Title: Investigation into the potential differences between Male Scottish International Field Hockey players based upon the location of their club team throughout a Domestic and International season

Volume 1

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Abstract

The aim of this study was to investigate and audit the potential differences of the intensity of training and gameplay experienced throughout a season within the Scottish Senior Men's hockey team dependent on the location of their club team. 25 elite male players (age: 25 ± 3.7) wore 10Hz Playertek Global Positioning Systems (GPS) over the course of a season to measure total distance, sprint distance and speed zones *(SZ1=0-11km·hr⁻¹, SZ2=11-15 km·hr⁻¹, SZ3=15-19 km·hr⁻¹, SZ4=19-23 km·hr⁻¹, SZ5=>23 km·hr⁻¹)* covered in both club and international training and games. The data was analysed both in an Non-Standardised fashion where durations were unaltered and separately the data was also analysed in a Standardised form to a rate of 60 minutes . All sessions were included in the analysis but only those found to have significant differences ($p<0.05$) were analysed in further detail. It was found that when comparing each region (Europe, Scotland, England) within one session type (Club Training, Club Game, International Game, International Training) that significant differences were found within club games and club training. Within club games the differences between regions were found to show that Scottish based players cover 7.0±1.6km, English based players to cover 7.1±1.2km and European based players to cover 5.9±1.4km on average. Separately when comparing between different sessions it was found that there was a significant difference between club games and club training with Scottish based players covering 6.0±1.5km in club games compared to 3.6±0.6km in training, English based players covering 6.1±1.1km in games compared to 3.9±0.9km in training and Europe covering 5.1±1.2km in games compared to 4.1±0.8km in club training. Finally speed zone analysis was carried out and it was found that as a whole each region performed similarly across each of the three regions. However, 2 players from the region of Scotland behaved differently from the rest, with each player covering between 26-30% and 15-19% in speed zones 2 & 3 respectively compared to the average of 19% for speed zones 2 and 12% for speed zone 3 for the remaining subjects. In conclusion, it was found that differences did occur in the intensity experienced within training and games in different regions and also across different types of international or club sessions. However whether these differences are down to the specific region that the players are within or a result of other factors such as training content, pitch time or other in inconclusive at this point.

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Authors Declaration

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is

the result of my own work and has not been submitted for any other degree at the University of Glasgow or

any other institution."

Printed Name: __________________________

Signature: __________________________

1 Introduction

1.1 Field Hockey

1.1.1 History of Hockey

The sport of hockey has been reported to have originated in Ethiopia in 1000BC, but the details of how the sport was played at this time are unknown. Conversely, the game we commonly know as hockey was first reported in the early 1850’s as being played in public schools, and in 1862 the first reference to a hockey club was made, resulting in Blackheath now holding the title of ‘first hockey club in the world’ (England Hockey). In 1886, with increasing popularity around the new sport, the Hockey Association was created made up by seven local London clubs (England Hockey). In the late 20th Century the sport began to increase in popularity, as it spread throughout the British Empire as a result of the British Army travelling and the sport gaining more exposure. In 1895 the first International game was played, with England beating Ireland by five goals to nil (England Hockey). From this, International hockey continued to grow and the 1908 Olympic Games, in London, saw the first Olympic hockey being played, with only England, Ireland and Scotland taking part (England Hockey). In the 1928 Olympics in Amsterdam, Men’s hockey became a permanent fixture as a result of the Federation of International Hockey (FIH) being setup in Paris four years earlier. Since that time hockey has been ever evolving, with regards to equipment, rules and playing surface. In the early 1970s, after years of playing hockey on grass, the introduction of ‘synthetic grass’ began and synthetic pitches were made mandatory in all major competitions by the FIH, just in time for the Montreal Olympics in 1976. Nowadays, hockey can be played on three types of artificial pitch (Water Based, Sand Dressed or Sand Filled).

1.1.2 Field Hockey Rules

Field Hockey is a team sport played across the world by both males and females. There are eleven players in a hockey team with another 5-7 players, subject to league or competition rules, being eligible as substitutes. Substitutions can be made throughout the game and an unlimited amount of interchanges can be made as the game progresses. A team usually consists of ten outfield players and a goalkeeper but in certain circumstances eleven outfield players can be on the pitch with certain goalkeeping privileges given to one individual, this person is commonly known as 'kicking back'. A typical game lasts 70 minutes (two 35 minute halves) with a 10-15minute interval, however, in March 2014 the FIH announced that from the 1st of September 2014 onwards all major international tournaments (Champions Trophy, Hockey World League and the 2016 Olympic Games in Rio) would adopt the new 60-minute game consisting of four 15 minute quarters instead of two 35 minute half's (FIH). The change in duration now means that there is a two minute break between quarters one & two and three & four with the standard 10-minute break between quarters two and three for half time. All international hockey, that the Scotland Senior Men's team has taken part in during season 2016-2017 (World League 2, World League 3 and European B Division), has adopted the four quarters and 60-minute duration style.

Hockey is played on an artificial pitch (91.40 metres by 55 metres) and each player has a stick with a rounded head, that must be within the FIH's guidelines and the ball has to be spherical and have a circumference of between 224 to 235 millimetres and a weight of 156-163 grams (FIH). The goalkeeper must have protective goalkeeping kit and a specific goalkeeping stick with an additional horizontal bend. Throughout the duration of play the main aim of the game is to score by putting the ball into the opposition team's goal. This can be done by passing the ball flat on the pitch or lifting the ball in an aerial fashion. Fouls are committed when the rounded side of the stick is used, a passage of play is deemed to be dangerous or the ball is controlled with any part of the body. Only goalkeepers are allowed to kick or control the ball with their body. In the result of a foul 'a free-hit' is given with serious or persistent fouls dealt with warnings delivered via a series of coloured cards. A green card gives the player a 2-5 minutes' suspension from play, yellow gives a five to ten minute suspension and a red results in removal from the game and a post-match tribunal (FIH).

1.2 Physiology

1.2.1 Physiological Demands of Hockey

The sport of hockey is frequently described as being intermittent in nature, which has been supported by Spencer et al. (2004) who stated that players have been found to sprint up to seven times in a row with limited recovery. Repeated sprints were defined within this study as being three or more sprints in a row with a mean recovery of less than 21 seconds between sprints. The high speed and intermittent sprint nature of the sport, was further supported by Lythe and Kilding (2011), who stated that players are often required to produce high speed efforts that exceed 30 $km \cdot hr^{-1}$. This shows that hockey places various demands on the body, not only anaerobically but also aerobically. It is thought that 70-80% of the game is aerobic, with the remaining percent being associated with a mixture of anaerobic glycolysis, ATP and phosphocreatine (Reilly & Borrie, 1992). This infers that hockey, because of its intermittent style, places demands on both the aerobic and anaerobic systems. In addition to energy systems, players require strength and stability to hit the ball, tackle and hold off opposition players, as well as being agile and reactive to adapt quickly to stimuli. This shows that hockey has a variety of aspects that are pivotal to a high level of performance.

1.2.2 Energy Systems

Carrying out any type of activity requires the consumption and production of ATP by the body. In very basic terms glucose is broken down to produce ATP through a series of stages and when carrying out high intensity bouts of exercise, such as repeated sprints, anaerobic glycolysis will take president (Girard, 2011). Anaerobic glycolysis often occurs as a result of there not being enough oxygen consumed in relation to the demands of the activity taking place, therefore aerobic glycolysis is only able to take place when the uptake of oxygen can meet the demands of the exercise undertaken. In addition, aerobic glycolysis is just as important for producing ATP during periods of prolonged lower intensity activity. The importance of one energy system over the other may take priority in other sports but within hockey all energy systems are utilized during different portions of a game. Therefore, each energy systems importance is equal and both should be trained appropriately to ensure optimal potential is reached (White & MacFarlane, 2014).

As stated above, the variety of different energy systems that are used during a standard 70-minute match is due to the non-continuous nature of the game and is dependent on the number or repeated sprints that are made. The stop start nature of the sport is, again, confirmed in a study by Spencer et al (2004), where time motion analysis was used to track the movements of players during an International match. The study only investigated one international game and only contained 14 players from the Australian national team and so the information gathered may be limited and not suitable to be applied to all general hockey. Nonetheless, the study found that on average walking and jogging (low intensity bouts of activity) made up 87 ± 7.6% of the total playing time for the individuals. Alternatively, high intensity bouts of activity such as sprinting accounted for on average 5.6 ± 0.9% of the total playing time. Again, the study cannot be applied to the wider hockey population due to its scale but if the results are accurate it would predict that hockey players need a substantial aerobic capacity as a main prerequisite for success in the sport of hockey. Similar studies are shown in Table 1.1 on page 11 (Lythe, 2006), this gives more information on the intermittent nature of the sport and physiological demands it places on the individuals.

Reference Details		
Johnston et al. (2004)	15 Scottish domestic players (19.5 ± 2.5 years) 1 national league match per player	Percent of time spent in locomotive states = Standing (0 km·hr^{-1}) 4.0%; Walking (0-6 km·hr^{-1}) 50.9%; Jogging (6-11 km·hr^{-1}) 29.6%; Cruising (11-15 km·hr^{-1}) 10.1%, Sprinting (>23 km·hr^{-1}) 4.7%
Spencer et al. (2005)	14 Australian International players (26.0 ± 3 years) 3 international matches	Percent of time spent in locomotive states = Standing (motionless) 7.4%; Walking (both feet in contact with ground at same time) 46.5%; Jogging (Airborne phase, low knee lift) 40.5%; Striding (Vigorous/Higher knee lift that jogging) 4.1%, Sprinting (max effort/extension of lower leg) 1.5%
Paun et al. (2008)	6 Australian domestic players (26.2 ± 3.9 years) 4 national league matches per player	Mean number of changes in tempo per match = 901 ± 116 Mean number, distance and duration of sprints performed (above 17km.h^{-1}) = 36 ± 9, 12.4 ± 9.9m, 2.5 ± 1.7s

Table 1.1 Table of studies investigating demands and activity within hockey specific activity patterns. *Reproduced from Lythe. J 2006*

1.2.3 Aerobic and Anaerobic Interactions and Adaptations

As previously described above, aerobic capacity can contributes to the intermittent nature of the sport. Various studies have suggested that there is a strong relationship between the ability of individuals to carry out repeated sprints and their aerobic capacity (Tomlin and Wenger, 2002, Aziz, 2005 and Dardouri, 2014). During repeated sprint bouts ATP, PCr and Anaerobic Glycolysis energy sources can become depleted. As this occurs, waste products such as Hydrogen (H+**)** will build up and the pH of the muscle will be altered, potentially disrupting the contractile process.

Due to the nature of the sport of hockey, the lower intensity walking or jogging phases that make up 70-80% of the game are the opportunities for recovery to commence and energy systems to be restored. Jones (2013) proposed that having an enhanced aerobic capacity could enhance the ability of the muscle to recover during these lower intensity bouts. It is proposed that an increased aerobic capacity could result in less stress being placed upon the non-oxidative system which in turn will enhance the recovery of the anaerobic system. Furthermore, with an enhanced aerobic system this will cause adaptations to the pulmonary, cardiovascular and neuromuscular systems in the body, which will in turn greatly improve the efficiency of the response and recovery during high intensity intermittent exercise. Adaptations as a result of endurance training to improve the aerobic base will affect and influence the body's main structures and mechanisms in many different ways to elicit an adaptation.

The pulmonary system adapts to allow more oxygen to efficiently be consumed; the lung capacity is increased to allow more air to be moved in and out of the lungs per breath. The respiratory muscles such as the diaphragm and intercostal muscles endurance is improved which in turn results in the respiratory muscles being able to support the intake and transfer of gases as effectively and as efficiently as possible. Capillarisation and the number of alveoli in the lung also increases to improve the amount of blood flow to the lungs and also enhance gas exchange per breath that is taken. Similarly to the pulmonary system, the cardiovascular system is similarly adapted. Stroke volume will increase due to an increase in strength of the heart, specifically the left ventricle, to allow for a stronger contraction and therefore more blood to be pumped through the body per beat (Bloomqvist, 1983). As a result, heart rate will decrease, resulting in a greater time for the left ventricle to fill with blood during diastole, which further contributes to the increased stroke volume and results in a greater efficiency of each beat to deliver oxygenated blood around the body. Within the blood itself hemoglobin levels will increase, this allows for more oxygen to be carried to the muscle per unit of blood (Sheuer, 1977). Adaptations will also take place in the muscle itself as the demand for oxygen will have increased as a result of the intensity of the exercise. This will cause capillary density to increase to allow for more oxygenated blood to supply the working muscle, as well as an increase in the efficiency of the delivery of oxygen as a result of pulmonary, cardiovascular and muscle adaptations. These adaptations will prevent premature fatigue as oxygen will be more efficiently delivered and waste products cleared to allow the exercise to continue for longer. These physiological adaptations could impact sporting performance as an improved aerobic capacity could reduce recovery time between high intensity bouts of exercise due to an increase in efficiency. (Evans, 1985).

Taking the importance of a good aerobic base into consideration, a key factor to determine aerobic capacity is an individual's VO_2 max. VO_2 max, also known as maximal oxygen consumption and defined as the maximal rate that the body can uptake and use oxygen. VO_2 max can be used as a measure of fitness and has been seen to change due to the adaptations described above as a result of an increase in aerobic fitness. VO_2 max can be measured or estimated via direct or indirect measures in a science laboratory or within the field. Moreover, research from Lythe and Kilding (2011) has shown that for male international hockey players, VO_2max ranges from approximately 55-65 $ml.kg^{-1}.min^{-1}$, with a study from Jennings et al (2012) reporting male players to have VO_2 max scores from the higher end of this scale at 64.2 $ml.kg^{-1}.min^{-1}$. However, it is important to state that within team sports, such as hockey with 18 players, it is not the case that all male international hockey players fall in to such a range. Separately, a question that has been asked by researchers with regards to VO_2 max is, does a difference between elite and sub-elite players exist and if so to what extent. Research in this area has given a mixture of conclusions, with Jennings et al (2012) reporting average VO_2 max values of approximately 64 ml·kg·min in elite players and Indranil et al. (2011) showing sub elite players to have maximal oxygen consumptions in the 56 $ml·kg^{-1}·min^{-1}$. It has been found that the indirect Multi-Stage Fitness Test (MSFT) can give VO_2 max predictions of 4.5 ml·kg·min lower than a direct measurement from a laboratory run treadmill test (Grant et al, 1995). It also important to add that within a team sport positional responsibilities will also result in different demands being placed on individuals and as a result the aerobic requirements for each player may be different. In an ideal world it would of course be beneficial for all of the team to be perceived to have a high VO_2 max and therefore be perceived to be in 'peak aerobic condition' however it could be predicted that across a number of team sports, not only hockey this is not always the case. Therefore using generalised figures to describe a sports VO_2 max could be unrepresentative due to the variety in positional and individual demands found within a team sport. This is supported by RESTRUCTURED

In addition to the measurement of aerobic capacity, assessment into an individual's anaerobic capacity is also a widely research area within a multitude of disciplines. When assessing aerobic measures, it was also found that there were various measurement implemented. One of the most commonly reported measures comes from that of the Wingate test. However, this test has little or no application to the majority of intermittent sports (Aziz 2004, Meckel 2009 and Dardouri 2014). Therefore, more recently Dardouri (2014) suggested, that the Maximal Anaerobic Shuttle Running Test (MASRT) was a reliable and valid way of testing anaerobic capacity that may be more suitable for team sports, a similar test is used within the Scottish Senior Men's team. Gharbi (2015) used this fitness test method in their study with 16 team sport athletes (soccer, basketball and handball) to determine the relationship between RSA and the aerobic and anaerobic systems. After comparing a 20m Multi Stage Fitness Test, 30 second Wingate Test, the Maximal Anaerobic Shuttle Running Test and Repeated Sprint Ability (RSA) total sprint time, it was found that aerobic fitness is an important influence on the body's ability to resist fatigue during repeated sprints as there was strong correlation between VO_2 max and RSA. It was also concluded that the MASRT was useful in contrast to the Wingate Test as a specific anaerobic testing procedure to test the contribution of the anaerobic system for RSA. As mentioned previously the senior men's hockey team used a similar study, the 30:15. Created by Busheit (2000)

Being able to make repeated sprints is vital in hockey as, due to the sports intermittent nature, you are required to perform high intensity bursts as the game progresses in order to track opponent players and contribute to your own teams play. Due to the rolling substitutions nature of the sport, intensity is high and so, for the time you are on the pitch, it is expected that you are playing to the highest intensity. In order to keep up with play and contribute to the fast-paced nature of the game, there will be periods where you are required to make several high intensity bursts of activity in quick succession and so having a suitable anaerobic system that can withstand this demand is important. Within a study by Spencer et al (2004) it was stated that the mean sprint duration recorded in the male field hockey players was 1.8+0.4 s. This is similar to that reported in soccer (2.0 s; Bangsbo et al., 1991), rugby (2.0 s; Docherty et al., 1988) and Australian Rules football (2.4 s; Dawson et al., 2002), but less than the 3.1+0.3 s reported in women's field-hockey (Lothian and Farrally, 1994). Moreover, on average it was found that the field-hockey players within a separate study had a change in movement patterns every 5.5 s during the game. A study by Yamanaka et al. (1988) found that when similar categories of motion were used there was also a reported change in movement patterns frequently (every 5–7 s) during soccer competition (Yamanaka et al., 1988). These results suggest that considerable amounts of energy would have been utilized due to the amount of acceleration and deceleration-based movements involved. Spencer and colleagues (2004) found that the mean number of sprints performed during hockey (71 min duration) was 30+14; this gives a mean recovery time between sprints of approximately two minutes. Separately, it has clearly been shown that when short sprints (approximately 5.5 s duration) are repeated every 120 s, there is no decrement in performance, even when 15 sprints are performed in succession (Balsom et al., 1992). In addition, when the recovery duration is reduced to 90 s, a significant decrease in performance time was only evident after the eleventh sprint (Balsom et al., 1992). However, the authors included in all studies that is was important to note that due to the unpredictable nature of team-sports, sprinting is not evenly distributed throughout a game and intense periods of repeated-sprint activity are possible and may be critical to the outcome of the game. It is also important to take into consideration that the speed zones applied in the various sports and across the various gender will vary and so what speed and duration is set to register a sprint will be different and so caution should be taken when comparing studies of a different nature.

When taking into consideration repeated sprint ability the anaerobic system and accumulation of lactate should also be considered. In general, non-sport specific terms, the anaerobic system will increase heart rate and stroke volume to maintain delivery of oxygen to the muscle for as long as possible (Balsom et al., 1992). The lactate threshold is defined as the level above which pyruvate, an intermediate product of anaerobic metabolism, is produced faster than it can be used aerobically. As a result, unused pyruvate splits into lactate (lactic acid) and positively charged hydrogen ions. Continued exercise above the lactate, or anaerobic, threshold results in accumulation of these ions—acidosis—causing exhaustion and intramuscular pain (Anderson's Medical Dictionary, 1990). Below the lactate threshold the cardiovascular, pulmonary and muscular systems will be able to deliver enough oxygenated blood to clear the lactate before it builds and causes discomfort. This discomfort is caused by the build up in lactate and subsequent H+ ions, an accumulation of these two components will cause a decrease in blood pH which will in turn increase the acidity of the blood. However, it has been suggested by Waldron et al (2014) that a decrease in the bloods pH, as a result of the increase lactate build up, is not solely responsible for reduced sprint capacity within intermittent team sport. It is important to highlight at this point that lactate will affect intermittent team sports individuals differently to that of intermittent exhaustive exercise. Within sports such a rugby and football, the average blood lactate concentration is typically seen to range between 7-9m·mol^{-1}. These figures show that although team sports player have to tolerate blood lactate, levels do not increase continuously to amounts that would cause a termination in physical activity, most commonly seen within exhaustive types of activity (Waldron et al., 2014). Additionally, it should be considered that although blood lactate concentrations will increase alongside H+ ions, resulting in a decreased blood pH, there are other factors such as the subsequent accumulation in inorganic phosphate and potassium, alongside the inevitable decrease in glycogen and blood glucose which are all in thought to have a significant impact, that in turn could directly impact repeated sprint ability more so than that of lactate. The patterns of lactate build up across a match of hockey was investigated by Ghosh et al (2004), focusing on 2 groups of field hockey players made up of 25 juniors and 29 seniors. The aim of the study was to investigate the build up of blood lactate across both training and games in training to assess the anaerobic demand of the game and the adaptability of the players to anaerobic metabolism. It was found that Blood lactate levels after warm up, training and the game were 2.1, 7.4 and 4.2 m·mol^{-1}., respectively for the juniors and 2.6, 7.7 and 5.6 m·mol^{-1}., for the seniors. The aerobic capacity (VO2 max) of the juniors did not differ from their senior counterparts, indicating a similar adaptability to aerobic metabolism. It was concluded that the higher blood lactate level in seniors after the game reflected that they played with greater intensity than the juniors, due to more experience, better motivation and skill.

With this in mind, there has however been various studies that have found significant findings with regards to lactate build up and repeated sprint ability within intermittent sports. Bangsbo et al. (2006) found within soccer that on average blood lactate levels of between 2-10mmol·1^{-1} has been observed during matches, with some individual cases showing values of >12mmol·1^{-1}. In a separate study by Krustrup et al (2006) lactate was measured throughout a friendly match to observe the effects before, during and after. It was found that lactate increased on average 4-fold to approximately 15mmol·kg dry weight^{-1} compared to resting values, with the highest individual figure reaching 35mmol·kg dry weight^{-1}. One of the most interesting findings from the Krustrup (2006) paper was that muscle lactate and blood lactate levels did not correlate. This is different to that found when undertaking continuous exercise, in which blood lactate concentrations were lower but well reflected the muscle lactate concentrations during exercise. These differences observed between the two different types of exercise are thought to occur due to differences in turnover rates, with muscle lactate and blood lactate clearance being significantly higher in muscle than in blood (Bangsbo et al. 1993). With regards to intermittent exercises such a soccer it is common for lactate levels to be significantly higher in muscle compared to in the blood (Bangsbo et al. 1993). As a result, the blood lactate concentration can be high even though the muscle lactate concentration is relatively low. There also appears to be a link caused by the activities carried out directly before sampling. This can result in a difference being found between muscle lactate and blood lactate, meaning that the high blood lactate concentration (Bangsbo,1993 ;Ekblom,1986; Krustrup, 2006) may not represent a high lactate production in a single action during the game, but rather an accumulated or balanced response to a number of high-intensity activities (Bangsbo et al., 1991; Krustrup & Bangsbo, 2001). Alongside research on the relationship between aerobic intermittent activity and lactate studies have also investigated different ways to measure lactate specific to the repeated sprint ability aspect seen within most team sports. Within a study carried out by Gharbi et al. (2014) in which multiple variations of sprints were carried out and blood lactate compared within team sports players, twenty male team sports players performed several repeated sprint sessions consisting of 1, 2, 3, 4, 5, 9 or 10 repetitions of a 30 meter shuttle(15m x 2) with a 30 second recovery in between. It was found that after three shuttles, blood lactate increased significantly reaching five fold of resting values ($9.4 \pm 1.7 mmol \cdot 1^{-1}$) and remained unchanged for sprints of 4 and 5. However when comparing sprints of nine and ten shuttles it was found that blood lactate further significantly increased to 12.6 and 12.7 $mmol \cdot 1^{-1}$. It was concluded from the study that sprint shuttles of five repetitions is the most representative of the blood lactate demands within a generalized team sport game. Moreover, various studies have investigated the importance of repeated sprints within hockey. It has been reported that this ability, to sustain a high intensity of repeated sprints, can be the difference between elite and district level players (Reilly and Borrie 1992).

It is, therefore, clear that both anaerobic and aerobic energy systems are important in order to allow team sports players to perform to the required intensity. However, there has been some conflict in the research over which energy system contributes most to the ability to produce repeated sprints throughout a high intensity match. A study by Spencer et al (2004) looked at predictors of repeated sprint ability (RSA) within female hockey players. Fourteen elite female hockey players took part in a repeated sprint ability test on a cycle ergometer (5x6s all out sprints every 30seconds) and a VO_2 peak test. Venous and capillary blood was sampled before and after the repeated sprints in order to determine lactate and any changes in ph. It was found that there was no correlation between VO_2 and total work or power decrement during the repeated sprints. However, it was found that there was a strong correlation between plasma concentrations of H+ and repeated sprint ability, whereby if concentrations of H+ were high the ability to carry out repeated sprints decreased. It was therefore concluded that VO_2 peak did not predict repeated sprint ability, however plasma concentrations of H+ could be a predictor, due to the fact that as H+ ions build up within the muscle the acidity increases (Krustrup and Bangsbo, 2006). In a separate study carried out by Spencer et al (2004) the effects of hockey training on repeated sprint ability was investigated. Eighteen female elite hockey players took part in a repeated sprint test on an ergometer of 5x6s sprints with 30 seconds in between, as well as a 20m shuttle test. The subjects carried out these tests before and after seven weeks of hockey training designed to improve repeated sprint ability. The training involved controlled hockey skills drills that were aimed to keep the subjects heart rate between 80-90% of max, small sided games and games against other National Championship sides. It was reported that, after seven weeks of training, there was a significant increase in total work performed during the ergometer test as well as a significant improvement in the 20m shuttle test. There was also a significantly decreased hydrogen ion concentration in the blood stream during the repeated sprint test after seven weeks of training. The increase in total work was attributed to an increase in lean muscle mass, however the decreased H+ concentrations was concluded to be due to an improved buffering capacity which, when paired with the improved total work performed, can be attributed to improvements in the anaerobic base.

Both studies have shown that H+ ion concentration and the ability to buffer the accumulation strongly correlates with repeated sprint ability. Spencer et al (2004) reported that, although VO_2 max in previous studies has been shown to correlate to repeated sprints (McMahon and Wenger 1998), these studies have typically involved untrained individuals. Spencer (2004) stated that, although there was an increase in 20m shuttle score, there was no change in total work or power decrement and so it was concluded there was no strong link between VO_2 max and repeated sprint ability and therefore, increasing aerobic fitness in well trained athletes, would not significantly impact in their ability to perform repeated sprints.

Conversely, Tomlin and Wenger (2002), stated that an increased VO_2 max was associated with a superior power output recovery across repeated bouts of high intensity exercise, as well as improved lactate removal and enhanced PCr regeneration. The study took place with 10 recreational soccer players that all took part in 10x6second sprints with 30 seconds rest in-between. The subjects were split into either a low or moderate aerobic power group (Low: VO_2max 34.4 (2.4) $mL·kg^{-1}·min^{-1}$ and Moderate: VO_2max = 47.6 (3.8) $mL·kg^{-1}·min^{-1}$). It was found that the Moderate group had a smaller power decrement over the 10 sprints and consumed significantly more oxygen when compared to the low aerobic group. It was therefore concluded that VO_2 max is related to both an increased aerobic contribution to sprint-recovery bouts but also to the enhanced ability of the higher VO_2 max (Moderate) group to resist fatigue during intense intermittent exercise.

Taking the current and past literature into consideration, it is important for intermittent team sports players to have an efficient aerobic and anaerobic base as both will greatly enhance their ability to recover and therefore perform repeated sprints to a high quality. Having a high level of aerobic fitness can impact on an individual's anaerobic fitness by enhancing recovery after intermittent high intensity efforts (Aziz, 2000). It has been found that player's high intensity bouts last on average five seconds in comparison to the lower intensity bouts of 18 seconds (Lemmink, 2006). Various studies have investigated whether a high VO_2 peak is related to repeated sprint ability (RSA) in field hockey, soccer and rugby as it has been thought that VO_2 peak is associated with the bodies increased ability to deliver and use oxygen, which can be the difference to recovery between sprints (Stone et al, 2009). As the studies above from Bishop (2003) and Spencer (2004) have shown H+ accumulation correlates strongly to an individual's ability to perform repeated sprints and it is therefore important that the individual can effectively buffer this build up.

1.3 Skill

There are several components of skill required to be proficient within the sport of hockey. In the most basic sense, the fundamental skills required to be competent within the sport include a front and reverse stick pass and hit, ability to receive the ball and tackle effectively. It has been identified that the speed at which you can travel with the ball and carry out certain aspects of skill could be a determinant of a novice or more experienced player (Thiel et al, 2012). The ability to control the ball when travelling at speed and with the added pressure of game specific decisions also has to be made, it becomes the basis of a variety of tests to determine competence within the sport. In a study carried out by Thiel et al. (2012), it was shown that it is possible through skill-based drills to identify a novice and experienced player. In the study, eleven male novices and nine state ranked hockey players took part in a series of three drills that each focused on specific hockey skill criteria. The first test, 'The Chapman Test' looked at the agility of the player and their ability to control the ball within a limited space. The second test named "Two Hits and a Flick' required the subjects to move the ball and then flick it at the goalkeeper and finally the test 'Trap and Flick' looked at the individual's ability to control and move the ball when receiving a pass. Each test was timed and a three-axis accelerometer was attached onto the stick to determine the speed at which the movements were carried out. It was found that there were significant differences between both groups in all three tests. This suggests that skill as a whole is an important component of an elite hockey player's overall ability as it impacts upon the speed and consistency of the movements they carry out. This has been further supported by Elferink-Gemser et al. (2010) who investigated any possible differences between players who were classed as having an average, high or very high level of performance. The classification was made depending on the level the individuals played at (Average= Regional, High=Sub Elite, Very High=Elite). 191 youth field hockey players of both genders participated in Tactical Skills Inventory for Sports (TACSIS), with scales for declarative ("knowing what to do") and procedural ("doing it") knowledge. Results showed that sub-elite and elite players outscored regional player on tactical knowledge (declarative skill) whereas elite were better than sub-elite for positioning and deciding skills (procedural skill). Additionally, there was no difference in the results between males and females. Both of these studies show the importance of being proficient and having a high level of skill, not only just with a stick and ball, but also in the declarative and procedural aspects of the game also. However, a potential weakness in the study by Elferink-Gemser et al (2010) is that self-report measures were used, which can make results susceptible to a person's self-confidence and so a low self-confidence may have affected the results (Mahoney et al. 1987; Woodman & Hardy, 2003). This emphasises the importance of not only good physiological fitness, but also shows that psychological factors, such as confidence, can also impact upon a player's development.

Additionally, a separate component that is very specific to the sport of hockey is the body positioning that players have to adopt when travelling with the ball. The semi-crouched posture is adopted when dribbling, passing, moving, receiving the ball and challenging the opposition. Therefore, as a main movement requirement, it places an additional strain on the players that other intermittent field sport players may not experience. This will also impact upon the skill aspects of the sport, especially for a novice, as the crouched stance is not a body position most will have experienced before. This can put a certain strain onto their joints and spine, as many studies have shown the forward flexion of the spine has been linked to lower back pain (Hertling, 2006, Little, 2005 and Nachemson, 1969) as well as the crouched position being associated with increased loads to the lumbar spine (Murtaugh, 2009 and Reilly 1992). In the study carried out by Murtaugh, where the rates of injuries experienced by field hockey players were reported, it was found that that the lower back was the most commonly injured region. It was also reported that 59% of female field hockey players experienced low back pain related to playing hockey and likewise it was separately reported that 53% of male field hockey athletes reported low back pain (Reilly and Seaton, 1990). Moreover, factors predisposing hockey players to back injuries include the

1. Growth spurt,
2. Abrupt increases in intensity or frequency of training sessions,
3. Improper technique,
4. Poor strength of back extensors,
5. Abdominal musculature inflexibility of the lumbar spine, hamstring, and hip flexors muscles may also contribute to chronic low back pain.
6. Additionally, excessive twisting may produce sprain and strain, the most common cause of low back pain in adolescents

(Orooj et al, 2016).

It is therefore important that hockey players not only have a high level of skills training but attention is also given, in the early stages of development, to proper technique.

1.4 Strength and Power

Strength and Power are two components that are very important within any field sport. Contractions within the musculature of the body can enable an individual to exert specific amounts of force to allow them to sprint, tackle, jump or change direction (Komi, 1993). The importance of training these muscles and processes, specific to the role they have within the sport, is widely recognised in a variety of different sporting fields. As a result, it is becoming more likely that teams and individuals alike are employing specific individuals as Strength and Conditioning coaches to train their bodies to the specific needs of their sport.

With regards to Scottish Hockey, from the age of 18 all players are given dedicated Strength and Conditioning programs and take part in regular testing sessions to track progress. These programs are tailored specifically for the teams needs and are usually written in four to six week blocks and carried out twice a week. All programs look to enhance or improve the strength in a certain area of the athlete’s body or enhance criteria such as co-ordination, force generation or separately to act as injury prevention. All muscular contractions that elicit movements are a result of concentric, eccentric and isometric movements. Training these movements, through strength and conditioning programs can elicit improvements in hockey specific manner.

Incorporating strength and power is important as mentioned previously it not only helps to prevent against injuries but also to improve running performance and sport specific movements that will have a direct impact on training and match play. Within several research papers the question asked has been if strength training elicits enough benefits for those athletes of which their sport is not specifically solely strength based such as rugby, football, hockey etc (McGuigan et al. 2012). When looking into the potential benefits strength training can have on team sports athletes and the specific benefits that strength training elicits on match play it has been found that performance measures linked to strength and power training such as strength and jumping measures have been shown to separate starters and non starter from match play. Studies across various sports such as American football, Australian rules football and rugby have shown that players with superior scores within the strength and power tests were shown to be most likely to start matches (Young et al. 2005). Separately, various studies have also found strong relationships to exist between physical capacities that are directly improved through strength training and on field performance. In a study by Nimphius (2010) it was found that relative strength had a very strong relationship with speed and change of direction ability over the course of a season within female softball players. Moreover, the role of maximal strength in sprint speed and vertical jump height in international soccer players revealed a high correlation between 1RM squat and 10 m sprint time, 30 m sprint time and jump height (Wisloff et al. 2004). Separately similar correlations between strength and power and sporting performance was found in a study by Sheppard et al. (2009) within volleyball in which 1RM squat strength had a moderate correlations with countermovement and spike jump performance. Various studies have shown strength training to be an important addition in improving sport specific qualities that impact upon performance as well as exposing individuals to load within key sport specific areas in an attempt to prevent overload or breakdown injuries throughout the course of the season. McGuigan et al. (2012) does however emphasise the importance of program design, specificity and periodisation to ensure the specific benefits required are obtained maintaining or improved sport specific performance.

1.5 Technological Support

Throughout the years, as previously described above, the sport of hockey has advanced, not only just in rules, but also within the technological support that now plays a pivotal role in monitoring the players' wellbeing and performance. The equipment that teams have primarily comes down to funding, as advanced equipment can be very expensive and therefore, unaffordable for smaller nations or clubs. Technological advancements have given teams the possibility to track player activity, heart rates, plan substitutions and track general wellbeing. Currently, Scotland Senior Men's team use Heart rate monitors, Global Positioning System (GPS) and Daily Wellbeing diaries to make sure their players are at the optimal physical and mental condition to perform at the highest level.

1.6.1 History of GPS

GPS originate from the First World War, as a tool to define the position of a target based on radio signals (Kumar & Moore, 2002) Advancements in GPS technology have come primarily from American and Soviet Union Sources, as when the Soviet Union sent Sputnik into orbit in 1957, they were able to receive radio signals from it. As a result, this prompted the American military forces to begin their research and development into space based navigation systems. The GPS program was approved in 1973 and by 1978 the first satellite was launched (Kumar & Moore, 2002). By August 1993 there were 24 satellites in space and now in 2016 there are 32 functioning satellites in orbit with 27 of these currently operational. At most points on Earth there are between eight and eleven satellites visible at any one time allowing for greater accuracy of signal (Dzurisin, 2006). Primarily, up until 1983, GPS was solely for military use, however, in 1983 after a Soviet Union attack on a Korean airliner the US president at the time, Ronald Regan, allowed the satellites to be used by other commercial airline companies. For the next 20 years the satellites were primarily used by the military during the Persian Gulf War of 1990 and other operations of its type to identify targets. In 2004 the US removed their stringent guidelines over the satellites and this allowed more concentration to be focused upon the commercial uses for the satellites (Kumar & Moore, 2002).

In 2004, the first mobile telephones were tested using GPS (Kumar & Moore, 2002) and in 2006 the leading sports GPS manufacturers Catapult were commercialized following their formation in 2001 (Catapult Sports).

GPS are based around the speed, distance and time equation. The use of this equation (Speed=Distance/Time) allows for the identification of an objects position on earth. Each satellite in orbit creates a circular signal and when 3 or more of these signals are present then their paths will cross over and these crossover points can be used to narrow down the location of the receiver on earth. There are currently 32 functioning satellites but to get a GPS network to function, a minimum of twenty four satellites have to be operational (Dzurisin, 2006). 24 satellites are required for the network to function, as the more satellite signals there are the more accurate the positioning will be, all GPS units will function with three satellites being present, however, the more satellites connected the more chance of greater accuracy (White and MacFarlane 2015). It is currently thought that, at any one time, there are eight and eleven satellites visible, this will increase the strength of signal and reliability of the data. Certain GPS provide a satellite count to allow the users to observe the number of satellites that are currently connected to ensure the strength of signal is effective enough. Additionally, radio waves and atomic clocks are used to further increase the information received from the satellite. These two components give information on the time the signal was sent and received as well as the signal speed, which allows the distance of each satellite to be calculated and more in depth information to aid the identification of the unit’s position.

As well as the ability to obtain information through radio waves and atomic clocks, most GPS units that are used within sport are accompanied with other technological devices to further the data they can provide. Alongside the GPS, which identifies the position and distance covered, there is commonly an accelerometer, gyroscope and magnetometer also included. These three devices work together to provide additional information on the devices movements at any time. Accelerometers are described as being an electromechanical device that measure acceleration forces. These forces can be static or continuous, such as the continuous force of gravity. Acceleration is defined as the change in velocity or speed, divided by the time and can give orientation as well as measure of acceleration. Typically, accelerometers are made up to contain multiple axes to allow identification of two and in some cases three dimensional movements. The sensitivity of accelerometers is high to detect even the slightest change in movement. Within a GPS unit accelerometers can provide a time or distance spent in each acceleration zone (Catapult Sport). In order to accurately measure an athlete's acceleration gravity needs to be removed from the equation; this is done through the information provided by gyroscopes. Gyroscopes detect forces which in turn determine angular velocity along one rotational axis and the direction that gravity is being applied. With regards to acceleration they determine orientation which in turn determines the direction of gravity; this is achieved through the identification of any rotational movements. The accelerometer can only detect changes in velocity, it cannot distinguish between acceleration in a certain direction, whereas, the gyroscope can quantify the direction, thus can provide information on which direction the object is travelling in relation to the earth's surface. It is important to note that gyroscopes do not measure the actual degree of change, but instead, give the velocity or rate of change. Finally, Magnetometers, detect the orientation of the device in respect to the earths gravitational field, in simple terms, it acts as a compass to determine in what direction the object is moving (Catapult Sport). The combination of all 3 of these devices, incorporated into the GPS unit, allows for in-depth analysis of not only location but speed of movement, tilt and direction, thus giving a detailed breakdown of the movements being carried out.

GPS units are currently being produced by a number of different brands and used by a variety of different sports teams. This has resulted in no standard method of use to yet be apparent. Depending on the sport, modern GPS units can provide information on multiple variables, not all of which will be useful to all sports teams, but the technological properties are such that most intermittent team sports will find some benefit from the data collected. In general, most team sports use GPS to monitor the physical activity of their athletes during both matches and training sessions. Subsequently, this allows them to monitor the load that the player is experiencing through analysis of their on-pitch efforts and through analysis of the speed and intensity of the session. This can provide information on the real time distances that individuals are covering within training sessions or matches which can be useful when implementing ‘return to play protocols’. Within the Scottish hockey team the GPS data is also used post match to identify the players that have covered the most total or sprint distance. This is useful as within hockey tournament setups where 5 games in 6 days is common place this information can be used to prioritise these players for specific recovery protocol measures, as well as highlighting them as potential injury risks should their distances be higher than their own individual norms. A study by Cummins et al. (2013) conducted a systematic review into GPS and team sports. The study was conducted with 1276 participants over 8 team sports. It was found that work rate patterns were most frequently reported within team sports and were obtained through the use of the micro technology sensor aspect of the devices. It was also found that information on impacts and accelerations were the least reported areas from the GPS devices. Speed zones were frequently used within and across team sport analysis, however, a lack of consistency was found in the definition of each speed zone as different teams applied a mixture of generic and individualised speed zones specific to their specific sport.

1.6.2 Validity and Reliability

Coutts (2010) investigated the validity and reliability of GPS in team sports specifically. The study aimed to look at the intra-model validity and reliability of different devices during high intensity intermittent sport. Sixteen Australian rules footballers took part in the study where time motion analysis was used on one to nine games per player during 2015-2017. Match running demands and the effect of periods of increased physical activity, on subsequent running performance in the Australian Football League, were analysed. They used 1Hz devices and concluded that total distance and peak speeds, during high-intensity intermittent exercise, may not provide reliable measures for higher intensity activities. They concluded that at speeds above 14.4 km.h^{-1}, resulted in decreased reliability of results. In another study, conducted by Castellano, (2011) it was found increased validity of GPS units at slower speeds and longer distances, with 5 Hz devices showing greater validity in short courses when compared to 10Hz devices. The study was carried out with 9 male trained subjects who each took part in 6 and 7 linear runs of 15m and 30 m respectively. The subjects all wore one GPS unit each and were instructed to complete the course as quick as possible with 1 minute recovery given between each set. It was found that the distance data classed as highly accurate, underestimating the distances at 15m by an average of approximately 1.4m. The accuracy of the data produced, increased with the longer distances and it was concluded that increased sampling frequency lead to increased accuracy of the devices. A separate section of this analysis was the comparison of intra-device reliability; all nine GPS units were compared to observe whether there was a significant difference between devices of the same sampling rate and model. It was concluded that only small variations occurred between devices.

As previously described above, generally studies show that the higher the sampling rate (10 Hz > 5 Hz >1 Hz) the more valid the data is for linear paths, longer distances and slower speeds. This is supported by MacLeod et al (2012) who, in a field hockey specific study, found that when using a 1Hz GPS device, there was a difference of 0.2 ± 1.09m; when running a straight path of 26.1m, 0.1 ± 0.94m when running a sprint shuttle of 52.3m and -0.1 ± 0.81m when running a 8.5m zig-zag type course, when compared to that measured by a trundle wheel. This shows that there is a degree of variability, however, there could be human error attributed to the trundle wheel measurements and additionally there is no reference to the effect speed had on the results or a comparison to a higher frequency device.

In a separate study carried out by Portas et al (2010), 1Hz devices were compared when walking and running at different speeds to that of a 5Hz device. The study used field sport players to take part in linear (32 trials), multidirectional (192 trials) and soccer specific courses (40 trials) to test the validity, reliability and bias of GPS against the measured distance. It was concluded that the 1Hz device had a standard error from the standard error of the estimate of the mean (SEEM) of; 2.6

to 2.7% compared to the 5Hz 2.9 to 3.1% when travelling in a linear fashion. When moving multi-directional the 1Hz had a SEEM of 1.8 to 6.9% compared to the 5Hz 2.2 to 4.4% and finally when participating in soccer specific movements the 1Hz SEM was 1.3 to 3.0% versus the 5Hz of 1.5 to 2.2%. This shows that for both the multi directional and sporting activity the 5Hz device deviated from the mean less than the 1Hz device. Therefore, both 1Hz and 5Hz devices were stated to have thresholds beyond which reliability was compromised, however 1Hz underestimated the distance and was less valid in the more complicated courses. Duffield et al (2009) supported the findings of Portas et al (2010) that GPS underestimates distance in confined spaces but that 5-Hz was more accurate at higher speeds in small spaces than 1-Hz. In this study one male subject performed 10 repetitions of 4 drills that replicated court based movement and 6 repetitions of random movements that would be performed within the sport of tennis. Two 1Hz and two 5Hz devices concurrently measured the distance and speed that all movements were made at. The results concluded that both 1Hz and 5Hz devices under reported the distance covered as well as the mean and peak speed. However, the inter unit reliability for distance and speed of both 1Hz and 5Hz was found to be low to moderate which is similar to the findings of inter unit differences by Castelllano (2011). Similarly, Varley and Aughey's (2012) study analysed both 5 and 10 Hz units during constant speed, acceleration and deceleration runs. Three participants completed 80 running trials, wearing a 5Hz and 10Hz GPS unit each. It was found that the highest variations occurred with 5 Hz devices during accelerations between 1 and 3 $m \cdot s^{-1}$ and decelerations between 5 and 8 $m \cdot s^{-1}$. The 10 Hz devices were shown to be more accurate for all runs, with the highest variation being 11.3 % for decelerations (compared to 33.2 % for 5 Hz). These studies show that there is always cause for a degree of variability when using a GPS device. However, a higher frequency 10Hz device appears to be the most valid for producing reliable results. When running a straight path 1Hz devices are sufficient but when movements start to become multi-directional and at speed then higher frequency units have a lesser degree of variability which in turn should produce more accurate results.

1.6.3 Speed Zones

As previously stated, Playertek GPS has the ability to record and report both time and distances covered in different set speed zones. The speed zones (Table 1.3) were set based from analysis of published research (White, 2014), as it is important when comparing and drawing insights from research that the set speed zones and specific sport criteria are taken into consideration. In a hockey specific piece of literature, walking was specified to be 0-6 km·hr^{-1} and jogging suggested to be between 6.1-11.6 km·hr^{-1} and low speed running at 11.1 - 14 km·hr^{-1} (Lythe and Kilding 2011). Moreover, parallels have frequently been drawn between football and hockey due to the similar intermittent high intensity bouts and with very similar formations and tactics. Within football literature walking is suggested to be 0.7 to 7.1km·hr^{-1}, walking and jogging is suggested to be within 7.2-14.3 km·hr^{-1} (Carling, Le Gall ad Dupont 2012).

Speed Thresholds (km·hr^{-1})		Description
Male	Female	
0 – 6	0 – 6	Standing/Walking
6 – 11	6 – 10	Jogging
11 – 15	10 – 14	Low Speed Running
15 – 19	14 – 18	Moderate Speed Running
19 – 23	18 – 21	High Speed Running
> 23	> 21	Sprinting

Table 1.2 Speed Thresholds for GPS used in female & male hockey. Reproduced from White.A & MacFarlane.N (2015)

However, research and literature into speed zones has suggested that there are various factors that need to be taken into consideration, as a 'one size fits all' approach may not be suitable within certain environments. As previously stated above the sport and its demands will impact upon the speed thresholds that should be applied to best represent the level of activity taking place. It has been found that the definition of slower speed thresholds, appear to be more easily defined compared to those of a higher intensity. With regards to the literature (Clarke et al 2017, Carling, Le Gall and Dupont 2012, Di Salvo, 2009, Abt and Lovell 2009).

The definition of low speed running is associated to that of a walk, jog or low speed run. Within the sport of hockey, with its intermittent nature, clear and informed application of thresholds is vital due to the obvious physical demands high speed running has on the athletes.

Many studies appear to have found conflict between their methods for defining at which point exercise becomes classed as 'high intensity' and so support for a more individualised approach to speed zone application has been suggested. Various studies have used different methods to attain a high intensity threshold measure. From analysis of the literature there seems to be two main methods used, the first being video analysis software that have subjective speed zones set to identify the threshold (Di Salvo, 2009). The second method that seems to be commonly used is the ventilatory threshold (VT); this is usually carried out on a treadmill where the higher intensity exercise can be identified as the point at which ventilation increases at a faster rate than O_2 uptake. The difference between the two methods can be quite significant with 5 $km \cdot hr^{-1}$ difference being observed between Abt and Lovell, 2009 compared to Carling, Le Gall and Dupont (2012). Additionally, a study carried out by Reardon el al. (2015) investigated the potential differences between individualised and generic speed zones for the reporting of high speed running within professional rugby union. The results of this study indicated that application of individualised speed zones results in a significant shift in the interpretation of the HSR demands of both forwards and backs and positional sub-categories (Reardon et al. 2012). It was concludes that although use of an individualised HSR threshold improves the interpretation of the HSR demands on a positional basis, inter-individual variability in maximum velocity within positional sub-categories means that players need to be considered on an individual basis to accurately gauge the HSR demands of rugby union. Within the senior men's Scottish hockey team the benefits of individualised speed zones were recognised. However due to the nature of the programme and subsequent the required means to accurately measure and apply individualised speed zones to all players within the study regardless of geographical location is something that at the time of the studies outset was not going to be feasible.

Moreover, another factor that has been documented is the gender of the athletes and the potential differences in speed zones. In a study by Clarke et al (2014) men and women's rugby union was analysed and speed zones for both groups were investigated. Previously, the speed zone thresholds had been applied to the women and so the appropriateness of this was questioned. The Ventilatory Threshold (VT) method was used to determine the point of high speed running and it was concluded that were previously for male rugby speeds >18km.hr^{-1} were classed as a high-speed running, for the female tests it was shown that their high speed running figure should have been reduced to >12.6km/hr. This shows that not only are speed zones sport specific but also dependent on the individuals within the team, both gender and fitness related. In a separate study by

1.6.4 Standard Figures in Hockey

The duration of a standard hockey match has recently changed, during season 2016-2017 all international games that Scotland took part in were four 15 minute quarters. All domestic club games were two 35 minute halves; therefore the structure and duration of the games are different depending on the competition you are playing in. This has impacted on the ability to compare games as there is 10 minutes of a difference when taking into consideration on pitch time. As this is a relatively new addition to the sport of hockey there are currently limited studies comparing the difference between the two styles of game duration. The majority of studies investigating the physiological demands and the standard distances achieved are taken from games lasting 70 minutes. There has only been one study to date that looks to compare 60 and 70 minute durations. Cai et al (2017)) found that when comparing the new and old rules regarding durations it was found that the 60 minute duration elicited a higher number of high intensity bouts. However the 70 minute duration was found to elicit a larger total distance on average.

In a study conducted by Buglione el al. (2017) the physiological and physical characteristics of male elite and sub elite Italian field hockey players was investigated. Twenty two players (12 elite and 10 sub-elite) took part in 6 games

(3 international and 3 national), each game was analysed by GPS and HR devices. It was found that the mean total distance covered by each player across the full tournament was 7063±1363m for the elite players and 6186±1615m for the sub-elite. It was found that between elite and sub-elite Italian hockey players there was no significant difference in the distance covered. In a separate study conducted by Spencer et al. (2004) the movement patterns during an international field hockey game were analysed during a 70 minute match. Fourteen players within the Australian men's hockey team were analysed in the first game of an international tournament against Germany. Time-motion analysis was used to calculate the frequency and duration of the players and the result can be found in Table 1.4. It was found that the players completed most movements at a jogging pace (326±58) for 5.1±1.0 seconds, defined as 'motion with an airborne phase, but with low knee lift' in comparison to sprinting that was found to have a frequency of 30±14 for the least time of 1.8±0.4seconds. It was concluded, that when comparing the exercise intensities and sprint activities observed, that there were similarities to those of elite soccer, rugby and Australian Rules football.

	Motion				
	Standing	Walking	Jogging	Striding	Sprinting
Frequency (n)	77±11	272±49	326±58	75±22	30±14
Duration (s)	3.6±0.6	6.9±1.0	5.1±1.0	2.1±0.3	1.8±0.4

Table 1.3 Frequency and Duration of Australian Hockey players in five speed zones. Reproduced from Spencer.M (2004)

1.7 Current Situation

1.7.1 Governing Bodies

As with many sports, hockey has a governing body known as the Federation of International Hockey (FIH) and separately each Nation has an organisation that controls hockey within that country. The Scottish Hockey Association (SHA) and the Scottish Women's Hockey Association (SWHA) were formed in 1900 and then amalgamated to come under the heading of the Scottish Hockey Union (SHU) in 1989 (Scottish Hockey). Scottish hockey aims ‘to provide the opportunity for more players to enjoy hockey to the highest level they desire throughout their lifetime’ (Scottish Hockey). They control hockey, both at domestic club level as well as at an International Level for both Male and Females at Senior, U21, U18 and U16 levels.

1.7.2 Domestic League Structure

Scottish leagues are split into male and female and then divided into National League, the highest tier which has three divisions, then Regional Leagues, split into two divisions and finally District Leagues that are split into three distinct areas and further separated into divisions for each district. In total there are 144 teams that make up the Male Scottish Leagues. Currently, there are nine Scotland Internationalists playing within the Scottish Domestic League setup.

English Hockey has a similar league setup up, with the top tier, premier division followed by three regional conferences and then further broken down to another five Regional leagues. The premier league is made up of 10 teams of which eight current male Scotland internationalists are players for and within the Regional conference leagues; another three current Scotland players are based. In the 2016-2017 season there were two English teams in the Last 16 of the European Hockey League, Holcombe and Wimbledon, alongside one Irish side, Lisnagarvey.

Internationally, hockey leagues in the Netherlands and Germany have attracted Scottish Internationalists over the last few years. Currently five Internationalists play in the European leagues. The structure of the leagues in both Germany and Holland are both very similar to that of Scotland and England. In Holland, the top tier of hockey is known as the Hoofdklasse and consists of 12 teams, currently three Scottish Internationalists play in this league. Moreover, in Germany the league is known as Hockey Liga and consists again of 12 clubs, of which two Scottish internationalists play for.

The standard of the European leagues can be seen from the number of teams that are competitive within the European Hockey League (EHL). The EHL is an annual hockey competition made up of the best teams in Europe. Qualification for the EHL is a result of being top in your respective hockey league. In the 2017 'Last 16 Knock Out' there were a total of 3 German and 3 Dutch teams joining the 2 English sides and Irelands Lisnagarvey. The other 7 teams came from Spain (Atletico Teressa, Club Egara & Real Club de Polo), Belgium (Royal Racing Club de Bruxelles, KHC Dragons & Racing Club de France) and Poland (WKS Grunwald Poznan). This shows the current standard of domestic clubs in Europe compared to those in England and Scotland. To further support this, since season 2007-2008 of the EHL the winners have come from either the Netherlands or Germany (EHL)

Currently, there are no Scottish clubs in the male or female leagues playing at the highest European standard. Kelburne have for the last seven years qualified to play in the European Men's Hockey League, they have qualified as the winners of the Scottish National 1 League. However, Kelburne, have never progressed past the 'Knock Out' Final 16 phase (EHL).

1.7.3 Standard of Competition

Another component that has to be taken into consideration is the standard of competition that each individual is playing at. Out of the eight players currently playing domestic league hockey in Scotland all play within the highest National league in Scotland, in England seven out of the nine subjects play in the Premier division, with two playing a league lower in the Conference East and North Division. Finally, with regards to the European leagues, out of the five subjects currently playing in Holland and Germany, four subjects play in the top leagues, Hoofdklasse and Hockey Liga respectively, with one playing in the lower Overgangsklasse in Holland. It is therefore important to note that the standard of league competition will be different not only between locations but also within locations also.

1.7.4 International System

Internationally, Scotland are 23rd in the FIH World Rankings with England currently sat in seventh, Ireland in ninth and Wales are twenty fourth (FIH) in the ranking table. However, Wales has a population of 3.063 million people in comparison to Scotland 5.295 (2011 Census) and they both compete at a similar level. Both Wales and Scotland qualified from World League 1 in September 2016, consequently with Scotland finishing third and Wales fourth in World League 2. As a result of Scotland's 3rd place finish they qualified for World League 3 for the first time in their history. Scotland, in August 2017, then took part in the European B championships. They had been part of the European B league since 2005, having not gained promotion to the highest European tier, the 'A division', for 12 years. In 2017, they were the 3rd highest ranked team in the competition and won the championship to compete in the A Division alongside Wales in Antwerp in 2019.

Scotland's successes in 2017 have not been funded by the Scottish Institute of Sport. In 2015 after failing to secure promotion to the European A division, the Scottish Senior Men's squad lost Scottish Institute funding. This has resulted in the team losing access to institute Sport Scientists, Physiotherapists, Strength and Conditioning coaches, Nutritionists and Psychologists, as well as significant funding shortfalls. As a result, more players within the International setup are relying on their domestic clubs to give them support in terms of fitness programs, medical and physiotherapy care as well as hockey education. However, these are areas that most domestic clubs in Scotland cannot sustainably supply; this has inevitably led to talented Scottish based players having to look out-with hockey in Scotland to find a better environment in which to develop.

1.8 Remote Monitoring

As a result of the number of Scottish Internationalists playing out-with Scotland it is vital that they are closely monitored whilst playing and training with their domestic club team. Players are monitored through GPS devices and wellness diaries to obtain information on their activity and load levels as well as their wellbeing.

1.8.1 Playertek

The GPS system currently used by Scottish Hockey is produced by Playertek. Playertek describe themselves to produce 'a professional-grade sensor device and web based software that measures physical performance, designed for football (Soccer, Rugby, GAA, Hockey, Lacrosse, American Football) and a range of smart sensors' (Playertek). The units are 10Hz (10 samples taken per second) and included a 10 Hz Tri-Axial magnetometer, 400 Hz Tri-Axial Accelerometer and Gyroscope. The Playertek units provide post-activity analysis but no real-time data can be obtained. There is currently no research or studies carried out on these units, this is due to the fact that they are relatively new additions to the GPS market. The information that can be obtained is vast including Total distance (km), Distance per minute, Sprint Distance, Top Speed and Player Load.

Although there are limited current studies specific to Playertek, there have been many studies conducted to investigate the validity of GPS units in measuring distances and speeds. A variety of techniques have been used, as previously described, involving trundle wheels, sledges attached to motorized vehicles or measuring tapes to determine whether the distances reported are accurate when compared to other methods of measurement. Similar to the studies previously mentioned, a study carried out by MacLeod (2012) analysed the validity of GPS units in assessing hockey specific movements. Nine hockey players completed 14 laps of a measured circuit that involved intermittent running and hockey specific movements representative of the movements made in a match. The route distance was measured by trundle wheel and speed was measured by speed gates. It was found that the mean distance recorded by the GPS system was 6821m compared to the actual distance of 6816m and the mean speed was 7.0 $km \cdot h^{-1}$, compared with the recorded mean speed of 7.0 $km \cdot h^{-1}$. It was concluded that a GPS system offers a valid tool for measuring speed and distance during match-play, and can provide objective information about certain movement patterns during competitive games.

Playertek devices allow for in depth analysis of a player's movements and provide information on various variables such as distance, sprint distance, accelerations, time and distance in speed zones, impacts, energy expenditure, to name a few. One of the main limitations of the Playertek device is that you cannot track the units live, which means that all analysis has to be done retrospectively. There is also no function to allow you to observe how many satellites the unit is connected to at any one time. With other brands of GPS units there is a function which gives a count of the satellites each pod is connected to, this allows the user to check the required number of satellites have been connected to before use commences. Having this function increases the reliability of the data produced as no measurements would be taken before the unit had connected to the desired number of satellites.

Recently a study by Raizaday and Scobie (2019) investigated the effects of weather and time of day on the Playertek devices. To our knowledge this is one of the first studies looking at the validity or reliability of specifically Playertek GPS devices. The study conducted looked at 9 adult subjects that were instructed to wear two GPS devices (Playertek and Catapult Optim Eye X4), all subjects completed one lap of an outdoor 420m oval running track at speeds of 5,6,9, 12, 15 and 18km/hr. Both devices outputs were then analysed to investigate the accuracy taking into consideration the weather conditions (clear, cloudy, rainy) as well as the time of day the session took place (9am-12pm, 12pm-3pm, 3-6pm, 6-9pm and 9pm-12am). It was found that when looking at both GPS devices collectively clear weather conditions may overestimate volumes whereas in comparison to overcast conditions that were found to underestimate both volume and intensity. It was suggested also that speed estimation did not differ significantly for different weather conditions or time slots, with different weather conditions not effecting the number of connected satellites or the Horizontal Dilution of Precision (HDOP). Conversely, it was found that the time slot did significantly effect the number of connected satellites and HDOP with specifically the time slot of 9am-12pm showing the highest number of connected satellites and the best HDOP values.

Additionally, Raizaday et al (2019) also carried out in a separate study analysis comparing the validity and reliability of the Playertek devices in comparison to the gold standard Catapult devices. The study design was identical to that described above with 9 individuals covering various speeds around a 420m running track. It was found that Playertek devices showed a high level of both validity and reliability with regards to straight line and change of direction distance and speed. It was concluded that although Catapult is seen to be the gold standard device, it did not prove a match for the Playertek devices, specifically over long distances and high speeds. Catapult devices were found to be most accurate when measuring speeds of 9-12km/hr, however least accurate when speeds of 15-18km were reached. It was summarized that as Playertek has been seen to be accurate and reliable as well as significantly lower in price it is a reasonable alternative to the current perceived gold standard Catapult device.

1.8.2 Wellbeing

Out-with games and training it is also important to monitor players as much as possible throughout training camps as well as when they are out with the International setup. Monitoring the player's wellness allows for both objective and subjective factors to be removed which can be important for injury prevention and general wellbeing. The Scotland squad currently use Playerdata as a monitoring tool; Playerdata describes itself as 'a customisable online data gathering platform. Playerdata enables your own questionnaires to be made, that all players in the squad have access to. The members within the squad fill out this questionnaire every night retrospectively about their day. The questionnaire allows the collection of information on what type of session they completed (International Match or Training, Club Match or Training, Conditioning or Rest Day), how long (minutes) and hard (0-10 RPE scale). In addition to this there are also questions on their mood that day, duration and quality of sleep as well as if they are carrying any injuries and an opportunity to add any additional comments on their day. The wellness diary allows the players to be monitored throughout the months when they are away from the International setup, it also allows for internal monitoring of load to be calculated. This calculation is carried out through the multiplication of session duration (minutes) by the Rate of Perceived Exertion score (0-10) to give an internal load figure (Foster et al 2001) . With limited contact to the players, monitoring of load is pivotal especially with the increased support of the 'Training-Injury Prevention Paradox' model. The model suggests that players who are accustomed to higher training loads have fewer injuries than those who are exposed to lesser loads. Additionally, it is also suggested that excessive or rapid increases in training load can also cause injuries to occur (Gabbett.T, 2016). This emphasizes the importance of player training load especially when balancing club and international training commitments. Analysis of load through the wellness diary allows training to be adapted on an individual basis depending on the weekly load fluctuations.

1.9 Aims of the Study

The aim of this study is to audit the training and match play data of the Scottish Male International hockey players, taking into consideration the location (Scotland, England, and Europe) of their Domestic club team. Domestic club training and game data will be analysed to observe if any potential differences exist in the variables decided when comparing club training sessions or league matches.

Separately, International training and games will be similarly analysed to observe whether the patterns found when comparing Domestic club hockey are similar or different to those of International training and games for the players within the set regions. Conclusions can then be made on how these differences impact upon the players when coming into International training following a nine month season with their club team.

2 Methods

2.1 Subjects

Twenty five elite male hockey players (25 ± 3.7 age and body mass of 76 ±7kg participated in the study. The athletes were all current players within the Men's Scottish Hockey team. Each player had been involved with the squad for a minimum of 1 year and currently played domestic club hockey with a team in Scotland, England or within Europe. All 25 players, as well as playing and training with their respective clubs, also received a tailored Strength and Conditioning program that was sent to each player in 4-6 weekly blocks. Prior to the study starting, all players were in good health and there were no current injuries. Due to the study looking at a season's worth of data, it was inevitable that injuries and illnesses occurred which impacted individual's data submissions during their period of inactivity. However, this did not have a significant impact on the overall results for each region.

If the injury or illness meant that they could no longer participate then they were removed from the study. During the course of the season there was 1 injury alongside 1 individual who dropped out of the Senior squad. Therefore, as a result of this a total of 2 subjects were removed from the study.

All of the participants involved with the study provided informed consent before its commencement. The University of Glasgow ethics committee approved all procedures.

Location	n	Age	Body Mass (kg)
Scotland	9	24 ±3	74±5
England	9	26 ±4	77±8
Europe	5	24 ±3	87±7

Tables 2.1 Participant information numbers included in the study, average age and average body mass for each of the 3 regions included

A total of 314 club games, 399 club training sessions and 379 International games and 387 international training sessions were collected via GPS analysis over the season. On average, each player wore their GPS unit for 14 club games, 17 club training sessions, 15 International Games over 3 International tournaments (WL2, WL3 and European B Division) and 17 International training sessions. All data was recorded during outdoor club training and matches, no data was collected for the indoor season.

2.2 Timeline

The timeline for the study ran for a full domestic and international season, commencing in September 2016 until August 2017. The schematic below (Figure 1.1) shows a timeline of both the club and international season with all international tournaments included.

2.3 Design

The study aimed to investigate the physiological demands of domestic and international field hockey. Scottish Internationalists were separated into 3 groups in relation to the location of their domestic club team (Scotland, England, Europe). Analysis was then completed on all domestic club games and training as well as all International training and games to observe whether any significant differences were present and if so what variables (Distance, Sprint Distance, Speed Zone Distance, Player Load) were affected. Comparisons could then be made to observe whether there were common differences depending on the location that domestic club hockey was played.

Figure 1.1 Timeline of full Club and International season

2.4 Protocols

2.4.1 GPS Analysis

The GPS units were worn as per the manufacturer's instructions, the units were worn in a neoprene bib, within a specially manufactured pouch, to ensure the unit is held secure between the shoulder blades. The players had experience using these devices and were instructed to wear the same unit to avoid any inter unit variability. The units were worn from the start of their warm up in both training and games.

2.4.2 Before Game or Training

When using the GPS unit during International training the handling and upload process was dealt with by the teams Sport Science staff. The units were fully charged and turned on 5-10 minutes before the players were going to warm up. When turned on the interface of three lights will flash with the left hand light flashing first. To ensure the unit is properly calibrated a 'GPS fix' needs to be acquired. Playertek manufacturer's instructions state that to acquire a good 'GPS fix' the pod should be switched on at least 5 minutes before use, when two to three lights display on every flash a GPS fix has been acquired (Playertek) and signal strength will be sufficient. At this point the GPS unit can be placed into the back of the neoprene bib with the light interface pointing outwards.

During domestic training and games players were responsible for the above protocols. All players were given out a detailed instruction sheet prior to the GPS being used for the first time to ensure they understood the protocols that had to be followed, each subject also had approximately 4-5 months experience using the GPS units within the team environment.

2.4.3 After Game or Training

After a game or training session, the device could be removed from the bib and turned off. During International games or training all units would be collected in and the upload and analysis process would be completed by a member of staff. Alternatively, when players were taking part in club commitments they were responsible for this themselves.

In order to upload the data from the GPS pod the Playertek 'Sync Tool' had to be downloaded onto a laptop or computer. The sync tool allowed the sessions from the unit to be uploaded to the online platform that could then be accessed by staff members. The units came with a USB cable that connected the GPS to the computer. Once connected the unit then had to be turned on and 2 lights showing on the device represented that the unit was in 'Sync Mode' and the sessions were ready to be uploaded. Once the session had been recognized by the computer they are then ready to be uploaded to the Playertek website. The duration of this process depends on the internet connection and the number of sessions that had to be uploaded at any one time. Once the sessions had been downloaded from the Playertek Sync Tool they were then available on the Playertek website and could be viewed by authorized members of staff.

The data that is initially uploaded to the Playertek website is in its raw form as it shows everything collected from the moment the GPS pod had been turned on to the moment it had been turned off.

It was necessary therefore to record the timings of the main components of both training and games. With regards to International Training and Games, details and timings were recorded as the session took place. The start and end timings of any drills included in a training session were recorded as well as the start and end times of each 15 minute quarter or 35 minute half. With regards to club training and games all session information was collected by the player themselves and recorded through the Playerdata online data form website. The process of recording the timings and session details was key to the collection of the data as through Playertek no information is given on the session type, the duration or timings of any relevant or irrelevant periods within the data. It is therefore necessary for the players to provide information on the details of their training or game to allow for any irrelevant data to be omitted to ensure it is not included in the session data. With regards to the tagging of training the warm up period was tagged and included in the session data, alternatively game data did not include the warm up and began as the game started. A recent paper by Williams et al. (2019) based upon soccer suggests that the warm up should be included in match analysis as should contributes to the overall load figure associated with a game. The paper suggests that the activities of the pre-match warm up add on average an additional 25-30% to the total load experienced, with starting players experiencing an 11-18% greater volume and 14% greater intensity than substitutes. It is concluded that the load experienced within the warm up should not be discounted. The exclusion of warm up data was considered within the study design and the rationale to remove it from the analysis was based upon two factors. The first being that the majority of hockey match data that is published solely analyses the match itself and so for comparison purposes it was beneficial to look at the game from start to finish. Secondly, the remote nature of the data collection meant that players were responsible for the calibration of their own pod. Although instructions had been given advising players turn their pods on 5 minutes prior to wearing the pod and to leave in a place with direct view of the sky there was no guarantee that each individual would follow this process. Therefore, the match data was priorotised and by discounting the warm up allowances were made to allow for the chance that individuals would turn their pod on and immediately start warming up without the specified calibration process being followed. This exception allowed for any inaccurate data to be excluded during the 30 minute pre-game warm up and allowed for more confidence that the pods were fully functioning for the start of the game.

Once the training has been tagged in relation to the information provided from Playerdata or the real time collection at International games and training, the players and staff could view the session breakdown and all variables relative to the session that took place (Total Distance, Sprint Distance, Speed Zones, Accelerations, Player Load etc.).

2.4.4 Collection of Session Information

The players recorded their sessions details through Playerdata which is an online data gathering platform. The online software allows a series of questions to be created in order to create a questionnaire style form that the players answer daily. The questions include areas such as what type of session they completed that day; training, match, conditioning rest etc. how hard they found the session (Rate of Perceived Exertion), this is scored from 0-10, 0 at rest and 10 being classed as maximal (Forster et al, 2006) . Finally, the duration of the session in minutes is also recorded, this allows for an internal load figure to be calculated (*Duration in Minutes x Rate of Perceived Exertion*= *Internal Load*). There is also a comments box included where the players are asked to input the details of their match or training session as well as any injuries.

The players are asked to keep track of timing's during their session and as accurately as possible to give information on which time each component of the training took place and for how long. (E.g. Warm Up 7:30-7:45, Shooting Drill 7:50-8:05, Small Sided Game (SSG) 8:10-8:30 etc.) This then allows the GPS upload to be tagged appropriately and any irrelevant data to be omitted, such as walking to and from the pitch.

2.5 Equipment

2.5.1 Playertek

The GPS units used during this study were from the manufacturers Playertek. The units were 10Hz (10 samples taken per second) and also included a 10 Hz Tri-Axial magnetometer, 400 Hz Tri-Axial Accelerometer and Gyroscope. The Playertek GPS units were worn in a neoprene bib, within a specially manufactured pouch, to ensure the unit is held secure between the shoulder blades. The GPS device provide information on distance, speed, acceleration, deceleration, impact forces, energy expenditure as well as position through a heat map.

The Playertek units provide post-activity analysis but no real-time data could be obtained. There is currently no research or studies carried out on these units, this is due to the fact that they are relatively new additions to the GPS market.

2.5.2 Speed Zones

The speed zone component to the Playertek devices allowed for both distances and time in each of the identified speed zones to be calculated. This is useful for intermittent team sports as it gives information on what speed zones the players spent most time or covered most distance in. However, as previously described it is important to set speed zones specific to the sport (Carling, Clarke, Le Gall and Dupont 2012, Di Salvo 2009, Lythe and Kilding 2011). The speed zones (Table 2.2) were set based from analysis of published research (White.A, 2014) and all movement demands were standardized for all individuals as $km \cdot hr^{-1}$

It has been found that parallels have frequently been drawn between football and hockey with regards to speed zones. It is thought that this is due to the similarities in high intensity bouts, tactics and formations (Carling, Le Gall, Dupont 2012). It is also important to note that not only will the classification of speed zones differ between sport, within the sport the classification of different movement patterns may also differ. Lythe and Kilding (2011) stated that for hockey walking was from 0-6 $km \cdot hr^{-1}$ and jogging from 6-11 $km \cdot hr^{-1}$, however a study by Di Salvo (2009) does not take jogging into consideration and started with walking and then low speed running. It is therefore important to take these differences into consideration as it differences between sports as well as the classification of zones within sports makes it difficult to compare between studies,

The importance of setting speed zones in relation to the sport is key due to the varying demands potentially altering the activity profiles of the players participating. With regards to the speed zones reported in Table 2.2, these were directly taken from another hockey specific study (White.A, 2014) that was carried out within the Scottish league and international team from a few years ago. In addition the figures chosen within this study were also founded by several other studies thought to be specific to the demands of hockey. Hockey specific studies by Lythe and Kilding, 2011 and Gabbett, 2010 were considered when selecting the speed zone thresholds. With regards to walking and jogging field hockey studies found values to be within the range of 0 – 6 km·hr-1 for walking, 6.1 – 11 km·hr-1 jogging and 11.1 – 14 km·hr-1 for slow speed running (Lythe and Kilding, 2011) which was also found to be similar to that of soccer (Di Salvo, Gregson, Atkinson, Tordoff and Drust, 2009). Conversely, high speed thresholds were found to be more varied dependent upon the sport they were applied to. With regards to those hockey specific on nature moderate speed running was stated to be between - 15.1 – 19 km·hr-1 and high speed running set to be 19-23 km·hr-1 due to its application within hockey specific studies (White & MacFarlane, 2014). Within other team sport studies such as those within soccer environment the speed zones set within this study may not be applicable. However, the choice to set the speed zones in relation to a similar hockey study seemed most appropriate to allow for effective comparisons and also given that the White and MacFarlane study was using a similar cohort within the Scottish Hockey structure being able to make these comparisons again seemed important. Separately, what should also be taken into consideration as outlined by White et al 2014 is the increments by which the speed zones range and increase. Literature has previously shown an error of between 11 and 33 % at speeds between 1 to 8 m·s -1 [3.6 to 28·8 km.hr-1 (Varley and Aughey, 2012)]. As seen within other literature a wider range of speed zones is seen to be preferable (Lythe and Kilding, 2011; Gabbett, 2010b; Di Salvo, Baron, Gonzalez-Haro, Gormasz, Pigozzi and Bachl, 2010; Bradley, Di Mascio, Peart, Olsen and Sheldon, 2010 and Carling, Le Gall and Dupont, 2012) in order to allow for any potential error to ensure all efforts are recorded within the correct speed zone. The stance taken within this study is the same as that of White et al 2014, which states 'whether zones are separated by 3 or 4 km·hr-1 is arbitrary and it was therefore decided that using zones as close to the other field hockey literature as possible would be most appropriate'.

Scottish Hockey Team Thresholds Playertek	Description
0-11	Standing/Walking
	Jogging
11-15	Low Speed Running
15-19	Moderate Speed Running
19-23	High Speed Running
>23	Sprinting

Table 2.2 Speed Thresholds used with Playertek GPS devices. Thresholds taken from previous literature with Scottish Hockey specific zones added. Adapted from A.White (2015).

2.6 Positional Differences

Within the sport of hockey and as with all team sports there are positional differences, forwards, midfielders and defenders. More recently there has been increased investigation into whether position specific training is necessary to meet the differing positional demands of team sports. In rugby, it has been found that there are significant differences in not only physical characteristics but also physiological demands depending on your position within the team (Deutsch et al., 1998 and Duthie et al. 2003). The differences that have been found within the sport of rugby have shown that forwards spend more total time taking part in high intensity work compared to the backs. However, the backs perform two to three times more high intensity running (Deutsch et al., 1998). Differences in the total distance and therefore total work performed is also significantly different depending on playing position. Therefore, build and body mass in rugby is specific to the role the individual has on the pitch. It is therefore, clear that with such differing roles and positional responsibilities a large proportion of training would have to be specific.

Within the sport of hockey, there are similar but less obvious differences in positional demands to that of rugby or football. One study investigating hockey specific differences was carried out by Johnston et al (2004). This study explored the difference in heart rates of defenders, midfielders and strikers during a competitive game. It was found that defenders had the lowest average heart rate (147 ±13 $b.min^{-1}$) and midfielders had the average highest heart rates (167±5 $b.min^{-1}$) over the course of a game. However, it was also found that the work to rest ratio was similar, regardless of your position on the pitch. (Johnston et al 2004). Separately another study looked into the potential differences in total distance covered across different lines. In a study by Jennings (2012) it was found that differences in the distances covered between positions varied, with midfielders running the most on average (10.2km ±215m) in comparison to strikers (9.8km±720m) and defenders (9.5km±579m).

Within the Scottish International team there is a varied spread of positions across the three different domestic club regions (Table 1.2). Although within this study, comparison will be made based on region and not take position into consideration it is important to take into consideration any potential influences position may have on the results. As Table 1.2 shows there is a broad spread of position across each of the three regions. As mentioned previously studies have shown the position an individual plays to impact upon the total distance covered and sprint distance within match play. As the sport of field hockey progresses and evolves the differences between positions and the specific role of each position can impact upon their activity within the game is becoming more apparent. The physical outputs of each individual within a team will be impacted heavily based upon their position, the tactics such as presses and formations as well as the opposition. The potential differences that could be observed between positions has been supported in various studies. As mentioned above with the study by Jennings et al. (2012) total distance covered across different lines is common, with defenders generally covering less distance in comparison to midfield and forwards. Within the Scottish senior men's national team it has been observed that differences within specific position groups is also common, especially within that of the defence. It is common for defenders to be split into half back and full back categories. The full back within the Scotland setup generally cover the middle of the pitch in comparison to full back whom cover the wider channels. As a result the full backs generally sit deeper and as a result of the squads tactics and formation generally spend the majority of the game within the defensive third of the pitch. Conversely the half backs can provide more of a supporting role to the midfield and therefore it is common place for them to play a vital role in not only the defence but also within supporting attacking movements. As a result it would be expected that the half back would cover more total and sprint distance than that of the full backs and some of this can be attributed to the position specific role that impacts their physical performance.

Region	Total	Defenders	Midfielders	Forwards
Scotland	8	3	2	3
England	9	4	3	2
Europe	5	1	1	3

Table 2.3 Breakdown of individuals within each regions

2.7 Game Timings

2.7.1 Comparing Games

As previously stated a hockey game can last either 60 or 70 minutes. During season 2016-2017 all domestic club games lasted 70 minutes and all International games adopting the four 15 minute quarter style. As a result, when comparing the intensity of club and international games there is a 10 minute difference in duration. To normalize the Domestic club game data for the different duration of game the formula below has been applied to standardize the data and scale all game durations up to 70mins.

Data Variable/60x70

This formula has been applied to standardize similar data in other sporting studies. A study conducted by Lythe.J (2006) with the New Zealand Hockey team and also in an Australian rules football study both used this formula for games of differing lengths (Brewer et al, 2010).

2.7.2 Comparing Training

With regards to training data a similar formula has been applied to standardize the data also. As all training sessions differed in duration it is important to standardize the data so comparisons can be made. The formula below was applied:

Training Variable/Actual Session Duration x 120

2.7.3 Comparing Training and Games

In the latter stages of the results analysis both games and training were analysed and compared to identify whether differences occur and if so the extent of these. In order to make easy comparisons the data was standardized for this particular section to a rate of 60 minutes. This allowed for games and training to be easily compared without having to make allowances for the difference of time. In this case the following formula was applied, this divided all variables by the actual session duration and then multiplied by the new rate of 60 minutes.

Training Variable/Actual Session Duration x 60

2.7.4 m/min

At this point it should be mentioned when taking into consideration the structure of standardising the data, applying a metres per minute (m/min) approach was considered. Consequently it was decided that due to the data collected in the study it and variables that could apply it may not be appropriate or representative to show the data as a m/min. Within that of a game, the actual time spent on the pitch was unknown and so to apply an estimated time to the data seemed wrong. Similarly, when considering training the duration given by the players was reported by the players based upon the timings that training started and finished. However when calculating a m/min there is a possibility the metric would not be able to separate activity such as walking to and from the pitch and ball collections etc. Therefore, although m/min was recognised to be a potentially useful measure of intensity the decision was taken to not include it unless absolutely certain that the information it would provide would be an entirely accurate representation of intensity. As this was something that at the time we could not guarantee due to the number of variables, it was chosen that at this time the metric of m/min would not be included.

2.8 Analysis

2.8.1 Data editing

Post-match, all data was uploaded from the Playertek sync tool to the Playertek online system. From here the game or training session was 'tagged' with the use of timings reported in the Playerdata wellness diary system. This allows the start and end times of drills and matches to be applied and any irrelevant data (i.e.. walking to and from the pitch) to be excluded.

Once the data had been tagged it was then transferred on to a Microsoft Excel document from the Playertek online system, at this stage any data that was incomplete or out with physiological norms were removed. Data was defined as being incomplete if variables were missing from any of the sessions. Data was seen as being out with physiological norms if any of the data variables were out with a realistic range. This would be the case if the data figures were thought to be physiologically impossible or unrealistic given the session details or duration, therefore it was concluded that this was more likely to be the result of a user or technology error. Data was also omitted if the session was incomplete, this was most likely due to the GPS unit running out of battery. Players reported their session duration through their wellness diary and so any GPS sessions that were shorter than the time specified by the player were removed as they were not a true representation of the session. The data was separated and filtered based on the region that training took place as well as the domestic club name and session type. This allowed analysis to be carried out not only just based on region but it was also possible to look at any differences present between club teams within the same area.

2.7.2 Statistical Analysis

Most analyses were based on General Linear Models (GLMs) involving random player effects and fixed effects of Region (Scotland/England/Europe), Type (Training/Game) and Level (International/Club) with corresponding interactions, if appropriate. Follow up analyses were generally simultaneous 95% multiple comparison interval estimates.

Speed Zone data were analysed using the ideas of Compositional Data (Reference : Aitchison(1986)*) with three levels only for simplicity (Speed Zones 2 and 3 were combined as were Speed Zones 4 and 5). Basically, this involves GLMs on the logarithms of the ratios of the Distance covered in each of the two combined zones relative to Speed Zone 1. Key Interest lay mainly in the relative distance covered in the combined Speed Zones 2 and 3 relative to that in Speed Zone 1 and it is the Estimated Coefficients for each player in the GLM of Combined Zones 2 and 3 relative to Zone 1 that are presented in the appropriate part of the Results Section. High values of these Estimated Coefficients thus represent players who spent a “larger than average” distance running in Zones 2 and 3.

3 Results

The first aspect that has been investigated analyses within region comparisons, Individuals have been grouped together depending on the location of their club; Scotland, England and Europe. Comparisons will be made for all types of session, Club Games and Training as well as International Games and Training will each be analysed and compared. The two measured variables that have been focused on at this stage are Total Distance covered (km) and Sprint Distance (m).

In this section, the data has been analysed in two forms Non-Standardised and Standardised data, Non-Standardised being the data without correction for time (actual duration that session lasted) and Standardised data which has been scaled up to allow for comparison (70 minutes game and 120 minute training). These durations have been picked for the initial analysis as they are the most common game and training times within the data set. Without standardising the data comparisons in this first section would not be able to be made, as duration of games and training varies across the 3 regions and also within club and international sessions.

3.1 Non Standardised

In this section each of the four session types (Club Game, Club Training, International Game and International Training) were looked at separately to firstly see whether there are differences when comparing the 3 regions within each session type.

3.1.1 Club Game

Figure 2.1 shows the spread of the data when analysing Total Distance covered within a club game. It shows that although the data will be grouped and averaged for each separate region, there are individual variations within each location that will not be reported when averages are calculated. It is important to note that this variety is not just from player to player but also on an individual basis, some players cover a more varied distance throughout a season than others. This individual trend will not be shown when the data is averaged.

The first part of the analysis looks at whether there are any differences in club game data depending on the location that the club is within (Figure 2.2).

Total distance within club games was the first variable to be investigated and it was found that significant differences did occur among the 3 regions ($p=0.024$). Multiple comparisons between the 3 regions were then carried out and it was found that England covered 7.1km (s.d 1.2km) and Europe 5.9km (s.d 1.4km) during club games. Further analysis has shown that the interval estimate is entirely positive (0.86,1.59**)**, so it can be concluded from analysis of confidence intervals that the average Scottish international player, based in England runs further than the comparable Europe based player by somewhere between 0.8 and 1.6 km in an average Club Game.

The second comparison made is between Scottish and European based players (Figure 2.2), it found that those based within Scotland run on average 7.0km (s.d 1.6km) and those based in Europe cover on average 5.9km (s.d 1.4km). Therefore again it was found that the interval estimate is entirely positive (0.68,1.40), so it is concluded that, on average, an international player based in Scotland runs further than a corresponding player based in Europe by between 0.7 and 1.4 km in an average Club Game.

The third of these interval estimates is for England and Scotland, with English based players on average covering 7.1km (s.d 1.2km) and Scotland covering 7.0km (s.d 1.6km). It was found that the interval estimate analysis contains the value zero (-0.21,0.54) and so it can be concluded that there is no significant difference between England and Scotland when comparing the average total distance run by an international player during a Club Game.

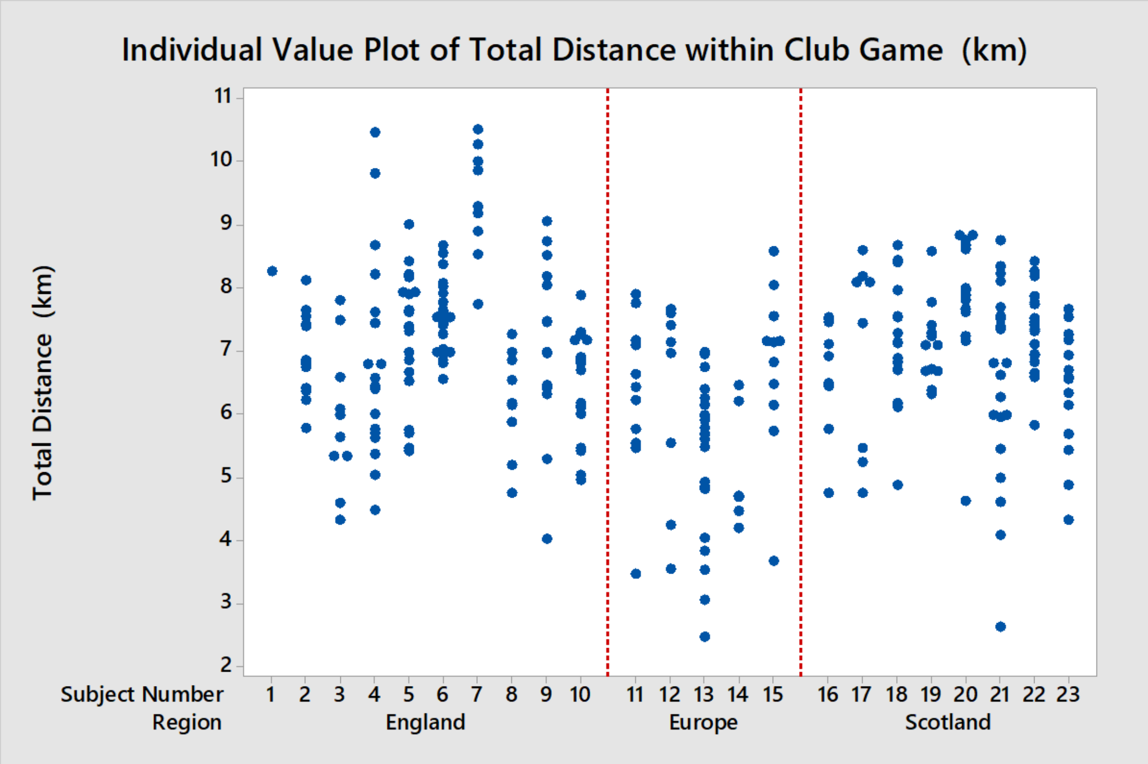

Figure 2.1 Individual Value Plot for total distance showing spread of data for 3 regions within a Club Game

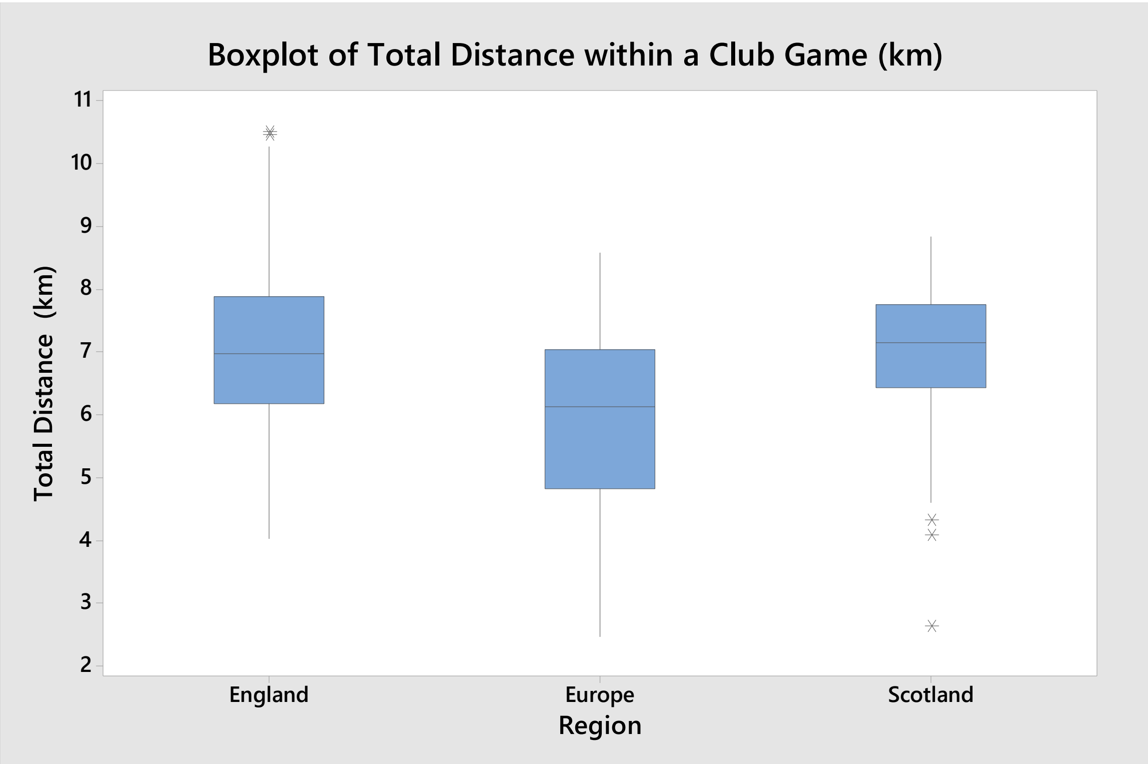

Figure 2.2 Boxplot of total distance data for Club Games

The second part of the Club Game analysis investigates whether there are any differences in sprint distance covered when comparing region. It was found that there was no significant difference (p=0.263) between the three regions when comparing the average sprint distance covered by an international player within a Club Match. Sprint distance covered by English based players was 693m (s.d 233m), compared to 560m (s.d 239m) in Europe and 670m (s.d 220m) in Scotland (Figure 2.4)

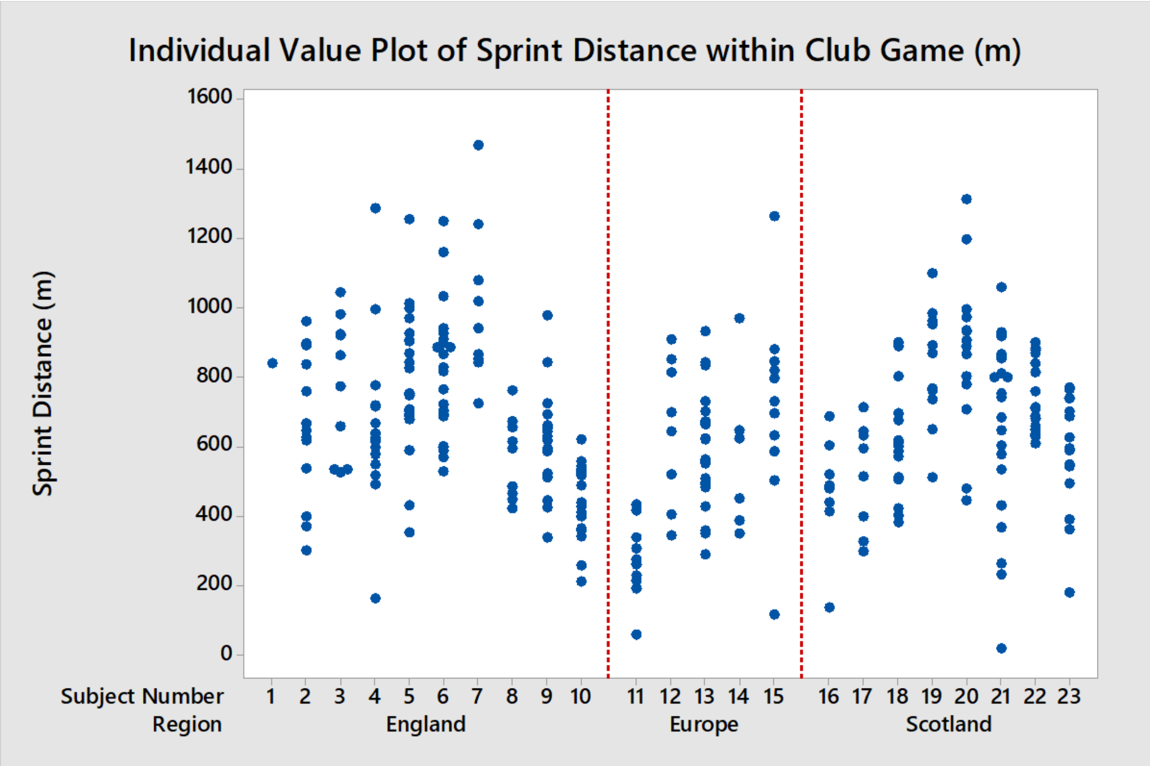

Figure 2.3 Individual Value Plot of sprint distance showing spread of data for 3 regions within Club Game

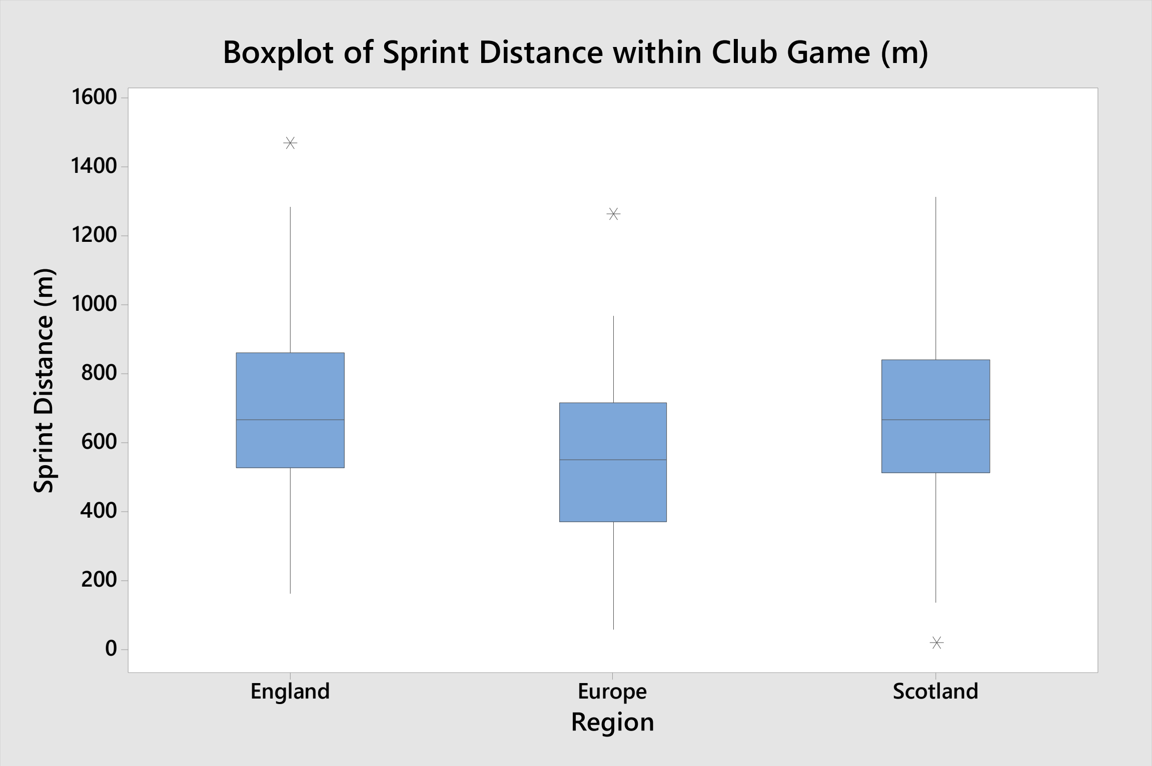

Figure 2.4 Boxplot of sprint distance for Club Game

3.1.2 Club Training

When comparing total distance covered by each individual in Scotland, England and Europe who took part in Club Training, it was found that there were no significant differences (p=0.146). It was found that the average English based player covered 6.08km (s.d 1.8km), Scottish based players 5.36km (s.d 1.4km) and European based players 6.3km (s.d 1.7km) (Figure 2.6) during the average training session. It should be noted that with regards to the club training data plotted below, there is significantly less data points plotted in comparison to the actual number of training sessions carried out within the season. This is due to a number of factors, however the main one being the number of sessions of partial sessions uploaded due to battery or calibration issues (Further explained in Section 4.5)

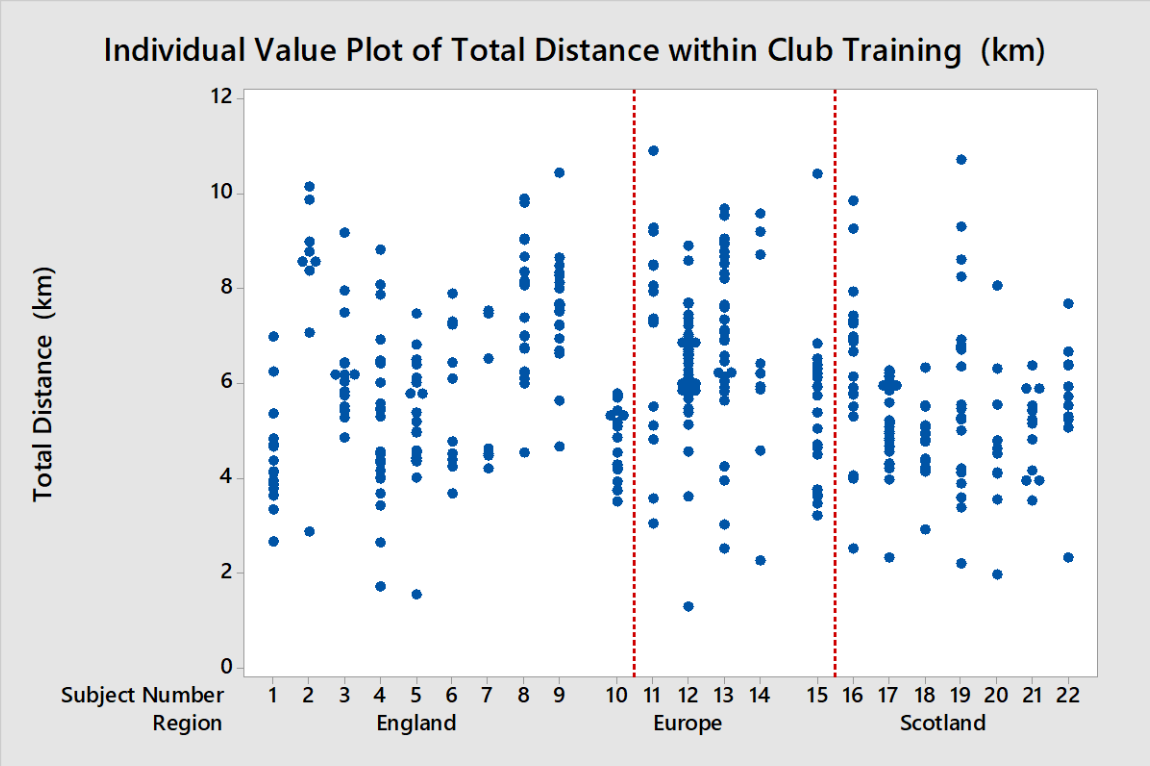

Figure 2.5 Individual Value Plot of total distance showing spread of data for 3 regions within club training

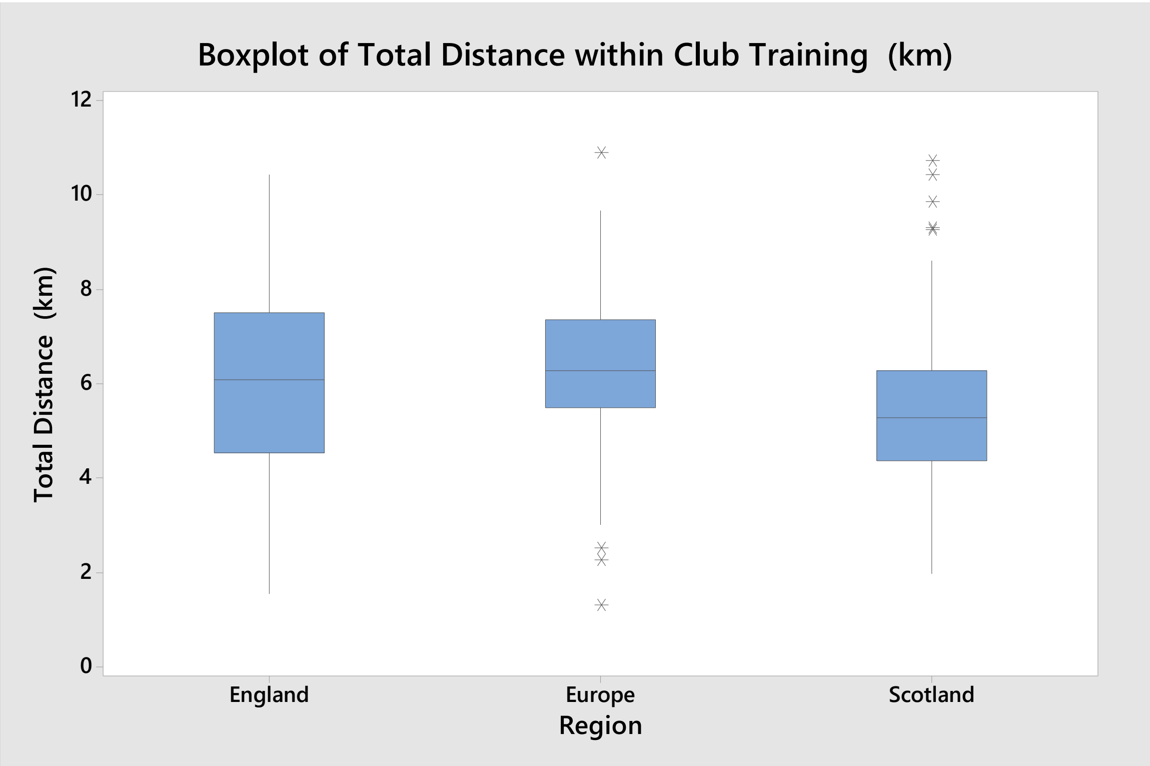

Figure 2.6 Boxplot of total distance for club training

Similarly, it has also been found that there was no significant differences (p=0.748) between the three regions when comparing the average sprint distance covered by a Scottish international player within Club Training. The average sprint distance covered across Scotland, Europe and England was 377m (s.d 280m), 388m (s.d 228m), 370m (s.d 237m) respectively (Figure 2.8).

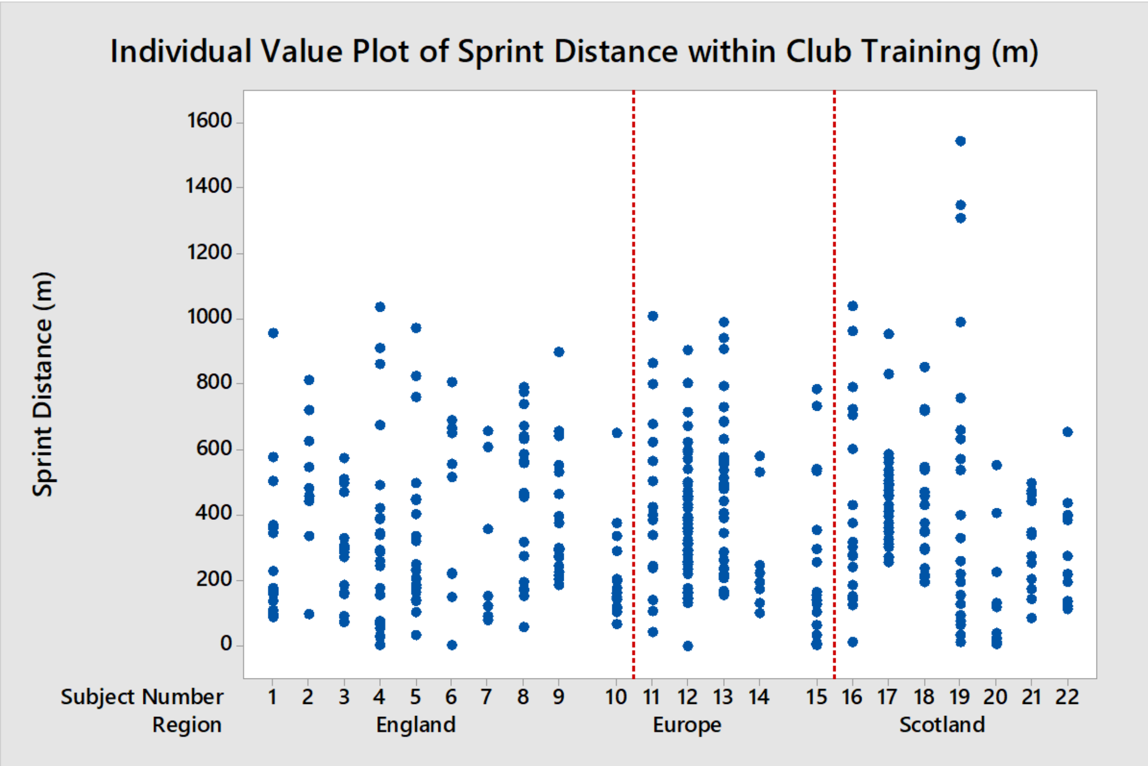

Figure 2.7 Individual Value Plot of sprint distance showing spread of data for 3 regions within club training

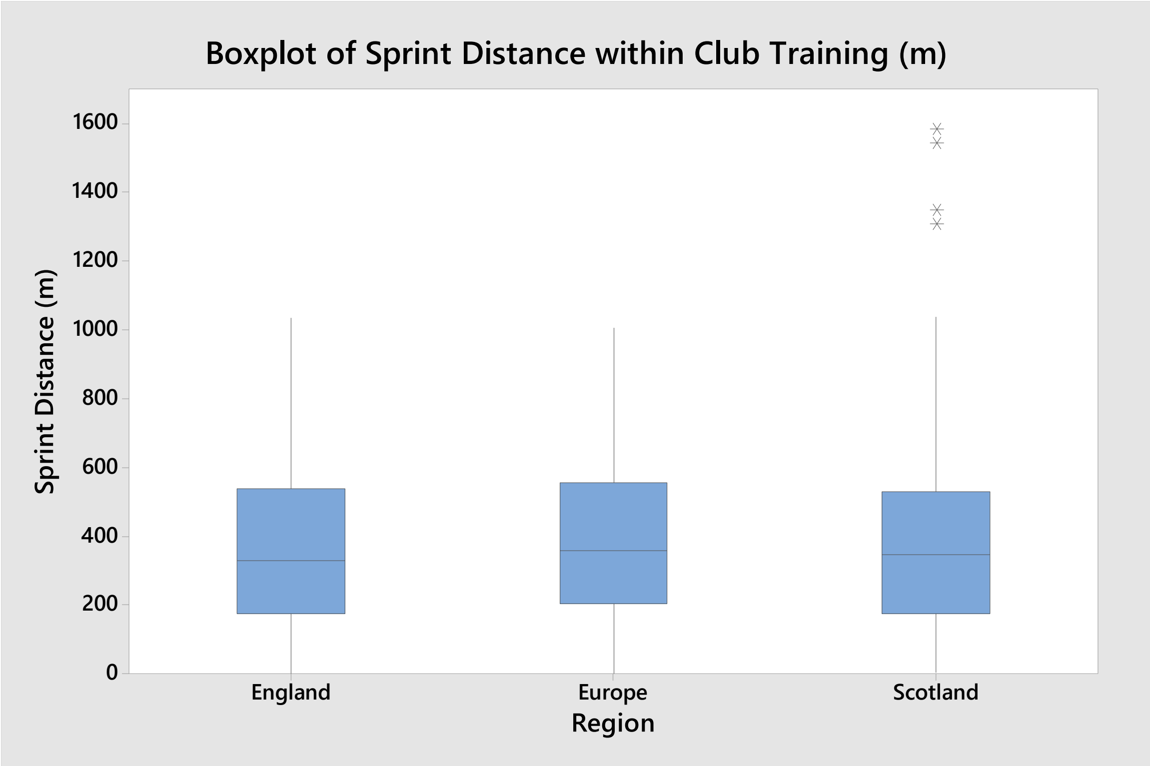

Figure 2.8 Boxplot of sprint distance for club training

3.1.3 International Game

As before distances are averaged over all games analysed. Therefore within International Games it has been found that there are no significant differences (p=0.701) amongst the three regions when comparing the average total distance covered. In the average international match the average Scottish based player covered 5.8km (s.d 0.8km), average English based player covered 5.9km (s.d 1.0km) and the average European based player covered 5.km (s.d 0.9km) (Figure 2.10).

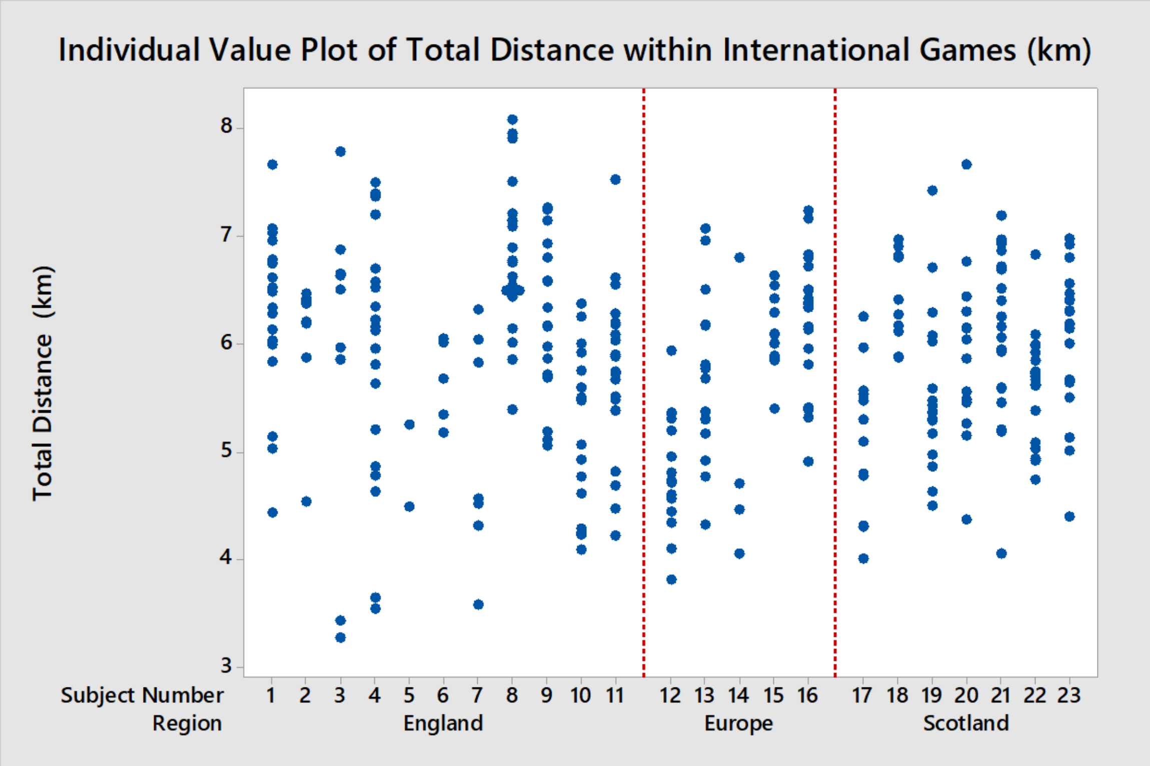

Figure 2.9 Individual Value Plot for total distance showing spread of data for 3 regions within international games

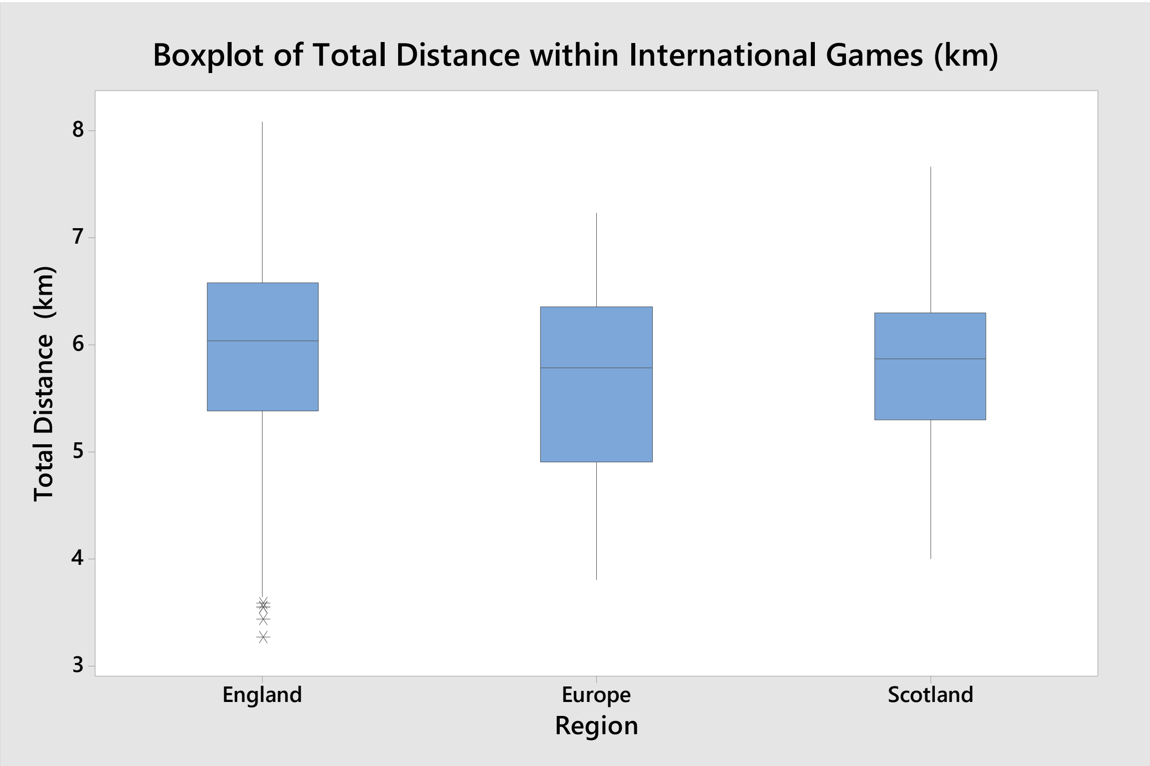

Figure 2.10 Boxplot of total distance for international games

With regards to the sprint distance covered during an International Game it was found that on average English based players sprinted 549m (s.d 204m), Scottish based players 582m (s.d 137m) and European based players 545m (s.d 182m) (Figure 2.12). There was no significant difference (p=0.950) between the three regions when comparing the average sprint distance covered by an international player within an International Game.

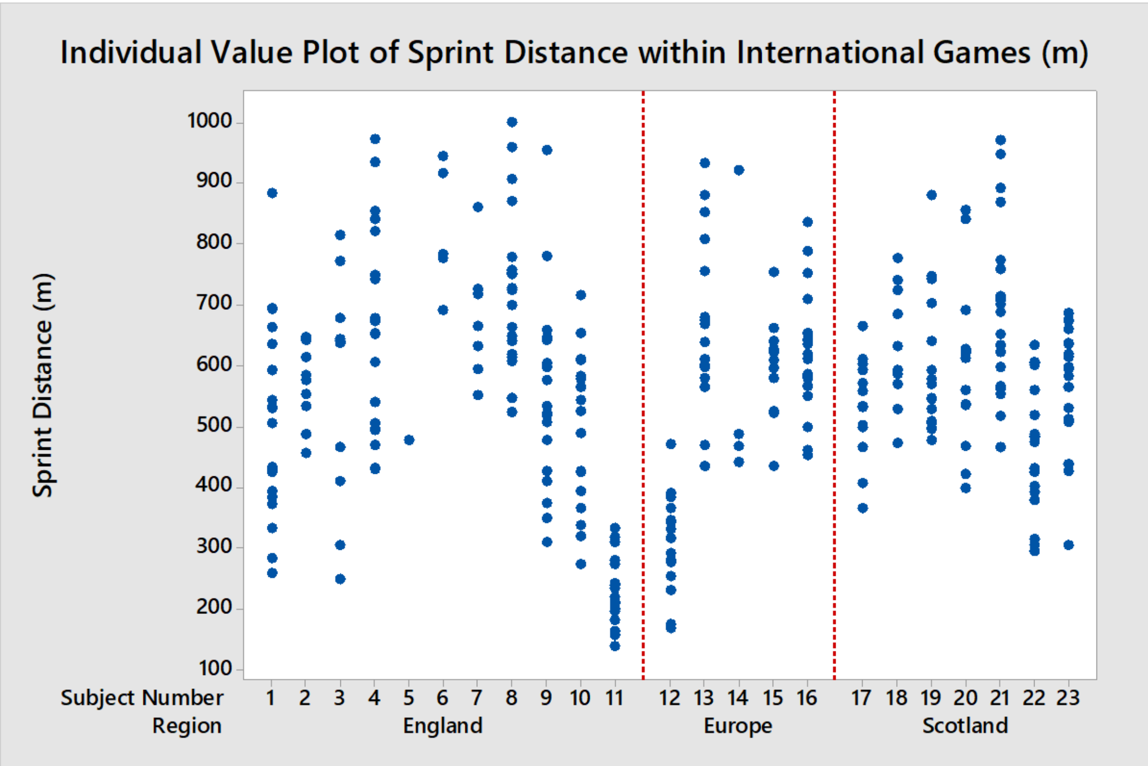

Figure 2.11 Individual Value Plot of sprint distance showing spread of data for 3 regions within international games

Figure 2.12 Boxplot of sprint distance for international game

3.1.4 International Training

Finally, within International Training it has been found that on average Scottish based players on average cover a total distance of 5.4km (s.d 1.7km), English based players cover on average 5.4km (s.d 1.8km) and European based players cover 5.5km (s.d 1.8km) during the average international training session (Figure 2.14). There are no significant differences ($p=0.996$) among the three regions when comparing average total distance covered during an international training session.

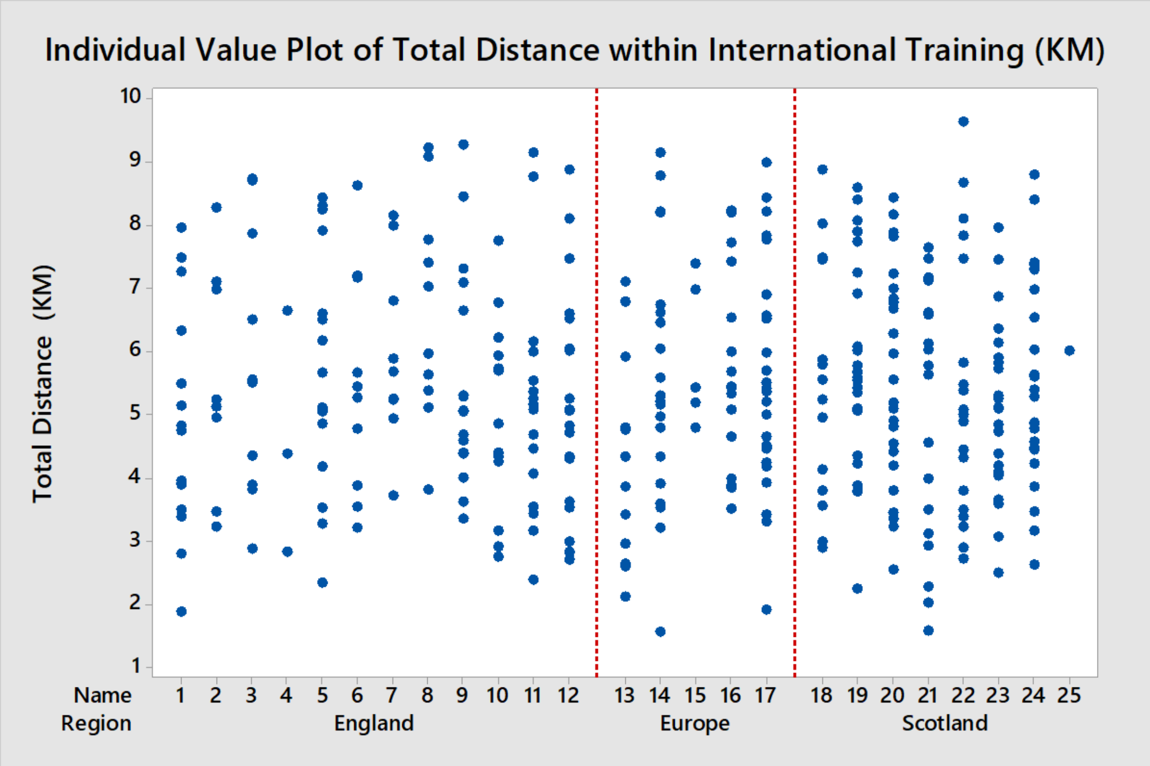

Figure 2.13 Individual Value Plot of total distance showing spread of data for 3 region within international training

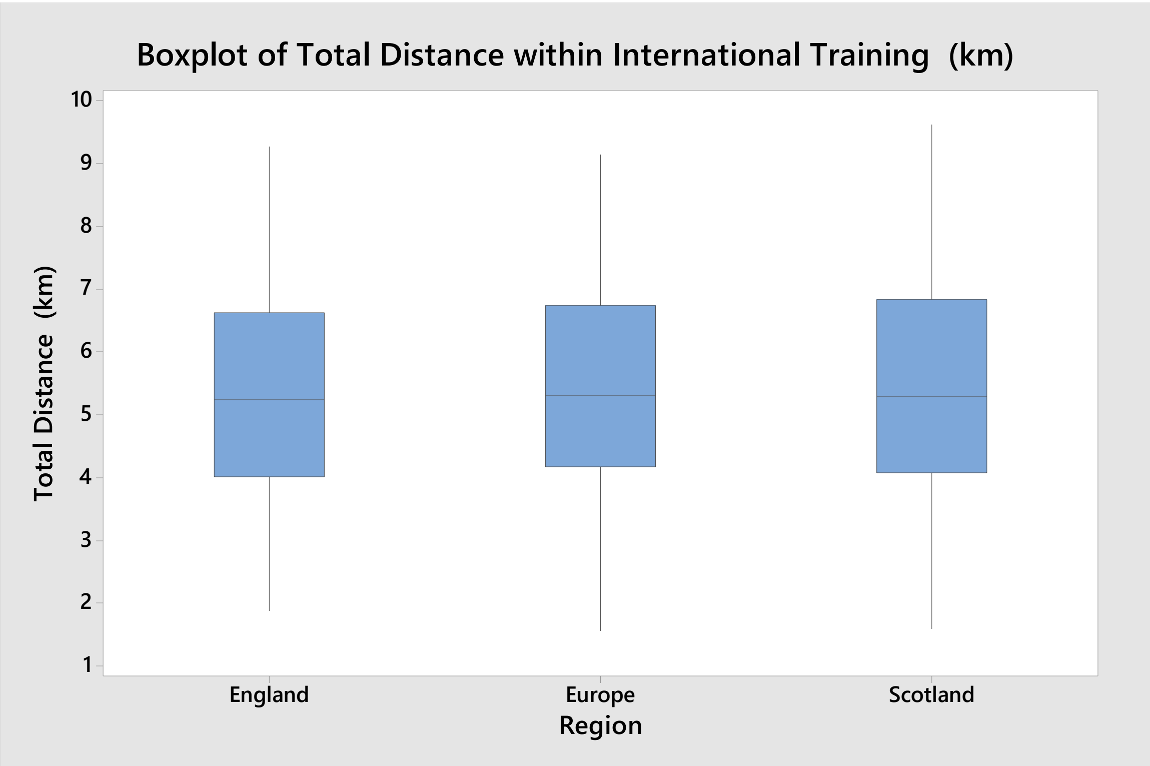

Figure 2.14 Boxplot of total distance for international training

With regards to the sprint distance covered during an International Training session, it was found that there was no significant differences (p=0.984). The average sprint distance covered in international training session was 290m (s.d 191m) for a Scottish based player, 286m (s.d 202m) English based player and 297m (s.d 198m) for players based in Europe (Figure 2.16).

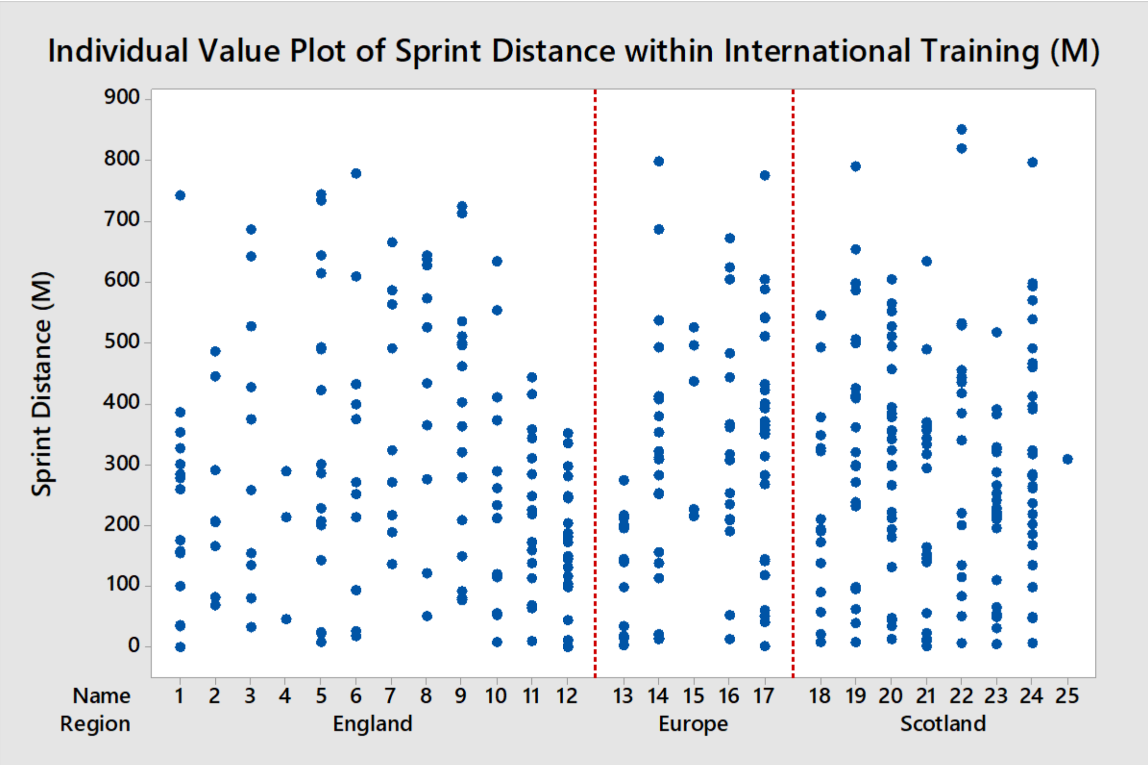

Figure 2.15 Individual Value Plot of sprint distance showing spread of data for 3 regions within international training

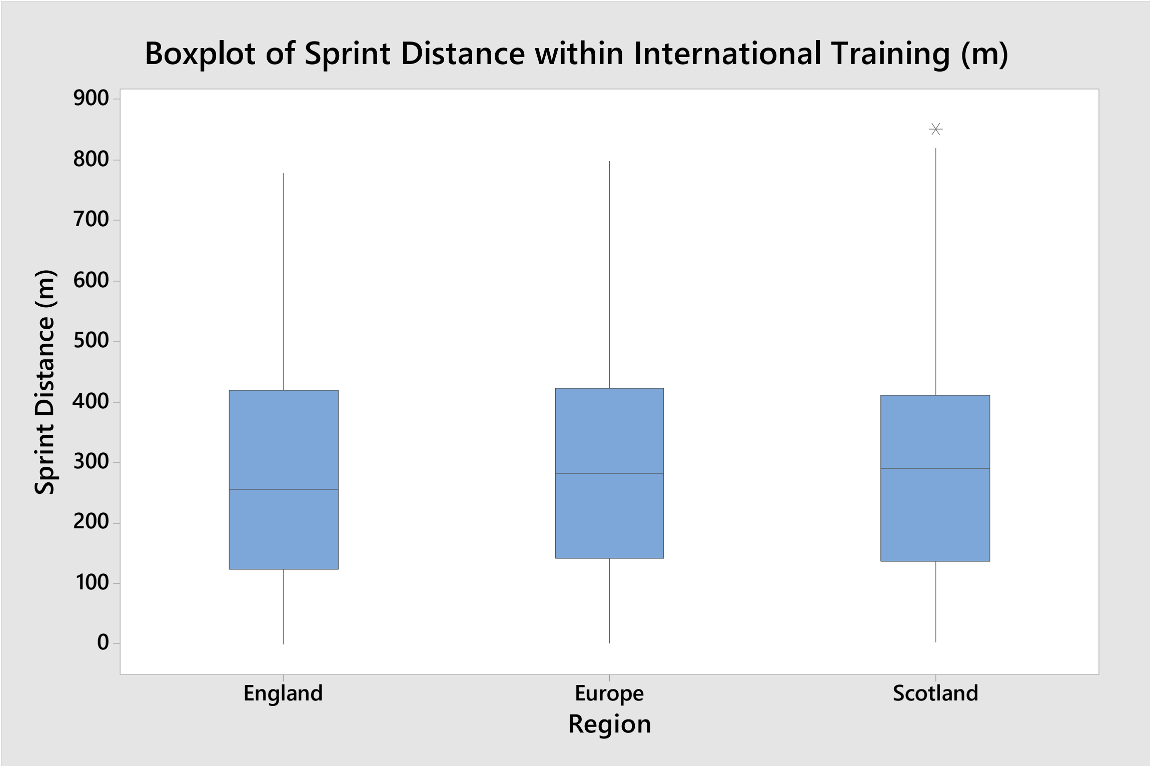

Figure 2.16 Boxplot of sprint distance for international training

3.2 Standardised

When standardising the data to the same time duration, it was found that there were no significant differences found across the 3 Regions for total distance or sprint distance respectively for international training and both international and club games, therefore no further analysis was carried out. There were however differences found for Club Training when the data was standardised to 120 minutes for total distance covered ($p=0.009$).

3.2.1 Club Training

In the analysis of standardised Club Training data, it was found that English based players on average during club training standardised to 120 minutes, ran 7.7km (s.d 1.6km) and Scotland covered on average 7.1km (s.d 1.3km) (Figure 2.18). Therefore it was found that the interval estimate was entirely positive (0.28,1.11), therefore it can be concluded that the average international player based in

England runs further than a player based in Scotland by between 0.3 and 1.1 km in an average Club Training session.

With regards to Scottish and European based players it was found that on average Scottish based players run 7.1km (s.d 1.3km) and European based players cover 8.1km (s.d 1.6km) (Figure 2.18). Therefore it was found that the interval estimate was entirely negative (-1.57,-0.75), so it can be concluded that on average an international class player based in Scotland runs less than a comparable Europe based player by between 0.8 and 1.6km in an average Club Training Session.

Finally, when comparing the average distance covered between England and Europe it was found that when standardised to 120 minutes English players ran 7.7km (s.d 1.6km) and Europe based players covered 8.1km (s.d 1.6km). Therefore it was found that the interval estimate was entirely negative (-0.87,-0.05), therefore it was found that on average an international player in England runs less than one in Europe by 0.1 to 0.9 km when comparing the average total distance ran during a Club Training session.

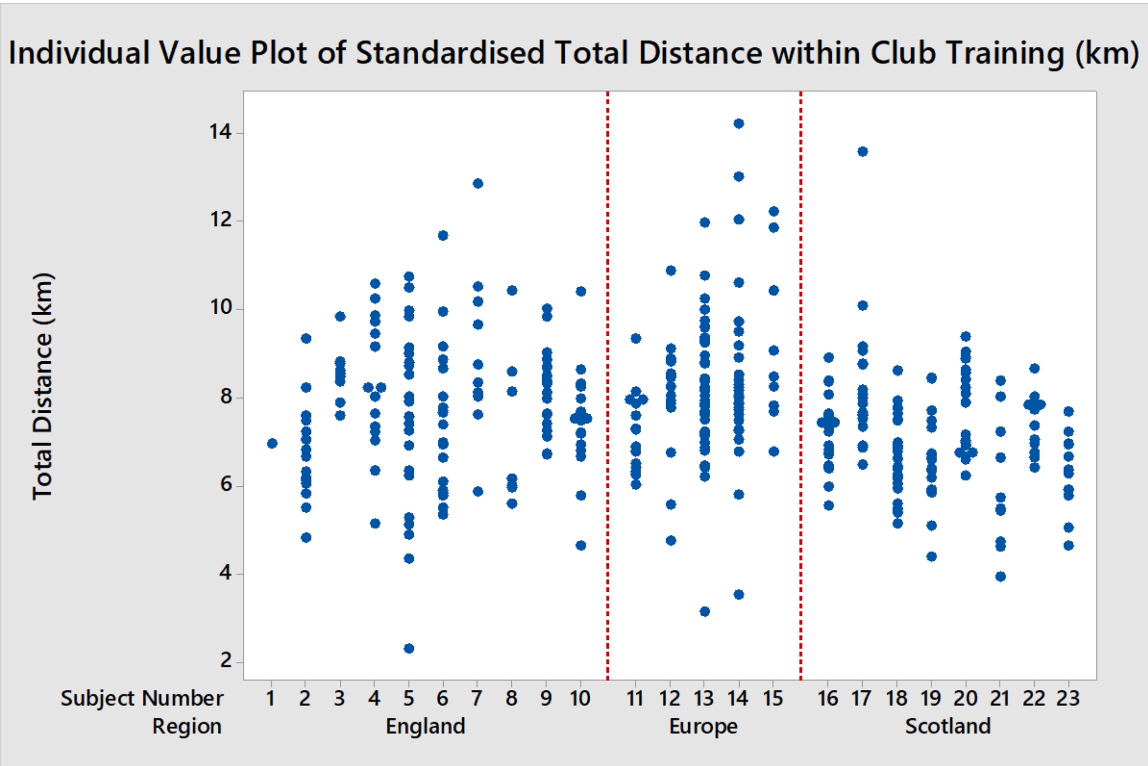

Figure 2.17 Individual Value Plot for total distance showing spread of standardised data for 3 regions within club training

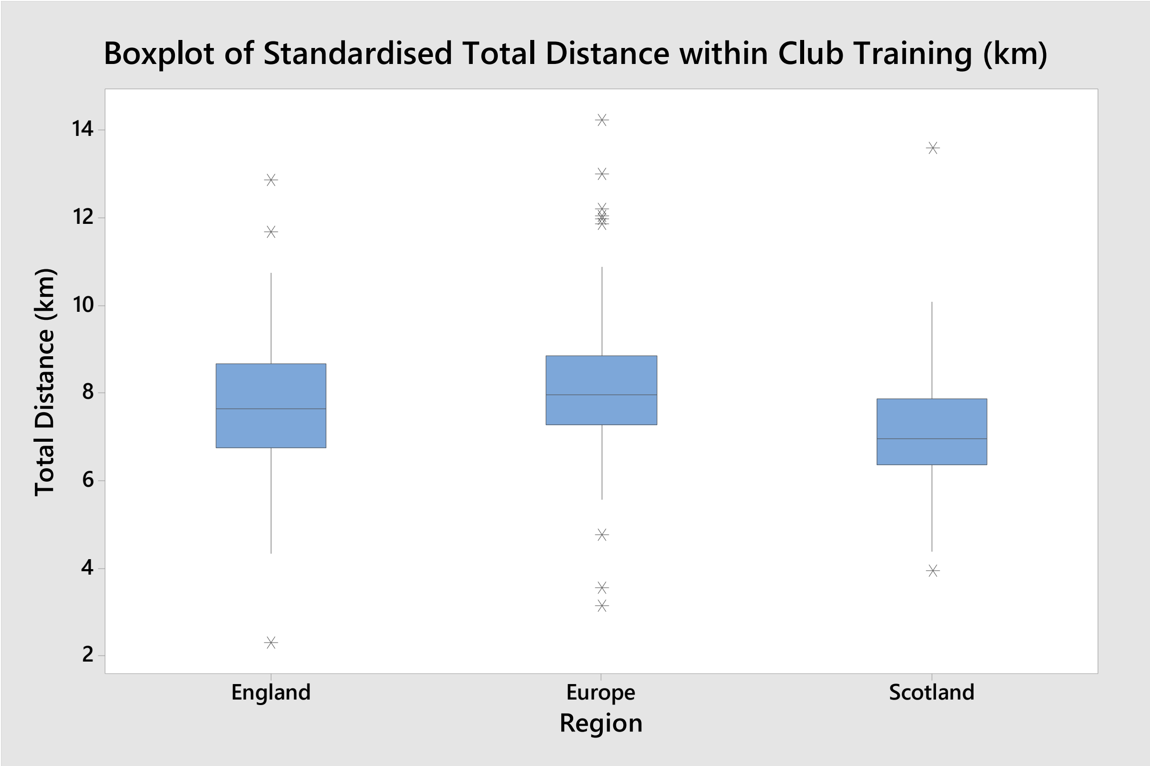

Figure 2.18 Boxplot of standardised total distance for club training

3.3 Summary

3.3.1 Non Standardised

With regards to the initial analysis carried out on Club and International sessions, it can be concluded that when comparing the non-standardised data, only Club Game analysis was found to have significant differences when comparing total distance and sprint distance covered for each region. For non standardised club game data it was found that English based players run on average between 0.8-1.6km more than players who play in Europe. Similarly, players based in Scotland were also found on average to run further than European based players by between 0.7-1.4km. Finally, there was no significant difference found between England and Scotland based players when comparing total distance covered during club games.

3.3.2 Standardised

With regards to the standardised data it was found that only total distance covered in Club Training was found to have significant differences. It was found that a player based with a club in England ran 0.3-1.1km more than that of a player based in Scotland. However, a player in England was found on average to run 0.1-0.9km less than that of a player based in Europe. Separately when comparing Scottish based players to players within European clubs it was found that Scottish players ran less by 0.7-1.6km on average than the European based players.

3.4 Differences between Sessions

The second part of analysis that has been carried out investigates whether there are differences in the total distance and sprint distance covered between sessions for each region. Whereas previously the comparison was only made within the session type itself (i.e. comparing each regions Club Game to Club Game) this section will now look into whether there are significant differences between different session types (i.e. Club Game v Club Training, Club Training v International Game). The analysis will highlight whether any significant differences occur and if so to what extent.

Unlike the previous analysis, only standardised data will be included in this section. This is due to the fact that comparisons will now be made between games and training as well as club and international games, where the durations of both the training and games will vary. For this part, all data has been standardised to a rate of 60 minutes to allow for comparison of all sessions and variables without the effect of duration played or trained.

To begin the analysis of the differing session types it was firstly required to investigate if differences occurred and if so to analyse in more details where these difference lay. Table 3.1 shows the p-values that were calculated and in what areas the differences were found. From the table, it was found that within Club Training and International Training for sprint distance there are no significant differences ($p=0.771$). This shows that the amount of running above the speed of

19km per hour for all three regions does not greatly differ from club to international training across England, Europe and Scotland.

Standardised (All to rate of 60 mins)						
	Total Distance (km)			**Sprint (m)**		
	Club Mean	**International Mean**	**p-values**	**Club Mean**	**International Mean**	**p-values**
Club Training vs International Training	3.8 (s.d 0.8)	3.4 (s.d 1.2)	0.009*	245.8 (s.d 164.3)	186.3 (s.d 156.9)	0.771
Club Game vs International Games	5.9 (s.d 1.1)	5.8 (s.d 0.9)	0.008*	565.5 (s.d 200.5)	559.5 (s.d 178.9)	0.012*
	Game Mean	**Training Mean**	**p-values**	**Game Mean**	**Training Mean**	**p-values**
Club Game vs Club Training	5.9 (s.d 1.1)	3.8 (s.d 0.8)	0.000*	565.5 (s.d 200.5)	245.7 (s.d 164.3)	0.001*
International Games vs International Training	5.8 (s.d 0.9)	3.4 (s.d 1.2)	0.952	559.5 (s.d 178.9)	186.3 (s.d 156.9)	0.332
***denotes significant difference**						

Table 3.1 Standardised data comparison of session type with p-values to show significant differences (<0.05) and identify any session comparisons where further analysis is to be carried out to identify extent of difference

Moreover, it can also be seen from Table 3.1 that when comparing International Games to International Training both Total Distance and Sprint Distance are found to have p-values of >0.05 (p=0.952 and p=0.332 respectively) and therefore it can be concluded that there are again no significant differences when comparing these variables. This shows that there are no significant differences between the total distance (km) and sprint distance (m) covered in International Games and Training when comparing across the 3 regions (English, Scotland, Europe).

The remaining figures in the table (denoted with *) all show p-values of <0.05 and therefore this shows that there are significant differences for remaining comparisons. However, the p-value alone does not show where the differences lie and what the range of differences are between the regions. To begin to quantify the differences, further analysis was carried out on any comparisons where a p-value of <0.05 was identified. A 95% confidence interval test was carried out on all combinations of session that were found to be significantly different to understand where for each region the difference lay.

3.4.1 Club v International Training

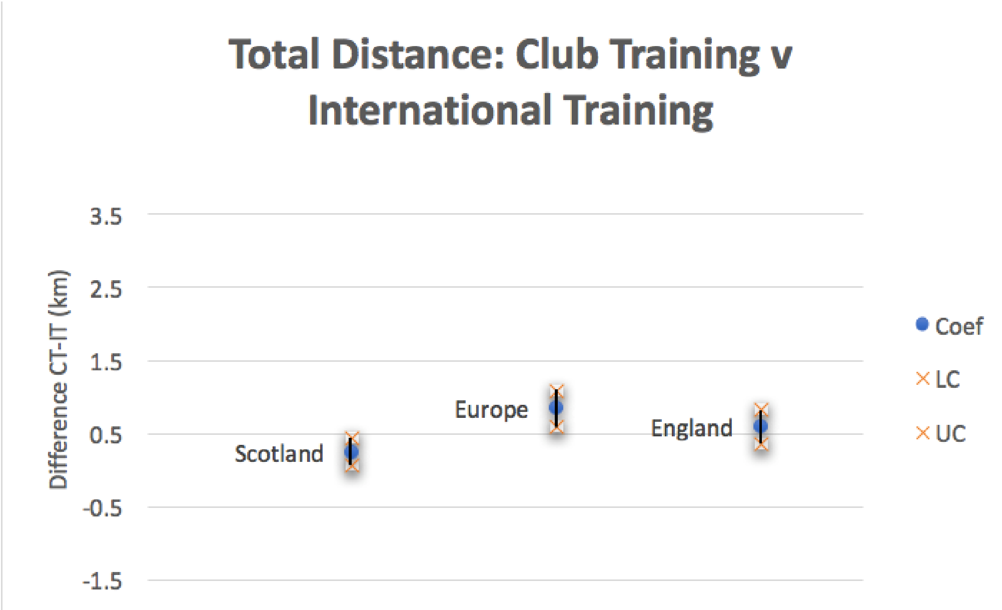

Figure 3.1 Club Training compared to International Training difference in total distance covered for each of the 3 regions *(LC= Lower Confidence Interval, UC= Upper Confidence Interval, Coef= Estimated Coefficient)*

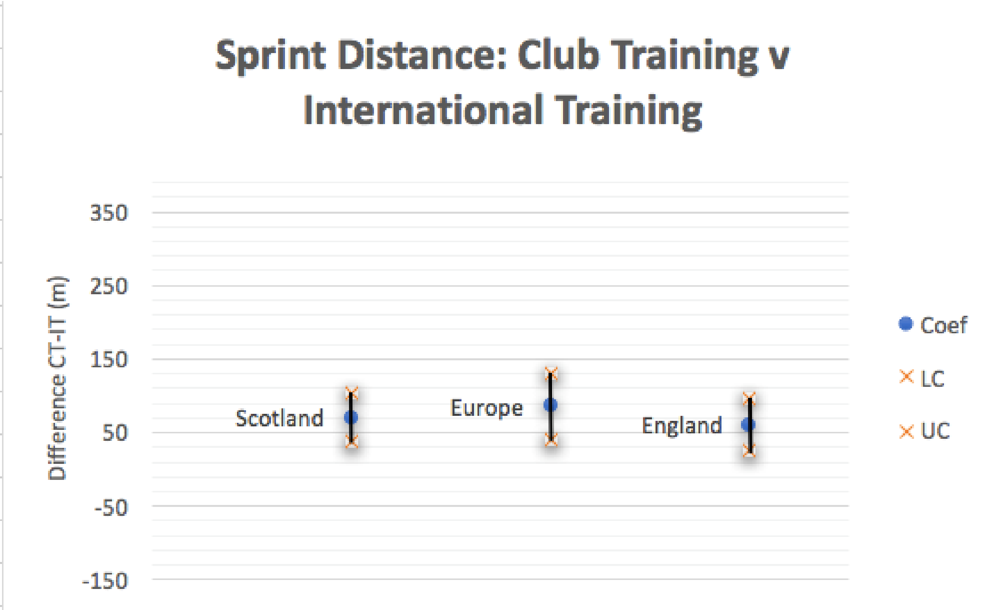

Figure 3.2 Club Training compared to International Training difference in sprint distance covered for each of the 3 regions *(LC= Lower Confidence Interval, UC= Upper Confidence Interval, Coef= Estimated Coefficient)*

Total distance was found to have a p-value of 0.009 and so further analysis was carried out to determine what the differences were between regions. Figure 3.1 shows a graph of the coefficients as well as the lower and upper confidence intervals for all 3 regions. It was found that when comparing Club training to International training, Scottish based players covered an average distance of 3.6km (s.d 0.6km) in club training and 3.4km (s.d 1.2km) in international training. Therefore, Scottish based players ran on average 241m (95% C.I: 53,429m) more in club training, covering anywhere between 53 to 429m more compared to that of international training. For a European based player, it was found that on average they covered 4.1km (s.d 0.8km) during Club Training and 3.3km (s.d 1.1km) during International Training. Therefore, it was found that European based players ran on average 836m (95% C.I: 592,1079) more during club training but were found to cover anywhere between 592 and 1079m more than that of international training . Finally a player based in England on average covered 3.9km (s.d 0.9km) during Club Training and 3.4km (s.d 1.2km) during International Training, therefore it was found that on average English based players ran 588m (95% C.I: 354,821) more during Club Training and therefore were found to run between 354 and 821m more than that of international training.

From this it can be concluded that all 3 regions were found to run more in Club training sessions.

In comparison, as previously described for Club and International training, sprint distance (Figure 3.2) was found to have a p-value of >0.05 at 0.771 and so it was concluded that there were no significant differences for this variable.

3.4.2 Club Game v International Games

Figure 3.3 Club Game compared to International Game difference in total distance covered for each of the 3 regions *(LC= Lower Confidence Interval, UC= Upper Confidence Interval, Coef= Estimated Coefficient)*

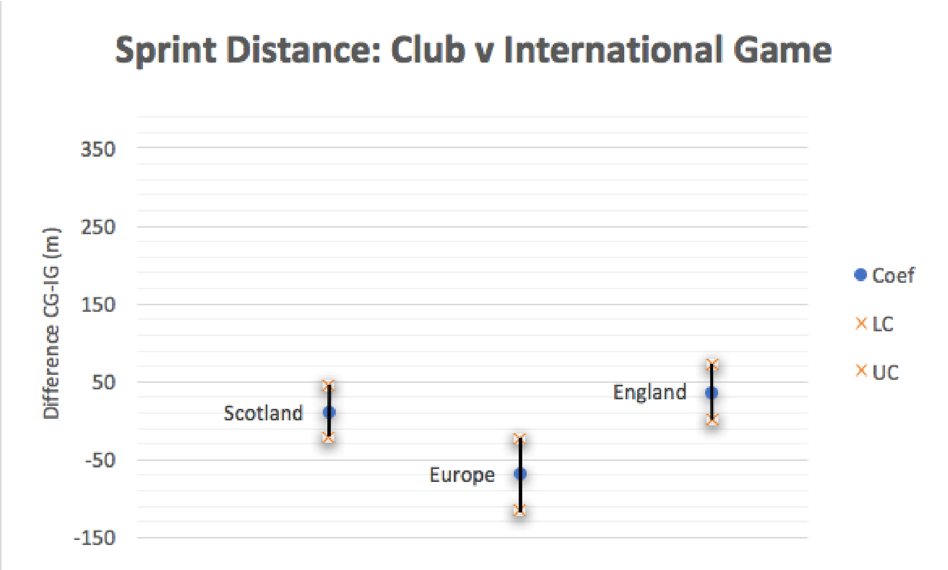

Figure 3.4 Club Game compared to International Game difference in sprint distance covered for each of the 3 regions *(LC= Lower Confidence Interval, UC= Upper Confidence Interval, Coef= Estimated Coefficient)*

When comparing Club to International games it was found that both total distance and sprint distance had p-values of <0.05 and therefore further analysis would need to be carried out to identify the differences. For total distance (Figure 3.3) it was found that the average Scottish based player covered in club games 6.0km (s.d 1.5km) and during International games 5.8km (s.d 0.8 km). Therefore, it was found that on average Scottish based player ran 298m (95% C.I: 110,486m) more during club games and so were found to run anywhere between 110m to 486m more in club games than that of international games. Similarly, the average English player was found in club games to cover an average of 6.1km (s.d 1.1km) and in international games cover 5.9km (s.d 1.0km). Therefore on average English based players covered approximately 303m (95% C.I: 81,526) more during club games and so were found to run anywhere between 81 to 526m more than that of international games. However, for the average European based player during the average Club and International games it was found they ran 5.1km (s.d 1.2km) in club games and 5.6km (s.d 1.0km) in international games. Therefore the average European based player covered approximately 315m (95% C.I: 11,619) more during International games and ran on average anywhere between 11 to 619m more than that of club games.

It can be concluded that both Scottish and English based players run a similar distance, covering more total distance when playing games Club compared to International, where as European based players were found to do the opposite and run a similar distance during Club and International games.

Moreover, when comparing sprint distance covered during club and international matches it was found that for the average English based player they sprinted on average 594m (s.d 200m) in club games and 549m (s.d 204m) in international games. It was found that on average English based players sprinted 37m (95% C.I: 1,72m) more during club games, sprinting anywhere between 1 and 72m more than that of international matches.

Conversely, the average Scottish player sprinted in club games 574m (s.d 189m) and international games 582m (s.d 137). It was found that on average Scottish based players sprinted 11m (95% C.I: -22,45m) more during international games. However the 95% interval contains 0 and so it can be concluded that there is therefore no significant difference in the average sprint distance for Scotland-based players between International Games and Club Games. Finally, European based players on average sprint in club games 480m (s.d 205m) and in international games 545m (s.d 182m) and so were found to sprint 69m (95% C.I: 23,114) more during International Games and therefore sprint on average between 23 and 114m more than that of club games.

To conclude this comparison, it was found that the average English based players run and sprint more in club games compared to international games by up to 526m and 72m respectively. The average Scottish based player runs up to 486m more in club games compared to international games and there was found to be no significant difference between club game and international game for sprint distance covered. Finally, European based players run and sprint more in International games compared to club games by up to 619 and 114m respectively.

3.4.3 Club Game v Club Training

Figure 3.5 Club Game compared to Club Training difference in total distance covered for each of the 3 regions *(LC= Lower Confidence Interval, UC= Upper Confidence Interval, Coef= Estimated Coefficient)*

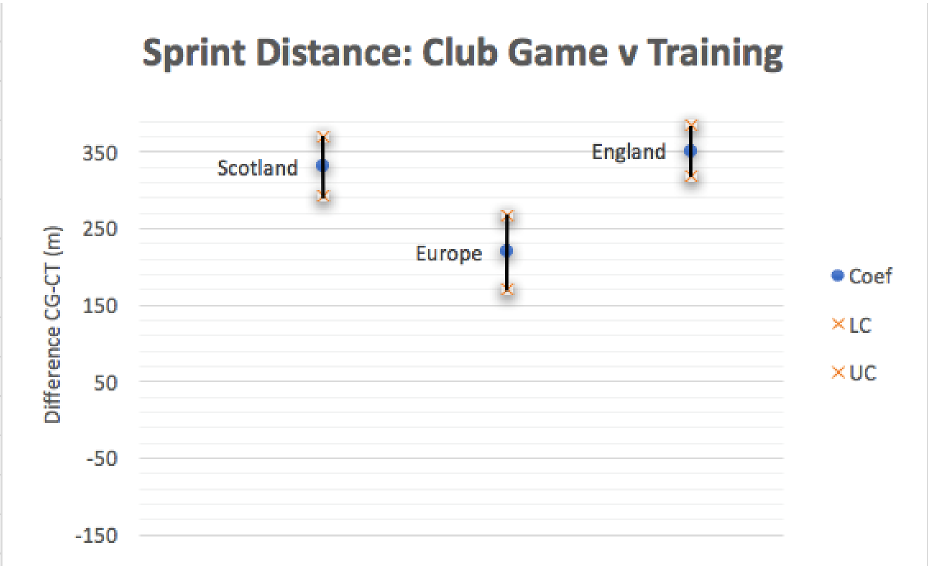

Figure 3.6 Club Game compared to Club Training difference in sprint distance covered for each of the 3 regions *(LC= Lower Confidence Interval, UC= Upper Confidence Interval, Coef= Estimated Coefficient)*

When comparing Club to International training it was found that again there were significant differences between both total distance and sprint distance covered and so further analysis was carried out to identify where the differences occurred. For total distance for the average Club game compared to the average Club training session it was found that Scottish based player on average ran 6.0km (s.d 1.5km) during club games and 3.6km (s.d 0.6km) in club training and so on average it was found that Scottish based players ran 2.5km (95% C.I: 2.4,2.7km) more during club games and therefore covered between 2.4km to 2.7km more than that of club training. In comparison, it was also found that the average English based player ran in club games 6.1km (s.d 1.1km) and in club training 3.9km (0.9km).

Therefore on average English based players ran 2.2km (95% C.I: 2.0,2.4km) more during club games and ran between 2.0 and 2.4km more than that of club training. Finally, the average European based players ran 5.1km (s.d 1.2km) in club games and 4.1km (s.d 0.8km) in club training, therefore they were found to run 904m (95% C.I: 0.7,1.2km) more during Club Games and anywhere between 0.7 to 1.2km more than that of club training. To summmarise, it was found that all 3 regions were found on average to run more in Club games compared to club training, with most difference in distance being covered by Scotland with an average of 2km more covered.

When comparing sprint distance for the same variable it was found that for the average Scottish players during Club games they covered 574m (s.d 189m) compared to training at 254m (s.d 185m), therefore Scottish players sprinted on average 331m (95% C.I: 293,369m) more during Club games and therefore sprinted between 292 and 369m more than that of club training. Moreover, on average English based players sprinted 594m (s.d 200m) in club games and 243m (s.d 169m) in club training, therefore on average English based players sprinted 351m (95% C.I 318,385) more during Club games and so it was found the average English based players sprinted more in Club games compared to training by between 318 to 385m. Finally, European based players sprinted again more in Club games covering an average of 470m (s.d 205m) and 262m (s.d 186m) during club training, therefore European based players run on average 219m (95% C.I: 169,268m) more so it was found that they sprinted more in club games compared to club training by anywhere between 169 to 268m.

Therefore, when comparing club games to club training it was found that for both total distance and sprint distance, all 3 regions on average covered a greater distance during club games compared to club training.

Comparison	Variable	Region	Estimated Coefficient	Lower C.I	Upper C.I
Club v International Training	Total Distance (km)	Scotland	0.24	0.05	0.43
		Europe	0.84	0.59	1.07
		England	0.58	0.35	0.82
	Sprint Distance (m)	Scotland	70.2	36.8	103.5
		Europe	85.6	40.7	130.4
		England	60.6	25.2	95.9
Club v International Games	Total Distance (km)	Scotland	0.29	0.11	0.48
		Europe	-0.32	-0.62	-0.01
		England	0.3	0.08	0.53
	Sprint Distance (m)	Scotland	11.2	-22.1	44.5
		Europe	-68.6	-113.8	-23.4
		England	36.8	1.16	72.4
Club Game v Club Training	Total Distance (km)	Scotland	2.53	2.36	2.69
		Europe	0.9	0.65	1.16
		England	2.15	1.97	2.34
	Sprint Distance (m)	Scotland	330.8	292.5	369.08
		Europe	218.6	169.43	267.77
		England	351.2	317.87	384.53

Table 3.2 Table of Simultaneous 95% Confidence Intervals for Total Distance & Sprint Distance for a combination of Club and International sessions

3.5 Speed Zones

Analysis was carried out on the distance covered over each of the five speed zones recorded within the GPS. Firstly, the data will be looked at as a whole, across all speed zones, for all session types. From this point if there are any clear differences between individuals, sessions or regions then further analysis will be carried out. The speed zone data comes in different formats, however for this study distance covered and percentage of distance covered in each speed zone will be the two metrics that are focused on.

3.5.1 Initial Speed Zone Analysis

Initially, the average distance covered within each of the 5 speed zones was calculated for the 3 regions across all session types (Figure 4.1), this shows the spread of the percentage distance data for each individual. Figure 4.1 shows that the percentage distance spent in each of the 5 speed zones decreases as the speed increases. Averages of each of the distances covered in each of the speed zones was calculated and it was found that 62±6% was covered in Speed zone 1, 19±3% in speed zone 2, 12±2% in speed zone 3 and 5±1% and 2±1% in the remaining 4th and 5th speed zone. Therefore it can be seen that most distance is covered in speed zone 1 (0-11km/hr) and the distance spent in each of the remaining speed zones decreases, with least time being spent in speed zone five which represents a sprint, this being anything over 23km/hr. It can also be seen that there are some outliers in Speed Zones 1,2 & 3 that need further analysis. Within speed zone 1, two individual points (Annotated in Figure 4.1 'Scotland 4' & 'Scotland 6') within the region of Scotland appear to perform less time in that given speed zone than the rest of the group. It can also be seen that the same subjects 'Scotland 4' & 'Scotland 6' are again outliers within Speed Zones 2 (11-15km/hr) and 3 (15-19km/hr). This shows now that these two individuals are again behaving differently from the group, however in this case they seem to cover more distance at these given speed zones than the rest of the plotted individuals. In order to investigate the outliers further a scatterplot comparing speed zones 2 & 3 to speed zones 4 & 5 for each of the four session types (Club game, Club training, International game, International training), that each of the three regions participated in was plotted (Figure 4.2). Again, it can be seen that in all 4 of the session types there are outliers and again the majority of the outliers are the same two Scottish subjects (S4 & S6). This can further be seen in Figure 4.3, the bar graph shows the mean percentage distance covered in speed zones 2 and 3 for each of the subjects within the three regions. Scotland subjects 4 and 6 (denoted with *) are outliers to the group with 26% and 15% distance covered in speed zone 2 and 3 respectively for Scotland 4 and 30% and 19% for Scotland 6. This shows that there does seem to be differences within the group with regards to the distance covered in each of the five speed zones. It is therefore important to investigate these further to understand the extent of the differences within the group and to also locate where they occur.

It is important to note at this point that the data points in Figures 4.1 and 4.2 come from averaged data. With regards to Figure 4.1 the data points are a result of their percentage distance covered in each speed zone over all sessions completed in a season. Figure 4.2 is different as it separates into each of the 4 session types, however again the data points come from an average percentage distance spent at each speed zone over the seasons collection of data.

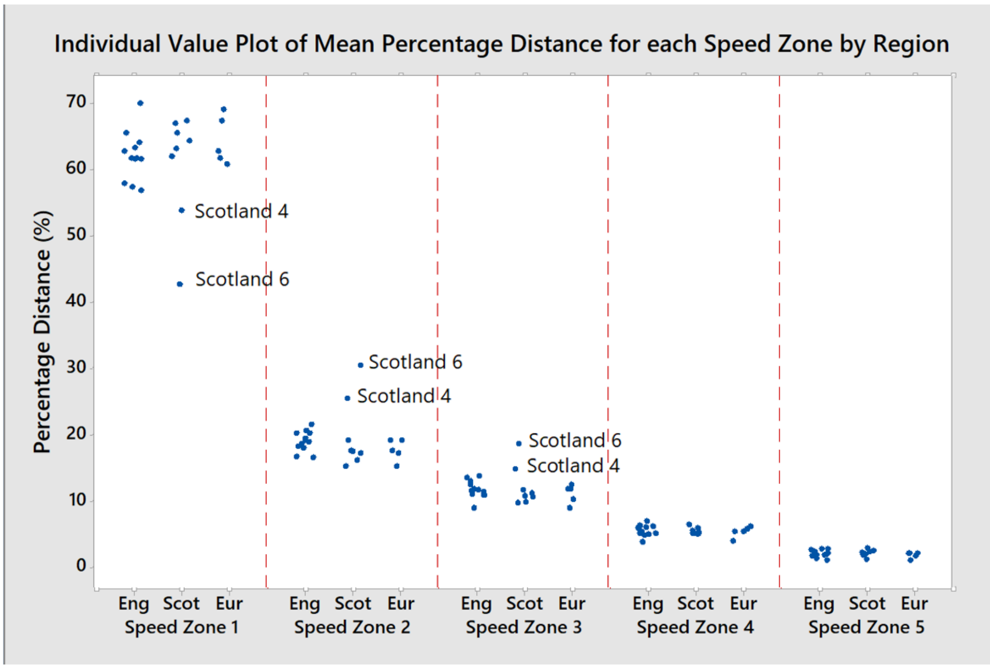

Figure 4.1 Annotated plot of mean percentage distance with the 5 speed zones across the 4 session types

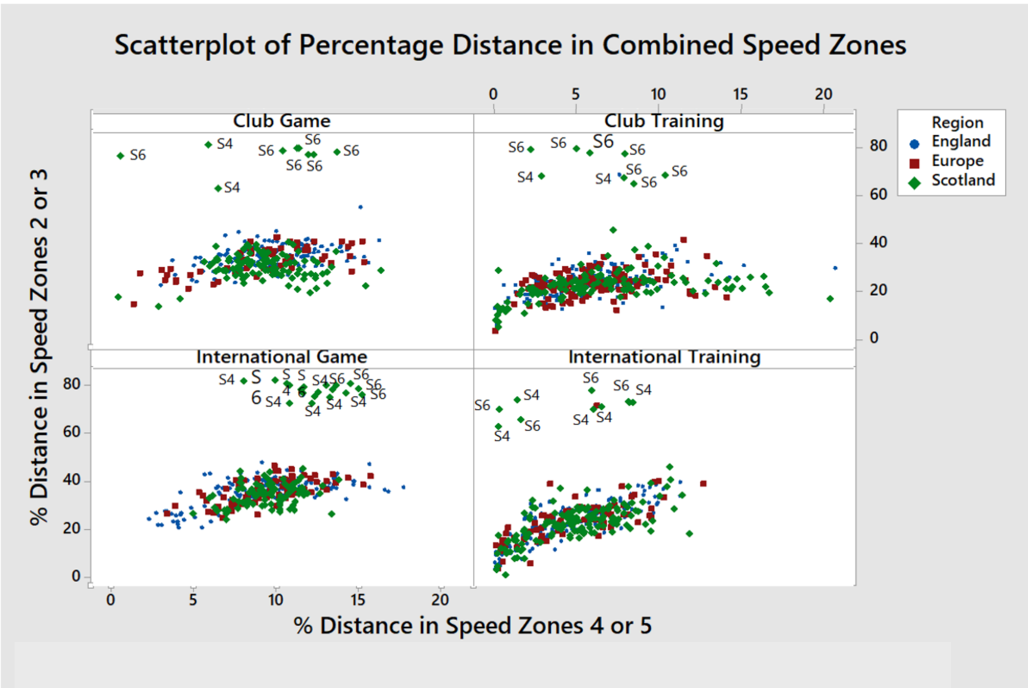

Figure 4.2 Scatterplot of percentage distance spent in speed zones 2 & 3 and 4 & 5 across the 3 regions

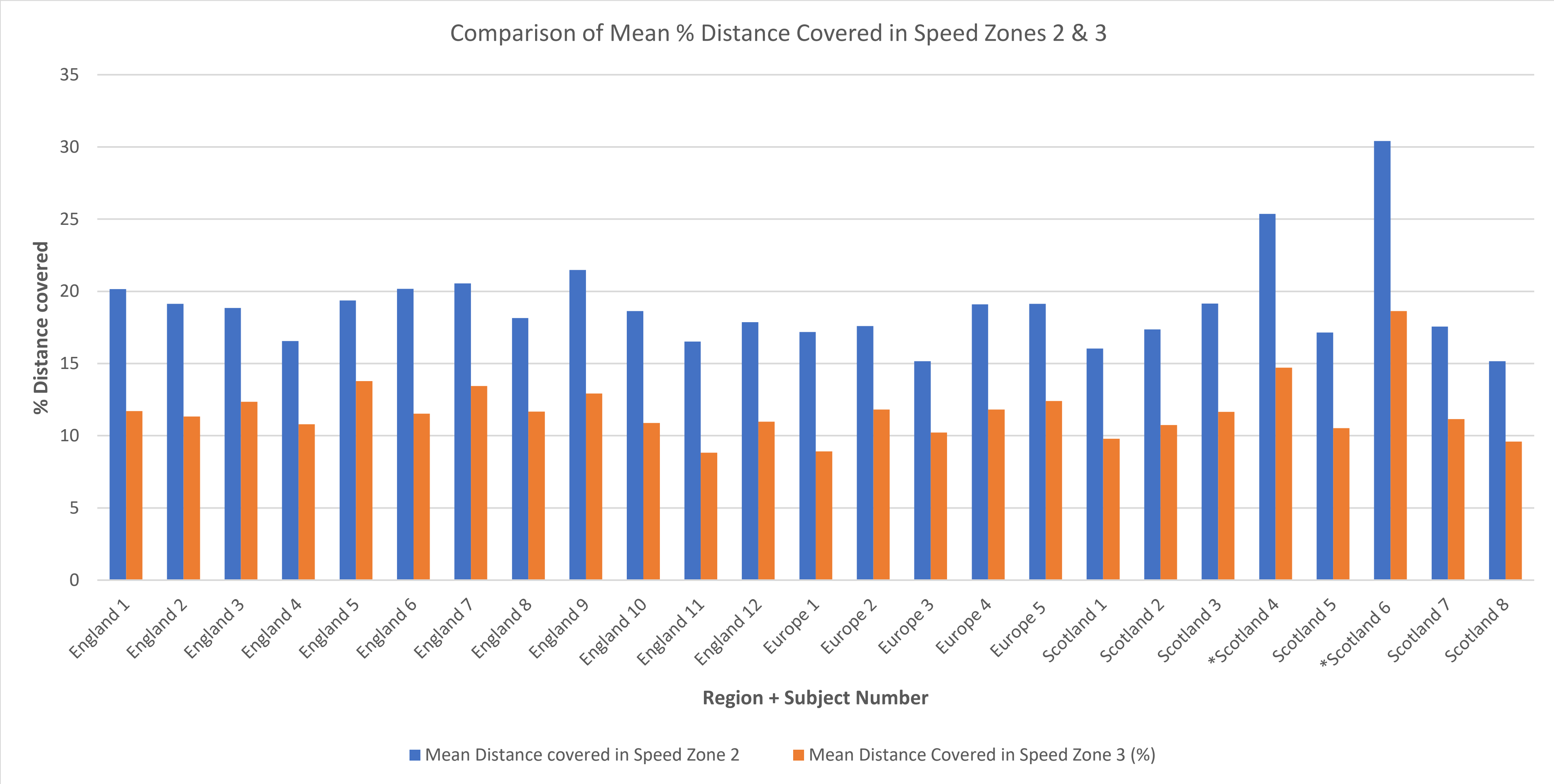

Figure 4.3 Bar graph of mean % distance in speed zones 2 & 3 (*) denotes outliers found in Figures 4.1 & 4.2)

3.5.2 Speed Zone Differences

As previously stated when plotting the average data for each of the five speed zones (Figure 4.1 & 4.2) it was shown that there were outliers in both figures. The next step was to look into these potential differences to understand where and potentially why they occur. From the previous analysis, it was recognised that the outliers appear in the first three speed zones with speed zones 2 and 3 behaving fairly similar to each other. Therefore from this point onwards, the focus will be on any potential differences between the distance covered in speed zones 1 and 2+3.

In order to investigate these individuals in more detail, a General Linear Model on the Logarithm of Ratio of the percentage distance covered in speed zones 2+3 compared to 1 was carried out, to analyse what impacts the different distances spent within the two speed zones. Individual, Region and Session Type were all included as possible explanatory factors as well as Total Distance as a potential covariate. The group was firstly investigated as a whole and it was found that Total distance (<0.0005), Session Type (<0.0005), Region (<0.0005) and Individual (<0.0005) as well as a session region effect (p=0.017) all have significant effects on the outcome variable. This shows that each of the variables named above has a significant effect on the different percentage distance spent in the two categories of speed zones currently being investigated. Due to the significant interaction between session and region, the next approach was to analyse each of the four session types separately to find out where each of the region and individual impacted.

3.6 Analysis of Region & Individual Effects within each Session

As described in the previous section, following on from the General Liner Model and Log Ratio analysis, it was found that there were interactions among all four of the effects (Total Distance, Region, Individual and Session Type). Therefore each of the 4 session types were analysed to compare where the differences lie. This analysis will look to explain what has most impact on the distance spent running or walking during each of the four session types (Table 3.3).

Effect	Club Game	Club Training	International Game	International Training
Total Distance	0.161	<0.0005*	0.123	<0.0005*
Region	0.285	0.120	<0.0005*	0.601
Individual	<0.0005*	<0.0005*	<0.0005*	<0.0005*
*Denotes significant difference				

Table 3.3 Table of General Linear Model Log Ratio p-values for the Region Session Effect

The analysis will now look at each session type in turn.

3.6.1 Club Game

It was found when looking at Club Games separately from the other session types, there were significant differences found within the three variables investigated. Total Distance within a club game was found to have a p-value of >0.05 (p=0.161), therefore there were no significant differences found for speed zones as a result of the total distance covered. Similarly, the region that the players played within was also found to not have a significant effect (p=0.285). However, when looking at the Individual effect it was found that there was a significant difference (p=0.0005). Therefore it can be concluded that for Club Games there were no significant differences found when comparing the Distance covered in each of the speed zones or within the three regions that the players compete within, however there did seem to be a significant differences when comparing the individuals within club game.

3.6.2 Club Training

Within Club Training, the 3 effects of total distance, region and individuals were again investigated. It was found that total distance was significantly different with a p-value of <0.05 ($p=0.0005$), as too was the effect of individuals within the session ($p=0.0005$). However the region effect again was not found to have a significant difference ($p=0.120$). This shows that the total distance covered within club training has an effect on the distances covered in zones 1,2 & 3, as well as there being differences based on the individuals taking part.

3.6.3 International Game

For International Games similar analysis to the previous sections for Club Game and Club Training was carried out. It was found that there was no significant difference found for Total Distance ($p=0.123$), however for both region and individual there were significant differences found ($p=0.0005$). This shows that for International Games there are significant differences for both the region the players compete within, as well as individual differences relating back to the difference in speed zone data.

3.6.4 International Training

When investigating International Training it was found that there were significant differences across 2 of the variables. Total distance and the Individual effect were both found to have significant differences ($p=0.0005$). However, region was found to have a p-value of >0.05 and so was not found to be significantly different when investigating the speed zone distance data ($p=0.601$).

3.6.5 Summary

Each session type was investigated in turn and it was found that the individual effect in each of the four session types showed significant differences. For both international and club training it was found that Total Distance covered was significantly different and therefore the total distance covered in each of these sessions could have an impact upon the distance covered in each of the three speed zones. Separately, in International games region was seen to have a significant effect, thus showing that the Region a player competes within for club seems to have an impact on the difference of distance covered within speed zones 1, 2 and 3 for international games only.

3.7 Individuals

In the previous sections the speed zone data has been looking at the averages of the group as a whole and has not focused on the individual differences that may be occurring. From the analysis carried out at the beginning of the speed zone section, Figures 4.1 and 4.2 show that aside from the analysis of the team and regions as collectives, there are individual variations that have not yet been investigated. Therefore, to understand the difference in speed zone data thoroughly and in particular understand why certain subjects are behaving in a certain way, more specifically Scotland subjects 4 and 6, more individual specific analysis needs to be carried out.

To investigate the individual differences, estimated coefficients for each individual across all session types were analysed. It is important at this stage to note that the coefficients (Appendix II) are estimates of the percentage distance speed zone data that has been collected for each individual and therefore factors such as the number of observations, which vary for each individual, will have impacted upon the coefficients reported.

A graph of the coefficients calculated for each individual can be found in Figure 4.4 which shows the spread of the data for each of the 3 regions within the four session types. Again, the spread of the data, as previously found in the analysis above is fairly similar for the group, across each of the three regions. There are, as expected, individual variations within each group and also differences between the session types. However, there are clear outliers that can be seen in Figure 4.5 (annotated Scotland 4 & Scotland 6).

From previous analysis it was clear that both Scotland subjects 4 & 6 were performing slightly differently, although it was not clear how differently each performed when the 4 separate sessions were compared. Figure 4.5 shows that the subject named Scotland 6 is a clear outlier when comparing speed zone coefficients in comparison to that of the rest of the team in all four session types. More specifically Scotland 6 has a similar speed zone coefficient for both club (1.46) and international games (1.42) and with regards to training has a slightly higher coefficient in international training (0.87) compared to that at club (0.6). When comparing Scotland subject 6 to Scotland subject 4, Figure 4.5 again shows there are differences, that previous figures may have not shown. With regards to Scotland 4 for club games and training, his coefficients are similar to that of the group and do not show as outliers. However, when analysing international coefficients it is clear that he is behaving differently to the estimated norm of the group. Similarly to that of Scotland 6, Scotland 4 has a high coefficient of 1.4 in international games and 0.65 in international training.

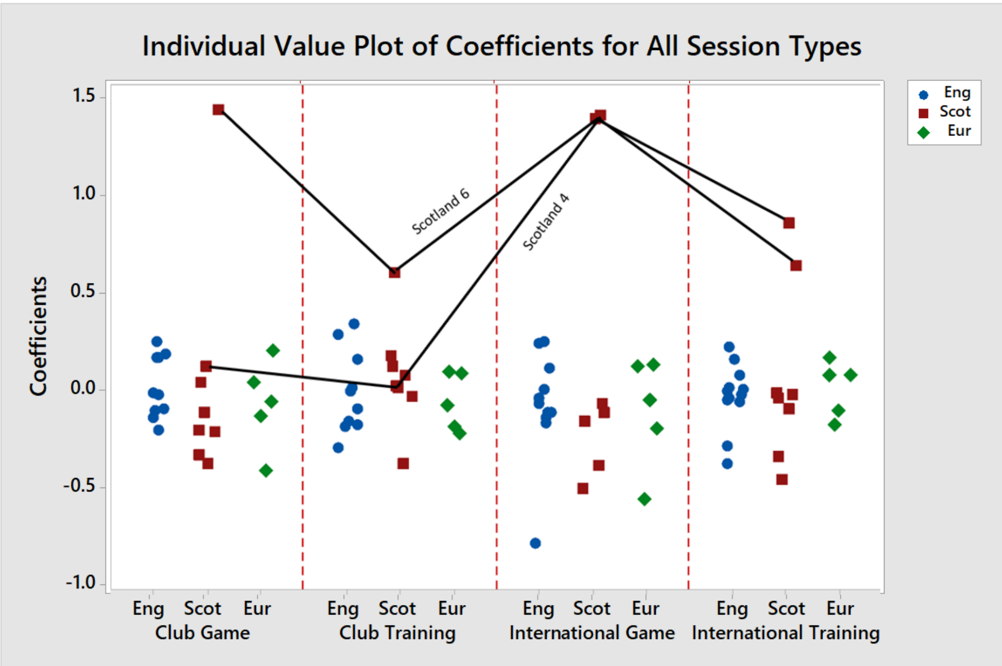

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Figure 4.4 Annotated Estimated Coefficient for Log of percentage distance covered in Speed Zones 2 & 3 relative to Speed Zone 1

3.8 Seasonal effect

It has been found through the analysis of coefficients that there are individual variations within the group, however as expected Scotland subjects 4 and 6 seem to be behaving differently out with the normal trend of data. Specifically, it has been found that Scotland subject 6 with regards to speed zone data covers more distance in speed zones 2 and 3 across all 4 session types when compared not only to his region but also to the rest of the squad (Figure 4.4). In comparison Scotland subject 4 seems to perform similarly when compared to the group with regards to speed zone distance in club commitments but behaves differently to the squad and similarly to Scotland subject 6 when participating in International games and Training (Figure 4.4)

Due to this finding, the last piece of analysis looks at the seasonal effect of the data. Everything that has been reported thus far has been an estimate or average of data across the full season and has not investigated the effect of time. More specifically, whether both Scotland subject 4 and 6 behave differently depending on the time of the season that they are competing within.

Figure 4.5 shows a time series plot for Scotland subject 6 across all 4 session types throughout a season. Interestingly, for both club games and training it shows a noticeable drop off in percentage distance difference covered in speed zones 2+3 compared to the second half of the season. During the months of April to June the data trend changes in comparison to the data collected for speed zones in November to March. The time series plots with regards to International games looks to follow a similar pattern to that of club commitments, with a change in the reported data from April onwards. With regards to club training there is a less noticeable change, the data does seem to vary throughout a season, however there does not seem to be a pattern as clear as the previous 3 session trends.

With regards to Scotland subject 4, Figure 4.6 shows again a time series plot looking at all four session types across the season. Similarly to the previous subject 6, Scotland subject 4 again appears to be showing a similar pattern, with there being a clear drop off in the percentage distance covered within speed zones 2 & 3 visible within club games and training after the month of April. With the international plots there are not as many data points but again there is a slight drop off again visible when comparing the earlier session dates to those closer to the end of season.

In summary, there does seem to be a seasonal effect, in each of the four time series plots the pattern of data changes at the same point in the season for club games and training. This pattern of behaviour can be seen across both subjects 4 and 6 for all four session types and at approximately the same point in the season. The degree to which the drop off occurs varies between individual and session type, however it is clear that when comparing the first half of the season to the second half, the pattern of speed zone data with regards to distance spent in zone 1 compared to 2 and 3 changes. It therefore seems that for the two subjects in question, towards the end of the season less time is spent in zones 2+3 (jogging) and more time is spent in speed zone 1 (walking) than was previous done at the beginning of the season, from November to April.

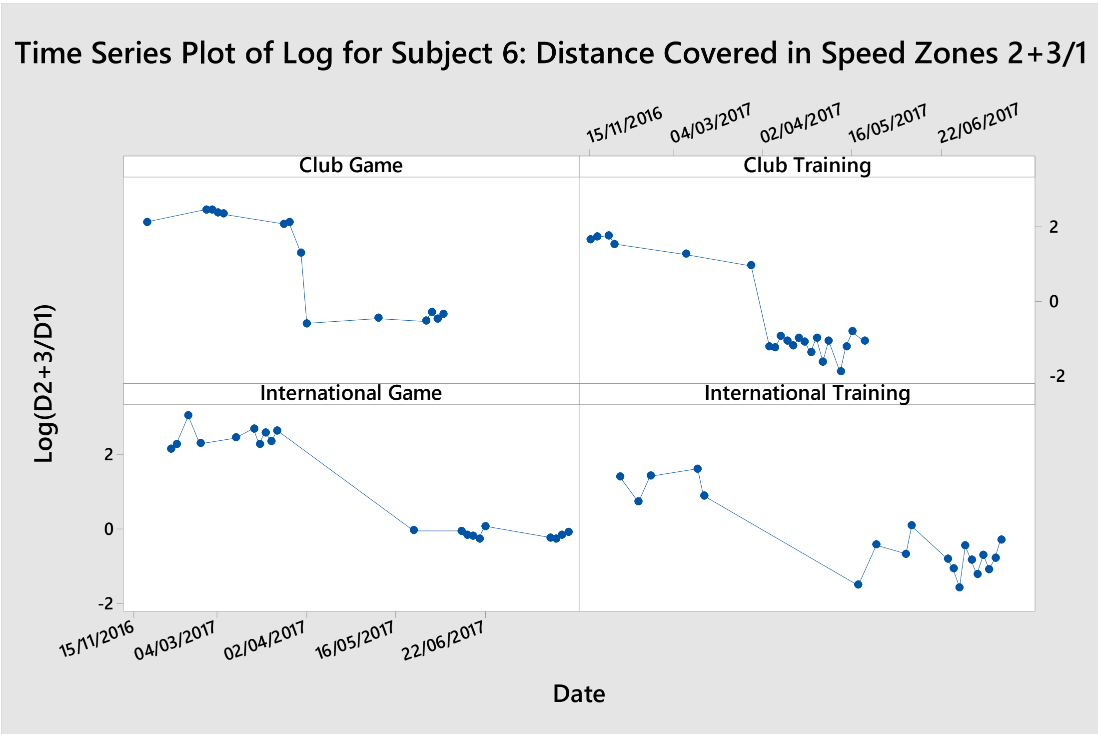

Figure 4.5 Scotland subject 6 time series plot comparing seasonal effect to distance covered in speed zones 1 compared to 2+3

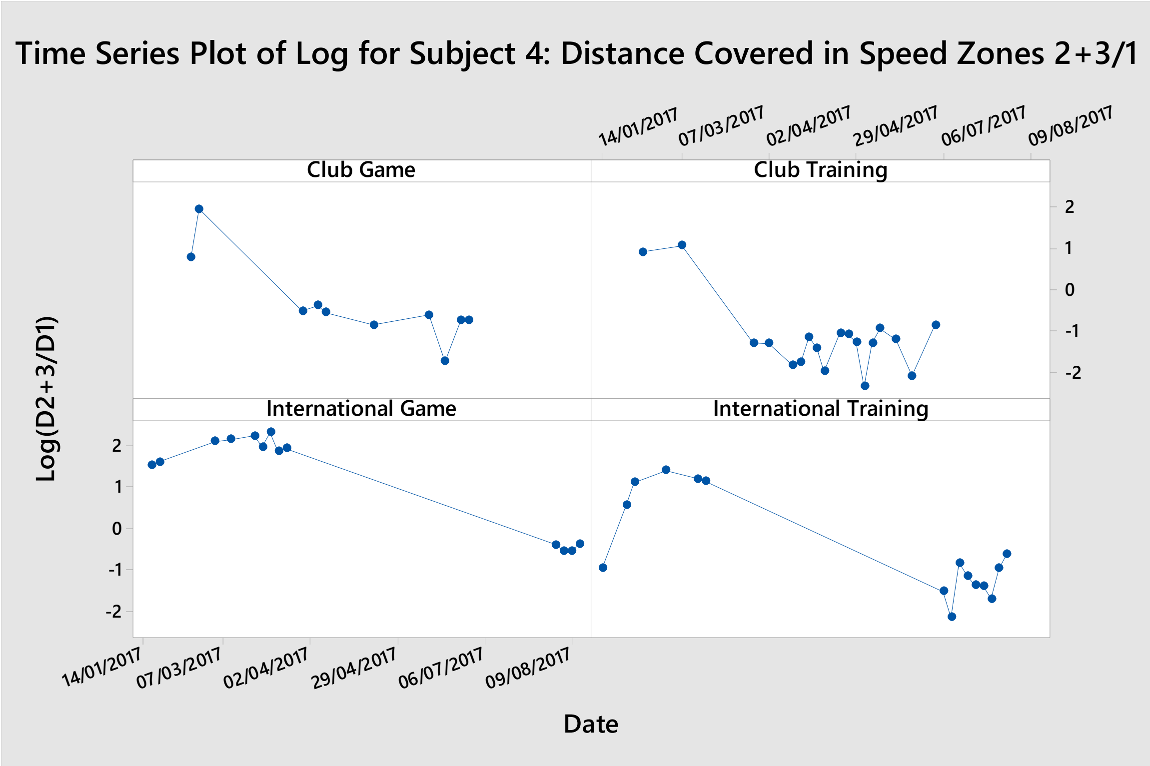

Figure 4.6 Scotland subject 4 time series plot comparing seasonal effect to distance covered in speed zones 1 compared to 2+3

4. Discussion

The aim of this study was to investigate if there are potential differences depending on the region in which each of the individuals club resides. The analysis looked to investigate the data in a progressive approach, with the initial results comparing only the three regions within one session type (i.e. Differences between players within Scotland, England and Europe within only one session type). Within this section data was split into non standardised and standardised to allow for comparison with and without the effect of session duration. It was found that for the non-standardised data only club games were found to have significant differences reported, with Scotland and England covering more total distance than that of Europe. Separately, it was found that when club training was standardised to 120 minutes, that significant differences also occurred. It was found that within club training, Scotland covered the least, with Europe covering more total distance on average. No other significant differences were found for any of the remaining session types for either total or sprint distance.

After this, between session analysis was then carried out to investigate whether there were differences that occurred between sessions (i.e.. Differences between Scotland, England and Europe when comparing one session type to another). Within this section, 3 main differences were reported with regards to Club & International Training, Club & International Games and Club Games & Club Training. Each was then investigated in more detail to understand where each difference occurred.

Finally speed zone analysis was completed to investigate any potential differences in the distance covered within each of the five speed zones, this section became more individually focused, instead of regionally, due to the initial findings of outliers from the main group. It was found that two individuals within the region of Scotland covered less average percentage distance in speed zone 1 for all of the session types when compared to the rest of the group and covered more average percentage distance in speed zones 2 and 3, again compared to the rest of the individuals within the 3 regions. Further analysis was carried out on the two individuals appearing to behave differently and it was found a seasonal effect may influence their behaviours and so further investigation into the effect club and international commitments could be having on these individuals in particular was then carried out.

4.1 Within Session Analysis

As describes previously within session analysis investigated the data for each session individually to analyse whether any differences between the three regions occurred.

4.1.1 Club Games

The initial key findings come from the non-standardised data looking at within session analysis. It was found that when comparing club game data within each of the 3 regions there was a significant difference found (p=0.024). Upon further investigation, those within the region of England and Scotland were found to cover a larger total distance (7.1±1.2 & 7.0±1.6km respectively) than that of Europe (5.9±1.4km), with no significant differences being found between England and Scotland. The distances reported for both Scotland and England are less than that found in a study by Liu.H et al. (2013) where 38 Chinese hockey players across 24 male field hockey matches were analysed within the Chinese Club Games. It was found that the average distance covered was 7.3±0.8km which is similar to the figures found for England and Scotland. However with regards to Europe the figures within the study by Liu et al. (2013) appear to be show a large difference.

This difference could possibly be down to the variation in substitutions across each of the three regions. As we have no record of the actual time each individual played during club games, due to the nature of rolling substitutions there will be differences, with not all players taking part in the full 70 minutes. When analysing why differences in club games total distance occurred, it could be suggested that the standard of hockey is perceived to be higher within England and Europe and therefore attracts a higher calibre of player. Therefore, within England and Europe it is a possibility that there is less difference in hockey ability between each member of the squad and therefore a more equal share of the time on the pitch as a result. Whereas within the Scottish leagues, the Scottish internationalists are more likely to be the best players within their team and less likely to be substituted as often (See Section 4.4.2).

A study carried out by Lythe and Kilding (2017) looked to investigate the possible impact substitutions had on physical and technical outputs of field hockey strikers described to be of international level, over five competitive matches between the same two teams. Three different frequency of substitutions were used; low where there were only 3 strikers and no substitutions were made, moderate where there were 4 strikers for 3 places and high where there were 5 strikers for 3 positions and therefore substitutions were made more regularly. It was found that through analysis of video, heart rate and GPS that frequency of substitutions had no impact upon the total distance covered per person (Sub5=8414±125m, Sub4=8422±34m, Sub3=8282±0m) or high intensity running over 19km/hr (Sub5=701±46m, Sub4=685±28m, Sub3=723±0m). However it was found that when 1st and 2nd halves were analysed that more frequent substitution reduced the decrement in both total and high speed distance between halves. Also greater substitutions were found to increase the number of total technical outputs compared to less substitutions (Sub5=241±35, Sub4=207±38, Sub3=173±0). Therefore, in relation to our findings the rate of substitutions as described above does not affect the total distance covered within this study, however rate of substitutions could impact upon performance of technical outputs and performance decrement across half's.

To show the differences that substitution frequency could have on the game, activity charts from the Playertek GPS outputs for each region have been collated and reported in Appendix IV, V and VI. Individuals activity charts for club games across each of the three regions have been analysed to show substitution differences. The assumption has been made that the blanks shown in the graphs are time off the pitch as a substitute and not a break in play or injury (substitutions marked as 'S'). At this point it is important to note that the reliability of this as a measure of time on the pitch is not appropriate, however it should show the extent of differences between the three regions that was previously intimated above.

As it can be seen from Appendix IV, V and VI above that there is a clear difference between the activity profiles of each of the three individuals. When reporting each of the three activity profiles it was ensured that they were accurate representations of a ‘normal’ club game for each of the regions. From Appendix V showing a Scottish players activity profile it can be seen that throughout the full 70 minutes the player was not substituted and the only break in his profile comes from half time, resulting in a total distance covered of 7.89km. In comparison, in Appendix IV for the European based player and Appendix VI for the English based player, more regular breaks of inactivity can been seen within the chart. With regards to the European based player you can see that the individual starts on the pitch and then is substituted again in the first half three times and twice in the second half, covering a total of 4.15km and spending an estimated time of 33mins on the pitch. In comparison, the English based player is substituted once in each half, covering at total distance of 6.05km and spending an estimated 47mins on the pitch. This shows that as previously mentioned it is common for Scottish players to play the majority of their clubs games with more frequent rotations seen in European and in some cases English club hockey. This is thought to be a result of a more even spread of ability throughout the squad which therefore could impact on the distances reported, as substantially more time on the pitch should result in more opportunity to increase the distance covered.

Another factor which could also impact upon the difference in the total distance covered between each of the three regions is tactics. The style of play that each club within each of the three region adopts, will impact upon the distance covered depending on how attacking or defensive their tactics are. Similarly, possession could also be a factor impacting upon the differences found between regions within games. It has been found that players in Scotland and England run further in club games compared to that of Europe. This could be attributed to different styles in play across the three regions. Potentially, teams in Europe could have more possession and control of the ball and therefore do not have to cover as much distance in order to regain possession. Conversely, in Scotland there is a perceived idea that turnover of play could be more frequent and therefore this could result in more need to chase in order to regain control of the ball.

With regards to the effect possession and team performance has on the distance covered within club games, a study by Bradely et.al (2013) looked to examine the effects of high and low percentage ball possession on physical and technical profiles in elite soccer matches within the English Premier League. High percentage ball possession teams (HPBPT) were classed as having 51-66% of ball possession with low percentage ball possession teams (LPBPT) having 34-50%. Match performance data was collected from 810 players competing within the Premier League with it being found that total (10690±996m vs 10778±979m) and high intensity running distance between 19-25km·hr^{-1} (931±299m vs 938±311m) did not differ between HPBPT and LPBPT. However, it was found that high intensity running when a high ball possession teams had the ball was 31% higher (449±266m vs 343±236m) than that of a low possession team but 22% lower when not in possession with HPBPT covering 423±153m compared to LPBPT who covered 539±177m. The conclusion from this study was that percentage ball possession does not influence the overall activity profile of a team. However, it can impact on the composition of high intensity running efforts both with and without the ball. In a separate study carried out by Lago (2009) in which 27 matches from the 2005-2006 Spanish domestic league season were analysed. It was found that when examining the effects of possession, possession of the ball was greater when losing compared to winning or drawing and playing against strong opposition was associated with a decrease in time spent in possession.

From the findings above from Lago (2009) it is clear that losing teams are considered to have more possession compared to those winning or drawing. With regards to the study carried out by Bradely et al. (2013) style of play, tactic or ability could dictate whether you are classed as a high or low percentage ball possession team which in turn appears to elicit potential differences as a result. Although total distance and high intensity running were not found to be effected as a result of ball possession there was a difference found when comparing the two different style of possession with and without the ball. It was found that when a HPBPT have the ball they cover more distance at high speed compared to when a LPBPT have the ball (449±266m vs 343±236m). Conversely, when not in possession of the ball the opposite applies with LPBPT covering more running at high speed than HPBPT (423±153m vs 539±177m). Therefore how much possession a team has of the ball can impact upon the distances they cover at high speed depending on whether they are a high or low percentage ball possession team.

Lastly, there could also be a potential opposition effect, in which the standard of the team that you are playing could impact upon the physiological outputs as a result. This was looked into further by White and Macfarlane in a study where 108 female field hockey players participated giving 186 club game analyses across the club National League within Scotland. It was found that physical demand of match play can be significantly decreased when teams are not matched with regards to league position. It was found that the distance covered by a mid-ranked team ranged from an average of 6498m (5583-7413m) against the top ranked team to 5949m (4726-7171m) against the lowest ranked team. Linear regression analysis found that a strong relationship existed between team average distance and opposition ranking. Similar results were found in a study carried out by Lago et al (2009), 27 matches played by the Espanyol Football Club during the 2005-2006 Spanish season was monitored. It was found that when investigating opposition effect, playing against strong opposition was associated with a decrease in time spent in possession of the ball. Each unit of distance in the end of season rankings, between competing teams, increase/decreased the teams possession by 0.2%. Both studies show that the opposition could have an impact on the total distance covered or possession of that ball which could have in turn impacted upon the reported figures from each of the three regions investigated above.

To conclude this section, there are multiple factors that could affect the results reported above. Substitutions, Tactics, Possession and Opposition effect could all impact upon the reported figures that show that when comparing players based in Scotland, Europe and England that English and Scottish based players cover more total distance than those in European countries.

4.1.2 Club Training

The next key finding came from the same within session analysis, however with regards to the standardised data. It was found that there was a significant difference found when comparing Club Training ($p=0.009$), that were not previously shown within the non-standardised data. It was found that within a club training session, England covered more total distance compared to that of Scotland (7.7±1.6km compared to 7.1±1.3km). However, Europe were found to cover on average more total distance than both England and Scotland (8.1±1.6km compared to 7.7±1.6 and 7.1±1.3km). This difference was not shown in the non-standardised data, which did not account for the varied session times, however when all sessions were standardised to a rate of 120 mins the above significant difference was found. This shows that European based players cover on average 0.7-1.6km more than a Scottish based player and 0.1-0.9km more than that of an English based player.

A potential reason for the difference in the average distance covered found between each of the three regions could be attributed to the content of the training sessions. It was found that Scottish based players cover less total distance in comparison to that of England and Europe with Europe covering the most. Therefore, what does the training content within the region of Europe have that causes a larger total distance to be covered? When analysing the diary reports which contained session details for all training carried out across the season, there was no noticeable difference in content of session that could be seen between each of the three regions. The majority of sessions across all three regions included very similar drills mainly focused around small sided games, attacking or defensive overload drills, tactical or set piece practice. A factor that has been the subject of investigation is that of small sided games, which could have had a significant impact upon the results reported with regards to club training. Small sided games are a popular training tool that are commonly used within hockey training. Over the last few years more studies has been released, examining the potential effect that size of pitch and numbers included within small games of this nature have on the physical outputs of players.

In a study carried out by Casamichana and Castellano (2010) they examined small sided games and the potential effects that a varied pitch size (~272m^2, ~175m^2 and ~75m^2) has on the physical outputs. Participants in the study were 10 male youth soccer players who took part in three 5v5, plus goal keepers, small sided games that lasted for 8 minutes with a 5 minute passive rest in between. It was found that when the playing area was larger, the total distance covered was higher (Large= 999.6±50m, Medium=908.9±30.6m, Small=695.8±37.1m) as well as maximum speed (Large=23.1±2.6km·hr^{-1}, Medium=20.4±1.9 km·hr^{-1}, Small=18.05±1.45 km·hr^{-1}) and distance covered per minute (Large=125.0±6.2m, Medium=113.6± 3m, Small=87.0±4.6m) were all also all found to be higher compared to that of a smaller pitch. Therefore showing that the size of pitch that is used with regards to small sided games within club training can impact upon the physical outputs as a result. As seen above total distance, distance covered per minute and top speed are all effected by the size of the pitch as with smaller areas it is harder to cover more distance as well as being more difficult to reach top speeds when you don't have the space in which to do so. This was further supported by Malone et al. (2017) who investigated the effect of pitch size within small sided games used for the sport of hurling. 24 hurling players were monitored during 4 minute small sided games where both GPS and heart rate monitors were worn. It was found that small sided games played with in a large pitch (80x20m) had greater running demands than that of medium (60x20) or small (40x20). Total distance covered at high speed (>17km·hr^{-1}) was found to be 354±111m on a large pitch, 254±72m on a medium pitch and 198±62m on a small sized pitch. This shows that the size of pitch that was used within the training sessions, across each of the 3 regions, could have had a significant impact upon the total distance and sprint distance covered. This is due to the findings that as the area that the small sided game covers will dictate potentially how easy or likely it is that large distances or high speed will be reached.

Following on from the content of the session, the numbers attending training could also have an impact. Clubs within each of the three regions were asked to report the average numbers that attend their training each week and whether these numbers are exclusively first team players or whether their training is also open to second team players also. Within Scotland and England the assumption is that it is more likely for both the first and second team train together and therefore numbers will be higher. In comparison within Europe it was expected that training would be exclusive to first team players. From the information collated from each club it can be concluded that the initial assumption was correct, when asking player for detail about the attendance of their club training sessions it was found that within Scotland training sessions were open to 1st and 2nd team players whereas in England and Europe training was more often exclusively for 1st team players with a few fringe players from the 2nd team being invited. It is thought that within training sessions involving less people, it is likely that more distance will be covered as there will be potentially less time spent waiting to be part of a drill or small sided game as numbers are low. However with higher numbers, small sided games are more likely to involve larger numbers (7v7 8v8) to ensure that everyone is included, therefore this could result in less high speed running and top speeds to be reached as there will be less space in which to elicit these results. This concept comes from the idea that if there is a larger number of people within a small area, then the m^2 that each individual has will be less than if there was the same amount of people within a larger space. When individuals have a higher m^2 in which to run then it is more likely that higher total and sprint distances will be covered due to more space in which to run and elicit maximal speeds.

A study by Hill-Haas et al. (2009) investigated the effects that different numbers within small sided games had on the physiological outputs of soccer players. Sixteen male youth soccer players completed three variations of small sided games (2v2, 4v4 & 6v6), the pitch size was altered to keep the relative pitch area per player consistent for each game format. It was found that players travelled less distance at speeds of 0-7km·hr^{-1} in the 4v4 compared with the 2v2 games (1128±10m and 1176±8m respectively). Average maximal sprint distances >18km·hr^{-1} were lower in 2v2 compared to 4v4 & 6v6 games (11.5±3.9m, 15.3±5.5m & 19.4±5.9 respectively) as well as in 4v4 compared to 6v6. It was therefore concluded that when small sided games formats decrease in size and relative pitch area remains constant, physiological workload increases. Further analysis was carried out by Randers et al. (2018) in which recreational football was investigated to gain more information on how the numbers involved within small sided games impacts upon the physiological responses. 11 untrained men took part in three football sessions comprising of 4x12minutes of 3v3, 5v5 or 7v7 with a constant pitch size of 20x40m. It was found that greater total distance and high speed running was covered during 3v3 (4.0±0.5km) compared to 5v5 (3.6±4.5km) & 7v7 (3.3±4.2km). It was also found that greater distances were covered at a sprint (>20km·hr^{-1}) in 3v3 (57±50m) compared to 7v7 (13±17m) and 5v5 (30±18).

Therefore it could be suggested that the difference found between club training sessions within the three regions are a result of not only the content of training but also the size and numbers included within the small sided games carried out. It is thought that if numbers within the group are larger as seen in Scotland that total distance covered could be lower as a result of a longer time waiting to take part in drills and also it being more likely that small sided games will be carried out to include as many individuals as possible and therefore potentially less space per person, meaning less opportunity to cover larger distances and reach top speeds. It could be suggested that informing coaches of the potential physiological effects that small sided games have with regards to numbers participating and size of pitch could be beneficial in ensuring the training session is adapted to the aims of the coach and or needs of the players.

4.1.3 Non Significant Findings

It can be concluded that for all other session types and variables other than those stated above, there were no significant differences. Therefore there were no significant differences for sprint distance between any of the three regions in each four session types, meaning that across all 3 regions there is a similar sprint distance covered. There was also no differences in total distance or sprint distance found between any region in any of the International sessions. This shows that the region that each player is based within does not affect their performance when comparing them within International training and again within International games, as the distance covered within each of these session types by all players does not largely vary and is not based upon their club location.

4.2 Between Session Analysis

Within this section all data was standardised to a rate of 60 minutes, as sessions of different durations were compared. The previous section (within session analysis) found that differences did occur when comparing outputs from the same sessions (Club Game v Club Game), the next step was then to investigate whether there were significant differences between sessions of different types (Club Game v International Game etc.).

4.2.1 Club and International Training

Within the comparison of Club and International Training it was found that across all three regions less distance is covered within International Training compared to that of Club ($p=0.009$). With regards to players based within Scotland for Club Training they covered on average 3.6±0.6km and 3.4±1.2 within international. With regards to the English based players they covered on average 3.9±0.9km during Club Training and 3.4±1.2km during international training. Finally European based players covered 4.1±0.8km during club training and 3.3±1.1km during International Training. This shows that on average Scotland covered 241m, Europe covered 836m and England covered 588m more during Club Training compared to International Training. Therefore to summmarise, there is a slight difference in distance covered within international training with those players based in Europe being found to cover on average slightly less than those players based in England and Scotland.

With regards to the potential reasons why these differences could occur, it is thought that those factors discussed within Section 4.1.2 will also be applicable with regards to Club and International Training. Content, Small Sided games and numbers within each session type will all have a potential effect. Separately, one potential difference that has not been previously mentioned, as it would only apply when comparing Club to International training is training week structure. With regards to club training it is common for training to take place twice a week usually on a Tuesday and Thursday. However with regards to International training there are normally several sessions that take place over the course of a weekend. Usually for International training there are 4 sessions, 2 on a Saturday and 2 on a Sunday. Due to the number of sessions within a 2 day period it is expected that the intensity of training will be lower. When analysing the content of each session it was normal that one session would be a high intensity small sided game with conditions, one session would be corners, another would be more technical or tactical and the last session would be of a moderate intensity based around shooting or defensive drills. It therefore could be suggested that less distance is covered across all three regions within international training due to the fact that compared to club training the frequency of sessions is higher over a two day weekend period, meaning that sessions need to be adapted to compensate for fatigue and therefore the most appropriate content to get the most out of players. Whereas for club training less emphasis is put on fatigue as sessions are only twice a week with a rest day in between.

4.2.2 Club and International Games

Club and International Games were then analysed and again it was found that significant differences did occur, in this case across both total distance ($p=0.008$) and sprint distance ($p=0.012$). Within Scotland it was found that the average player covered more total distance in club games 6.0±1.5km when compared to international games 5.8±0.8km and for sprint distance there was found to be no significant difference between the two. For English based players it was found again that they covered more total distance and more sprint distance in club games, with 6.1±1.1km in club games compared to 5.9±1.0km in international games and for sprint distance 594±200m in club games and 549±204m within International games. However, conversely players based in Europe were found to behave oppositely to England and Scotland described above and covered more total distance and sprinted more in international games compared to that of club. Within club games European based players covered 5.1±1.2km and sprinted 480±205m compared to international games where they covered a total distance of 5.6±1.0 and sprinted 545±182m. A study by Lythe and Kilding (2011) looked to determine the physical demands of elite male field hockey. Within this study 18 elite male players participated within 5 matches during which GPS was worn and analysed. It was found that the average distance covered was 6.7±2.0km. High Intensity running (>19km·hr^{-1}) was on average 479±108m. When comparing this to our findings, it can be seen that the figures reported by Lythe and Kilding (2011) are larger than that reported for all three of the regions. Separately, a study by White & MacFarlane (2015) found the total distance for male Scottish international athletes, within international competition, to be more similar to our findings, at 5.9km which is the same as that covered by players based within England (5.9±1.0km), slightly more that that covered by Scottish players (5.8±0.8km) and more than that covered by those based within Europe (5.6±1.0km).

A study by Jennings et al. (2012) looked to investigate the difference between international and club games. Two sets of 16 athletes, one group performing in the Australian National League (ANL) and the other in the International tournament Champions Trophy (CT) were compared. It was found that international competition was found to increase the running profiles of hockey players across all positions for total distance and high speed running (>15km/hr). When both groups were compared it was found that average distance covered was 9776±720 m and 8589±623 m for CT and ANL matches, respectively. International players performed 42.0% more High Speed Running (2294±433 vs. 1652±416 m) and 7.6% more Low Speed Running (7441±511vs.6905±447m) than national players. It was also found that the Australian hockey league players showed a larger decrement across both halves compared to those competing in the Champions Trophy. When comparing these findings to those above it can been seen that only European based players covered more within international games compared to club games with both English and Scottish based players behaving oppositely from the Jennings study by being found to cover move total distance in club games compared to international games. The average total distance covered was also found to be much larger in Jennings findings than that found for our Scottish, English or European based players.

When investigating why these differences potentially occur across the regions, as mentioned previously substitutions were identified as a reason which could impact upon the total distances reported when comparing games of any type. Specifically within this section, club and international games have been compared, with club games having been reported to elicit a higher average total distance than that of international training for both Scotland and England and Europe being found to behave oppositely. A factor effecting this could be if there is a significant time difference that each individual is spending on the pitch within club and international games. As previously described within each of the three regions it was suggested that differences in 'on pitch time' occurred which were not clear, due to the fact that within club games there was no way to easily track the time each player was on the pitch or substituted. However, within international hockey, substitutions were timed and tracked for every international game. When analysing the times that each player from the three regions spent on the pitch during international games it was found that there was little difference between each region (England 36.7, Scotland 36.6 and Europe 36.8 minutes). Conversely as was previously mentioned, it is expected that there will be substantial differences between the on pitch time of each individual dependent on their region with regards to club games.

A separate factor that may also have an impact on the findings is the potential difference halves or quarters have on the results. During the collection phase of the study club games across the 3 regions were all played within the structure of two 35 minute half's. However, conversely all international hockey games that were played adopted the structure of quarters, whereby the game duration was 60mins instead of 70mins and the structure was four 15minute quarters with a 2 minute break between quarters 1 & 2 and 3 & 4, with a half time duration similar to that of half's. The duration that the two different style of games last (60 v 70 minutes) should not affect the results, as the data was standardised to allow for this variation. However, what can't be accounted for are any potential differences as a result of the more frequent breaks of 2 minutes between quarters and potentially shorter substitution rotation spells for each individual during each quarter. In a study carried out by Ihsan (2018) the effect of the new quarter format was investigated. 28 male international hockey players were analysed via GPS devices worn across 14 matches over a year long period. It was found that there was a progressive decline in total distance in Quarter 2 (2072±141m) to Quarter 4 (2055±212m) compared to Quarter 1 (2171±195m). It was found that the decline in total distance was due to a decrease in low intensity activity (<15km·hr) with high intensity running (>15km·hr) being found to be consistent throughout. Positionally there were also differences found with defence accumulating the lowest total distance at 7631±753m on average compared to midfielders and forwards. Therefore it was concluded that within the new format of four quarters there was a progressive decline in total distance across the four 15 minute periods, with high intensity running being maintained throughout regardless of playing position.

4.2.3 Club Games and Club Training

Club Games and Club Training were further analysed and it was found that again both total distance and sprint distance were found to show significant differences. Within all 3 regions, for both variables, it was found that there was more total and sprint distance covered in club games when compared to club training. Within the region of Scotland it was found that within club games an average of 6.0±1.5km was covered compared to 3.6±0.6km within club training. With regards to players based in England a similar pattern was also found with 6.1±1.1km covered in club games and 3.9±0.9km covered within club training. Finally for players based within Europe an average of 5.1±1.2km was covered in club games and 4.1±0.8km was covered within club training. Therefore on average Scotland cover 2.5km, England cover 2.2 and European 904m more during Club games compared to that of Club Training.

The same pattern was found also for sprint distance with Scottish players covering 574±189m during club games compared to 254±185m during training, European based players sprinted 470±205m within club games compared to 262±186m in club training and finally English based players covered 594±200m in club games compared to 243±169m in club training. Therefore on average Scotland sprinted

331m, Europe sprinted 219m and England sprinted 351m more in club games compared to club training.

This is different to the findings of White and Macfarlane (2015) who found that the absolute total distance covered during full training containing small sided games, running, tactical and full game elements was greater than that than of the total distance covered during club games at 7.3km and 5.9km respectively. This is the opposite to our findings as club games across all three regions (England Europe & Scotland) were found to cover a larger total distance than that of club training.

When analysing the results, although differences occur for both club training and club games across all three regions, Europe in particular stand out as having least difference between the two sessions at 904m in comparison to England and Scotland with an average difference of 2.2km and 2.5km respectively. Therefore it could be suggested that the training that takes place in Europe in comparison to that in England and Europe is most suited to the demands of a game.

In a study carried out by Gabbett.T (2010) analysis was carried out in elite women's field hockey into any potential differences between game based training and competition. Fourteen elite women's field hockey players performance within 19 training sessions focused around game based drills and 32 Australian Hockey League appearances were analysed. Data was reported into 3 velocity categories (low intensity: 0-1$m \cdot s^{-1}$, moderate intensity=1-3$m \cdot s^{-1}$ & high intensity=5-7 and >7$m \cdot s^{-1}$) and it was found that players covered on average 6.6km (range 3.4-9.5km) over the course of a match, which is slightly more than the figures found within our study for England and Scotland (6.1±1.1km and 6.0±1.5km) and considerably more than that of Europe (5.1±1.2km). In comparison to competition, game based training sessions resulted in more time spent in low-intensity activities, with less time being spent in moderate and high intensity zones. It was therefore concluded that game based training is likely to be useful for improving skill level, however to elicit a more demanding physiological response to align training closer to that of games, modification of the group size and possibly the complexity or design of the drill would be recommended.

4.3 Speed Zones

With regards to speed zone analysis it was found that there was a difference in distance covered between each of the 5 speed zones when comparing all 4 regions together. It was found that 62% of distance covered was in that of speed zone 1, 19% in speed zone 2, 12% in speed zone 3 and 5% and 2% in the remaining speed zones 4 and 5. Each of the 4 session types were also looked at individually and a similar pattern was also found and can be seen in Table 4.1 below, however although a difference occurs they were not found to be statistically significant. It was clear that percentage distance decreases as the speed zone increases across all 4 session types, however when analysing each in more detail less distance was reported to be covered in speed zone 1 in games compared to training. This means that on average within club and international games less distance is spent walking compared to that of club and international training. This is to be expected as it is known that within training sessions there will be breaks between drills as well as tactical or technical discussions which will involve more walking. A study by Spencer et al. (2004) looked at fatigue over the course of an international tournament across 3 games in 4 days, investigating specifically the time spent in the 5 different speed zones. It was found that the percentage time spent standing significantly increased across the 3 games of a tournament (7.4±2%, 11.2±2.7% and 15.6±5.6% respectively). Conversely, the percentage time spent jogging significantly decreased from Game 1 to 2 and from Game 2 to 3 (40.5±7.3%, 34.8±7.4% and 29.4±5.7% respectively). Although the metric being percentage time, is different from percentage distance reported above, the pattern of reduced time in the higher speed zones compared to increased time in speed zone 1, constituting a walk, is found not only across a game but also across multiple games in a common tournament setup. When comparing these findings to our average of international games, it can be found that 52% of the total distance covered within our findings is at a standing or walking pace, with 23% at a jog and 15% at a low paced run and then only 7% at and 1% classed as a high speed run or sprint respectively.

Average Percentage Distance Covered in Each Session Type (%)					
	Speed Zone 1	Speed Zone 2	Speed Zone 3	Speed Zone 4	Speed Zone 5
Club Game	55	22	14	7	2
Club Training	68	16	10	5	2
International Game	52	23	15	7	3
International Training	70	16	9	4	1

Table 4.1 Table of average percentage distance covered within each speed zone across the 4 session types

Once the data had been plotted as a whole and group differences in percentage speed zone had been analysed, it was then found that there were two individuals both from the region of Scotland who appeared to be performing differently from the rest of the group (Figure 4.1 and 4.2), not just differently from that of their fellow players in Scotland but including those based in England and Europe also. When further analysis on the two individuals was carried out, it was found that they both performed similarly, each covering more percentage distance in speed zones 2 and 3 and less distance in speed zone 1 on average across a season (Figure 4.3). This pattern occurred for both individuals across all 4 session types investigated, showing that they covered more distance at a jog to slow running pace and less distance at a walking pace.

When investigating why this difference might have occurred the players clubs and positions were identified in case they had a bearing on the results. It was found that both individuals played within the same Scottish club and positionally for club both played the within the midfield, however for international commitments one played as a striker. Therefore, it was concluded at this point that the position seems to have less bearing on the results found, as differences occur regardless, within both club and international sessions. This leaves the commonality of club team and so gives the idea that something that both players are doing within that club setup is impacting them across the full season, for both club and international commitments. To gain further information, seasonal analysis was carried out to view where the differences occurred and from this it was found that from the start of the season in September til April, in the last month of club before International commitments begin, both individuals were seen to behave differently from the rest of the subjects. It was then found that from April until the end of the International season in August, the 2 individuals performed similarly to that of the rest of the group (Figures 4.5 & 4.6). This finding supports the previous suggestion that the differences are most likely to occur as a result of the club season.

Therefore, with the fact that differences occur between September and April, which is the months of the club season and also taking into consideration that both players play for the same club it was concluded that the factors impacting upon the two players differing behaviour is most likely to come from that of club training and therefore further analysis would need to be carried out on this session type to observe the speed zones in further detail. As the differences were found when averages across a full season were analysed it was therefore important to obtain a better understanding of whether the two players performed differently within club training, consistently throughout the season or whether larger differences within individual sessions were the cause.

Within Appendix VII and VIII the percentage distance covered within speed zone 2 and 3 throughout club training for both subjects (Scotland 4 and Scotland 6) have been plotted. This was carried out to observe whether the differences seen within the group average graphs are the result of independent training sessions or were a norm throughout various sessions within a season. From Appendix VII and Appendix VIII it can be seen that both individuals behave similarly. It is important at this point to note that when comparing both subjects, Scotland 4 has slightly less sessions to compare, which could be down to injury at the end of the 1st half of the season (November to December 2016) or unavailability, whereas Scotland 6 has sessions that start in November 2016 and continue through to May 2017. Therefore as a result our further analysis will investigate subject Scotland 6 in more detail to ensure the lack of a full seasons data throughout the club calendar is not a factor. What is clear however is that both individuals percentage distance in speed zones

2 and 3 appear to decrease within the month of April 2017 and stay at this level until May/June 2017 when the club season finishes. The decrease is most apparent within speed zone 2 which for Scotland 6 decreases from 54% in November 2016 to 15% in May 2017.

Diary and GPS entries from November 2016 to April 2017 were re-analysed to see if there was a clear reason that such a substantial decrease occurred. When investigating GPS data again for each individual, sprint distance was plotted to observe whether any patterns occurred. With regards to subject Scotland 6 it can be seen from Appendix XIV that from November 2016 until April 2017, the point at which the percentage distances reported previously in speed zones 2 & 3 are seen to decrease, sprint distance covered within club training is relatively consistent ranging from 500 to 650m. However, from April to May 2017, when previously it had been reported that distance within speed zones 2 and 3 decreased, sprint distance covered becomes more varied ranging from 75m to 1540m, which in some cases is more than double that of the average covered from the beginning of the season.

In order to observe the effects the increased sprint distance had on the speed zone analysis, the percentage distance in speed zone 5 was plotted and from Appendix X if can be seen that a similar pattern is observed with an increase in percentage distance covered from November to April. This is to be expected as with more sprint distance being covered within the sessions from April to May 2017, there is a larger percentage distance covered within speed zone 5. Following on from this analysis, the distance covered in speed zones 1 and 5 were plotted (Appendix IX) to see again if any pattern occurred. It was found that due to the variation in sprint distance from April to May and subsequent increase in distance covered within the highest speed zone 5, the distance covered within zone 1 at a walking pace also increased. It can therefore be concluded at this point that the sessions included within club training from April to May 2017 had a more varied intensity, with sprint distance covered ranging from 100-1500m. Subsequently this resulted in an increase in distance covered in speed zone 5 but also an increase in distance in speed zone 1 at a walking pace. This shows that during the first part of the season where sprint distance was lower and more consistent, more percentage distance was spent within speed zones 2 and 3. However, when sprint distance became more sporadic in the months of April to May, so did the percentage distance covered in speed zone 1 at a walking pace, this is thought to be a result of the increased intensity meaning more walking is required to compensate and recover.

Although this analysis potentially explains the reason for the drop off in distance covered in speed zones 2 & 3 within the months of April and May for Scotland 4 & 6, it does not explain why from November to April both subjects are reported to do more jogging and less walking than the rest of the individuals within all three regions. One potential explanation is that the two subjects, Scotland 4 & 6, consistently cover a smaller and more consistent sprint distance, compared to that of the subjects within the other regions, who's sprint distance is more varied. If this is the case it would mean that during the months of November to April subjects Scotland 4 and 6 behave differently from the rest of the analysed players by having less variation in the sprint distance recorded or intensity of the distance they cover and that from April to May something within their training or season changes to result in them behaving the same as their international teammates.

In order to investigate this further to identify whether the rest of the regions players sprint distance does vary throughout the season, one player from each of the three regions club training sessions were analysed and plotted. From Appendix XI, XII and XIII it can be seen that as expected the three subjects Scotland A, Europe B and England C have a varied sprint distance across a season's worth of club training sessions. For 'Scotland A' across the season sprint distance ranges from 215m-855m (Appendix XI) , 'Europe B' ranged from 160-990m (Appendix XII) and finally 'England C' ranged from 2-1670m (Appendix XIII) over the course of a season, in comparison to Scotland 4 & 6 that from November to April ranged from 250-650m.

Therefore, as expected when total sprint distance is higher, the distance covered in speed zone 5 also increases to reflect the increased speed and as a result there is a similar pattern of behaviour with regards to speed zone 1 to compensate for the increased intensity. When a lower sprint distance is covered, less distance is spent within speed zone 1 due to the decreased intensity and therefore less need to walk, meaning that more distance can be spent in speed zones 2 and 3 at a jog or slow running pace. With regards to the two subjects found to behave differently it can be concluded that the content of their club training sessions during the months of November to April elicited a constant and fairly low sprint distance total from week to week (~500-650m) which in turn resulted in less time walking (Speed Zone 1) and more time jogging (Speed Zone 2 & 3). In comparison the rest of the regions showed a more varied sprint distance total from week to week, however what was found was that when training involved larger distances sprinting (speed zone 5) less time was spent jogging (speed zone 2 & 3) and more time was spent walking (speed zone 1) to recover from the high intensity bouts of activity.

In summary, it is therefore important that coaches understand the physiological effects that their training will have on the players. As previously mentioned altering factors such as numbers and pitch size during small sided games will change demand that are out on the players and therefore impact upon their physical outputs. Understanding the effects that certain sessions will have on players will ensure coaches get the most from the session but also improve more specifically certain elements of players tactical, technical or physical aspects of the game.

One of the potential factors that could impact upon the speed zone findings, is the application of zones within the group. The speed zones set were chosen as a result of previously literature, however individual speed zones have been investigated more frequently as it is thought that this could impact upon the accuracy of the results. In a study carried out by Casamichana et al (2018) the effects of generic and individualized speed thresholds within field hockey were investigated. 16 males players from the same club participated in the study, the peak speed of each participant was established at the end of the data collection period through analysis of all training and playing data throughout the season and compared to the default thresholds of the GPS manufacturer. The peak speed of each of the players was then used to split them into three groups slow (5 players at 29.2-30.2km·hr^{-1}), moderate (6 players at 30.7-31.5km·hr^{-1}) and fast (5 players at 32.2-33.7km·hr^{-1}). It was found that significant differences were observed between generic and individualized speed zones for the distances covered in moderate, high and very high thresholds. It was found that positionally midfield (G=645.3±167.1m vs I=545.6±241.6m) and forwards (G=638.7±28m1 vs I=517.2±144.8m) high speed running was over estimated within generic analysis and defenders very high speed running (G=50.3±39.6 v I=65.1±48.9m) and sprinting (G=0.09±0.67m vs I=0.41±1.71m) was underestimated.

Separately, in a study carried out by Abt and Lovell (2009) where high intensity running was examined using a default zone within a ProZone match analysis system in comparison to an individualised ventilatory speed threshold zone. 10 professional soccer players took part in a treadmill test to obtain their maximal ventilatory threshold (VT), match data was also analysed though a ProZone match analysis system where high intensity running was classed at (19km·hr^{-1}). It was found that the mean high intensity running speed, based from the VT test was 15 km·hr^{-1} (range 14-16 km·hr^{-1}), which was less than the default speed of 19 km·hr^{-1}. It was therefore found that high intensity running is substantially less when comparing the default figure to that of the VT, resulting in the ProZone match analysis system substantially underestimating the distance covered within a high intensity speed zone. This shows that default speed zones can over or underestimate the distance covered within different intensity speed zones depending on the individuals and also the position that is being measured. Therefore, when relating this back to the findings reported above it results could potentially have been more accurately reported if individualised speed zones had been set specific to the maximal speed of each player, which in turn could have impacted upon the results reported.

4.4 Case Study

Throughout the analysis of the results section and subsequent discussion, several variables have been outlined most frequently surrounding the content of training or the differences between individuals. It is important that it is understood that the data points reflect actual players that individually will each have their own differences that may impact upon the results reported. It has been taken into consideration that as this study looks to audit the Senior Men's Hockey team, just looking at the players as data points, without any real context could mask some key information that might explain the pattern of results displayed throughout the results sections and subsequently may allow more conclusions easier to report. In order to investigate these individual differences in more detail, three case study examples have been taken, one from each region to give some additional information on the player, their club, position and fitness level to potentially help understand some of the patterns of results reported throughout.

The players chosen to be included as case study examples have been done so as they have shown some unexplained individual variety in one or more of the analysis sections as part of the reported results. It was thought that by looking at these players in more detail, answers to some of the questions raised by the pattern of behaviour reported across the analysis might be given and in turn these answers might also be applicable to some of the other unexplained variety shown within certain other areas of the studies analysis.

4.4.1 Player Background

Within the region of England the individual chosen will be referred to as 'England A' and can be found on each of the relevant figures within the results section with an 'A' below each of their designated axis titles. This particular individual was chosen due to both the varied pattern in their reported data. Within total distance and sprint distance club game analysis (Figures 2.1 and 2.3) it can be seen that the subjects data ranged from 4.3 to 7.8km. With regards to the sprint distance a similar pattern occurs with the data points ranging from 526 to 1044m. Moreover within International games it can be seen that the range of data reported is similar with total distance ranging from 3.5km To 7.5km and sprint distance ranged from 430m to 973m. By looking into the individual in more detail as part of case study it is hoped that the potential reasoning for the large but similar pattern of data points across both International and Club games may become clear.

The subject at the time of the data collection was 25 years of age and had been playing within the English league for 7 years and within that time has only played for two teams. Within both his domestic clubs and international team, England A has consistently played within a midfield position role and has done so for the majority of his career. Out with hockey the subject maintains a full time office based job and has done so for a number of years, resulting in him having to obtain an effective work and hockey balance allowing him to find time to train out with office hours to maintain his place within the international setup

Within the region of Europe the individual chosen will be referred to as 'Europe B' and can be found on each of the relevant figures with a 'B' below each of their designated axis titles. This particular individual was chosen due to the very similar pattern of displayed data point across both club and international commitments. Europe B was also chosen as within most of the figures they display an unusually low range of data points in relation to not only those within their region but also the group as a whole. With regards to Club Games the total distance ranged from 3.4 to 7.9 with the majority of data points falling between 5.4 and 7.9km. With regards to sprint distance within club games 59m to 560m again with the majority of data points falling between 190m and 560m. In comparison to the other subjects within Europe, European B appears to show a significantly lower patter of distances in comparison to the group, that on average have data points regularly ranging from 300-900m. A similar pattern is found within that of International Games with the player 'European B' covering distances between 3.8km and 5.9km with the groups average falling between 4.0km and 7.2km. Again a similar pattern is seen within sprint distance with 'European B' covering 168 and 471m with the group average for that region again being shown to be higher at 401m to 932m.

The subject highlighted at the time of the data collection was 26 years of age and had been playing within the Dutch leagues for 6 years for again just 2 teams. Before his move to Europe the player had played his full hockey career from the age of four at the same club within Scotland. Positionally the individual has played consistently the same full back defensive position for the majority of his career within both club and international teams. Similarly to a lot of the team, Europe B has a fulltime office based job where we works throughout the week and so training had to be carried out around these working commitments

Within the region of Scotland the individual chosen can be referred to a 'Scotland C' and can be found on each of the figures within the results section with a 'C' below their axis title . This particular individual was chosen due to the variation in the data points reported across both club and international commitments and within both training and game session types. Within club games Scotland C was found to cover a range of between 6.3km to 8.5km and a sprint distance of 510m 1098m. In comparison to that covered at International Games the subject was seen to cover 4.3km to 7.6km and sprint distance of 399 to 856m.

The subject was aged 22 at the data collection start point and had played all of their hockey within Scotland primarily for one club. Positionally for their club they were used within a variety of roles however found themselves mainly playing within an attacking midfield role. Separately when playing internationally the individual was played within defence as a half back (right or left defensive wing). At the start of the data collection Scotland C was a relatively new member to the senior squad, having progressed through the U21 pathway he had taken a year out before being invited to re-join in 2016. At this stage the subject as attending University and so was combining his studies and both club and international hockey.

4.4.2 Fitness Level

When considering the potential variables that could have impacted the pattern of results shown above, the first area refers to the physical fitness of the players in question. With regards to the Scottish Senior Men's Team, fitness testing was carried out approximately twice a year. Due to the remote nature of the program, as described previously, this brought some logistical issues, one of which was the implementation of regular team testing throughout a season. The most commonly used test with the team was that of Buchheit's 30:15 Intermittent Fitness Test. The test is described in a study by Buchheit et al (2009) as 'a graded intermittent and shuttle field test, leads to a maximal running velocity (V_{IFT}) that is determined through an effort involving physiological variables similar to those solicited during shuttle interval training sessions (i.e. ability to change direction and both aerobic and anaerobic energy systems).' The test begins at a speed of 12km/hr and increases by 0.5km/hr at each stage. The test is made up of 30 seconds of work with 15 seconds rest, within the 30 seconds a series of beeps dictate the running speed. The athlete has to run 40m shuttles that have 3m zones positioned at either end of the shuttle. As the running speed increase as do the beeps sounded and termination of the test is elicited when an individual does not enter the corresponding zone before or on the sounding of the beep on two consecutive occasions. The speed that the individual previously completed before their removal from the test is taken as their final score. The test is commonly used by team sports athletes because of its simultaneous maximal aerobic function, anaerobic capacity, neuromuscular and COD qualities and inter-effort recovery ability (Bucheit, 2009). When investigating the scores elicited across a range of team sports athletes it can be seen from Figure??, taken from Buchheit's review paper (2010), that the speeds reached vary depending on the level, sport and gender of the athletes taking place. Within Figure?? It can be found that the field hockey example, taken from the English men and women's team, is found to show that both genders score highly on the test, with the men sitting second from top with an average score of 21km/hr and the women with the highest score for their group with an average of 19km.hr.

Taking this into consideration the Scottish Senior Men's hockey team when tested during the data collection phase of this audit scored an average of 21.5, 0.5 lower than that of the average reported by Bucheit. When isolating and analysing the subjects in more detail it was found that as expected there was individual variations in their 30:15 fitness scores over the course of the season. The test scores reported were recorded at the start of the international summer campaign and showed England A to achieve a level of 22km/hr, Europe B at 20km/hr and Scotland C at 20.5km/hr.

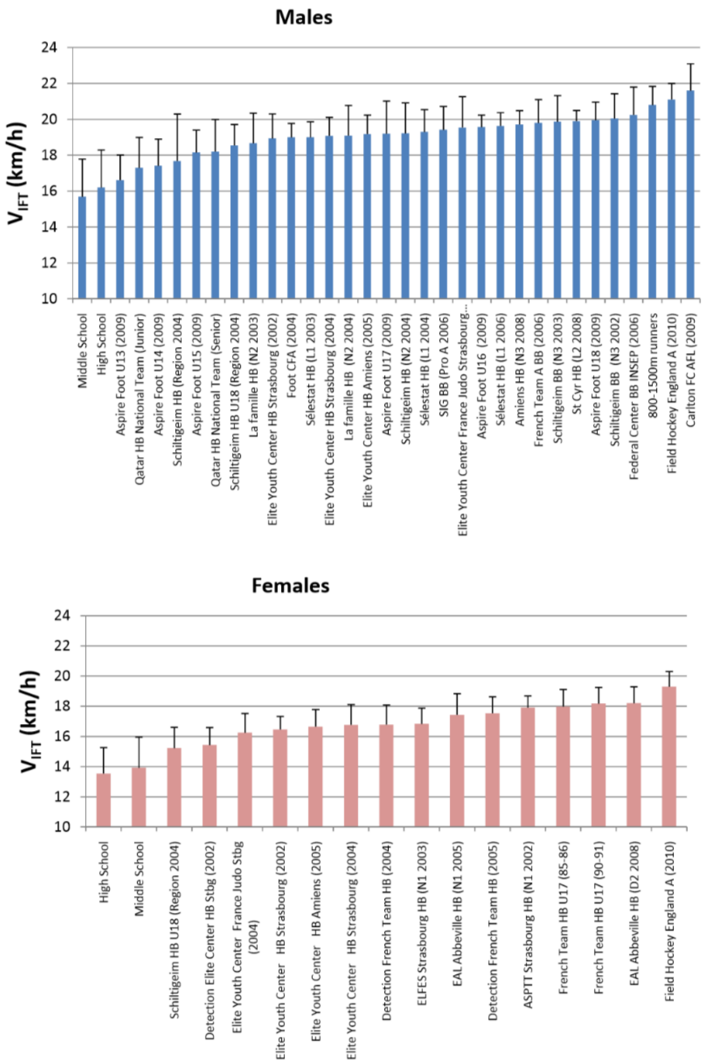

Figure 5.1 VIFT values measured for different teams (male and female) in different sports and competing at various levels (Taken from Buccheit 2010 ‘The 30:15 Intermittent Fitness Test: A 10 Year Review’)

4.4.3 Position

Another factor that should also be taken into consideration at this point, is the position of each of the subjects and the potential impact this could have on the data collected. With regards to the fitness data it can be seen that England A scores the highest, reaching a 30:15 level of 22km/hr with Europe B scoring the lowest at 20km/hr which is 1.5 levels lower than the squad average for that given test. However, what we know to be true is the variation in position across each of the case study examples. This poses the question that could the position that each individual plays paired with their fitness test results impact upon the pattern of their results reported? Taking this into consideration, it could be suggested that as Europe B is a defender there is less requirement for him to cover as much distance as the other positions, such as England A for example, who is a midfielder or Scotland C who plays across both midfield and defensive lines. The effect position has on distance is investigated further in a study by Lythe and Kilding (2011) that looked at the physiological responses of elite field hockey. It should be noted that this study was particularly unique as it was one of the few studies found that split the defensive line into full and half back roles. This is specifically important as within the Scottish senior men's team it is apparent that the role of both the full and half backs is significantly different, with the half backs regularly having more freedom to adopt a more attacking wing position alongside their defensive duties. Alternatively the full backs will more often find themselves sitting in a deeper, holding position. This is further supported within the Lythe and Kilding study as full backs were described as being 'unique' with regards to their positional role. Their role in particular was described as 'the ability to organise, control and manage space in the defensive half of the field'. Additionally it was found that despite being on the pitch for the highest amount of time in comparison to the other positions, full backs had the lowest average speed, covered the least total distance and performed a greater proportion of their distance at a low intensity and a lower proportion at moderate and high intensities. Across all other position types it was reported that unlike the full backs they all performed similar patterns of behaviour. In a separate study carried out by Reilly & Borrie (1992), although carried out within female field hockey, a similar pattern of conclusions were drawn. It was reported that forwards displayed greater speed, power and strength necessary in attacking play. This was partly supported in a study by Verma et al. (1979) which stated that forwards had a higher vertical velocity in a stair run test than backs and halfbacks; however, goalkeepers had a higher vertical velocity than the outfield players. Furthermore in a study by Jennings (2010) it was reported that the average total distance covered varied across a tournament within in three positions of forwards, midfield and defence. The mean tournament total difference for all of the countries involved in the 2009 Men's Champions Trophy (England, Korea, Holland, Germany and Spain) was reported. It was found that the position of midfield covered the largest total distance across the tournament at 10,160±215m, forwards covering 9819±720m and defenders covering the least at 9453±579m. This further supports our suggestion that positional difference could be a significant factor effecting the pattern and variability of results shown not only across the three case study examples but also across the wider group.

When looking back at the pattern of activity shown across the results section, positions for both club and international commitments could impact the data points reported. With regards to the subject Scotland C the position that he plays across club and international commitments could have had a significant impact on the results reported. As stated previously the position line played within has been shown to impact upon the distances covered, with midfield and forwards typically covering more than that of the defence. Within club games Scotland C was found to cover a range of between 6.3km to 8.5km and a sprint distance of 510m 1098m. In comparison to that covered at International Games the subject was seen to cover 4.3km to 7.6km and sprint distance of 399 to 856m. This shows that when playing predominantly within the midfield line at club, the player covers a smaller and slightly higher average range of total distance and sprint distance than that covered when playing defensively with Scotland internationally. It could be suggested that due to the players common selection into the half back position of the defensive line that this has an impact on the bigger range of total distance figures reported, as a result of tactics or opposition. Depending on the tactics or opposition the role of the half backs could vary significantly. In the most basic terms, if the opposition are more attacking then the role of the half back could be to sit deeper defensively and as a result their total and sprint distance figures could reflect the tactical or opposition influences of the game instead of their physical abilities. Separately, if the opposition or style of game meant that Scotland found themselves in a more attacking role then the half backs could find themselves supporting the attacking play and therefore more runs predominately up the wing could be carried out.

In contrast with regards to Europe B, although there were still differences within the total and sprint distance figures reported between club and international commitments the differences could be described as lesser or more consistent than that of Scotland C. Within club games Europe B covered an average of 3.4-7.9km and 59-560m of sprint distance in comparison to the 3.8-5.9km and 401-932m covered within international games. Again, as mentioned previously tactics and opposition will play a part in the differing results. What should also be taken into consideration alongside the opposition played is the standard of tournament that the individual would have participated in and therefore how this potentially impacted upon the role that they played as a result of the opposition played against. For example across the data collection period within the international setup, Europe B played within World League 1 in Glasgow where 2nd place was achieved with the team ranked 1st, World League 2 in Belfast where the team finished 3rd with a tournament ranking of 4th, World League 3 where a seeding of 10th and final placing of 10th in London where and finally European B Division in Glasgow where Scotland gained promotion to the A Division and finished 1st having a tournament ranking of 3rd. It therefore could be suggested that through a period of relative success for the Scottish team there will have potentially been less defensive games where Scotland would be sitting deep and absorbing the pressure from the opposition and more of an attacking style of play. Therefore the standard of the opposition could impact upon the data displayed.

4.4.4 Game Timings and League

Finally, what should also be taken into consideration is the potential importance of each player within their club team. As has been stated previously within international games all positions are run on timed rotations, this means that the 16 outfield players that are selected will play a role in the match regardless of the starting team. As a result the coaches selected starting 11 (10 outfielders and 1 goalkeeper) will only be the team for approximately three minutes until the rolling substitutions begin. This is different to a lot of sports, specifically football, where the starting 11 play the majority of the match, this is not the case within hockey, not taking injuries into consideration everyone should play equal minutes unless otherwise stated by the coaching staff due to tactics. With regards to club games, as has been previously stated the time played by each player across all club games is unknown (this has been discussed further in section??). Although there cannot be too much emphasis placed on the variation of time between games due to lack of control from a club perspective, what could be significant is club lead tactical or league differences. Tactical differences could be linked with that discussed in the previous section referring to positional differences and their effect on the data presented. For example as previously associated with position, the attacking or defensive nature of the game could have an influence over the behaviour of the player. Separately, as also mentioned previously, from an international point of view the standard f tournament or from a club perspective the league position (more in section??) could also impact the behaviour and therefore the data of the players reported. One factor not mentioned with regards to the case study examples is the way in which the team, club or international, play the individuals within their team, as the difference in roles could result in more or less running depending on the structure adopted and the personnel available. For example with regards to Europe B who played consistently in a full back position for both club and international team it has been suggested that there is less variation in his total distance figures due to the fact he will play within the same line and so his role will always be the same, with running demands only changing depending on the style of opposition. However when referring to team tactical and league differences what could also impact is the way teams use specifically their full back position. Within hockey full backs can be used as a 'marking defender' or as a 'free man'. The difference between the roles refers to the individuals role within the defensive tactics of the team. It is common that one of the full backs will be nominated as the 'free man' it is his role to pick up any unmarked players but most commonly he should not have anyone to mark and should play in support of the other defenders who will be tracking their designated men. The difference between the two roles could effect the results, as it could be suggested that the 'free man' will have to do less running than that of the 'marking defender' due to the fact the players marking will have to track the runs of their designated opposition forward. With regards to the data presented the differences in club and international running distances between club and international games could be a result of the players role within in the team. With regards to Europe B it is known that for his club team he was consistently played within the 'free man' role, however with Scotland internationally he was more commonly played as a 'marking defender'. Therefore, although there is limited data to support this suggestion, the style of play or tactical decision or designated roles of the players, due to coaching or opposition could also impact the results show.

4.4.5 Summary

To conclude this section, the aim of this particular chapter was to give more information on the individuals reported in the data and to highlight the potential differences that might be effecting the results. Within the results section it was clear that there are always going to be differences as a result of a number of factors, that cannot always be accounted for. Within a team sport, with a variety of subjects, it is always going to be difficult to give the background information on each individual to account for the variety in the results. However, through the three case study examples given, more information that should support and aid the understanding of the results and discussion sections. Alongside this they should also be an example that although the team are grouped, analysed and averaged as a whole group or within their regions, there are subjects that played and trained behind each data point and as a result a number of factors that will have impacted the way that they behaved within any given session. Where possible ways to limit the potential variables that could impact upon the results have been implemented but with a study of this kind it is not going to be possible to control every factor and so recognising and highlighting there is important.

4.5 Limitations and Variables

When reviewing the study, variables and limitations were identified that could have impacted upon the findings reported above. Variables and limitations were taken into consideration in the initial planning stages, however as expected not all were able to be eliminated.

4.5.1 Variables

The first variable that was identified was the number of subjects within each of the 3 regions included. As there is no control over the teams that each player choses to compete for, it was not possible to control the number participating within each of the subject groups. Within the national setup it is common each season for individuals to move, not just within leagues but also to other countries in order to improve their hockey. Within the study Europe has slightly less subjects in comparison to England and Scotland which could have impacted slightly on the reported results.

As mentioned above, due to the lack of control over the number within each region it was also difficult to then account for the position that each player was assigned. It was out with our control where both International and Club coaches decided to play each subject and so there may have been individual variations that could not be accounted for.

The standard of club hockey that each individual played, within each region could again be described as a variable that was out with control. As with the position and region of the player there was no control over the club team that any of the individuals played with over the course of the season. It was expected that due to the fact the player was of an International standard that their club team would also be of an appropriate level. However, there was variation in the league level that each player played within and against, that could not be directly influenced.

Finally the last variable is related to the different structure of matches included within the study. As previously stated the data was standardised to 60minutes to account for the differences in match duration with club games lasting 70 minutes with two 35 minute half's and international matches being 60 minutes with four 15minute quarters. However, although the difference in timings have been taken into consideration, what can't be accounted for is the increased breaks within the 60 minute quarter matches. When comparing the 60 and 70 minute games there are two extra 2 minute intervals between quarters 2 and 3 and 3 and 4 which are not included within the 70 minute match. It also should be noted that substitutions may also run differently due to the fact that teams rotations may be different due to the different structure.

4.5.2 Limitations

Alongside the variables there have also been limitations identified. The first of which has been mentioned previously and is the unknown duration that each individual spent on the pitch. Within International games, time on the pitch is tracked for each individual and therefore at the end of each match the total time each player spent on the pitch can be compared and analysed. However, tracking of substitutions is not something that commonly is monitored within the club game currently and so with the data collection coming from the remote upload of GPS, it was impossible to know how long every player spent on the pitch, for each club over the course of a season. This limitation also applies similarly to that of club training, through the diary reporting process each player was asked to report the duration of their training session but this relies on the players correctly reporting the time and also does not account for their activity duration or allow for any time standing discussing tactics or warming up.

Following on from this, content of training is another aspect that could be seen as a limitation and again each player was asked to report the content of each session in as much detail as possible. However, this relies on each individuals interpretation of the drill and so although compliance in uploading session details was good, the reliability of the information could be questioned. In the starting phases of data collection it was a possibility that each club coach would be contacted and weekly session plans would be received from them. However, with this involving approximately 15 club coaches the feasibility of regularly receiving the information would have been difficult and so the information was instead retrieved through the self-reporting diary format. It was considered at the outset of the study to investigate the effect of training on different nights of the week with regards to the proximity of the game. As stated earlier, the majority of clubs training sessions occurred twice a week, however this was no the case for everyone with certain club training three times a week and even cases of double training sessions within one day. There is also the variation in game days, it is common within hockey for there to be two games in a weekend at least 3 to 4 times a season within Scotland and England. Within the Dutch league games in the Hoffklasse are always scheduled to take place at 14:45 each Sunday. Due to the variation across each region it was chosen that this should not be a sub section to the study and instead should be recognised as a potential subject for a future study to investigate whether training day in relation to match proximity has a significant relationship.

Limitations can also be found with regards to the remote nature that the GPS data was collected. The players were all sent their GPS unit with detailed instructions on how to use, upload and charge their unit, the instructions also included information on how long to wait until using the unit to ensure it had properly calibrated and would most accurately collect the information. However there is was no way to track or monitor that each subject was following the usage instructions properly and therefore ensure that each pod was being used in the same standardised way. There was also compliance issues throughout the season that meant a number of sessions were missed or not recorded due to lack of unit charge or players forgetting to wear the unit. Again, this was hard to monitor due to the remote nature of the data collection, however every step was taken to ensure that as little data was lost as possible.

Another limitation that also should be mentioned is regarding speed zones. When analysing speed zone data the thresholds were set based upon previous hockey specific literature. However, it may have been more appropriate to set individual speed zone thresholds based upon the maximal speed of each player. It could be suggested that for some players with a lower maximal speed, they will never reach zone 5 as they do not have the capacity in which to do so, in which case the data could be impacted upon, if found that the speed zones are not specific to the group of players in which they are being applied. This is something that was considered however access to all the players at the outset of the study to be able to calculate these thresholds was limited.

The final limitation that could not be accounted for was injury throughout the season. Session information was lost due to players getting injured, however to ensure that this did not impact upon the information collected it was set out that should any players injury cause them to miss more than 3 weeks' worth of training or games then they no longer were eligible to participate in the study. As previously reported 2 subjects dropped out of the study due to injury.

4.5.3 Adaptations

With regards to the limitations and variations stated above there are a few aspects of the data collection phase that if reproduced could be adapted to produce more valid and reliable results. The two main factors mentioned above that impacted most upon the results and any conclusions were the unknown substitution times and the content of sessions. If reproduced, substitution times could be collected by the club or player themselves through a team stopwatch app used by many international squads or simply by players timing their own spells on the pitch. Understandably the accuracy of this will not be as accurate as that gained at international level however it would give more idea of total duration played. Conversely, the duration on the pitch could also potentially be monitored through the GPS activity charts, substitutions will be shown via the GPS charts as blank 'no activity sections' and so time off the pitch could be monitored through the analysis of this. However, this would be time consuming to measure for every player for every game and still may not be accurate as with both a degree of human error is involved. Conversely, knowing the actual duration that each individual spent on the pitch would allow for a more accurate comparison of club and international hockey, as the distances could be related to actual minutes on the field of play instead of averaged out over the duration of the game, which does not account for the time spent as a substitution.

Secondly, as mentioned above reliable information on the content of each of the club training sessions is again something that could have impacted upon the final conclusions made. As the data was collected via the players interpretation there us a degree of unreliability. In this case to ensure the information is valid, communication with all club coaches would be valuable to enable them to send weekly session plans for comparison of sessions should differences occur between regions. This would allow for more reliable information on the club sessions and therefore allow for more confidence in concluding that the content of training sessions were an important factor in the differences observed could have been reported.

4.6 Recommendations

The aim of the study was to investigate whether differences occur within the Scottish National Men's Hockey team, as a result of the region that they play their domestic club hockey within. It was assumed prior to starting the study that there would be large differences found in the intensity in which they train and play at with their clubs, due to the perception that the quality of hockey within the Scottish League was lower than that found within Europe and England. Although the analysis has found significant differences, the findings have not shown the Scottish league to be any lower in intensity when comparing it to the other regions. However, differences have been found within both International and Club setups and so to ensure progression within both environments it is important to understand where these main differences occurred and how they could be reduced to improve the hockey specific performance going forward.

4.6.1 International

With regards to the findings found within the International setup, significant differences were found between Club and International training and Club and International games for the variable of total distance. However, the differences found between Club and International was minimal, therefore the distance covered within the club environment was similar to that experienced at International training and games. However, this does not account for the quality of hockey or level of coaching that they were exposed to within each environment. More importantly it should not be overlooked that there were no significant differences found across all three regions when comparing International Training and International games. From this point of view this shows that the intensity of International training is appropriate to the total and sprint distance that players are going to be exposed to within the International game.

Due to the current situation within the Scottish International Hockey team, players will only train with their International teammates on average up to 6 weeks before a major tournament and this is usually for only 3 days at a time. This is not comparable to the International setups of some of the best teams in the world, that Scotland will find themselves playing against in August 2019 when they play in the highest league of European competition at the A-Division. Their opposition there such as Germany, the Netherland and England all have full time programmes, the majority of them full funded where they will train with each other daily. Therefore, I would suggest that more emphasis has to be put on the content and intensity of training within the club environment as this is where players will spend most time in a season. Therefore, International players will not be together long enough before an International tournament to make any substantial physiological differences within the International environment, thus emphasizing the importance of the club training content.

4.6.2 Club

Following on from the International findings, there should be an increased emphasis on the players club environment for two reasons; to ensure that players when coming into International camps are prepared and secondly when looking to continually improve the quality of the domestic league within each region.

The main finding with regards to club games and training was that players within all three regions cover more total distance in club games compared to that of club training. European based players were found to have the least difference between training and games (904m), however for England and in particular Scottish based players (2.2 and 2.5km respectively) the difference is substantially larger. If club teams within Scotland and England's aims are to train in order to prepare their players for the demands of a match, then the total distance that players are exposed to within training appears to be significantly lower. It is expected that during some training sessions the focus will be on tactics or skill which will inevitably decrease the distance covered. However, the figures reported were taken across a season's worth of data and so it would be suggested that in order to prepare players to perform under the load and potential physiological demands that club matches will subject them to, they should be exposed to a similar environment regularly within training in comparison to that of a club game.

Currently within Scotland and England players train twice a week usually on a Tuesday and Thursday, in comparison to Europe where training usually takes place three times a week. Within Scotland and England, a potential solution could be to have one training session a week, probably better suited to a Tuesday, where the intensity of the training is deliberately planned to be higher. Earlier in the week would be more suited than later due to the proximity of the weekend and competition. This would mean that for one session a week players are being physically trained closer to the demand of the game, working under fatigue which will challenge their decision making skill and ability to perform skill. This would then allow a Thursday to be lower intensity prior to a weekend but more focused on tactics, set pieces and skill based drills.

With regards to the content of the recommended higher intensity sessions, SSG's if used appropriately could elicit the results, within a game based context. A study by Scobie & Breckenridge (2019) investigated the impact of the numbers of players and pitch size of SSG's on the total distance and sprint distance covered within a similar group of players from the Scottish Senior Men's International hockey team that was used within this study. It was found that games of 8v8 played over a full pitch (90m length, 55m wide) for a duration of 10 minutes for 5 repeats and 3 minutes rest in between was most suited for eliciting speeds recognised as sprints (>23km·hr^{-1}). Conversely, for more focus on high speed running (19-23 km·hr^{-1}) games of 6v6 within a 50m length by 30m wide pitch for game durations of 5 minutes for 9 repeats with 2 minutes rest between bouts were found to be optimal. As mentioned previously, this shows that the type of SSG used can impact differently depending on the players and size of pitch chosen. If used properly and focused specifically to the needs of the players and session plan, SSG's could be ideal for use within a high intensity session once a week. SSG's would place physiological demands on the players without taking time out of the hockey specific session to do running, that could otherwise be done individually. They would allow players to make decisions under fatigue in an environment that is as close to a hockey game context as you can recreate, as well as allowing them to perform skill under various types of pressure.

4.5.3 Future Directions

Going forward there are two areas that this study has highlighted, which could benefit from additional research. The first of these is speed zones, which were found to be an important section within the study and were found to show limited differences between each region but instead more pronounced individual differences between each of the speed zone thresholds. As has been done within other sports, for hockey it would be beneficial to understand speed zones when they are individualised to each player. This would mean not applying generic thresholds but applying the zones specific to each players maximal speed, as players who are slower may never reach the >23km·hr^{-1} speed bracket and so will never be classed as sprinting, which will in turn then give unrepresentative results of not just the player but the group as a whole. Gaining an insight firstly to the different speed abilities within a team would be useful in understanding each players ability but also if individualised thresholds could then be applied it would ensure each player is performing within their own limits.

The second recommendation would be to further analyse the different training sessions within a week, instead of looking at training as a whole. It has been previously suggested that a more high intensity session in a week, closer to the demands of a game within the domestic league setup would be beneficial, however this could already be happening. Investigating the potential differences between training session across Scotland and England, where two training sessions a week is the norm and conversely in Europe where generally three training sessions in a week take place could further inform the content, intensity and therefore benefit of each of these sessions. Moreover, understanding the demands placed on players from session to session and week to week could better inform us on the periodised approach clubs take across a season. For international athletes there is little break in a season, with domestic leagues generally running from September to May and International seasons running from June to August, resulting in there being limited chance for downtime or recovery. It therefore could be informative to see if week to week the intensity of training sessions within clubs remain the same or whether a periodised approach to planning is applied. If a greater understanding is achieved when looking at players speed ability as well as understanding a clubs weekly schedule, more informed decisions could be made to ensure a higher and lower intensity is achieved as and when it is most appropriate within the context of a season.

5. Conclusion

In conclusion, several differences have been identified within the Scottish National Men's Hockey team, when comparing club and international training and games across the course of a season. Differences were identified both within and between session types as well as speed zone analysis, showing that differences may also occur between individuals. Various factors have been suggested to impact and influence the differences reported, such as content of training sessions, time on pitch within games and the league standard or player ability. However, the study has shown that it is not always the league or player with the most skill or ability that will cover the most distance, there are various elements that must be taken into consideration. It is important that these factors are tailored as much as possible, to ensure that they place specific demands on the player or team in order to impact and improve, regardless of the league, region or team in question.

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Appendices

Appendix I

GPS Protocol: Player Instructions

PRE MATCH
GPS UNITS TURNED ON
LEFT FOR 5 MINUTES TO OBTAIN ‘GPS FIX’
UNITS PLACED IN BACK OF NEOPRENE BIBS
IMMEDIATELY AFTER GAME
UNIT REMOVED FROM BIB
UNIT TURNED OFF
DATA UPLOAD
UNIT CONNECTED VIA USB CABLE TO COMPUTER
PLAYERTEK SYNC TOOL DOWNLOADED AND OPENED
UNIT RECOGNISED BY SOFTWARE & SESSIONS UPLOADED TO ONLINE PLATFORM
DATA TAGGING
SESSIONS NOW AVAILABLE TO VIEW BY STAFF MEMBERS
SESSIONS IN ‘UNTAGGED’ FORMAT (NO DETAILS)
DETAILS FROM WELLNESS DIARIES USED TO TAG SESSION APPROPRIATLEY REMOVING ANY DATA THAT IS OUTWITH THE SESSION TIMES GIVEN

Appendix II

GPS Measures: Variables & Units

Variable	Unit/ Descriptors
Frequency	Session per day/week/month
Time	Seconds, Minutes, Hours
Intensity	Absolute, Relative
Type	Modality, Environment,
Maximal Efforts	Maximum mean power, jump height
Repeated Efforts	Number of Efforts, quality of efforts
Training Volume	Time, Intensity
Perception of effort	RPE
Biochemistry/Hormone Analysis	Baseline response to exercise
Psychology	Stress, Anxiety, Motivation
Sleep	Quality, Quantity, Routine

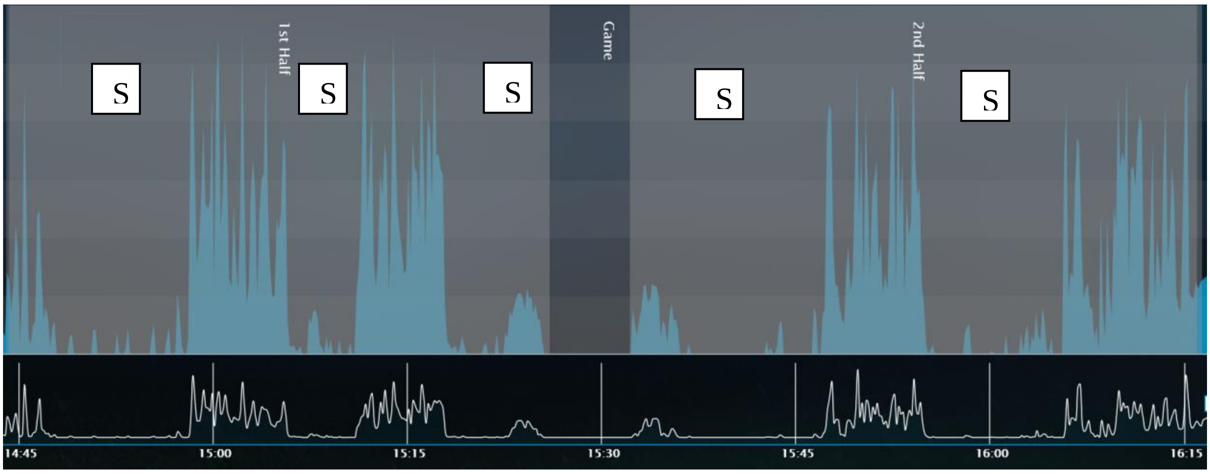
Appendix III

Within session analysis: p-values

	Non Standardised		Standardised	
	Total Distance	Sprint	Total Distance	Sprint
Club vs International Training	**0.001***	0.838	**0.009***	0.771
Club vs International Games	**0.003***	**0.006***	**0.008***	0.012
Club Game vs Club Training	0.000	0.013	0.000	**0.001***
International Games vs International Training	0.826	0.596	0.952	0.322
*Indicates significant difference				

Appendix IV

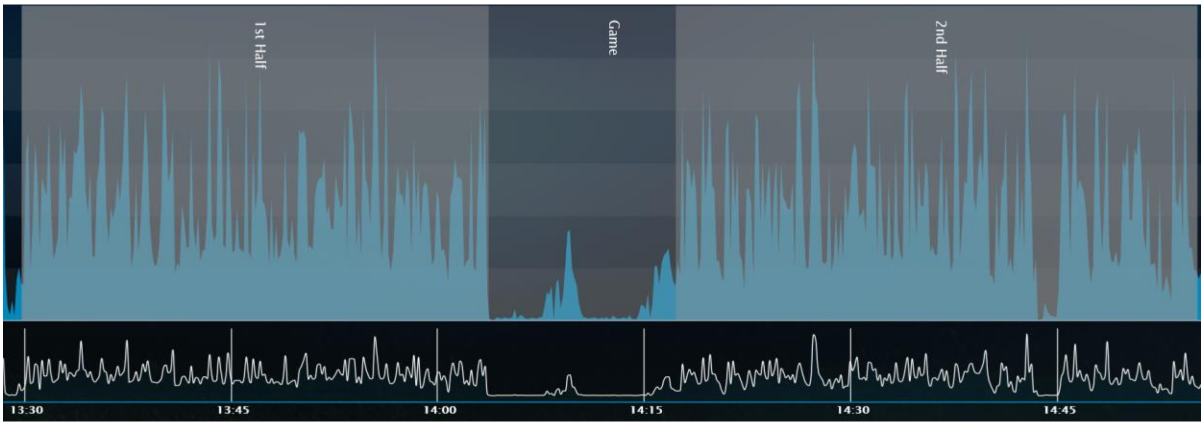
European Player Club Game Activity Graph: Distance: 4.15km & Estimated Time on Pitch: 33mins



S=Substitution

Appendix V

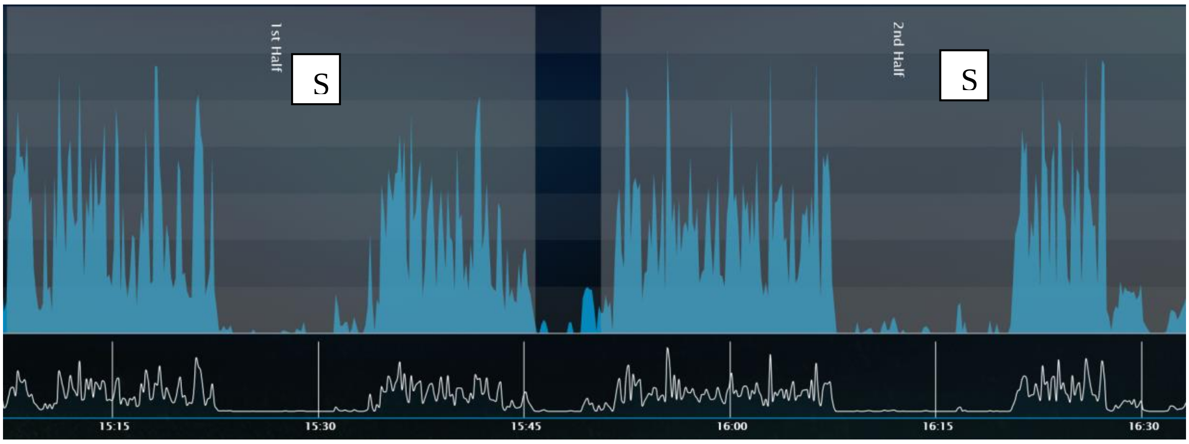
Scottish Player Club Game Activity Graph: Distance: 7.89km & Estimated Time on Pitch: 70mins



S=Substitution

Appendix VI

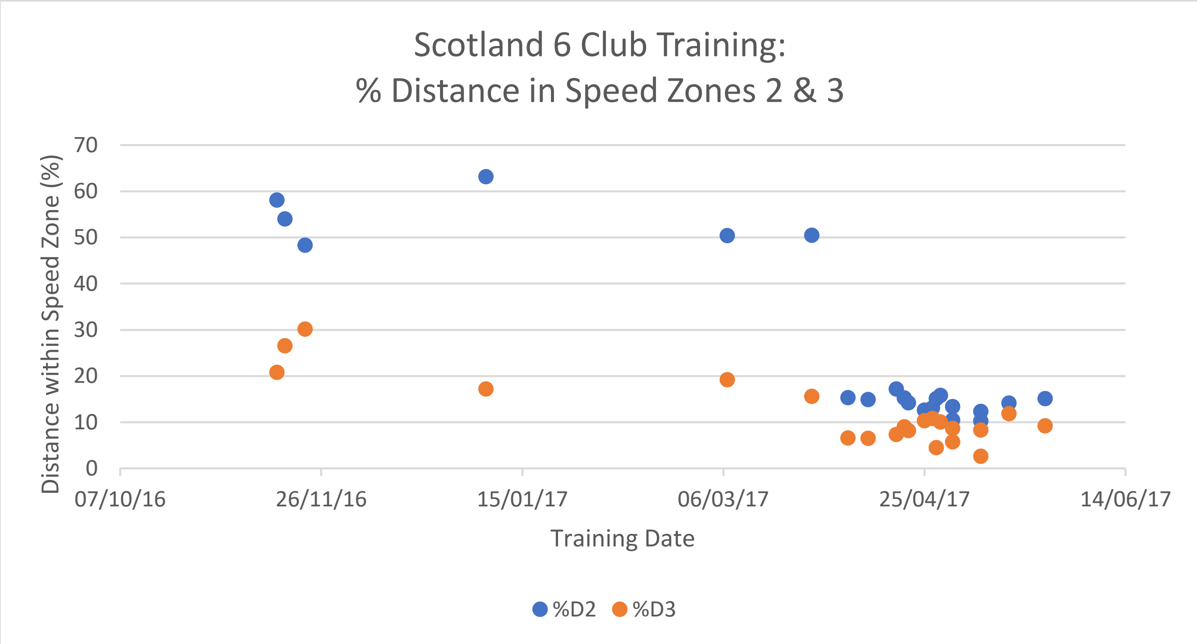
English Player Club Game Activity Graph: Distance: 6.05km & Estimated Time on Pitch: 47mins



S=Substitution

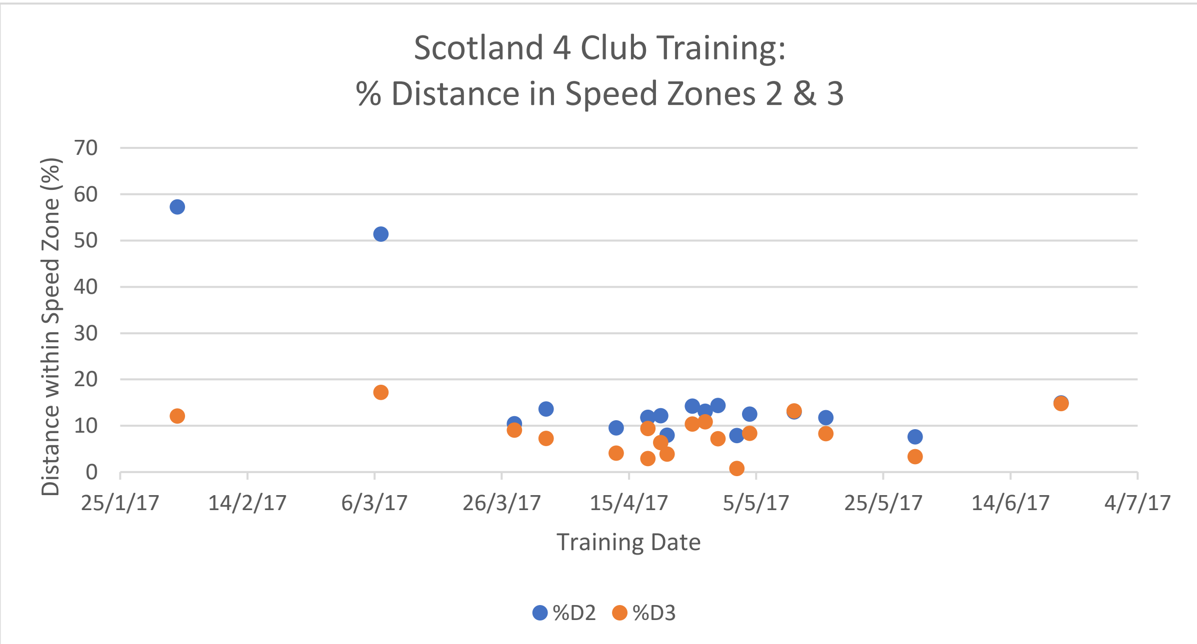
Appendix VII

Scotland Subject 6 Club Training Scatterplot of Percentage Distance in Speed Zones 2 & 3



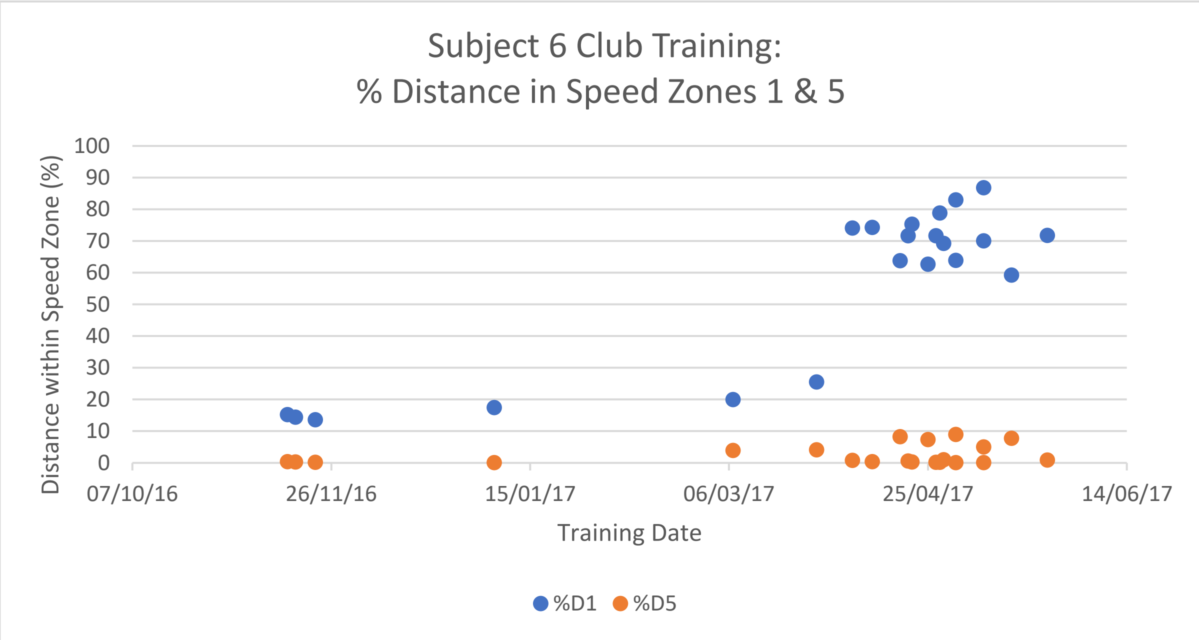
Appendix VIII

Scotland Subject 4 Club Training Scatterplot of Percentage Distance in Speed Zones 2 & 3



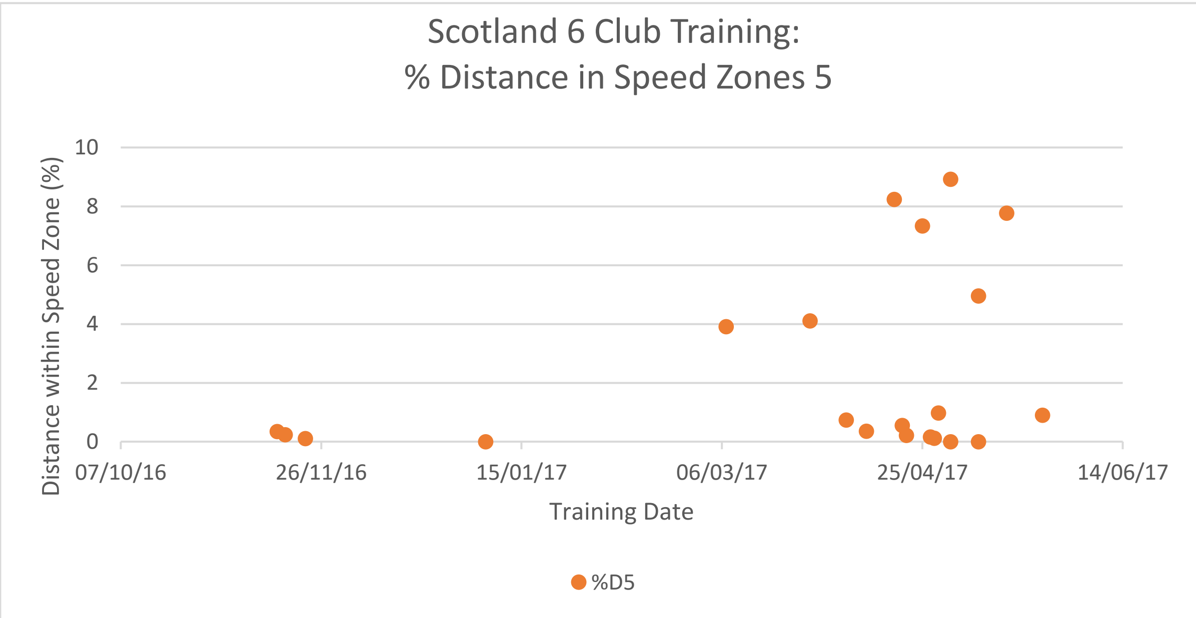
Appendix IX

Scotland Subject 6 Club Training Scatterplot of Percentage Distance in Speed Zones 1 & 5



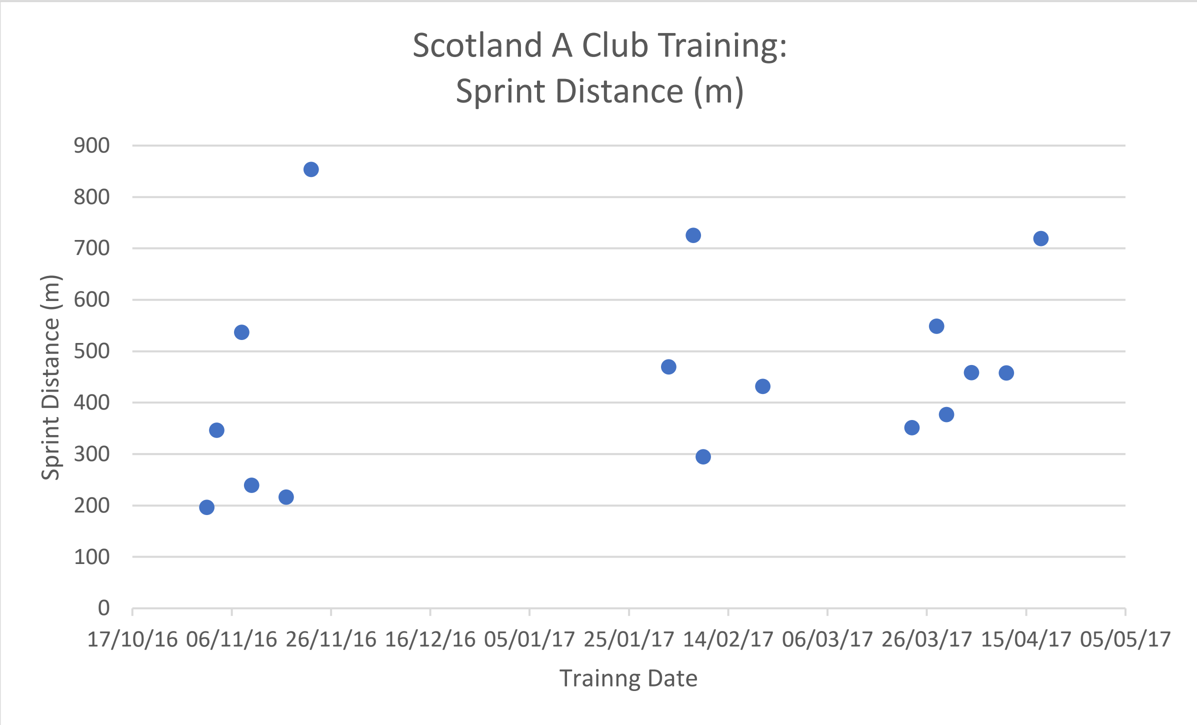
Appendix X

Scotland Subject 6 Club Training Scatterplot of Percentage Distance in Speed Zone 5



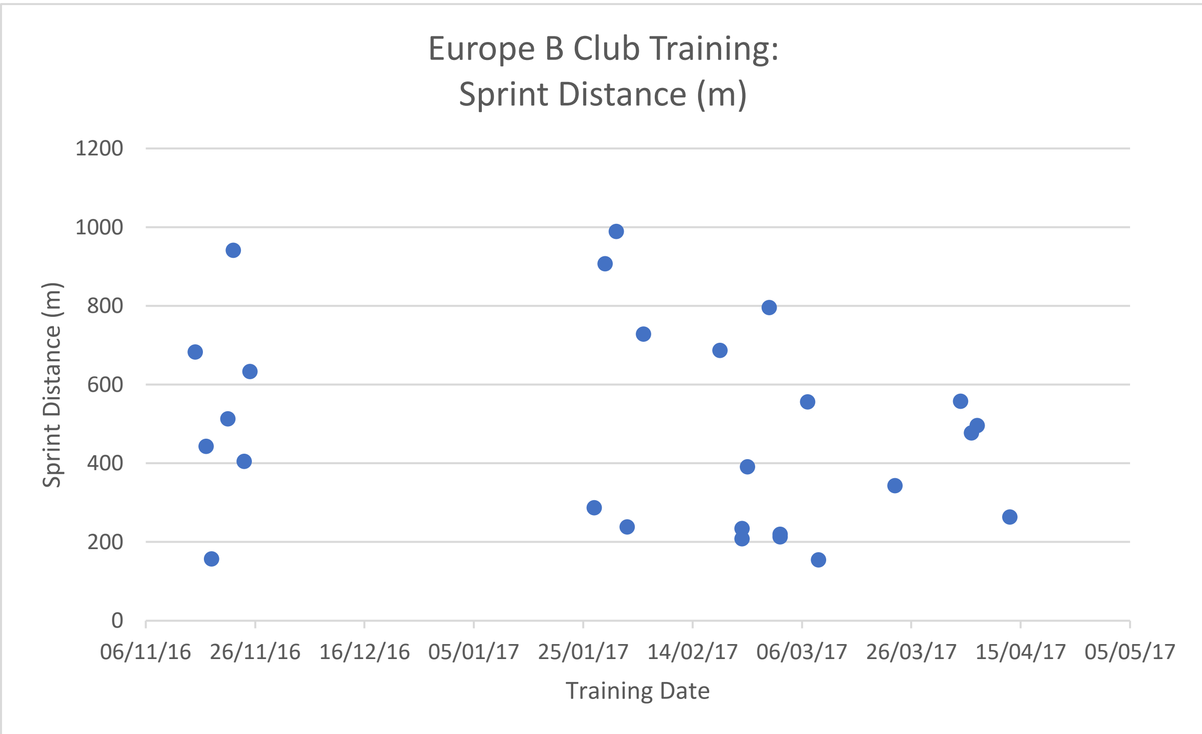
Appendix XI

Scotland Subject A Club Training Sprint Distance



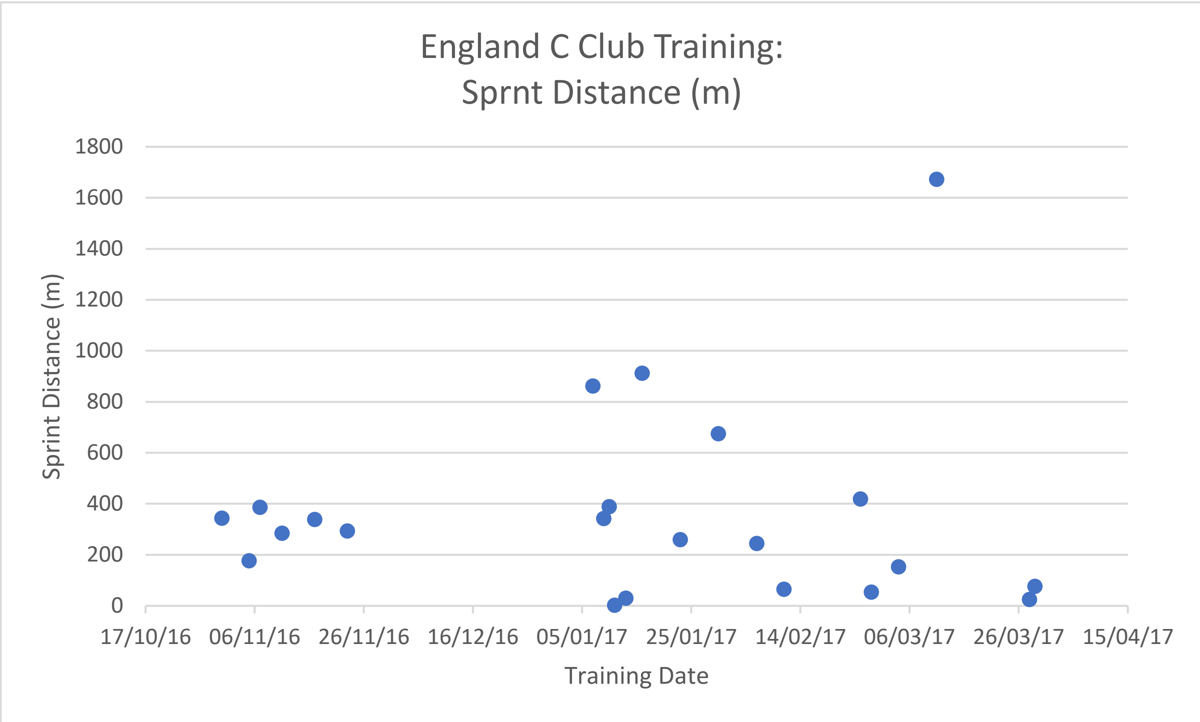
Appendix XII

Europe Subject B Club Training Sprint Distance



Appendix XIII

England Subject C Club Training Sprint Distance



Appendix XIV

Scotland Subject 6 Scatterplot of Training Sprint Distance