1587	432 ± 153	104 ± 60	537 ± 200	8.5 ± 0.7
CF	1.03 ± 0.02	1.36 ± 0.28	2.1 ± 2.1	1.40 ± 0.26	1.07 ± 0.06
RTc	9656 ± 1610	444 ± 161	149 ± 86	548 ± 198	8.5 ± 0.7
T	0.29	0.63	3.12 **	0.55	0.28
df	29	29	26	29	29

**p<0.01, All data M±sd

The rLOA for all variables are shown in table 2.3 below.

Table 2.3: rLOA for all variables

	RT	PS	rLOA (SB */÷RE)
RZ (s)	2898 ± 1265	2955 ± 1299	1.06 */÷1.13
BL (AU)	206 ± 61	209 ± 62	1.01 */÷1.09
OD (m)	9350 ± 1587	9650 ± 1587	1.03 */÷1.03
HSD (m)	327 ± 119	432 ± 153	1.33 */÷1.55
SD (m)	65 ± 45	104 ± 60	1.57 */÷3.15
HI (m)	392 ± 142	537 ± 200	1.37 */÷1.51
MV($m \cdot s^{-1}$)	7.9 ± 0.7	8.5 ± 0.7	1.08 */÷1.08

All data M±sd

2.4 Discussion

The data monitored in RT is shown to be significantly inaccurate relative to the PS data for the EL parameters of MV, OD, HS, HI and SD. This is consistent with previous research conducted using another GPS tracking system (Aughey & Falloon, 2010) which found strong correlations but differences RT to PS for overall distance and time spent in specific speed zones. The RT monitoring of the IL parameters, BL and HR, was not significantly different relative to the PS data. These results support the hypothesis that the GPS speed and distance measurements are different in RT relative to PS. As such, it is important that users of RT systems are aware of these differences especially if basing any conditioning parameters on PS data.

For all of the variables which are strongly correlated from RT to PS a CF can be applied to the RT data resulting in no significant difference between the two datasets. The higher speed zone SD, was the only EL variable where a CF did not result in a difference from RT to PS. However, for the combined SD and HS variable, HI a CF can be successfully applied. This is probably due to the RT logging of additional HS distance if the resolution of the system cannot capture all of the SD. As a result, when SD and HS distances are combined and corrected no difference occurs. The rLOA indicates that if the systematic basis is negligible then the differences between the two data sets will differ by no more than the range of random error in either a positive or negative direction. This then offers a percentage range of within which the two datasets will be agreeable.

The reason of the inaccuracies between the two sets of data, for the EL parameters, is likely due to difference in sampling frequency. The RT data is captured at a rate of 1 Hz whereas the units log at 15 Hz for the PS data. If a player is in the HS and SD speed zones over 5.5m and 7m can be covered each second respectively. Small intermittent entries into these speed zones of less than 1s in duration can cause PS data to accumulatively log more distance covered which is not reported in RT. This will subsequently have an effect on the OD recorded. However the EL parameter of HR is logged both in RT and PS at 1 Hz resulting in no difference between the two datasets. The BL parameter is calculated by the GPS unit based on the 100 Hz tri-axial accelerometer data again at a resolution of 1 Hz which again is at a resolution sufficient for the RT system. Any wireless transmission loss between the GPS units and the RT receiver which may occur will result in lost packets of data contributing to the differences in datasets.

Newer RT systems, from the manufacturer of the system presented here (GPSport) and others; now use multiple sensors to increase the wireless bandwidth so the resolution of the PS and RT data is closely matched. However this will not aid in the elimination of transmission loss. A potential solution would be for the GPS units to calculate and periodically transmit to the RT receiver the time spent in each speed zone, instead of the RT software calculating time spent in the zones based of the lower resolution data. Other solutions could include the transmission of a cyclic redundancy checksum (CRC) with the data so the receiver knows if any data is lost and then subsequently either attempts to correct the data, based on packets lost, or alert the user that the RT data is not the true reflection of the players physical activity. Alternatively the CF can be applied within the RT software which will result in no difference to the PS data.

2.5 Practical Applications

Team sports conditioning coaches who utilise tracking of players by RT GPS systems need to be aware of the margin of error and inaccuracies in the EL parameters. The players RT training and match conditioning benchmarks should not be based on PS data parameters unless the CF is applied, apart from for the IL parameters HR and BL.

3.0 A comparison of two football motion tracking systems in a competitive match and controlled environment

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3.2 Abstract

Intro: Professional footballers are monitored using motion camera tracking (MCT) systems in competition and global positioning satellite (GPS) systems in training to quantify total training load. To use the data interchangeably any differences in the systems needs to be quantified. This study aims to establish any differences for an MCT and GPS system (part one) and establish further validity of the systems to measure high velocity movement (part two).

Methods: Part one: In a Barclay's premier league reserve team fixture, nine outfield players wore GPS Sport SPI Pro X II units and simultaneously tracked by the MCT system Prozone. Data for overall distance (OD), sprint distance (SD) (> 7m.s^{-1}), high speed distance (HS) (>5.5m.s^{-1}) was compared from Prozone to GPS. Part two: 14 amateur footballers completed eight trial runs through timing gates at a range of velocities wearing Sport SPI Pro X II units whilst being tracked by Prozone.

Results: Part one: GPS significantly (P<0.05) recorded less OD (m) 9141±1220 to 10209±1266 , HS (m) 344±103 to 704±179 and to SD (m) 72±54 to 264±116 compared to Prozone (All data mean±*s*). GPS (4 ± 3) recorded significantly less SD entries Prozone (40 ± 18). Part two: SD entries were recorded 39 times (Prozone) and 9 (GPS) with 23 (Timing gates) resulting in 170% of confirmed SD entries (Prozone) and 39% (GPS).

Discussion: As data for all parameters was significantly different between the two systems, caution should be used if using data interchangeably. As Prozone significantly recorded more SD entries and GPS less than confirmed by the timing gates caution should be utilised if basing high intensity conditioning sessions from this data.

Abstract word count: 270

3.3 Introduction

The sports science and physical conditioning staff at professional football clubs and other team sports are increasingly monitoring players in both completion and training in order to determine performance and fitness levels *(Carling, Bloomfield, Nelson & Reilly, 2008)*. Typically globally positioning satellite (GPS) systems are used in training and semi-automated motion camera tracking (MCT) systems are used in competition due to practical and financial considerations. When the movement patterns from both training and competition are combined the complete longitudinal external workload on the player can be deducted. The benefits of this include ensuring that training is of the correct intensity, identifying individual physical strengths and weaknesses, monitoring fatigue in an attempt to avoid over training and enabling periodization of training loads so players can peak on match days. Therefore the accuracy and variation between the systems is off high importance to ensure that the data can be used interchangeably.

The movement patterns are typically categorised by distances covered within various speed zones. There are typically six speed zones and are defined as standing, walk, jog, run, high speed (HS) run and sprint (SD). The two highest speed zones of HS and SD are defined as >5.5 ms-1 and >7ms-1 respectively *(Randers, Jensen & Krustrup 2010)*. Overall high intensity (HI) running is the combined distance in the HS and SD zones. The HI match components are of an increased importance as they indicate physical performance and require more recovery time (*Bangsbo, 1994)*.

Previous research has validated the accuracy of the different type of systems individually and also compared their relative accuracy. To summarise, GPS systems with a higher sampling frequency have an increased accuracy *(Aughey, 2011)*. At high velocities of movement the coefficient of error increases reducing the reliability of the GPS systems accuracy *(Jennings, Cormack, Coutts, Boyd & Aughey, 2010)*. Additionally, a 10Hz GPS system coefficient of variation reduced from 10.9% to 5.1% when the length of sprint from a standing start was doubled from 15 to 30m *(Castellano, Casamichana, Calleja-González, San Román & Ostojic, 2011)*. This indicates that sprints of shorter duration are more inaccurate. Changes in direction have also been reported to increase the error in GPS systems which are also typical of the movement patterns in team sports *(Aughey, 2011)*.

The eight camera 10Hz MCT system Prozone was compared to movement patterns through a series of timing gates *(Di Salvo et al., 2006)* and found to be highly correlated (r=0.99) with average velocity for a series of straight line and curved 50 and 60m runs at predetermined speeds. Similar high correlations were found for a 10m maximal sprint and 20m sprint with a 90 degree turn at 10m of r=0.970 and r=0.960 respectively. However, as only average velocity was considered over a certain distance it does not indicate if peak speed and time in the important higher velocity zones are reported accurately.

To the authors knowledge there are two studies which have compared the datasets for the same movement patterns from GPS and MCT systems. The first *(Randers, et al., 2010)* compared a 25 Hz MCT (Amisco) system with a 1 Hz and 5 Hz GPS system in a training match. Overall distance (OD) was higher for both GPS systems compared to the MCT system but lower for distances in the higher speed zones. The thresholds for the speed zones were slightly lower for this study due to the differences in the movement data between Amisco and Prozone. The datasets from both of the GPS systems were highly correlated with the MCT system. All of the systems compared showed the same physical performance decrements over the course of the match.

The second study *(Harley, Lovell, Barnes, Portas & Westen, 2011)* compared the data from Prozone and catapult MinimaxX 5 Hz GPS system from six players in a competitive match environment. The findings showed that Prozone reported lower overall distance relative to the GPS system and higher distances in all of the speed zones by 9% (>4ms-1), 16% (HS) and 40% (SD). However, SD was the only speed zone which was significantly different. Both of the papers conclude that there are large between system variations for reporting the same movement patterns and that care should be implemented if using the data interchangeably.

The aim of the current experiment is to determine any differences between an MCT and GPS system, specifically across the higher speed zones and to calculate a correction factor if any exist. Furthermore, the accuracy of each system to report the SD covered is investigated.

The experiment is conducted in two parts. The first part is in a competitive match environment with the players competing wearing GPS units in an MCT equipped stadium so that the data from the two systems can be compared in a manner similar to the previous research *(Randers, et al., 2010, Harley, Lovell, Barnes, Portas & Westen, 2011)*. The second part is conducted in a controlled training environment. The participants completed a series of runs through a series of timing gates to further investigate the accuracy of each systems ability to report distance covered in the highest speed zone.

The first hypothesis is that the MCT system will result in a greater magnitude of distance covered in the higher speed zones compared to the GPS system. Secondly, it is hypothesised that the Prozone system will report higher amount of entries into the highest speed zone than indicated by the timing gates.

3.4 Materials and Methods

3.4.1 Part One: Competitive match environment

In a Barclay's premier league reserve team fixture 10 outfield players wore SPI Pro X II GPS units (GPSports, Fyshwick, Australia) and were simultaneously tracked by the Prozone MCT system. The participants consisted of a mix of first team (n=3) and elite development squad (n=7) professional soccer players. The average (mean ± S.D.) age was 22.0 ± 5.8 years old, body weight 79.6 ± 7.1 kg, height 181.7 ± 6.8 cm and a VO_2peak 58.7 ± 2.8 $ml^{-1}·kg^{-1}·min^{-1}$. VO_2peak was determined by a graded exercise test to exhaustion (1 kph increment per minute until 16 kph followed by 1.4% grade increment per minute) on a treadmill (Woodway) at the end of pre-season training of the UK 2011/12 soccer season. Breath analysis was conducted (Cortex Metalyzer 3B) and HR monitored (Activio) throughout the test.

The match was undertaken at the Molineux stadium, (Wolverhampton, UK), home ground of Wolverhampton Wanderers Football Club (WWFC) which is installed with Prozone and fully calibrated at the start of the 2011/12 season. The match commenced at 19:00 hours in clear conditions. The units were placed in either a vest or bra garment based on the players own personal preference. Both of the garments are specifically designed to support the unit on the back between the shoulder blades. All players were familiar and comfortable with wearing the GPS units from training and prior reserve team fixtures.

3.4.2 Part Two: Controlled training environment

The participants (n=14) were all male, healthy, active individuals selected from the local university football team. The average (mean ± S.D.) age was 20.6 ± 1.3 years old, body weight 78.6 ± 11.2 kg, height 178 ± 7.3 cm. They were all familiar with physical demands and repeated sprint exertions required in the game of soccer. The participant's selection was based on reaching the minimum sprint speed in an experimental familiarisation procedure (n=24) where the same protocol was followed. All of the participants gave written informed consent and institutional ethical approval was obtained. The initial testing provided the participants of both the experience of the wearing of the GPS units and the experimental protocol. This was conducted at the Compton training ground of WWFC. The full experimental procedure was conducted at the Prozone equipped Molineux stadium at 16:00 hours in clear conditions.

The experimental protocol consisted of a steady state run, at a self determined jogging pace around a measured area of the pitch in order to warm up the participants. This was followed by eight specific trial runs through a series of timing gates at differing speeds. The participants were given feedback on their run speed based from the timing gate data in an attempt to ensure they were in the correct speed zone for each trial. This also ensured that enough distance was covered in the SD speed zone.

The timing gate Speed Fusion (Fusion Sport, Coopers Plains, Australia) and Brower TC system (Brower Timing, Utah, USA) were set between 0 and 42 m for the eight trials and are summarised in table 3.1. The straight line running trial area and steady state area was measured using a tape measure

Table 3.1: Showing the timing gate location for each specific trial. * = Brower gates, & = Speed Fusion gates

Trial	Description	Timing gate Location - Distance (m)						
	(% effort)	0	10	15	20	25	30	42
1	Fast Walk	*	*		*		*	
2	Jog (50%)	*	*	&	* &	&	* &	
3	Jog (70%)	*	*	&	* &	&	* &	
4	HS (80%)	*	*	&	&	&	* &	*
5	HS (80%)	*	*	&	&	&	* &	*
6	SD (100%)	*	*	&	&	&	* &	*
7	Jog (50%)	*	*	&	&	&	* &	*
8	SD (100%)	*	*	&	&	&	* &	*

The participants were instructed to stand stationary prior to commencing each trial and then to run at the requested speed until the 30m mark which was clearly indicated with poles and cones. From this point they were to slow to a walk and then stand stationary at the 42m mark. This was to aid in the identification of each individual trial and so a direct comparison could be made with the timing gate data. The Brower timing gates were spaced at the perimeter of the trial run section in order to capture the whole trial and are referred to as the perimeter section. The Speed Fusion gates were spaced within the perimeter section at a closer proximity and are referred to as the timed section. This was done in order to capture the participants at their peak velocity of each trial and to provide a higher resolution of data. There were two different timing gate set-ups due to technical difficulties at the start of the trials.

3.4.3 Data analysis methods

Following the competitive match all data from the GPS units was subsequently downloaded and the files truncated removing time prior to kick off, half time and the final whistle using GPSport SPI EZY (version R1 2011.16 P10) software. All GPS data was then imported into teamAMS (version R1 2011.16 P10). Following the controlled training environment the data was downloaded in the same manner with the warm up run and each individual trial identified and the movement data outside of these regions removed.

For the MCT system the movement data was analyzed and extracted using Prozone MatchViewer (version PZ3 12.0.0.0). For the competitive match environment Prozone player movement data was analysed in the same manner as in all competitive matches. For the controlled environment only the participants movements for the warm up and trial timing gate runs were captured so a direct comparison could be made with the truncated GPS data.

For the competitive match environment, fitness data from each system showing the distance covered in each speed zones of interest was compared. This is reported in the results section 3.5.1 – Overall system comparison.

The number of entries into the highest zone, SD, was then also compared. Even though Prozone is a 10 Hz system the minimum time recorded in a speed zone is 500ms. Likewise, the SPI Pro X II units have a resolution of 15 Hz on sampling the GPS signal the minimum time spent in a speed zone in teamAMS is one second and then at a resolution of 10 Hz. Sprints shorter than 1s in duration are classed as short sprints with sprints over 1s classed as long sprints. Additionally GPS sprints (entries and distance) were compared to Prozone long sprints. This is reported in the results section 3.5.2 – Sprint frequency.

To further analyse the accuracy of each system in the SD zone the timing gate data from the controlled environment was compared to the data from both Prozone and GPS. Prozone does not allow the extraction of the movement data across a specific time period when it is over 90 minutes so the final trial (trial 8) could not be extracted. As a result only the first seven trials through the timing gate could be used as trial eight occurred after ninety minutes. If SD was recorded by either system or through the timing gate it was then further analysed. This is reported in the results section 3.5.3 – Sprint distance comparison.

3.4.4 Statistical Analyses

Statistics analyses were calculated using SPSS Statistics for Windows Version 20 (Armonk, NY: IBM Corp.). Comparison between Prozone and GPS was completed using a 2-tailed paired samples t-test with significance set at P<0.05. Correlations were tested by the Pearson correlation coefficient (r) with statistical significance set at P<0.01. Comparison between Prozone and GPS was completed using a 2-tailed paired samples t-test with significance set at P<0.05. Correlations were tested by the Pearson correlation coefficient (r) with statistical significance set at P<0.01. The relationship between the mean and absolute difference between the 2 datasets was examined using Pearson's correlation coefficient. If r^2 was between 0 and 0.1 the data was considered homoscedastic. Heteroscedasticity was indicated if positive relations were observed and $r^2 > 0.1$. If heteroscedasticity was indicated logarithmic transformations of the data were then performed. Systematic bias (SB) and random error (RE) for the ratio LOA (rLOA) were then calculated.

In order to compare either systems accuracy of recorded an entry into the SD zone as confirmed by the timing gate a chi-squared test was used with significance set at P<0.05.

3.5 Results

3.5.1 Overall system comparison

The differences between the two systems for distances covered in the competitive match environment and the correction factor (CF) between them are shown in table 3.2 for the nine players who started and finished the match. To calculate the CF between the two systems variables the Prozone value was divided by the GPS value.

Table 2.2: Correction factor and dependent sample t-tests for distance, high speed distance, sprint distance and high intensity distance in the competitive match environment comparing Prozone to GPS. **p<0.01, All data M±sd

	OD (m)	HSD (m)	SD (m)	HI (m)
Prozone	10209 ± 1266	704 ± 179	264 ± 116	970 ± 285
GPS	9141 ± 1220	344 ± 103	72 ± 54	416 ± 133
CF	1.12 ± 0.05	2.10 ± 0.36	4.44 ± 1.45	2.39 ± 0.39
GPSc	10226 ± 1365	723 ± 216	319 ± 241	995 ± 317
T	2.47E-5 **	1.64E-5 **	8.62E-6 **	1.89E-6 **
Df	8	8	8	8

The mean CF was then multiplied to the GPS data. The corrected GPS data (GPSc) was then compared to the Prozone data as shown in table 3.3.

Table 3.3: Dependent sample t-tests for distance, high speed distance, sprint distance and high intensity distance in the competitive match environment comparing Prozone to GPSc data. All data M±sd

	OD (m)	HSD (m)	SD (m)	HI (m)
Prozone	10209 ± 1266	704 ± 179	264 ± 116	970 ± 285
GPSc	10226 ± 1365	723 ± 216	319 ± 241	995 ± 317
t	0.45	0.34	0.15	0.34
df	8	8	8	8

Pearson's correlations (r) were calculated for all variables from GPS to Prozone. The variables OD (r=0.95), SD (r=0.82) and HI (r=0.84) are all highly correlated (r>0.8) with HSD (r=0.77) approaching a strong correlation.

The rLOA indicates that if the systematic basis is negligible then the differences between the two data sets will differ by no more than the range of random error in either a positive or negative direction. This then offers a percentage range of within which the two datasets will be agreeable. Table 3.4 below shows the rLOA for all of the variables.

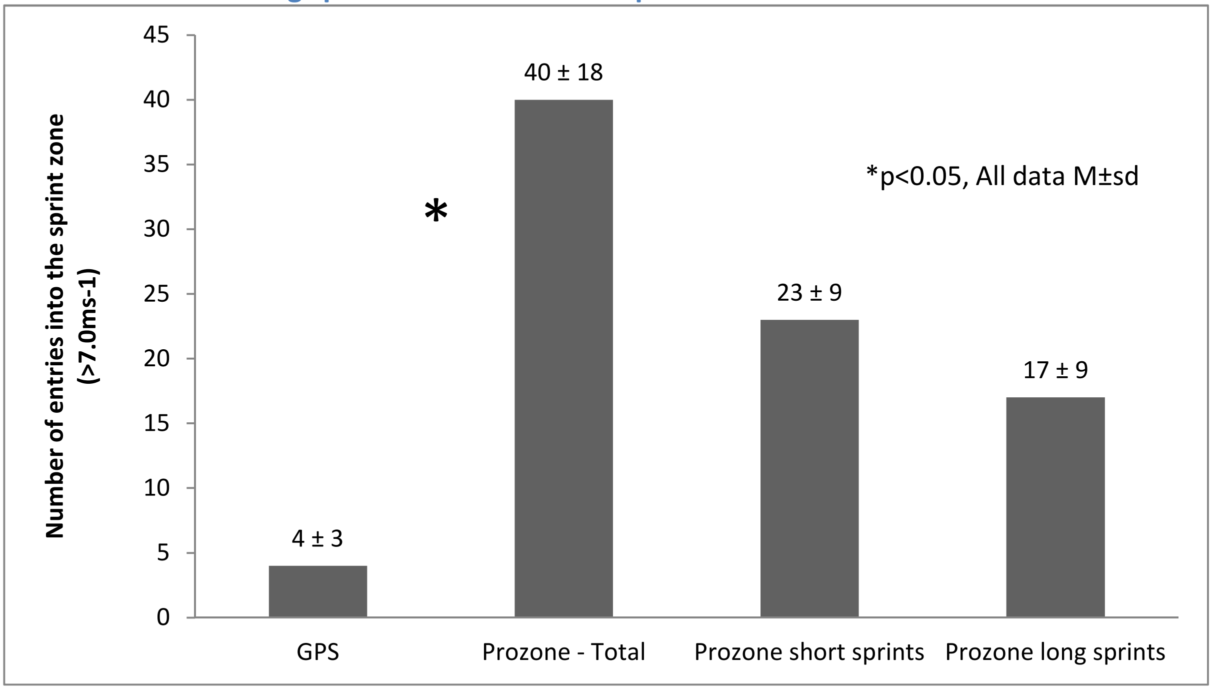
Table 3.4: rLOA for all for distance, high speed distance, sprint distance and high intensity distance in the competitive match environment comparing Prozone to GPS data. All data M±sd

	Prozone	GPS	rLOA (SB */÷RE)
OD (m)	10209 ± 1266	9141 ± 1220	1.12 */÷ 1.08
HSD (m)	704 ± 179	344 ± 103	2.07 */÷ 1.44
SD (m)	264 ± 116	72 ± 54	4.16 */÷ 2.02
HI (m)	970 ± 285	416 ± 133	2.35 */÷ 1.39

3.5.2 Sprint Frequency

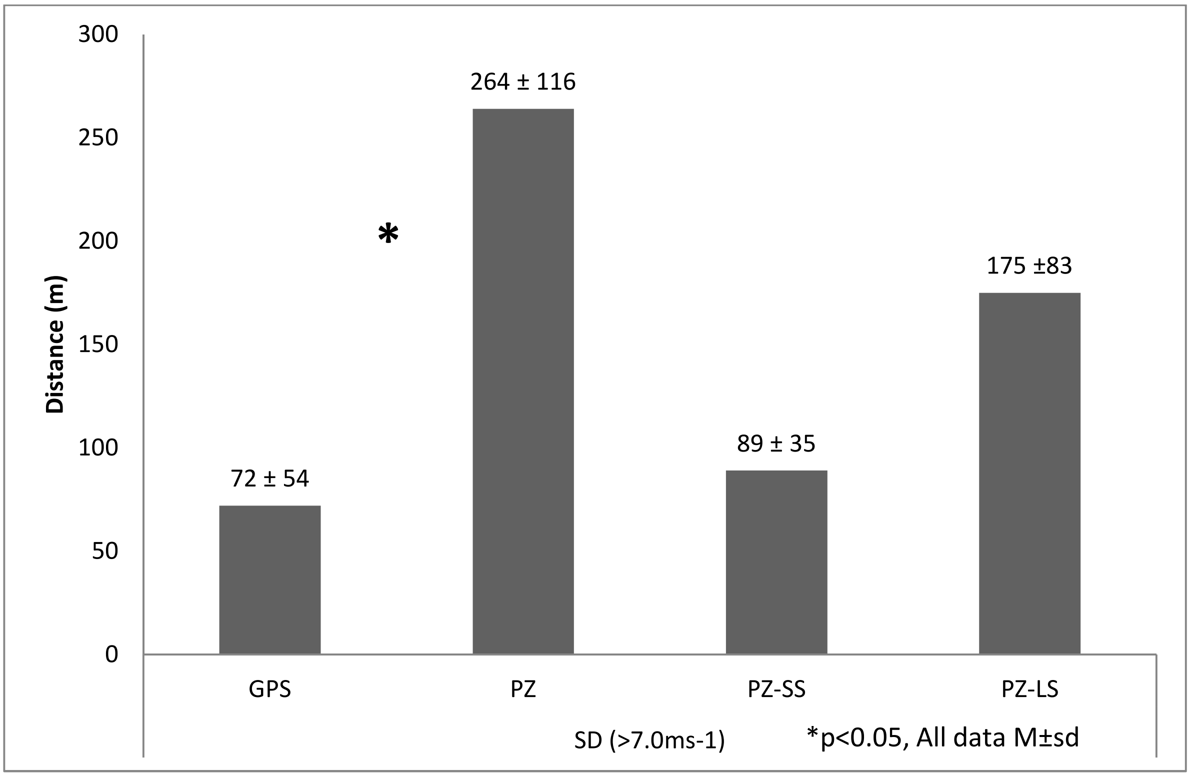
Figure 3.1 shows the frequency of entry into the SD speed zone for the nine outfield players whose participation was the longest in the competitive match environment. Entry captured by the GPS system is significantly different to both Prozone total sprints and long sprints. Prozone reported that every single player had more entries into the SD zone as short sprints as opposed to long sprints.

Figure 3.1: Dependent sample t-tests for entries into the SD speed zone, comparing the GPS system to Prozone for total sprint entries as well as for the Prozone short sprint and long sprint entries in the competitive match environment.



As the GPS system cannot record short sprints the SD for the Prozone long sprints was compared to the GPS SD. The results are shown in figure 3.2. Every single player had more distance covered in the SD zone as long sprints as opposed to short sprints.

Figure3. 2: Dependent sample t-tests for the SD speed zone, comparing the GPS system to Prozone for total sprint entries as well as for the Prozone short sprint and long sprint entries in the competitive match environment.



3.5.3 Sprint distance comparison

Table 3.4 shows the average speed reported at each timing gate location for a trial run when either of the systems reported SD in the controlled environment. The average speeds highlighted in grey indicate when a sprint was recorded within a 5m length of the timed section. If either one of the two systems or the timing gate indicated that the highest speed zone, SD, was entered then the trial was selected for further analysis. Of all the trials available, 41 met this criterion. Of these 41 trials the timing gate indicated that the SD zone was entered 23 times, leaving 18 non-sprints. On two occasions a sprint occurred but was not captured by either system (trial4-unit10 and trial5-unit10). The GPS system recorded SD once when the timing gate data indicated no sprint occured (trial4-unit15). For Prozone this occurred on 18 occasions (trial3-units3-7-8-9-11, trial4-units5-14-15-16-20, trial5-units5-7-8-9-11-15-20 and trial 6-unit12). This resulted in Prozone recording that a sprint occurred 170% higher than that indicated by the timing gate and GPS only capturing 39% of the sprints that occurred. The chi-squared test proved significance for both of these measurements.

Table 3.4: Sprint distance comparison. Average speeds through the timing gates and SD reported by the MCT and GPS system. PS = perimeter section gate. TS = timed section gate.

		Timing gate speed (ms^{-1})							SD (m)	
Trial	Unit	PS-g1	TS-g1	PS-g2	TS-g2	TS-g3	PS-g3	Timing Gate	Prozone	GPS
3	2	5.13	7.03	5.81	6.75	6.49	6.00	Sprint	7.4	0
3	3	5.08	6.33	5.65	6.24	5.89	5.67	No Sprint	3.7	0
3	7	5.24	6.22	5.75	6.30	6.10	5.86	No Sprint	3.6	0
3	8	5.71	6.36	6.04	6.68	6.54	6.24	No Sprint	11.5	0
3	9	5.18	6.62	5.73	6.45	6.29	5.89	No Sprint	7.7	0
3	11	4.81	5.93	5.26	5.98	5.87	5.45	No Sprint	3.7	0
		PS-g1	TS-g1	TS-g2	TS-g3	PS-g2	PS-g3			
4	2	5.56	7.17	7.37	7.21	6.55	-	Sprint	18.9	0
4	3	5.85	7.09	7.05	6.78	6.49	4.70	Sprint	11.1	0
4	4	5.56	6.95	7.09	7.08	6.58	5.62	Sprint	15.3	0
4	5	5.29	6.28	6.38	6.14	5.85	5.05	No Sprint	7.8	0
4	7	5.46	7.08	6.83	6.66	6.28	4.75	Sprint	11.6	0
4	8	5.59	7.50	7.25	7.37	6.65	5.97	Sprint	19.4	0
4	9	5.46	7.36	7.21	7.25	6.55	5.47	Sprint	19.5	5.7
4	10	5.15	7.00	6.70	6.38	6.02	5.66	Sprint	0	0
4	14	4.98	6.33	6.54	6.46	5.84	5.02	No Sprint	7.1	0
4	15	5.18	6.83	6.75	6.68	6.12	4.64	No Sprint	7.9	11.7
4	16	5.15	6.79	6.68	6.70	6.11	4.76	No Sprint	7.4	0
4	20	5.29	6.61	6.60	6.57	6.10	5.10	No Sprint	11	0
5	2	5.32	6.90	7.05	6.95	6.29	-	Sprint	11	1.4
5	4	5.85	6.85	7.14	7.15	6.67	5.76	Sprint	19.4	0
5	5	4.78	6.13	6.13	5.91	5.48	5.03	No Sprint	4.3	0
5	7	5.41	6.56	6.78	6.67	6.25	4.84	No Sprint	11.4	0
5	8	5.56	6.48	6.44	6.63	6.28	5.62	No Sprint	7.7	0
5	9	5.41	6.54	6.71	6.43	6.09	4.84	No Sprint	11.7	0

5	10	4.90	7.04	6.77	6.22	5.71	4.56	Sprint	0	0
5	11	5.00	6.11	6.17	6.22	5.76	5.08	No Sprint	3.6	0
5	15	5.29	6.71	6.89	6.80	6.17	4.92	No Sprint	14.5	0
5	20	5.10	5.88	6.06	6.01	5.74	4.76	No Sprint	3.5	0
6	3	5.75	7.85	8.05	8.07	7.06	6.42	Sprint	31.6	22
6	4	5.68	7.75	7.79	7.68	6.83	6.81	Sprint	26.8	0
6	5	5.62	7.39	7.37	7.27	6.59	5.96	Sprint	22.9	0
6	7	5.88	8.67	8.40	8.59	7.35	6.42	Sprint	28.2	22.7
6	8	6.21	7.68	8.05	8.05	7.26	6.89	Sprint	24.2	0
6	9	6.10	7.62	7.97	7.89	7.13	6.72	Sprint	24.2	24.8
6	10	5.62	7.72	8.00	7.87	6.90	6.09	Sprint	19.9	0
6	11	5.29	7.68	7.76	7.83	6.67	6.71	Sprint	27	8.8
6	12	4.74	6.60	6.68	6.42	5.81	5.10	No Sprint	3.5	0
6	14	5.46	7.97	8.20	8.19	6.93	6.58	Sprint	24.2	0
6	15	5.99	7.74	7.76	7.82	7.03	6.26	Sprint	26.5	20.5
6	16	5.85	8.08	8.23	8.15	7.11	6.38	Sprint	27.6	24.4
6	20	6.17	7.20	7.58	7.47	7.06	5.82	Sprint	23.4	0

Pearson's correlations (r) were calculated for SD covered across a trial for each system to average velocity across the timed section and resulted in a strong correlation for Prozone (r=0.91) and a moderate correlation for GPS (r=0.56). A moderate correlation was found (r=0.58) for SD comparing the two systems.

3.6 Discussion

The movement data from the competitive match environment is shown to be significantly lower across all the speed zones and OD from GPS to Prozone. The supports the first hypothesis that the MCT system will result in a greater magnitude of distance covered in the higher speed zones compared to the GPS system. However even though the two systems are different they are highly correlated across all the speed zones and OD. Prozone also recorded more entries into the SD speed zone for both the total sprints, short sprints and long sprints.

These findings are consistent with previous research in terms of the higher speed zones but different in terms of OD. Both of the previous studies found the GPS system to report a higher OD than Prozone. Additionally the magnitude of the difference in the higher speed zones between the two systems is much greater in the current study than previously found. The difference in direction of difference for OD in this study could be due to the use of a different GPS system in this study relative to the previous research.

The differences in the SD speed zone cannot be accounted for by the resolution of each system in relation to capturing a players movement across a speed zone as both SD and number of entries into this zone were significantly different when comparing with the short sprints removed which the GPS system cannot measure.

Using the data from the competitive match environment a CF was calculated which when applied to the GPS data resulted in no significant difference to the Prozone data. This will aid in the movement profiles captured from professional soccer players in competitive matches, by Prozone, to be used interchangeably with movement profiles captured by GPS in the training environment. Subsequently this will then allow the total external load on a player to be tracked across the whole season.

The second, controlled environment, part of the study investigated the accuracy of each system to reliably report distance covered in the highest speed zone. The timing gate data confirms if a sprint occurred if the average speed was greater than $7ms^{-1}$ within a 5m timing gate of the timed section. The GPS system failed to capture entries into the sprint zone when they occurred, as confirmed by the timing gate, with only 39% of entries successfully captured. For the Prozone system the opposite was found and 170% more entries into the SD were captured. This supports the second hypothesis that the Prozone system will report higher amount of entries into the SD zone than confirmed by the timing gates.

The timing gate data confirmed sprints occurred on 23 occasions, of which 21 were captured by Prozone and on 7 occasions by GPS. On an additional 18 occasions Prozone reported SD when it was not confirmed by the timing gate and once by GPS. It is possible that SD was achieved after the final timed section timing gate but it is unlikely as on all 18 occasions the third timed section timing gate shows that the participant was slowing down. Furthermore, all participants were instructed to reduce speed after this point and then walk to a standstill at the end of the perimeter section.

Across the 39 entries into the SD zone captured by Prozone the average speed at the 30m gate from the start of the run when the timing gates did not confirm a sprint was 5.05 ± 0.36 ms^{-1} and 6.02 ± 0.59 ms^{-1} when one was confirmed. This suggests that the Prozone speed threshold and subsequent algorithmic calculation for detecting entry into the SD zone is set too low. When the timing gates did not confirm a sprint zone entry, Prozone reported an average distance of 7.77 ± 3.41 m compared to 18.50 ± 8.58 m when a sprint did occur. This shows that Prozone records a lower SD when a sprint was not confirmed relative to when one did occur. Due to the limited number of timing gates available it is not possible to say accurately the minimum SD achieved by the participants. However, on 14 of the 23 occasions SD was confirmed by the timing gates, all participants were above the minimum SD threshold across the whole of the TS showing that a minimum of 15m SD occurred. Across these trials Prozone reported SD of 24.29 ± 3.74 m. As the participants were instructed to sprint to the 30 m location from a standing start it is possible that the SD reported by Prozone is marginally high due to the distance needed to accelerate into the SD zone. Further research using more timing gates will be able to confirm the accuracy of a systems ability to record SD.

Previous research has validated the Prozone system and has shown very strong correlations in average speeds across a set distance with the timing gates. The current results show a strong correlation from SD reported by Prozone and the average speed across the timed section. However, as shown in this paper, Prozone significantly records entry into the SD zone when it is not confirmed with the timing gates. This will then result in the reported distance across the SD zone being too high. This subsequently brings into the question the accuracy of distance covered in the lower speed zones if the correct average speed is to be maintained.

Both of the previous papers have expressed caution when using the data from the different systems interchangeably. The results presented here support that argument and highlights that differences can be found across different GPS systems for OD. As demonstrated, it may be possible to use the data from the two systems under test interchangeably if a CF is applied. Additionally the accuracy of Prozone for SD has been highlighted for the first time. As a result it is important for fitness coaching and sports science staff to be aware that Prozone records higher SD than what is actually achieved. The data from competitive fixtures for the SD speed zone may be too high and caution should be used when basing sprint conditioning drills in a training environment from this match data.

4.0 Overall Conclusions

The study aimed to answer three research questions. In answer to the first question it found that RT is significantly different to PS data for all external parameters and the same for all internal parameters. As the external parameter data from RT to PS was highly correlated a CF was calculated so that any physical benchmarks set from PS data can be applied in a RT setting. Additionally the ratios of the limits of agreement were calculated providing the systematic basis and random error across which the two data sets are agreeable. The findings show that the application of 1-Hz RT monitoring is not practically applicable to a sport which is characterised by a high level of short high velocity repeated sprint movements. As such, users of such equipment should be aware of these limitations before basing decisions on RT data. Manufactures of RT monitoring equipment should increase the frequency in which the data is transmitted to match the frequency in which it is logged in order to eliminate differences in the datasets. Alternatively the units could calculate and log the distances covered in each speed zone and periodically transmit this data. This would increase computational requirements in the units but a lower transmission frequency should then be adequate.

The second question asked if the movement profile data from an MCT and GPS system can be used interchangeably and found, consistent with previous research, that they cannot. However, for the first time in research of this type a CF was calculated so that they can be used interchangeably in a simple manner. Again the ratios of the limits of agreement between datasets were calculated. The wide range of random error indicates why a CF could not be calculated for the high velocity parameters. Sports science staff at professional football clubs should be made aware of these limitations and exercise caution when using the data from one system to set performance targets which are then measured by the other system.

Thirdly, It was found that GPS significantly under reports and Prozone significantly over reports SD entries. This is the first study which has shown that Prozone is not accurate at the higher velocities for sprint characteristics that are typical in a game of football.

One of the main limitations in the current research is the application of the CF to data from which it was calculated. Further data should be collected in both a training environment and competitive match environment to confirm its validity. It should also be noted that different CF should be used for different movement patterns. For example, the GPS-MCT CF from the competitive match environment could not be applied to the participants from the controlled training environment as the task of the trail runs through the timing gates was not of a similar movement profile to players in a game of football. The overall SD covered and the participants maximum velocity was lower and there were no changes in direction. However, the CF presented in the two experiments in this study have provided working values which can and have been applied in a real life application and setting. The high range of random error in the ratio of the limits of agreement demonstrates why a CF cannot be calculated for all datasets and for these parameters the data cannot be used interchangeably. Ultimately, the ratio of limits of agreement dictates how agreeable the two systems are and users of the systems should be aware of these values if attempting to use the datasets interchangeably.

The sports science staff at professional football clubs often considers the movement profile data from Prozone as the ‘gold standard’. This is due to the previous research highly correlating Prozone with the timing gates average velocities. In contrast, this study has been shown that Prozone records more SD entries than actually occur by a significant amount. These entries will then result in a higher overall SD reported from Prozone. It was the initial aim of the second experiment to quantify SD reported by Prozone with actual SD covered in addition to the entries into that zone (for more information see design document – appendix 4). Due to a limited availability of the number of timing gates available this was not possible. Future research should attempt to quantify the accuracy of Prozone when measuring movement profiles at the higher velocities. Prozone can then use this information to adjust the algorithm used to calculate distance covered and as a result improve the accuracy of the system.

As highlighted throughout this report it is highly important for the data from the two different types of system to be used interchangeably. This could be overcome by future technological advancements enabling the same system to be used in both training and competition i.e. mobile MCT systems at the clubs training grounds, or smaller and more compact GPS devices possibly located inside the players kit. It is evident that both types of system need to be more accurate at tracking high velocity movement which is typical within a game of football.

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Appendix 1 – ECSS Abstract

Comparison of a team sport global positioning system (GPS) and a video based motion tracking system in an elite competitive football environment

Dallaway, N.[1, 2], Daley, T.[2], Li F-X.[1]

1: School of Sport and Exercise Sciences, University of Birmingham (UK), 2: Wolverhampton Wanderers Football Club (UK)

Introduction

Professional football clubs are increasingly utilising GPS tracking systems to monitor players speed and distance run during training sessions in order to quantify the work load. Additionally, the video-based motion analysis system Prozone (PZ, Leeds, UK) tracks the players' movements in competitive matches. When both systems are used together they potentially provide a comprehensive account of the total distance and speeds covered by players in both training and competition. However, the relative accuracy of each system has not yet been evaluated. The aim of the study is to investigate the differences in the physical performance data from the PZ and GPS systems in an elite competitive football environment.

Methods

In a Barclay's premier league reserve team fixtures, ten outfield players wore GPSport (Fyshwick, Australia) SPI Pro X 15Hz GPS units and were tracked via the PZ motion camera system. Data for overall distance, sprint distance (> 7m.s^{-1}) and high speed distance (>5.5m.s^{-1}) was compared between the 2 systems.

Results

In all cases GPS recorded lower distance and number of sprints than PZ. No significant difference was found for overall distance (GPS: 7717m ± 2389, PZ: 9341m ± 3288, p=0.25). However significant differences were found between the high speed running (241m ± 140 compared to 645m ± 252, p= 6.12E-07) and sprint distance (62m ± 50 compared to 248m ± 122, p= 3.34E-05) speed zones. Significant differences (p=1.8E-06) were also found in the number of sprints between the 2 systems with GPS recording 4 ± 3 and PZ 36 ± 17.

Discussion

Although GPS and PZ recorded similar overall distance run, in the high intensity running zones and in the number of sprints these differences were significant. It is possible that the sampling frequency is the source of these differences. The GPS system only records sprints at 1Hz whereas the PZ system samples at 10 Hz. The accumulative distance of sprints shorter then 1s recorded by PZ accounts for the majority of the differences in this speed zone between the 2 systems.

Due to the differences between the 2 systems care should be taken when using data from them interchangeably to log the total load on players, in particular, when the GPS system is used to monitor the work load of a player returning from injury. Future research should be conducted to determine a correction factor between the 2 systems to allow a direct comparison of the data.

Appendix 2 – ECSS Oral Presentation slides

Tracking movement in football: GPS vs. Video

Li F-X.[1], Dallaway, N.[1, 2], Daley, T.[2]

1: School of Sport and Exercise Sciences, University of Birmingham (UK),
2: Wolverhampton Wanderers Football Club (UK)

Introduction

- Team GPS tracking systems monitor players speed and distance run during *training sessions*
- Video-based motion analysis systems track the players' movements in *competitive matches*
- Used together they provide the total distance and speeds covered by players in both training and competition

- Are they interchangeable?

System accuracy

- **Accuracy of Prozone** (Di Salvo et al., 2006. *Int J Perf Anal Sport*)
  - Average velocity of 60m and 50m multidirectional runs at various speeds correlated (r=0.99) between PZ and timing gates
  - Average maximal 15m and 20m sprint velocity showed excellent correlation (r=0.97) between PZ and timing gates
  - Only long sprints & average velocity

- **Accuracy of SPI Pro X units not validated** (Aughey, 2011. *Int J S Phys Perf*)
  - The review summarised papers on units up to 10 Hz
  - GPS units found to be more accurate with higher sampling resolution
  - The higher the velocity and the more changes in direction the lower the validity of measurements
  - Published info on 10Hz units reported SEM in a 15m sprint as 10.9%

System comparisons

- **Comparison between Amisco and 1 Hz (SPI Elite) and 5 Hz (MinimaxX v2.0) GPS units** (Randers et al., 2010. *JSS*)
  - Overall distance for 5HZ GPS and Amisco not significantly different
  - Both 1Hz and 5 Hz GPS significantly different in the higher running speed zones
  - Good correlations in physical performance with each other

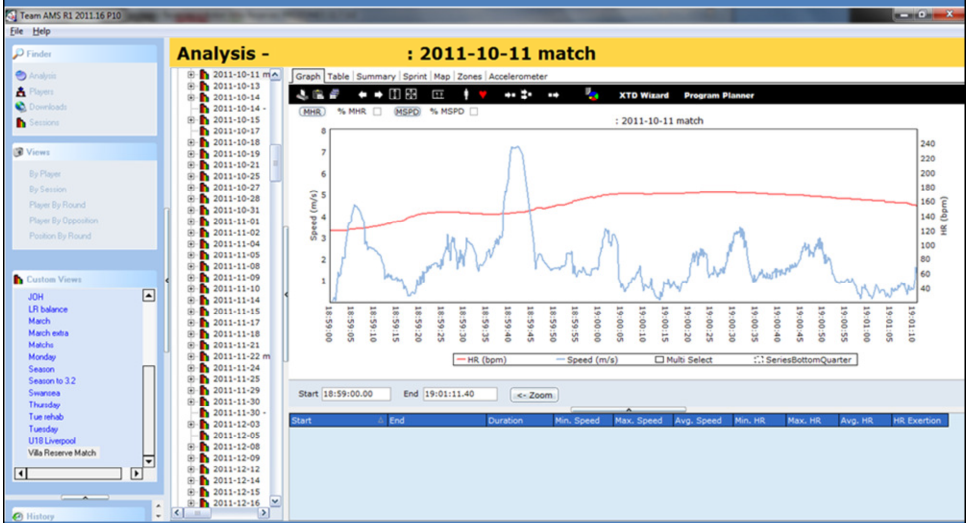
- **Comparison 5 Hz (MinimaxX v2.0) and PZ**
  - GPS reported higher overall distance than PZ
  - PZ reported higher distances for high speed running and sprinting than GPS

- Both studies conclude to use caution when using data between the 2 systems interchangeably

Training and competition: 2 different systems

SPI Pro X GPS units Training only	Prozone Competition only
• 15 Hz GPS • 100 Hz tri-axel accelerometer • Integrated heart rate sensor • Sprint > 1s • 10 Hz	• 8 fixed cameras fitted into football stadiums – 3 cameras in 2 opposite corners and 1 in the other 2 corners • Sprint > 0.5s and >1s • 2 Hz

GPS TeamAMS – Screenshot: Speed profile



Prozone – Screenshot: Speed profile

Aim

- To compare 2 systems currently use in training or in competition by UK premier league teams, but not in conjunction.
- Competitive football match setting.

Methods

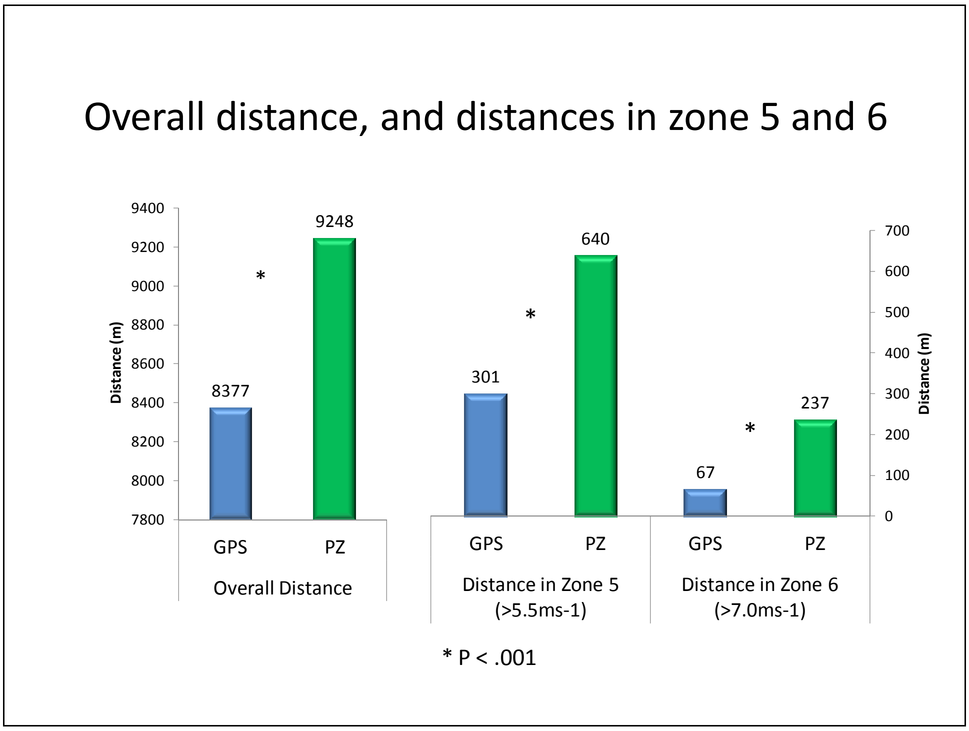
- Barclay's premier league reserve team fixture
- 11 outfield players
- Wolverhampton Wanderers Molineux Stadium
  - GPSport (Fyshwick, Australia) SPI Pro X 15Hz
  - Prozone (Leeds, UK)

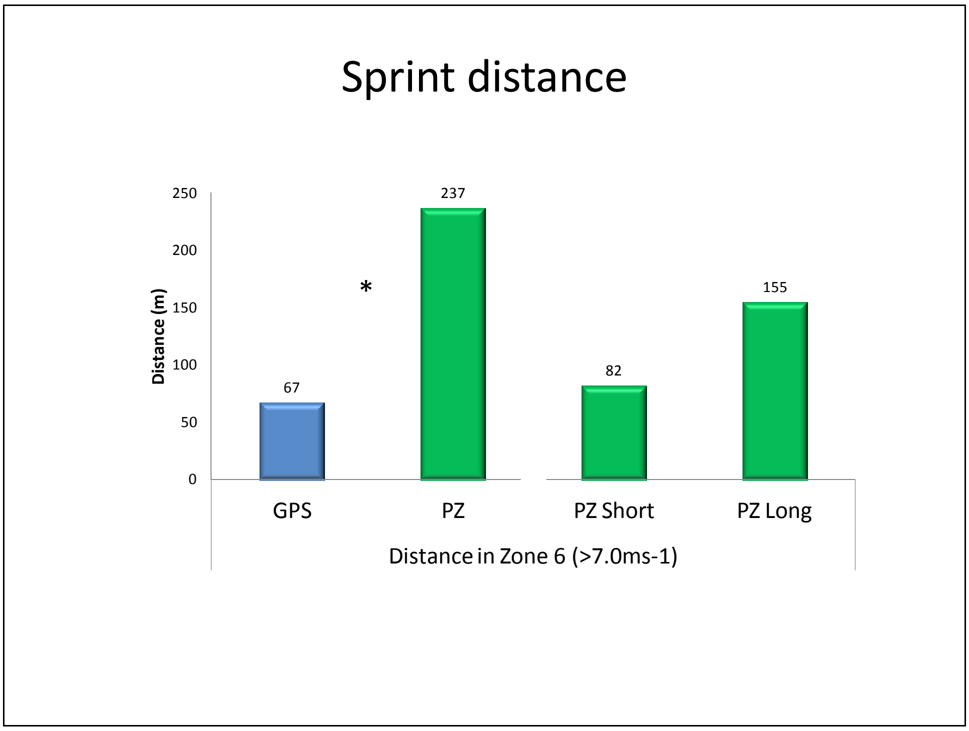
Speed Zones

- Time spent in the top 2 high intensity speed zones

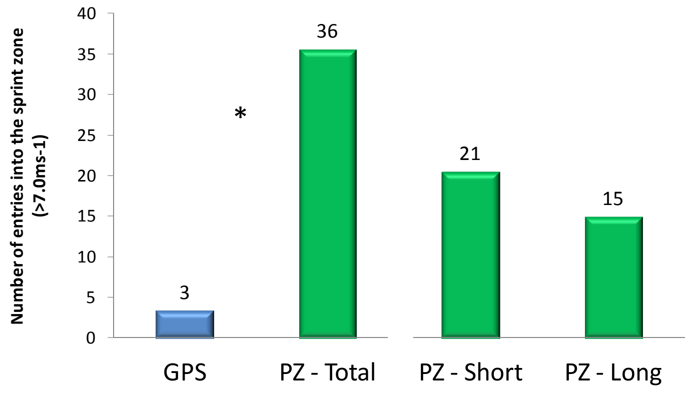
Movement	ms^{-1}	kmh^{-1}
Still	0	0
Walk	0.2 - 2	0.72 - 7.2
Jog	2 - 4	7.2 - 14.4
Run	4 - 5.5	14.4 - 19.8
High speed run	5.5 - 7	19.8 - 25.5
Sprint	> 7	> 25.5

(Prozone, 2009)


Overall distance, and distances in zone 5 and 6
Distance (m)
9400
9200
9000
8800
8600
8400
8200
8000
7800
9248
8377
*
640
301
*
237
67
*
700
600
500
400
300
200
100
0
Distance (m)
GPS
PZ
Overall Distance
GPS
PZ
Distance in Zone 5 (>5.5ms-1)
GPS
PZ
Distance in Zone 6 (>7.0ms-1)
* P < .001

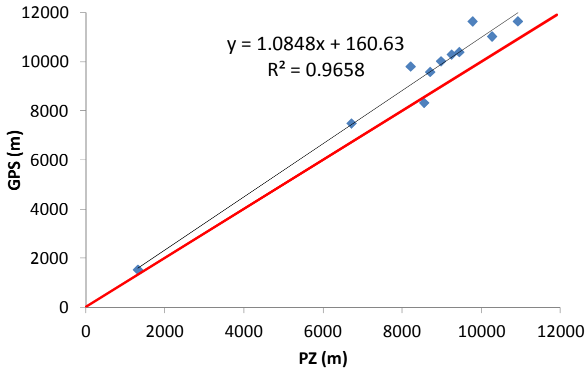

Sprint distance
Distance (m)
250
200
150
100
50
0
67
237
*
82
155
GPS
PZ
PZ Short
PZ Long
Distance in Zone 6 (>7.0ms-1)

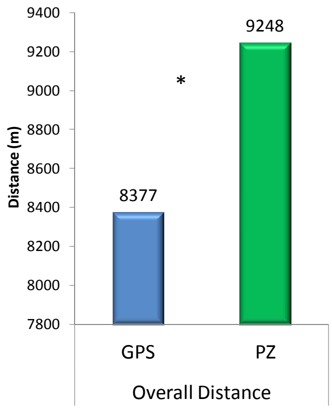
Number of sprints



* P < .001

Overall distance: correlated but different





$F(1,10)=25.49$, $p=.001$, Eta= .718

Discussion

- The results are consistent with previous research that shows motion camera tracking systems record more high intensity activity than team sport GPS systems.

- However these results also show a difference in overall distance between the 2 systems.

- Data between the 2 systems should not be used interchangeably when fitness staff are conditioning the players in training ready for competition.

Any Questions ?

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prozone

GPSPORTS

Further Investigation

- Compare:
  - time in speed zones as well as distance
  - peak speeds between the 2 systems
  - sprint length between the 2 systems
- Can the speed thresholds be lowered in the GPS software?
- Establish and quantify signal dropout when in a stadium environment

Further Research

- Establish a correction factor for the 2 systems so the data can be used interchangeably
- Perform a controlled study using timing gates to further validate each system and a direct comparison between them

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Appendix 3 – Ethics forms

UNIVERSITY OF BIRMINGHAM APPLICATION FOR ETHICAL REVIEW

Who should use this form:

This form is to be completed by PIs or supervisors (for PGR student research) who have completed the University of Birmingham Ethical Review of Research Self Assessment Form and have decided that further ethical review and approval is required before the commencement of a given Research Project.

Please be aware that all new research projects undertaken by postgraduate research (PGR) students first registered as from 1st September 2008 will be subject to the University's Ethical Review Process. PGR students first registered before 1st September 2008 should refer to their Department/School/College for further advice.

Researchers in the following categories are to use this form:

1. The project is to be conducted by:
    - staff of the University of Birmingham; or
    - a research postgraduate student enrolled at the University of Birmingham (to be completed by the student's supervisor);
2. The project is to be conducted at the University of Birmingham by visiting researchers.

Students undertaking undergraduate projects and taught postgraduates should refer to their Department/School for advice.

NOTES:

- Answers to questions must be entered in the space provided – the beginning of an answer field will be indicated by a grey bar ( ).
- Use the up and down arrow keys to move between answer fields; use the side scroll bar to navigate around the document.
- An electronic version of the completed form should be submitted to the Research Ethics Officer, at the following email address: Please **do not** submit paper copies.
- If, in any section, you find that you have insufficient space, or you wish to supply additional material not specifically requested by the form, please it in a separate file, clearly marked and attached to the submission email.
- If you have any queries about the form, please address them to the Research Ethics Team.

UNIVERSITY OF BIRMINGHAM APPLICATION FOR ETHICAL REVIEW	*OFFICE USE ONLY:* Application No: Date Received:

1. TITLE OF PROJECT

Bike fitting optimisation: Mechanical efficiency and self selected Q Factor

2. THIS PROJECT IS:

University of Birmingham Staff Research project ☒
University of Birmingham Postgraduate Research (PGR) Student project ☒
Other ☐ (Please specify):

3. INVESTIGATORS

a) PLEASE GIVE DETAILS OF THE PRINCIPAL INVESTIGATORS OR SUPERVISORS (FOR PGR STUDENT PROJECTS)

Name: Title / first name / family name	Dr François-Xavier Li
Highest qualification & position	Lecturer
School/Department	School of Sport and Exercise Sciences
Telephone:	
Email address:	

Name: Title / first name / family name	
Highest qualification & position held:	
School/Department	
Telephone:	
Email address:	

b) PLEASE GIVE DETAILS OF ANY CO-INVESTIGATORS OR CO-SUPERVISORS (FOR PGR STUDENT PROJECTS)

Name: Title / first name / family name	
Highest qualification & position held:	
School/Department	
Telephone:	
Email address:	

c) In the case of PGR student projects, please give details of the student

Name of	Neil Dallaway	Student No:	
Course of study:	PhD	Email	
Principal	Dr François-Xavier Li		

Name of student:		Student No:	
Course of study:		Email	
Principal			

4. ESTIMATED START OF PROJECT

Date: May 2012

ESTIMATED END OF PROJECT Date: June2012

5. FUNDING

List the funding sources (including internal sources) and give the status of each source.

Funding Body	Approved/Pending /To be submitted
Supervisor School-funded research account	Approved

If applicable, please identify date within which the funding body requires acceptance of award:

Date:

If the funding body requires ethical review of the research proposal at application for funding please provide date of deadline for funding application:

Date:

6. SUMMARY OF PROJECT

Describe the purpose, background rationale for the proposed project, as well as the hypotheses/research questions to be examined and expected outcomes. This description should be in everyday language that is free from jargon. Please explain any technical terms or discipline-specific phrases.

Professional football clubs are increasingly utilising global positioning satellite (GPS) tracking systems to monitor players speed and distance covered during training sessions. Additionally, the Prozone (Leeds, UK) motion analysis system tracks the player's movements in competitive matches. When both systems are used together they provide a comprehensive account of the total distance and speeds covered by players in both training and competition.

Wolverhampton Wanderers Football Club (WWFC) is using the GPSport (Fyshwick, Australia) SPI Pro X system during the 2011/12 Barclays Premiership season. In addition to the GPS receiver the SPI Pro X unit consists of a tri-axial accelerometer, to estimate the forces on the player, and an integrated heart rate (HR) monitor.

Many studies have investigated the reliability and accuracy of GPS tracking devices in team sports. Most of these studies (Courts et al, Portas et al, Castellano et al, Jennings et al) have been completed on systems with a sampling rate of 1 and 5 Hz, and one system at 10 Hz (Grey et al) whereas the SPI Pro X system is 15 Hz.

In a 2008 review paper (Namel et al) it was mentioned that there has been no scientific validation of motion analysis systems such as Prozone, and the difficulty of comparing such a system to training based GPS systems due to players being prohibited from wearing the devices in competitive match's.

In order that accurate comparisons can be made between competitive matches and the

7. CONDUCT OF PROJECT

Please give a description of the research methodology that will be used

The participants (n=20) are to be recruited from local athletics and football teams. This will ensure that they are capable of the physical demands of steady state running and repeated sprint efforts. All participants will sign an ethics form and give full consent to participate in the two experiments. A brief document outlining the experimental protocol will be given to each participant prior to the trials so they are familiar with the requirements and timeframe. Each participant will be requested to wear their usual sport or training kit, alongside the GPS vest and HR monitor strap.

Experiment One: Familiarisation and GPS calibration

The aim of the first experiment is to familiarise the participants with the tasks involved, the wearing of the GPS vest and unit and to ensure that they can reach the speeds required for the main experiment. It will also enable the 15 Hz GPS system to be validated for speed and distance measurements. This is to be undertaken at WWFC Compton training ground. It is anticipated that the experiment will take approximately one hour to set up and two hours for the participants to complete the required tasks.

The participants will be required to run 2km as a warm up around a set course and then complete a series of repeated sprints through timing gates. The total amount of sprinting is within what would normally be covered in their weekly training activity. Plenty of rest between the sprints and drinks will be made available to the participants.

Experiment Two: Comparison of the Prozone and GPS Systems

The second experiment is a repeat of the first experiment but will take place at the Molineux, the stadium of WWFC which is equipped with the Prozone motion tracking system. The experimental protocol is the same as the first apart from they will have to wear WWFC football kit so that they can be identified by the Prozone tracking system.

8. DOES THE PROJECT INVOLVE PARTICIPATION OF PEOPLE OTHER THAN THE RESEARCHERS AND SUPERVISORS?

Yes ☒ No ☐

Note: "Participation" includes both active participation (such as when participants take part in an interview) and cases where participants take part in the study without their knowledge and consent at the time (for example, in crowd behaviour research).

If you have answered NO please go to Section 18 . If you have answered YES to this question please complete all the following sections.

9. PARTICIPANTS AS THE SUBJECTS OF THE RESEARCH

Describe the number of participants and important characteristics (such as age, gender, location, affiliation, level of fitness, intellectual ability etc.). Specify any inclusion/exclusion criteria to be used.

With written consent, thirty healthy male and female subjects aged between 18-40 years will be recruited for this study. Participants will be accustomed to playing team sports at least once per week. All subjects will be assessed by the General Health Questionnaire. They should have no physical impairment preventing them from running activity.

10. RECRUITMENT

Please state clearly how the participants will be identified, approached and recruited. Include any relationship between the investigator(s) and participant(s) (e.g. instructor-student).

Note: Attach a copy of any poster(s), advertisement(s) or letter(s) to be used for recruitment.

Subjects will be recruited via advertisements emailed to local sports clubs

11. CONSENT

a) Describe the process that the investigator(s) will be using to obtain valid consent. If consent is not to be obtained explain why**.** If the participants are minors or for other reasons are not competent to consent, describe the proposed alternate source of consent, including any permission / information letter to be provided to the person(s) providing the consent.

Subject will receive an information sheet and consent form. Additional briefing will be provided. Subjects will then be asked if they agree to take part in the experiment to sign the consent form prior to the testing taking place.

Note: Attach a copy of the Participant Information Sheet (if applicable), the Consent Form (if applicable), the content of any telephone script (if applicable) and any other material that will be used in the consent process.

b) Will the participants be deceived in any way about the purpose of the study?

Yes ☐ **No** ☒

If yes, please describe the nature and extent of the deception involved. Include how and when the deception will be revealed, and who will administer this feedback.

12. **PARTICIPANT FEEDBACK**

Explain what feedback/ information will be provided to the participants after participation in the research. (For example, a more complete description of the purpose of the research, or access to the results of the research).

Participants will be fed back information about their peak running speed and accelerations.

13. **PARTICIPANT WITHDRAWAL**

a) Describe how the participants will be informed of their right to withdraw from the project.

Through the subject information sheet (as below) and verbal briefing before participation.

b) Explain any consequences for the participant of withdrawing from the study and indicate what will be done with the participant's data if they withdraw.

Data will be securely kept in the School of Sport and Exercise Sciences for 10 years unless requested to be deleted/removed, but will not form part of the study report.

14. COMPENSATION

Will participants receive compensation for participation?

i) Financial

Yes ☐ **No** ☒

ii) Non-financial **Yes** ☐ **No** ☒

If **Yes** to **either** i) or ii) above, please provide details.

If participants withdraw, how will you deal with compensation?

Subjects are allowed to withdraw at any point during the experiment. Feedback will be given on the collected data.

15. CONFIDENTIALITY

a) Will all participants be anonymous? **Yes** ☐ **No** ☒

b) Will all data be treated as confidential? **Yes** ☒ **No** ☐

Note: Participants' identity/data will be confidential if an assigned ID code or number is used, but it will not be anonymous. Anonymous data cannot be traced back to an individual participant.

Describe the procedures to be used to ensure anonymity of participants and/or confidentiality of data both during the conduct of the research and in the release of its findings.

Participant data will be associated with a code to ensure confidentiality during analysis and storage and accessed only by the lead supervisor and postgraduate student.

If participant anonymity or confidentiality is not appropriate to this research project, explain, providing details of how all participants will be advised of the fact that data will not be anonymous or confidential.

In order for the GPS and Prozone data to be allocated to the correct participant it is not practical to ensure participant anonymity. Participants will also be completing the experiment in the presence of other participants. Participants will be informed that the experiment is not anonymous both verbally and through the subject information sheet.

16. STORAGE, ACCESS AND DISPOSAL OF DATA

Describe what research data will be stored, where, for what period of time, the measures that will be put in place to ensure security of the data, who will have access to the data, and the method and timing of disposal of the data.

Data will be stored upon laboratory computers. Access will be restricted to the lead supervisor and postgraduate student, and password protection will be in place. Data will be accessible and stored for ten years after the completion of the research study.

17. OTHER APPROVALS REQUIRED? e.g. Criminal Records Bureau (CRB) checks

☐ YES ☒ NO ☐ NOT APPLICABLE

If yes, please specify.

18. SIGNIFICANCE/BENEFITS

Outline the potential significance and/or benefits of the research

Professional football clubs will be able to use the data collected in training, via the GPS system, and through competitive matches, via the Prozone system, interchangeably. This will mean the total physical load on the players is more accurately quantified.

19. RISKS

a) Outline any potential risks to **INDIVIDUALS**, including research staff, research participants, other individuals not involved in the research and the measures that will be taken to minimise any risks and the procedures to be adopted in the event of mishap

The risks involved with participation in maximal exercise are covered and will be led by the School Code of Practice.

b) Outline any potential risks to **THE ENVIRONMENT and/or SOCIETY** and the measures that will be taken to minimise any risks and the procedures to be adopted in the event of mishap.

20. ARE THERE ANY OTHER ETHICAL ISSUES RAISED BY THE RESEARCH?

Yes ☐ No ☒

If yes, please specify

21. CHECKLIST

Please mark if the study involves any of the following:

- Vulnerable groups, such as children and young people aged under 18 years, those with learning disability, or cognitive impairments ☐
- Research that induces or results in or causes anxiety, stress, pain or physical discomfort, or poses a risk of harm to participants (which is more than is expected from everyday life) ☒
- Risk to the personal safety of the researcher ☐
- Deception or research that is conducted without full and informed consent of the participants at time study is carried out ☐
- Administration of a chemical agent or vaccines or other substances (including vitamins or food substances) to human participants. ☐
- Production and/or use of genetically modified plants or microbes ☐
- Results that may have an adverse impact on the environment or food safety ☐
- Results that may be used to develop chemical or biological weapons ☐

Please check that the following documents are attached to your application.

ATTACHED **NOT**

		APPLICABLE
Recruitment advertisement	☒	☐
Participant information sheet	☒	☐
Consent form	☒	☐
Questionnaire	☒	☐
Interview Schedule	☐	☒

22. DECLARATION BY APPLICANTS

I submit this application on the basis that the information it contains is confidential and will be used by the University of Birmingham for the purposes of ethical review and monitoring of the research project described herein, and to satisfy reporting requirements to regulatory bodies. The information will not be used for anyother purpose without my prior consent.

I declare that:

- The information in this form together with any accompanying information is complete and correct to the best of my knowledge and belief and I take full responsibility for it.
- I undertake to abide by University Code of Conduct for Research (http://www.ppd.bham.ac.uk/policy/cop/code8.htm) alongside any other relevant professional bodies' codes of conduct and/or ethical guidelines.
- I will report any changes affecting the ethical aspects of the project to the University of Birmingham Research Ethics Officer.
- I will report any adverse or unforeseen events which occur to the relevant Ethics Committee via the University of Birmingham Research Ethics Officer.

Name of Principal investigator/project	Dr Francois-Xavier Li
Date:	19/04/12

Please now save your completed form, print a copy for your records, and then email a copy to the Research Ethics Officer, at aer-ethics@contacts.bham.ac.uk. As noted above, please do not submit a paper copy.

Attachment 1: Information sheet

Subject Information Sheet

GPS / Prozone System Comparison

This study is investigating the differences between GPS and Prozone team sport tracking systems.

Methods

You will be required to visit WWFC training ground (visit 1) and match day stadium (visit 2) on 2 separate occasions separated by 48 hours.

Visit 1 will consist of a 2km steady state run followed by a series of repeated sprint efforts through timing gates. You will be required to wear a GPS vest and your usual training kit. All speeds and distances will be comfortably within what you complete in a normal training session. Drinks will be made available during a rest period in between the sprint efforts.

Visit 2 will be exactly the same protocol as visit 2. You will be required to wear numbered WWFC football kit (provided). This is to ensure that the Prozone system can identify each individual participant.

Risks

The only injury risks during this study are those usually encountered during steady state and sprint running.

Confidentiality and withdrawal

All your data will be treated confidentially. You are free to withdraw at anytime during the study without having to explain or give a reason, and you may also request your data to be withdrawn and deleted.

Investigator

Neil Dallaway, MSc

School of Sport and Exercise Sciences

University of Birmingham

Birmingham

B15 2TT

[redacted]

Attachment 2: consent form

School of Sport and Exercise Sciences

Consent Form

Investigation: GPS / Prozone system comparaison.

Investigators: Dr François-Xavier Li
Neil Dallaway

Subject:

Name ---

DOB --------------

I have read the attached information sheet and discussed the investigation with .... who has explained the procedures to my satisfaction. I am willing to undergo the investigation but understand that I am free to withdraw at any time without having to give an explanation and that doing so will not affect any treatment or care I may receive.

Signed -----------------------

Witnessed -------------------

Date -------------

UNIVERSITY OF BIRMINGHAM

School of Sport and Exercise Sciences

General Health Questionnaire

Name: ....

Address: ....

....

....

Mobile Phone number: ....

Name of the responsible investigators for the study:

....

Please answer the following questions. If you have any doubts or difficulty with the questions, please ask the investigator for guidance. These questions are to determine whether the proposed exercise is appropriate for you. Your answers will be kept strictly confidential.

1.	You are.......	Male	Female
2.	What is your exact date of birth? Day........... Month...........Year..19........ So your age is.......................... Years		
3.	When did you last see your doctor? In the: Last week............ Last month.......... Last six months............ Year................. More than a year...........		
4.	Are you currently taking any medication?	YES	NO
5.	Are you currently taking any supplements?	YES	NO

	If yes please specify…		
6.	Has your doctor ever advised you not to take vigorous exercise?	YES	NO
7.	Has your doctor ever said you have "heart trouble"?	YES	NO
8.	Has your doctor ever said you have high blood pressure?	YES	NO
9.	Have you ever taken medication for blood pressure or your heart?	YES	NO
10.	Do you feel pain in your chest when you undertake physical activity?	YES	NO
11.	In the last month have you had pains in your chest when not doing any physical activity?	YES	NO
12.	Has your doctor (or anyone else) said that you have a raised blood cholesterol?	YES	NO
13.	Have you had a cold or feverish illness in the last month?	YES	NO
14.	Do you ever lose balance because of dizziness, or do you ever lose consciousness?	YES	NO
15.	a) Do you suffer from back pain b) if so, does it ever prevent you from exercising?	YES YES	NO NO
16.	Do you suffer from asthma?	YES	NO
17.	Do you have any joint or bone problems which may be made		

	worse by exercise?	YES	NO
18.	Has your doctor ever said you have diabetes?	YES	NO
19.	Have you ever had viral hepatitis?	YES	NO
20.	If you are female, to your knowledge, are you pregnant?	YES	NO
21.	Do you know of any reason, not mentioned above, why you should not exercise?	YES	NO
22.	Are you accustomed to vigorous exercise (an hour or so a week)?	YES	NO
23.	Has your bodyweight remained constant for the past 2 months (no greater difference than 20kg)?	YES	NO
24.	Have you ever have a ECG to assess any heart abnormalities?	YES	NO

I have completed the questionnaire to the best of my knowledge and any questions I had have been answered to my full satisfaction.

Signed: ....

Date: ....

Health Questionnaire:

Notes for the investigator

This questionnaire is for use in circumstances where you are intending to carry out a procedure which has been approved by the Ethics Subcommittee (Section 2 of the *Health and Safety Issues* document) but where a health screen is indicated. Questions 3 and 4 should be used to test, discretely, the veracity of the other answers.

If your subject is within the age group specified (usually 18 to 30 years) and has answered NO to questions 5-20 and YES to question 21, you may include him or her in your study.

If you are using this, or a similar, questionnaire for subjects outside this age range or with possible pathologies, you must have agreed with the Ethics Subcommittee the criteria for accepting subjects into the study and safeguarding their health.

Appendix 4 – Study 2 Design Documentation

The Comparison of a Team Sport GPS and Video Motion Tracking System.

Professional football clubs are increasingly utilising GPS tracking systems to monitor players speed and distance covered during training sessions. Additionally, the Prozone (Leeds, UK) motion analysis system tracks the player's movements in competitive matches. When both systems are used together they provide a comprehensive account of the total distance and speeds covered by players in both training and competition.

The clubs coaching and sports science staff monitor, amongst over parameters, the overall distance a player covers and time spent in different speed zones to quantify the physical load on a player in order to ensure that they are physically conditioned to compete at the required level. Of particular interest is the time and distance spent during high intensity running. High intensity running encompasses the top two speed zones of greater than $7m.s^{-1}$ which is classed as 'sprinting' and greater than $5.5m.s^{-1}$ which is classed as 'high speed running'.

In order that accurate comparisons can be made between competitive matches and the training environment it is of importance to quantify the accuracy of each system and the difference in terms of distances and speeds recorded between the two systems.

Aims:

- Calibrate each system's accuracy for distance, velocity and acceleration
- Compare systems' accuracy on
    - Constant speed over a range of speed zones
    - Variation of speed (from one zone to another)
    - Acceleration (positive and negative)
- Determine a correction factor between the Prozone and GPS systems

Participants:

The participants (n=20) are to be recruited from the university of Birmingham athletics and football teams. This will ensure that they are capable of the physical demands of steady state running and repeated sprint efforts required for the experiment.

Experiment One: Familiarisation and GPS calibration

The aim of the first experiment is to familiarise the participants with the tasks involved, the wearing of the GPS vest and unit and to ensure that they can reach the speeds required for the main experiment. It will also enable the 15 Hz GPS system to be validated for speed and distance measurements. This is to be undertaken at the University of Birmingham 400m running track. It is anticipated that the experiment will take approximately one hour to set up and two hours for the participants to complete the required tasks.

Experimental setup:

- GPSport real time setup to continuously monitor the participants during the experiment. This will enable approximate feedback to the participants on their running velocity.

- 12 timing gates will be used in total. 10 timing gates, one every metre along the straight section of the track which will be referred to as the 'timing section'. 2 'entry gates' will be placed 10m and 20m from the start of the timing section and will be called the 'approach section'.

Tasks:

1. Run around a circuit of set distance, for a total of 2 km (5 x 400m). This will act as a warm up before the repeated sprint efforts. Each participant will set of at 10s intervals and are to run at a self-selected speed. Upon completion of the 5 laps each participant is to stand still at the finish line for 10s.
2. Short break of approximately 2 minutes from when the last participant has completed task 1.
3. Steady state running for 10 metres. The approach section to the timed section is to be used to approximately obtain the required speed. Steady state velocities of 3 $m.s^{-1}$, 4.5 $m.s^{-1}$ and 6 $m.s^{-1}$ are to be aimed for.
4. 30m maximal sprint effort x 2. One is to be completed starting from the timed section and the other to be completed from the approach section.
5. Short break of approximately 2 minutes from when the last participant has completed task 4.
6. From steady state to maximal velocity. Running at a steady state velocity (3 $m.s^{-1}$, 4.5 $m.s^{-1}$ and 6 $m.s^{-1}$) through the approach section and then at maximal speed through the timed section.
7. Short break of approximately 2 minutes from when the last participant has completed task 6.
8. From standing still a maximal run for 10 metres through the timed section, turn around, back through the timed section and stop x 3

Task Number	Task Description	Duration	Distance (m)	Sprint Distance (m)
1	Warm Up x1	15	2000	0
2	Break	2		
3	Steady state x3	30	90	0
4	30m sprint x2	10	60	60
5	Break	2		
6	Steady to maximal x3	30	270	90
7	Break	2		
8	Acceleration x3	20	60	60
	Total	111	2480	210

It is anticipated that the overall timeframe of approximately two hours and a distance of 2.5km and 200m of sprinting will be within the capabilities and willingness of the participants.

Experiment Two: Comparison of the Prozone and GPS Systems

The aim of the second experiment is to compare the GPS and Prozone systems. This is to be undertaken at Molineux, the stadium of Wolverhampton Wanderers Football Club (WWFC). The experimental protocol will be exactly the same as in the first experiment.

Experimental setup (different from experiment one)

- The participants will be divided into two groups of ten. One group will wear WWFC home kit and the other the away strip. Both groups will wear shirt numbers two to eleven.
- The experimenters (ND, TD, and FXL) will wear goal keeper strips numbered one, 13 and 31 as well as GPS units. This will provide more data for comparisons on 'standing' and walking distances of the two systems.
- All participants and experimenters will stand in a typical team formation prior to kick off at the start of the experiment in order for Prozone to tag each individual correctly.
- As there is no running track inside Molineux, a set course will be marked out for the warm up run. The participants will complete the required number of laps to complete the 2km distance.
- The timing gates will be set up the same with an approach and timing section. These will be placed in the middle of the pitch in order to eliminate GPS reception dropout which may occur in close proximity to the spectator stands. There will be four different areas used for the repeated sprint trials in order not to excessively use one particular area of the playing surface. These four areas will be marked out with cones in order for the 12 sets of timing gates to be moved from one area to another as quickly as possible.
- The repeated sprint efforts will be monitored on the GPS real time system. If a GPS signal dropout is observed during the sprint the participant will be requested to repeat the sprint.
- It is anticipated that the second experiment will take approximately half an hour longer to complete due to the potential moving of the timing gates and repeating sprints due to lost GPS signal.

Appendix 5 – Study 2 Participant Information Sheet

WWFC – PROZONE / GPS COMPARRISON STUDY PARTICIPANT INFORMATION SHEET

Background

Professional football clubs are increasingly utilising GPS tracking systems to monitor players speed and distance covered during training sessions. Additionally, the Prozone motion analysis system tracks the player's movements in competitive matches. When both systems are used together they provide a comprehensive account of the total distance and speeds covered by players in both training and competition.

The clubs coaching staff monitor the overall distance a player covers and time spent in different speed zones to quantify the physical load on a player in order to ensure that they are physically conditioned to compete at the required level. Of interest is the time and distance spent during high intensity running. High intensity running encompasses the top two speed zones of greater than $7m.s^{-1}$ which is classed as 'sprinting' and greater than $5.5m.s^{-1}$ which is classed as 'high speed running'. In order that accurate comparisons can be made between competitive matches and the training environment it is of importance to quantify the accuracy of each system and the difference in terms of distances and speeds recorded between the two systems.

Requirements

You will be required to attend **2 training sessions** involving a short steady state run and a series of short sprint efforts through a set of timing gates. The overall duration is expected to be approximately **2 hours** and the physical demands will be within what you usually experience in a football training session.

- Please bring your usual training kit and both football boots and trainers.
- In addition you will have to wear a GPS unit in a vest (provided) which is designed to be worn during training sessions.
- For the second date you will be required to wear a WWFC shirt (so the Prozone camera system can track your movements) which will be provided.

Study 1 – **Arrive 4pm** – Tuesday 8th May
Sir Jack Hayward Training Ground
Douglas Turner Way
Compton Park
Wolverhampton WV3 9BF
(Postcode for sat nav: WV6 9DU)

Study 2 – **Arrive 4pm** – Thursday 10th May
Wolverhampton Wanderers FC
Molineux Stadium
Waterloo Road
Wolverhampton WV1 4QR

Any questions please contact Neil Dallaway on [redacted] **or email** [redacted]

Appendix 6 – Initial Postgraduate Research Proposal

The validation and analysis of GPS and accelerometer training data across a premier league football season.

Neil Dallaway

Introduction

Professional football clubs are increasingly utilising GPS tracking systems to monitor players speed and distance covered during training sessions. Additionally, the Prozone (Leeds, UK) motion analysis system (14) tracks the player's movements in competitive matches. When both systems are used together they provide a comprehensive account of the total distance and speeds covered by players in both training and competition.

Wolverhampton Wanderers Football Club (WWFC) is using the GPSport (Fyshwick, Australia) SPI Pro X (1) system during the 2011/12 Barclays Premiership season. In addition to the GPS receiver the SPI Pro X unit consists of a tri-axial accelerometer, to estimate the forces on the player, and an integrated heart rate (HR) monitor.

The training data from these units is to be collected in addition to the player's daily subjective ratings of fatigue, wellness, sleep and rate of perceived exertion (RPE) during training sessions providing a unique opportunity to research and analyse the training load of a premiership football club across an entire season.

Aims

The aim of the proposed research is to validate the measurements obtained from the SPI Pro X units of both the GPS and accelerometer data. To examine the data collected over the season and determine if there are any correlations of training loads with match performance and injury occurrence.

Validation Objectives

- To validate the distances obtained from the 15 Hz GPSport SPI Pro X units and obtain a co-efficient of variation across sessions and a margin of error of measurement.
- To compare the distances covered and speeds achieved between the GPS SPI Pro X units and the Prozone motion analysis system in the WWFC Molineux Stadium in both a training session and reserve team fixture.
- To compare the measurements of the 100 Hz accelerometer data in the field based SPI Pro X units with a high standard 1000Hz laboratory based accelerometer.
- To assess the validity of measurements made when the SPI Pro X unit is located in the on the players back between the two scapula, compared to various lower limb positions.

Descriptive Objectives

- To describe the data across the season in terms of training loads, RPE, HR GPS and accelerometer data and examine if there are any correlations of injury occurrence and match performance with training loads.

- To make recommendations based on the data for subsequent seasons training loads, especially in quantity of high intensity running, in order to reduce injury occurrence and increase match performance.

Previous Research

Many studies have investigated the reliability and accuracy of GPS tracking devices in team sports. Most of these studies (2, 3, 4, 5) have been completed on systems with a sampling rate of 1 and 5 Hz, and one system at 10 Hz (6) where as the SPI Pro X system is 15 Hz.

In a 2008 review paper (7) it was mentioned that there has been no scientific validation of motion analysis systems such as Prozone, and the difficulty of comparing such a system to training based GPS systems due to players being prohibited from wearing the devices in competitive match's. The WWFC reserve team are permitted to wear the GPS units and HR straps in fixtures.

Accelerometers are an underutilised resource in team sport monitoring and fewer validation studies have been completed relative to the GPS measurements. However some research has been completed in terms of football specific movements (8), gait analysis (9) and validation studies (10).

Descriptive research has detailed player injuries across a competitive season but without analysing training loads which may contribute to injury occurrence (11). An intervention study (12) has shown that it is possible to increase maximal aerobic running speed and decrease sprint time over a set distance with an in-season period of high intensity training. Additionally it has been shown (13) that increasing the amount of high intensity anaerobic interval training reduced the prevalence of hamstring injuries and the total amount of injury time across the season. Both of these studies demonstrate the importance of monitoring high intensity running during the season to ensure the players are completing enough distance in the higher speed zones to facilitate adaptations to training, decrease injury risk and improve match performance

References

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Appendix 7 – Further Postgraduate Research Proposal

The interpretation and analysis of professional football training load data

Neil Dallaway MSc. & Dr. François-Xavier Li

The aim of this document is to outline the research and funding proposal to transfer from MPhil to PhD position to be completed by Neil Dallaway at Wolverhampton Wanderers Football Club (WWFC) under supervision and guidance of Dr. François-Xavier Li at the University of Birmingham School of Sports and Exercise Sciences. Areas to be considered include:

1. Background
2. Studies Completed during 2011/12 M.Phil.
3. Conversion to PhD
4. Timeframe of PhD
5. Funding of PhD
6. Day-to-day duties at WWFC

1. Background

Professional football clubs are increasingly utilising GPS tracking systems to monitor players speed and distance covered during training sessions. Additionally, the Prozone (Leeds, UK) motion analysis system tracks the player's movements in competitive matches. When both systems are used together they provide a comprehensive account of the total distance and speeds covered by players in both training and competition.

WWFC used the GPSport (Fyshwick, Australia) SPI Pro X system during the 2011/12 Barclays Premiership season. In addition to the GPS receiver the SPI Pro X unit consists of a tri-axial accelerometer, to estimate the forces on the player, and an integrated heart rate (HR) monitor. Moving forwards into the 2012/13 season WWFC will use the Statsports Viper (Armagh, Ireland)15Hz GPS system which has essentially the same technical specification as the previously used GPSport system but offers substantially improved analytical software and accurate real-time performance.

The training data from these units is to be collected in addition to the player's daily subjective ratings of fatigue, wellness, sleep and rate of perceived exertion (RPE) during training sessions providing a unique opportunity to research and analyse the training load of a professional football club across an entire season.

2. Studies Completed during 2011/12 M.Phil.

As well as collecting WWFC first full season of training and competitive match data, 3 main studies were completed during the 2011/12 season. All of these are associated with validating the measurements of the GPS system, the GPS real-time system and the differences of the GPS system with the PZ system and are summarised below.

Paper 1 – Validity of GPS Real time vs. GPS upload

Investigate the accuracy of the GPS real time system in comparison to the uploaded data. The main aim is to find which parameters can be reliably used in a real time setting.

The main outcome is that the high intensity distances cannot be used in a real time setting as they are significantly different to the uploaded distances, but bodyload may be useable as it is not significantly different between upload and real time. Bodyload is well correlated with the distance (r=0.83) and speed exertion scores (r=0.86). It a very weak correlation to high speed running zone (r=0.3). This paper also questions the differences between GPS and PZ based on the data from the same players in preseason friendlies (GPS) and the start of the premiership (PZ) and that there is need for a direction comparison in future research (paper 2).

Paper 2 – PZ vs. GPS in a competitive match setting

The data was obtained from the WWFC vs. AVFC reserve team fixture. The main outcome is that we confirm previous research that that GPS under reports high intensity speed zone running and a correction factor is needed for data from the 2 systems to be used interchangeably (paper 3). The abstract for this paper has been accepted for an oral presentation the forthcoming European College of Sports Science (ECSS) conference in Bruges.

http://www.ecss-congress.eu/2012/index.php/scientific-programme/oral-presentations

(Search page under ‘dallaway’, and click ‘read’ for full details.

Paper 3 – Reliability of PZ and GPS independently and a direct comparison between them

The main aim is to determine the accuracy of each system and then to compare them in terms of speed zones, and to provide a correction factor so the data from the 2 systems can be used interchangeably. The data for this study has been collected on the 8th and 10th of May at the Compton training ground and Molineux stadium respectively.

All 3 papers are currently in the process of being written up with the aim to be submitted for publication in the Scandinavian Journal of Medicine & Science in Sports, and Journal of Strength and Conditioning Research.

3. Conversion to PhD

The UoB has recommended that the current research is continued and transferred from an M.Phil. to a PhD. Initial ideas on areas to research include:

- Validation of location of accelerometer relative to other bodily positions.
- Accuracy of the field based GPS 100 Hz accelerometer data relative to lab standard 1000 Hz accelerometers
- Profiling of the 1st team squads running patterns in terms of accelerometer data and left-right leg running balance. Once the player’s base line profiles are determined for a variety of different running drills subsequent long term monitoring will determine if deviations correlate with injury occurrence. Additionally if a player is injured and a deviation has occurred monitoring will determine if the return to their base line correlates with a return to fitness.

- Profiling of various conditioning drills using the GPS system to determine a series of training sessions to incrementally prepare a player returning from injury for full football training.
- Statistical analysis over 3 whole seasons of 1st team training data to determine optimal training loads on players in order that they are in peak condition on match day.
- Statistical analysis over 3 whole seasons of 1st team training data to investigate if longitudinal GPS data and subjective player ratings can be used to predict or warn of injury.
- Comparison of seasonal training loads and physical match data between academy, reserves and the 1st team.

The PhD will be supervised by Dr. Francois-Xavier Li (School of Sports and Exercise Sciences) and co supervised by Dr. Jill Ramsay (School of Nursing and Physiotherapy).

As the PhD is to be co-supervised by a physiotherapist it provides the club an opportunity to combine the monitoring of elite football players via GPS technology within the sports science department and the injury prevention and rehabilitation activities of the medical department and to become world leaders and experts in this field.

4. Timeframe of PhD

The PhD is to be completed by October 2014.

5. Funding of PhD

The current M.Phil. was self-funded by Neil Dallaway at the UoB at the full time postgraduate fee rate for the 2011/12 academic year. The day-to-day data collection was completed as a paid internship at WWFC. The fees for this supervision are due to expire on October the 1st and the contract for the internship by June 2012.

In order to continue and expand the work which has already been completed and to transfer to a PhD position it is requested that WWFC fund the fees to cover the supervision at the UoB for the next 2 academic years. This will be paid at the full-time fee cost of £3900 per year from WWFC to UoB from October 2012 alongside a tax-free stipend of £13,600 per year from July 2012 through to and including June 2014, covering both Neil Dallaway's research activity as well as his day-today duties at WWFC.

6. Day-to-day duties at WWFC

Neil Dallaway will continue in the same day-to-day role at WWFC collecting data as laid out in his job description. It is anticipated that as all research and analysis of data is such an integral part of his daily role it can be completed concurrently as demonstrated this year.

This is a unique opportunity to continue the research which has already been completed, to raise the profile of the WWFC Sports science and medical department through research publications and conference presentations and to build a long term relationship with the UoB and WWFC.