Physiological response to systematic training in adolescent footballers

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Abstract

The studies presented in this thesis examined the physiological impact of a systematic training programme on adolescent footballers. The main variables of interest in each study were maturation, training session time and baseline fitness. The current thesis comprises of four studies.

Study 1 analysed the birth date distribution of the players in the Performance School programme compared to the general population, as well as how physical prowess was effected by the distribution of birth dates. The results indicated that the Relative Age Effect (RAE) was present within the Performance School programme and an overrepresentation of players born earlier in the selection year was found in every year group. Despite the presence of the RAE, there were no differences found with regards to physical performance between players born at the start or end of the selection year.

Study 2 extended the findings in Study 1. Study 2 aimed to examine the contribution of certain variables; training session time, progression in maturity offset and baseline fitness, to change in physical performance over one competitive season. The results in Study 2 indicated that baseline fitness was the largest contributing variable to change in physical performance over time from baseline.

Study 3 examined the stability of ranking players based on physical performance in a 20m sprint, change of direction test (COD), SJ assessment and the Yo-yo intermittent recovery test level 1 (YYIRTL1). The study also aimed to assess response to training on an individual, rather than a group, level. The results in Study 3 indicated that stability in ranking differs depending on age group and on measure of physical performance. With regards to individual response, Study 3 showed that performance in YYIRTL1 was most likely to change, given the training stimulus.

Finally, Study 4 aimed to assess the differences in physical performance and rate of change in physical performance between groups of adolescent footballers who train and compete at different levels in Scottish football. The findings in Study 4 indicated that, firstly, the only attribute that was able to discriminate between playing standard was the 20m sprint. Furthermore, the only attribute that was suggestive of a greater training session time was performance in the YYIRTL1. However, despite differences in playing standard and training session time, there were no differences found in rate of progression in any of the physical attributes tested.

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Research Thesis Submission

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Glossary of abbreviations

20m   –   20 metre sprint test

COD   –   Change of Direction

GR   –   Grassroots

ICC   –   Intra-class correlation coefficient

MBI   –   Magnitude Based Inference

PHV   –   Peak Height Velocity

PS   –   Performance School

PY   –   Professional Youth

RAE   –   Relative Age Effect

SFA   –   Scottish Football Association

SJ   –   Squat Jump

SWC   –   Smallest Worthwhile Change

Talent ID   –   Talent Identification

TE   –   Typical Error

YYIRTL1   –   Yo-Yo Intermittent Recovery Test Level 1

Chapter 1: Introduction and Literature Review

Football has been described as the most popular sport in the world (Bangsbo, 1994). In 2007 FIFA (The Fédération Internationale de Football Association) estimated that 265 million people worldwide were participating in football – at the time this was the equivalent to 4% of the world's population. There are varying levels of participation in the sport; youth recreational grassroots, professional youth, senior amateur, senior semi-professional and senior level full time football. Senior level full time football has proven over recent years to be extremely lucrative, as well as providing a sense of national pride, for nations that qualify to play in major tournaments such as the World Cup and the European Championships. The rewards for success or even qualification in these tournaments could be one explanation for the increasing focus on youth development (Smolianov, et al. 2015). Football associations and governing bodies now appear to be implementing player development strategies at younger ages; ultimately to improve the product at the senior level of the game (Miller, et al. 2015). Success in the sport, on an individual level, is dependent on a number of different aspects. These can be categorised as a player's physiological capacity, technical skill and tactical awareness (Ali, et al. 2007). Although all are important, it is suggested that mastery is not essential in each, but a blend of the three can make for success in the game. There are a number of physical aspects that can be assessed and appear to have specific relevance to performance and progression of adolescent football players. These include (although are not limited to); running speed, lower limb power, agility and change of direction, aerobic capacity, flexibility and the monitoring of maturity status (Stølen, et al. 2005; Chamari, et al. 2004; Abernathy and Bleakley, 2007; Bucheit and Mendez-Villaneuva, 2013).

A major factor in a young football player's development is the effect of maturation on their performance (Bucheit and Mendez-Villaneuva, 2013; Malina, et al. 2000). A single playing group can contain early, on time and late maturing individuals (Bucheit and Mendez-

Villaneuva, 2013) and as greater body dimensions and physical capacity can affect performance (Malina, et al. 2007; Stølen, et al. 2005) both in training and match play, it is imperative that maturity is taken into account when developing and assessing adolescent football players. Assessment of maturation is particularly important when the focus is to have young players fed into elite academies where the goal is to have them play at senior level, full time.

As well as the importance of physical prowess in football it is important that young football players are fit and available to train throughout the playing season. This will help to maximise their development time (Dvorak and Junge 2000; Junge et al. 2000) as Gledhill and Harwood (2015) have discussed the importance of frequent and repetitive practise for young football players who aim to play at senior level. Furthermore, researchers have shown that youth elite football players can miss up to 6% of their training and development time through injury over the course of 2 seasons (Junge, et al. 2000).

<u>Measuring Maturity</u>

There are different ways that maturity can be measured and each of these has advantages and disadvantages. Skeletal, somatic and sexual are among these. The biggest difficulty when measuring and monitoring maturity status is that each individual may experience different timing and rate of growth. In order for the following measures to be accurate it is important that they are repeated frequently to provide an update on a person's maturity status (Mirwald, et al. 2002). A single measurement may be misleading, again, as a result of differing timing and rate of growth.

Skeletal maturity covers the entire growth curve from childhood through to adulthood so could therefore be viewed as the most desirable method of quantifying maturity status (Malina, et al. 2004). In childhood, the skeleton consists of cartilage prenatally and in adulthood changes to fully developed bone. Malina et al. (2004) states that as this process is the same for each individual then skeletal maturity is a valuable assessment. In order to assess skeletal maturity, x-rays of the hand and wrists are taken and are then compared to typical radiographs of the hands and wrists to determine skeletal age (SA) (Buchheit, et al. 2011).

One method that can be used to determine SA is the Tanner-Whitehouse method (Tanner, et al. 1962). The Tanner-Whitehouse method requires analysing several individual bones that are shown on a hand and wrist radiograph. From the examination of these bones, a score is generated in relation to each bone and its stage of development. The final score is then compared to a scale that ranges from zero (immaturity) to one thousand (maturity). This method has been adapted since it first came into use as comparisons are now available for different populations (Buchheit, et al. 2011). However, an update in the method may pose a

new problem as comparisons between two contrasting populations can provide inaccurate results. The Greulich-Pyle method requires the comparison of a hand and wrist x-ray to referenced samples in an attempt to discover the closest match (Greulich and Pyle, 1959). The samples that are used in comparisons show hand and wrists x-rays at known chronological ages (CA). For example, when an individual's x-ray is compared to the existing samples, the sample that shows the closest match will be used to determine SA. It may then be the case that a child with a CA of 10 years old could have a SA of 13 years old. In this instance the individual could be described as early maturing or advanced in maturity. Similar to the Tanner-Whitehouse method, the Fels method also follows a protocol of analysing various bones from the hand and wrist x-ray and assigning them a score (Roche, et al. 1988). Each of these methods is able to provide an estimate for skeletal maturity but would likely be impractical for longitudinal monitoring of maturity. Due to the nature of the assessments – i.e. where hand and wrist x-rays are required – cost, time and exposure to radiation are severe limitations to these methods. Dvorak et al. (2007) state that as MRI scanning of the hand and wrist is now available and this method will negate the issue of exposure to radiation. Moreover, the authors go on to suggest that the high cost and time constraints of using MRI scanning still make it unsuitable for use in an applied setting when monitoring maturity status. Although these are all established methods of measuring SA, Malina et al. (2004) state that each of these methods reaches a different SA from analysis of the same radiograph. It is possible that the discrepancies in the measures are as a result of the samples being taken from various populations and differing generations. The authors go on to explain that a change in normalised anthropometric data of the general population may be evident due to increased SA being presented in more samples taken over the last 50 years.

The use of somatic measurements have also been proposed as an appropriate method for assessing maturity status. The somatic measurements required would be stature and mass but it is important to note that the method does not measure maturity in isolation (Malina, et al. 2004). Moreover, this may be an appropriate protocol when collecting longitudinal data as somatic measurements can indicate the timing of certain stages on the growth curve (Malina, 2011); one of these stages being an individual's peak height velocity (PHV). PHV is the adolescent growth spurt and is the time where the most rapid period of growth occurs (Malina, et al. 2004; Malina, 2011). By measuring stature, seated stature and mass and applying Mirwald's et al. (2002) multiple regression equation to the data, an age at peak height velocity (APHV) can be calculated. The method is able to provide a predicted APHV to ±1 year. The authors do, however, state that this analysis is most suitable for categorising individuals into pre and post-maturity groups but also mention that with frequent measures the output becomes more robust. Mirwald's et al. (2002) method for measuring may then be considered the most suitable for use in an applied setting due to its simplistic nature.

Secondary sex characteristics can also be used to quantify maturity status. Assessment of secondary sex characteristics provides a method of calculating an individual's sexual maturation. Tanner (1962) developed a criteria for categorizing these characteristics. Indications for assessing sexual maturity are often the development of genitals for boys, breasts for girls and pubic hair for both boys and girls. It can be difficult to classify each of these stages as out with the initial and latter stages of puberty, categorizing secondary sex characteristics is subjective (Malina, et al. 2004). For example, it may be simple to tell the difference between the very first and very final stages but difficult to determine exactly when the second last stage moves into the last stage of development. One potential advantage of this protocol is that it comes with a much lower cost than using x-rays or MRI scanning,

however, use of this method in quantifying maturity status has a number of limiting factors. Classification of sex characteristics often requires direct examination by a practitioner in a medical setting so is not easily transferable to an applied setting (Wu, et al. 2002; Malina, et al. 2004). This can be undesirable for young adolescents and parents due to the ethical issues it raises. Schlossberger et al. (1992) suggests that one possible solution for this is for individuals to assess themselves. The authors go on to explain that this also presents more inconsistencies in reporting sex characteristics as individuals can under or over estimate what stage they are at and in turn effect the accuracy of the data. Furthermore, this method is only applicable during puberty and does not encompass the entire growth spectrum.

Mirwald's et al. (2002) multiple regression equation may seem like the most viable option for use in an applied setting as the data required is relatively easy to collect, is not time consuming and is cost effective. Mirwald's et al (2002) method of measuring maturity has also been shown to positively correlate with results from hand and wrist x-rays (Mirwald, et al. 2002), however, a poor correlation has been found between Mirwald's et al (2002) equation and the Fels method. The relationships between the Greulich-Pyle and Tanner-Whitehouse methods are not yet understood (Malina, et al. 2012). As mentioned previously each method produces different estimates of maturity status and as a result Malina et al. (2012) has suggested that the Mirwald equation is less suitable for categorizing players into maturity groups but was still suitable for defining pre and post-maturity groups. Measuring SA with hand and wrist x-rays is the method that is most sensitive to change and is therefore considered to be the more accurate and reliable method (Malina, et al. 2004); although its use in an applied setting may be unrealistic.

Maturation

It is imperative that an attempt is made to account for maturity in any research studying performance in youth sport, (Mirwald, et al. 2002) as in the early phase of adolescence (approximately 11-15 years old) players in the same age group can display large variations in maturation (Malina, et al. 2005). For example, differences of up to 35cm in height within a single playing age group have been found (Malina. et al. 2000). Malina et al (1991) and Bucheit and Mendez-Villanueva (2014) also reported maturity related differences in mass, speed, strength and endurance in cohorts of children with identical chronological age (CA) classifications. Malina et al. (2005) further explained that is it likely a single age group will contain early, on-time and late maturing individuals. The authors also point out that it is not always the players with the oldest CA who are physically the most mature and that these differences between individuals are often most pronounced around the time of the adolescent growth spurt (PHV) (Iuliano-Burns et al. 2001). The average age at PHV in 32 Welsh football players was presented as 14.2 ± 0.9 years (Bell, 1993) and the same was found from research carried out using 8 Danish footballers (Froberg, et al. 1991); although the sample size in the study was small. Research involving 33 Belgian youth footballers saw an APHV reported (13.8 ± 0.8 years) (Phillippaerts, et al. 2006). Although both previously mentioned samples have been taken from sporting populations, Tanner et al. (1975) and Rogol et al. (2000) both presented a similar estimated age at PHV of 11 years for girls and 13 years for boys in the general population. Figure 1 displays the average age at PHV for boys and girls (Bailey, 1999).
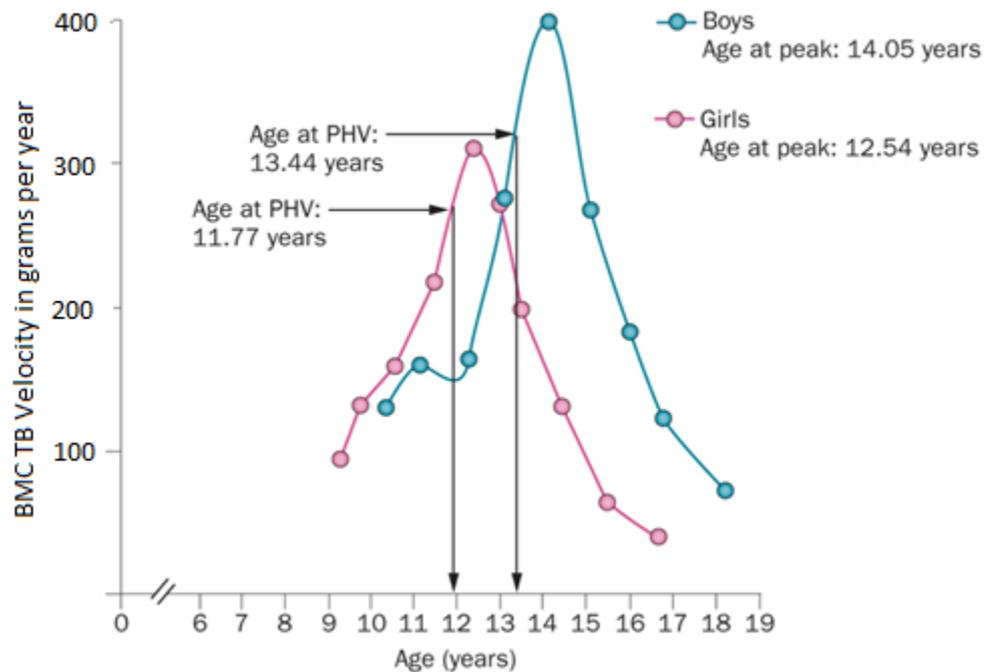
Figure 1. The TB (total body) PBMCV (age at peak bone mineral content velocity) curve for boys and girls, illustrating velocity at peak and ages at peak BMC (bone mineral content) (Bailey, 1999).

Perhaps the most important factors to consider when monitoring maturity status are the timing and rate of growth (Beunen, 1989; Malina, 2000). The timing and rate of growth are different for each individual, for example, a child who is classified as late in maturing at a young age may not still be classified as this when they move into adolescence.

Maturity and Indicators of Success in Football

More mature individuals often dominate youth and adolescent sport due to their physical prowess (Buchheit and Mendez-Villanueva, 2014). Football is a sport in which pronounced physical characteristics can determine success during adolescence (Ali, et al. 2007; Stølen, et

al. 2005). In fact, the literature is consistent in showing that early maturing individuals are more likely to be successful in football during mid and late adolescence (Phillippaerts, et al. 2006; Malina, 2003) and therefore more likely to progress to senior level football. Physical attributes that can be affected by maturation include an individual's anthropometric characteristics, linear speed, change of direction and agility, lower limb power and aerobic capacity.

Body dimensions are related to age, stature and mass (Vandendriessche, et al. 2014). Changes in these as a result of growth and maturation are important factors that affect strength and motor performance (Malina, et al. 2004). It has been shown that tasks which involve the projection of body weight such as short sprints and jumping have a negative correlation with body weight (Philippaerts, et al. 2006). It was further noted the same applies for tasks that require body weight to be raised, such as pull-ups. The researchers found the opposite when looking at correlations in similar strength tasks between stature and mass; these tend to correlate positively. From these findings it could be suggested that taller and heavier individuals are often stronger. As the relationship between performance and body size is enhanced partly by age it is important that these are controlled for when looking to quantify their impact on variations in performance. Montoye, et al. (1972) carried out research that examined percentage of variation in performance whilst accounting for age, stature and mass. The researchers found that while flexibility accounted for 5-18% variation in running performance, more complex motor skills showed 33-61% of the variation in performance. However, short sprints and longer 600 yard runs were described by the authors as complex motor skills in the study. It could be argued that these tasks are basic skills, as a change of direction or agility measure is more likely to be described as complex. Malina (1975) also found correlations between leg length and performance in motor tasks and limb

circumference on power tasks. As well as this, researchers (Malina and Buchang, 1985; Malina, 1994; Benefice, et al. 1999) have examined different populations with varying health and nutritional backgrounds to determine the effect of these variables on body size. The authors found that few of these variables added anything significant to the variation of performance relative to body dimensions. Inferences can therefore be made that age and variation in body size alone have an impact on strength and motor performance in children (Malina, 1995; Benefice, et al. 1999; Malina, et al. 2004). Furthermore, there have been several studies conducted that have reported in favour of the selection of older and physically taller individuals for youth sport; in particular football (Brewer, et al. 1995; Simmons and Paull, 2001). This results in fewer late maturing individuals being selected from the age of 13 years onwards (Malina, 2003).

Linear speed is a frequently tested measure of performance that can be impacted by maturation (Philippaerts, et al. 2006). For example, the ability to sprint in football, can have a positive impact on key moments during the game (Mendez-Villaneuva, et al. 2012; Amonette, et al. 2014). Key moments are often characterised as moments of high intensity movement with and without the ball; for example where possession is won and lost, or goals are scored and conceded. Sprint speed alone has been described as a differentiating factor between elite and sub-elite youth football players (Reilly, et al. 2000). Elite level youth football players have been shown to perform a bout of sprinting approximately every 90 seconds during a game of football. These bouts last on average from 2-4 seconds each and can make up between 1-11% of the total distance covered in the game (Tomas et al 2014; Stølen, et al. 2005). These figures suggest that success during the game of football requires acceleration as well as maximum speed components (Bangsbo, 1994). Buchheit and Mendez-Villanueva (2014) carried out research with 36 highly trained football (under-15 age group)

players on the effects of maturation on running performance. The research examined match running performance during games as well as carrying out sprint tests with the players. GPS (global positioning system) technology was used to track player movement demands during games and 40m sprint with 10m split times to assess maximal sprinting speed. The results of the study showed that the more mature players were largely older, taller and heavier as well as presenting faster maximal sprint speed times during the field tests. During match play the more mature players were also able reach faster peak speed and perform more high intensity actions than their less mature team mates. It is worth noting, however, that the magnitude of difference (large, >0.7–0.9) in the field tests was greater than those in match play (trivial, ≤0.1), suggesting that technical ability and tactical awareness may dictate match play activity more than physical prowess. Bradley et al. (2011) and Carling and Bloomfield, (2010) also found this to be the case. Research involving 61 highly trained young football players was carried out and produced similar findings (Mendez-Villanueva and Buccheit, et al. 2011). The authors examined the relationships between acceleration, maximum running speed and repeated sprint performance. While the authors found that all of these measures were strongly correlated, they also state that sprint performance improved with age and maturity in each measure as well. The authors concluded that the differences in sprint performance relative to age groups were almost solely as a result of differences in maturation.

Change of direction and agility are frequently tested aspects in most team and individual sports (Jovanovic, et al. 2011) and are highly desirable attributes for football players (Stølen, et al. 2005; Buchheit and Mendez-Villanueva, 2014). Players can change direction every 2-4 seconds, with up to 1200-1400 changes of direction taking place in a 90 minute game (Jovanovic, et al. 2011). Agility is an important component for successful performance in football as the fundamental movement patterns of the game make it an essential requirement.

Although change of direction and agility cannot be described as the same thing there are several different ways to measure change of direction in an attempt to best replicate the movement demands in the game of football (Sporis, et al. 2010). Agility comprises of both the ability to turn, cut, decelerate and accelerate effectively and is coupled with perceptual decision making (Brughelli, et al. 2008). As the majority of tests measuring change of direction are pre-determined they can be used as indicators of agility but cannot be labelled as exactly the same qualities. Figueiredo et al. (2010) used 16 youth football players to assess the differences in maturity groups when testing functional capacities; change of direction being one of the measures. The researchers separated the participants into two groups – an 11-12 age group and a 13-14 age group. They found that the advantages of being taller and more mature were evident with better performances in tests of power (measured using the vertical jump), running speed and change of direction in both groups. Figuerido's (2010) research is in agreement with Gil, et al. (2014) who carried out similar assessments with elite adolescent football players. They found that the more mature players were taller, had longer legs and outperformed their smaller and less mature teammates in tests of velocity and change of direction. The authors suggest that one of the limitations in the study was a small sample size. Although a group of 88 players were used a larger cohort may have been useful in exploring some of the subtle differences found between the maturity groups. Furthermore, an increase in mass was reported amongst those advanced in maturity. Body composition was not reported in the study, however, it could be suggested that an increase in mass was caused by greater muscle mass (Temfemo, et al. 2009). Increased muscle mass has been found to be strongly related to better jump performance, maximal strength and power output (Tonson, et al. 2008) and these attributes have been shown to correlate with a player's ability to change direction (Meylan, et al. 2010).

Lower limb power is important in football as it can determine how fast a player runs and their ability to change direction (Tonson, et al. 2008) – both important aspects of the game. This is a frequently used measure of performance and assesses muscular coordination, as the fluency and timing of the movement in the test are important for success, as well as lower limb power (Malina, et al. 2004). Research has shown that improvements in lower limb power (measured by CMJ) positively correlate with improvements in agility and sprint speed (Jovanovic, et al. 2001). Beunen et al. (1981) conducted research involving Belgian adolescent footballers of differing maturity status. The participants in the study completed various performance measures, one of which measured lower limb power; using the vertical jump. The results of the study showed that there was a larger variation of difference between the maturity groups (as much as 58%) when assessing lower limb power compared to the differences between groups in speed and endurance tasks. Lefevre, et al. (1988) produced findings that are in agreement with this, also using adolescent Belgian footballers, to show that early maturing individuals outperformed their on time and late maturing team mates on tests of lower limb power; as well as in other performance measures such as speed, agility and endurance tasks. More recently Philippaerts et al. (2006) suggested that maximal gains in muscular strength and power occur, on average, after PHV. Malina et al. (2004) explains that this is likely to be caused by the increase in muscle mass that also occurs at this time. Estimated velocities for lower limb power can continue to remain positive for some time following PHV and it is believed this may be as a result of continued muscle growth as well as the effects of progressive sports training (Malina, et al. 2004; Philippaerts, et al. 2006). It is possible that this is the case, however, neither study was able to quantify the training session time or load of their participants between measures. As a result the context of their sports training is unknown and makes it difficult to determine if the training is contributing towards the continued development of muscle mass post-PHV. Meylan, et al. (2014) did, however, find

an increase in muscle mass and strength post-PHV, during an 8 week training programme, in adolescent males. The authors found the largest improvements in strength within the mid and post-PHV groups, who showed a 10% improvement during a one-rep max maximum strength test as well as a 20% and 9% improvement in tests of maximum power and force, respectively. Motor performance, strength and power are significantly related to both SA and CA; meaning assumptions can be made that older, more mature individuals perform better in tests measuring speed, change of direction and power. However, it has been stated that when CA is statistically controlled, the correlations between performance and SA are reduced and that this is the case on most performance tasks. The relationship between SA and power tasks, however, is persistent (Espenschade, 1940; Jones 2000; Malina, et al. 2004). These findings would suggest an influence of maturity on power, independent of CA.

Maintaining flexibility and range of motion through the major muscle groups involved in football is important, especially for young players who are still growing (Stølen, et al. 2005). A lack of flexibility can negatively impact upon the ability to run, jump and change direction along with increasing the likelihood of injury (Stølen, et al. 2005). Hamstring injuries are the most commonly recorded injuries in football followed by injuries to the ankle (Abernathy and Bleakley, 2007) and the majority of these injuries occur during moments of high intensity movement. Moments of high intensity movement are vital in football and can be the difference between scoring or conceding goals or winning or losing possession of the ball. Vadendriessche, et al. (2012) investigated the use of fitness parameters as part of a selection process for adolescent football players aged 15-16 years old. Amongst measures of strength, speed and agility the researchers also measured hamstring flexibility using the sit and reach test. The results of the study showed that the older and more mature players outperformed their less mature counterparts in all of the fitness parameters apart from the flexibility test.

Research conducted with Belgian (Beunen, et al. 1988) and Canadian boys (Ellis, et al. 1975) found that, on average, the biggest gains in hamstring flexibility were observed one year after PHV. Philippaerts, et al. (2006) also used the sit and reach test to measure flexibility and found that the biggest gains in flexibility were around one year post-PHV. There is some disparity however over the use of the sit and reach test as some studies have used it to measure hamstring flexibility, while Philippaerts, et al. (2006) used it to measure trunk flexibility. Hui and Yuen (2000) note the difficulties in using the sit and reach test to measure a specific type of flexibility as it is difficult to be exact about the area that is being tested; the hamstrings or the lower back. For example, a person may have poor hamstring flexibility but this goes unnoticed during the sit and reach test due to having a flexible lower back, or vice versa. Yague and De La Fuente (1998) also state that one year post-PHV was when maximum gains in trunk flexibility was found in Spanish boys. It is also important to note that the aforementioned research, excluding Philippaerts' et al (2006) study, used a cohort comprising of the general population.

Football can be described as an intermittent sport as it involves a combination of short bursts of high intensity activity interspersed with moments of lower level activity. The nature of the sport is related more to bouts of speed, agility, and explosive power more than it is to maintaining a continuous level of submaximal work (Bansbo, 1991; Bangsbo, 1994). There are several tests that measure cardiovascular endurance, aerobic capacity and ability to recover from high-intensity exercise; most involve incremental exercise in the form of shuttle runs. These tests are used to best replicate the movement demands of intermittent sport; i.e. football. These types of tests have been suggested as appropriate for talent identification and monitoring development of adolescent football players (Castagna, et al. 2010), as Castagna, et al. (2010) found that performance in intermittent field tests were significantly related to a

number of match physical activities – for example, high intensity sprints. Carvalho, et al. (2014) completed a longitudinal study that examined the effects of physical growth on intermittent endurance run performance in adolescent male Basque football players. The authors found that a non-linear effect of age on intermittent endurance run performance was evident. The results showed that there was a steady improvement in endurance performance from 10-15 years old with the biggest increases in performance being between 10-11 years and 14-15 years of age. Systematic football specific training was attributed to this improvement. Their rate of improvement, however, slowed down around the ages of 12 and 13 years. It is suggested that the male adolescent growth spurt may have caused the decrease in improvement at this age as this was the average PHV for the cohort used. However, post-study the authors questioned their method of quantifying maturity status through use of somatic maturity measures. Somatic maturity status and body size did not provide a sufficient explanation on the development of endurance run performance when controlling for age. A longitudinal study using measures of skeletal maturity may provide more definitive answers to the results presented in the aforementioned research. More mature players have been shown to possess greater cardiovascular endurance capacities during intermittent running tests, outperforming their younger less mature team mates (Stølen, et al. 2005; Phillippaerts, et al. 2006; Buchheit and Mendez-Villanueva, 2014; Lefevre, et al. 1988). Figueiredo, et al. (2009), however, presented findings that contrasted with previous research. The authors found that late-maturing individuals possessed poorer endurance performance during intermittent field tests. They attributed this difference to greater body mass than early and on time maturing participants, stating that this may have had a negative impact on their performance due to increased effort required during deceleration, acceleration and turning phases of the assessment. It is important to note that Figueiredo's et al. (2009) research

contained a very small cohort of mature participants, therefore it is difficult to draw any definitive conclusions from this study.

Maturity and Performance

In a sporting context, it could be suggested that older, more mature individuals have an increased likelihood of success during competition and training in football. More mature players often possess greater physical prowess in running speed, lower limb power, agility and change of direction as well as ability to recover from high-intensity exercise (Stølen, et al. 2005; Chamari, et al. 2004; Abernathy and Bleakley, 2007; Bucheit and Mendez-Villaneuva, 2013). The evidence provided above suggests that maturation can cause a large variation in performance in adolescent sport. With older, more mature individuals consistently, physically, outperforming their younger and less mature counterparts there is a tendency for more mature players to be overrepresented in sports academies – as is the case for football (Figueiredo, et al. 2009; Vandendreissche, et al. 2012; Reilly, et al. 2000). Less mature individuals often drop out of the sport as a result, as age and sport specialisation increases (Pittoli, et al. 2010). Thus, potential talent can be lost from the sport due to an individual developing physically at a slower rate compared to others. The selection and recruitment of adolescent football players is difficult because other than the use of performance indicators, which clearly favour early maturing players in talent identification, the process is fairly subjective and opinion based (Wolstencroft, et al. 2002). Musch and Grondin, (2001) and Boucher and Mutimer, (1994) discuss the impact of this, which has been labelled the "relative age effect" (RAE). The RAE states that players born in the early months of the selection year are more common in sport than players born later in the year when

compared with the birth date distribution of the general population. Helsen, et al. (2000) examined the RAE and found that children born earlier in the year are more likely to be identified as skilled in their sport as their advanced relative age and, in turn, maturity status is mistaken for talent. Conversely, sport specific skill appears not to be impacted by maturity status and Reilly et al. (2000) suggested that there may be a threshold above which physical capacity is unable to differentiate between players who progress from youth to senior level football. Technical skill may be a better discriminating factor for anything above this physical threshold. However, with age groups around the time of PHV (12-14 years) individuals are likely to be in the early, on time and late stages of maturation. As a result, physical prowess may dominate a coach's impression of a player rather than how technically gifted they are. Matthys, et al. (2012), Vandendreissche, et al. (2012) and Figueiredo, et al. (2009) all designed and carried out studies that attempted to measure technical skill. Technical skill is difficult to quantify, however, these studies looked at sport specific aspects such as shooting, dribbling and passing. The authors all found that technical skills did not differ between maturity groups. It is important to note that although measuring technical skill is difficult, football involves a number of permutations and constantly changing stimuli that make equally, if not more important, attributes such as tactical awareness and decision making hard to quantify and measure.

Physiological Impact of Maturation

Based on the evidence presented previously, advanced physical maturity is likely to be beneficial for success in adolescent sport. More mature individuals are consistently presented as being faster, more agile, stronger with greater power, with a higher aerobic capacity and greater recovery capacity from high-intensity exercise (Stølen, et al. 2005; Chamari, et al.

2004; Abernathy and Bleakley, 2007; Bucheit and Mendez-Villaneuva, 2013). The reasons can be attributed to greater neuromuscular function and motor skills as a result of their advanced maturity status (Malina, et al. 2004; Hebestreit and Bar-Or, 2008). One measure that provides less conclusive evidence is the development and maintenance of flexibility during maturation; in which the evidence appears to be equivocal (Vadendriessche, et al. 2012; Philippaerts, et al. 2006.)

Linear speed, change of direction, agility and jumping tasks are frequently used as performance indicators in sport (Stølen, et al. 2005; Bucheit and Mendez-Villaneuva, 2013). These measures are often dominated by more physically mature individuals as a successful performance in the test is dependent on greater force production and power output (Bucheit and Mendez-Villaneuva, 2013). Sprinting is a function of stride rate and stride length, (Miller, et al. 2012; Krysztop and Mero, 2013) however, it has also been argued that faster running speeds are achieved with greater ground forces and not by more rapid leg movement (Weyand, et al. 2000). Weyand, et al. (2000) carried out research using male football players and suggested that ground reaction force and force development during the initial running phase are determinants of acceleration. The authors then goes on to propose that football players with greater power and force generating capabilities may be able to run faster than players with lower power and force generating capabilities. Meylan, et al. (2010) conducted a review of the recent literature explaining the role of maturity status on physical, physiological and technical characteristics during talent identification in football. The authors discussed numerous research studies in which more mature individuals outperformed younger individuals in explosive tasks, tests of sprint speed and agility and change of direction measures, despite the more mature groups being heavier; likely because of increased muscle mass in more mature groups. However, assumptions of an increase in muscle mass are only

conjecture as muscle mass was not measured in any of the research in question. It is possible that more mature individuals perform better in these tasks because as they grow, they experience greater contractile properties and improved length of myofibrils resulting in qualitative changes in the muscle. These changes in muscle characteristics favour greater force and power output (Van Praagh and Dore, 2002). Beunen and Malina (1988) state that activities involving the stretch-shortening cycle (SSC) (these include running, jumping and sprinting) have better performance capabilities in adults when compared with children. Due to the nature of these activities they require the performer to strike and rebound against the ground with their lower limbs. The lower limbs, in particular the musculo-tendon system, are required to store and release energy during these movements (Oliver and Smith, 2010). The performance of this system can determine the rebound capability of the individual and indicate maximal sprinting capacity in adults as well as children (Bret, et al. 2002; Chelly and Denis, 2001). During movements like this it is understood that although some aspects of neural control are similar in adults and children stretch-reflex potentiation may remain underdeveloped in less mature children (Russell, et al. 2007; Moritani, et al. 1989). Oliver and Smith (2010) assessed neural control in leg stiffness during hopping activities in young boys and men and found that when hopping at low frequencies there was little difference between the boys and men but found that men were able to hop significantly faster, with shorter contact times and longer flight times when the frequency was increased. The adults dominance in the hopping tasks at increased frequencies was attributed to increased neural control and reflex muscle activity that allowed them to hop with greater leg stiffness. Lloyd, et al. (2011) examined the adaption of the SSC performance in pre and post-pubescent boys. The study involved a large cohort of 250 male youths aged between 7-17 years and participants were tested using the countermovement jump, standing jump, reactive strength index and leg stiffness. The authors found that there were windows of accelerated adaption,

during which an adolescent athlete was in a period of optimal trainability. These periods

occur around the time of the pubescent growth spurt (PHV) and the authors also state that

improved performance in the tasks was linear with the increase in age. Previous literature

shows similar age related trends in physical parameters such as speed (Philippaerts, et al.

2006), strength (Lillegard, et al. 2007; Vrijens, 1978), aerobic endurance (Naughton, et al.

2007), and muscular power. It could therefore be assumed that development in SSC function

can be attributed to similar neural and muscular adaptations (Beunen and Malina, 1988;

Blanksby, et al. 1984).

A player's aerobic capacity and ability to recover from high-intensity exercise can be integral

to successful performance in football since a large period of the game is performed

aerobically and is interspersed with bouts of high intensity, anaerobic exercise (Stølen, et al.

2005). Elite players have been shown to cover an average of 10-12 km on average during a

competitive match and work at approximately 75% of their maximal oxygen uptake ($\dot{V}O_{2max}$)

(Bangsbo, 1994; Helgerud, et al. 2001). Peak oxygen uptake increases from childhood

through to adulthood (Armstrong, et al. 1994; Bouchard, et al. 1997; Viru, et al. 1999),

however, aerobic development is unlikely to occur at a specific age but is linked more to the

development of cardiorespiratory systems and muscular metabolic capacity. Furthermore, it is

important to note that there are several factors that can impact aerobic performance during

adolescence as alterations in body size and body composition, as well as changes in motor

skill, having an impact on efficiency of movement occur at approximately the same time

(Bouchard, et al. 1997). A number of researchers (Stølen, et al. 2005; Phillippaerts, et al.

2006; Buchheit and Mendez-Villanueva, 2014; Lefevre, et al. 1988) have already expressed

the dominance of more mature individuals during intermittent field tests measuring

cardiovascular endurance. The authors further explain that although heart rate decreases

during growth, the product of stroke volume and cardiac output increases. Figueiredo, et al. (2010) assessed the difference in performance between more and less mature players in different field tests – one of which was an intermittent test used to measure cardiovascular endurance. Although they found that more mature individuals performed better in tests measuring speed and power the researchers state that there was no consistent difference in aerobic endurance between the maturity groups. One possible explanation offered for there being no difference in aerobic endurance between maturity groups is that the less mature group are smaller and are carrying less mass, allowing them to turn and accelerate with less effort and greater efficiency – requiring less oxygen to be transported to working muscles. Less mature individuals carrying less mass and requiring less oxygen coupled with the more mature individuals' experience of training may contribute to the lack of difference between the groups. This highlights another important area when considering changes in aerobic fitness during maturation. The biomechanics of running and the ability to move economically can impact on measures of aerobic fitness. Early research carried out by Cavagna, et al. (1983) showed that children and less mature adolescents are less economical when running than more mature adolescents and adults. The authors suggested that younger and less mature individuals use more energy per unit of body mass when running and also that older and more mature individuals are more capable of using pacing strategies and possess better movement biomechanics. Malina, et al. (2004) is in agreement with the presence of an "adolescent awkwardness" around the time of PHV and states that this is likely to negatively impact on coordination and motor control.

Football players can benefit from being flexible and maintaining flexibility (Stølen, et al. 2005). High levels of flexibility allow individuals to use their bodies to meet the unpredictable demands in football (i.e. stretching to receive a pass). A lack of flexibility can

negatively impact on an individual's ability to run, jump, change direction and perform striking actions; as well as increasing the susceptibility for injury (Abernathy and Bleakley, 2007; Stølen, et al. 2005). There appears to be less conclusive evidence about the effects that maturation has on flexibility. More recent research (Philippaerts, et al. 2006) contrasts with earlier studies (Beunen, et al. 1988; Ellis, et al. 1975) on peak gains in flexibility at the time of the adolescent growth spurt. The time at which flexibility has its greatest change may be less clear, however, the authors concur that a period of "adolescent awkwardness" is sometimes present during the growth spurt and is caused by the timing and rate of growth in different body parts. Malina, et al. (2004) supports the theory that this can lead to disruption in coordination and motor control during the stage when an adolescent experiences their most rapid period of growth. Disruptions may be the cause for any decrements in flexibility in and around the time of the adolescent growth spurt. The authors suggest that variation in the development of flexibility may be as a result of the difference in timing and rate of growth observed between the legs and the trunk. The growth of the legs reach peak velocity before PHV and the trunk reaches peak velocity after PHV (Malina, et al. 2004).

Training Load

The intensity and frequency of training are commonly researched topics in sport. Understanding the effects that certain types of training and the volume of training could have on an individual can be beneficial to sports coaches and sport science personnel (Low, et al. 2013). Monitoring training load can help inform training schedules and reduce the incidence of injury. It has been shown consistently in the literature that specific training programmes can have a positive impact on performance indicators (i.e. speed, power, and aerobic endurance) in adults (Kotzamanidis, 2005; Dupont, 2004; Impellizzeri, 2008). Although some

literature is available for children and adolescents, the findings are less consistent, and few studies have examined the impact of high training loads in adolescence longitudinally.

Influence of Training on Growth and Maturity

It is important first of all to establish the difference between "physically active" in adolescents and adolescents who are training. Being physically active may refer to simple tasks such as walking or recreational bike riding whereas, training suggests that an individual is taking part in specific, regular, systematic activity in order to improve in a certain discipline or physiological function (Malina, et al. 2004). One issue with this area of research is being able to appropriately quantify the activity that is being taken during physical activity or training. There are many factors that can influence training including the environment, psychosocial factors, quality of coaching and the relationship with coaches.

Early research (Laron and Klinger, 1989 and Theintz, et al. 1993) made suggestions that intense physical activity and training had an adverse effect on the adolescent growth spurt and could cause delayed or supressed puberty. Some authors (Theintz, et al. 1993) concluded that excessive intensive gymnastics training stunts the adolescent growth spurt – specifically with regards to leg length. Theintz, et al. (1993) described this research as longitudinal, however, data was only collected over a 2 year period so it is fair to be sceptical of these observations. The Medical Association and the American Dietic Association (1991) suggested that in competitive situations where body shape is altered through strenuous activity to maximise competitive edge that sexual maturation may be delayed, as well as decreased bone growth and ultimate height. These findings would be most applicable to

sports such as gymnastics and ballet, where a later PHV and smaller ultimate height may be beneficial for success (Malina, et al. 2004). In contrast, adolescents who participate in sports such as volleyball, distance running, basketball, cycling and ice hockey and individuals who systematically train for these sports are found to have the same estimated growth rates as those who are non-athletes (Malina, 1994; Malina, 1998; Rogol, et al. 2000). Assumptions can be made from these findings that regular training for sport does not affect adult height, however, the data collected for the research (Malina, 1994; Malina, 1998; Rogol, et al. 2000) was over a shorter period of time than desirable for making strong conclusions. Vadocz, et al. (2002) also found that individuals who systematically trained for sports competition had, on average, the same APHV as those who did not take part in regular sports training. The same was noted for both boys and girls. One aspect that is known to change as a result of training in adolescence is body mass with an increase in fat-free mass also occasionally present (Malina, et al. 2004). Athletes and non-athletes have been noted as having a decreased relative-fatness during adolescence, however athletes show lower relative-fatness than non-athletes at this time (Malina, et al. 2004). Malina (1994) and Malina and Bielicki, (1996) both noted that skeletal maturation (assessed by hand and wrist x-rays) also remains unaffected by training for sport and the finding was presented alongside evidence that chronological age and skeletal age displayed similar gains in both active and inactive adolescent participants.

Training, Maturation and Physical Prowess

There is a growing body of literature examining the effect of different types of training on adolescents. It is difficult to draw definitive conclusions from research in this area as a lot of the time the aspects being assessed (for example, speed, power or aerobic capacity) are being measured at the time around PHV. It could therefore be the case that positive changes in

physical ability are recorded at the same time as normal growth and maturity, making it difficult to partition the effects that any type of training may be having. Malina, et al. (2004) suggest that negative influences on growth and maturation are often attributed to training without consideration of the factors that are known to impact these processes. One example given by the authors is the nature of selection and recruitment of athletes. Individuals are often selected due to possession of specific features such as morphology and advanced maturity status.

Rumpf, et al. (2012) conducted a review of literature explaining the effect of different training methods on sprint times in youths. From the review the authors state that plyometric training was the most effective type of training for pre- and mid-PHV participants while a combined method, consisting of two types of training (i.e. plyometric and strength training), was most effective for post-PHV participants. It may be the case that plyometric training helps to develop greater neuromuscular control and coordination for less mature individuals, whereas more mature individuals can cope with the stressors of strength training.

It is important to make the distinction between differences noted in individuals who enter a training regimen from a sedentary lifestyle compared to those who are already trained. Kotzamanidis et al. (2003) found small to moderate effect sizes in 0-20m, 0-30m and flying 20-30m sprint times after carrying out sprint training programmes with nonathletic boys. Veturelli et al. (2008) also found moderate improvements for 0-20m sprint times in already trained football players after taking part in a sprint training programme. The already trained participants in the aforementioned study however, carried out more training per week and for more weeks than the nonathletic participants. Although this research provides an insight into the effects of different training methods in young athletes, the methods involved do not quantify the duration or intensity of the training undergone and therefore make it difficult to

note the appropriate quantity of training needed. Authors suggest that these findings are a result of improved coordination and synchronicity; more so than muscle hypertrophy, however Veturelli's et al. (2008) study did not measure muscle mass. Resistance training has been shown to improve endurance capacity in elite young cyclists (Aagaard, et al. 2010). An 8% improvement on a 45-minute time trial was recorded and the authors suggested that muscle hypertrophy was not responsible for the improvements but that gains in maximal muscle force likely were. Although Aagaard's et al. (2010) research furthers the idea that specific training methods can improve aspects related to physical performance, an older cohort was used (average age of 19 years) by which point the participants will be post-PHV meaning it is difficult to explain whether this type of training would be appropriate for younger, less mature individuals. McMillan, et al. (2005) also found that aerobic endurance improved as a result of training for football. A sub-maximal blood lactate measure was taken during an incremental treadmill protocol and significant improvements in aerobic endurance were noted from pre-season into the early weeks of the season; evidenced by increases in mean running velocity. The research examined a training session time of average hours per week but since this study was carried out using an older cohort with an average age of 18 years, it is unclear whether maturation would have an impact on the results. Rosch et al. (2000) conducted a study that examined maturity-associated variation in growth and functional capacity in youth football players from Germany, France and the Czech Republic. The study recruited participants from two age groups, at two different levels of participation. These were a highly-trained group and a group involved in lower levels of participation. The study measured explosive power, running speed and aerobic endurance using the vertical jump, 30m dash and yo-yo intermittent endurance tests, respectively. The players were tested over a 2-week period and by comparing the highly trained group to the control group, it was found that systematic training for football was a significant contributor to aerobic

performance, whereas stature and mass were significant contributors to the vertical jump and sprinting tasks. These findings are in agreement with Buchheit and Mendez-Villanueva (2014), Mendez-Villanueva and Buccheit, et al. (2011), Phillippaerts, et al. (2006) and Malina et al. (2004) who all attributed improvements in functional capacity such as speed, change of direction, and lower limb power to growth and advanced maturity status. The researchers (Malina, et al. 2004) do not provide any quantification of training session time or training content – they simply state that the individuals involved completed 2 weeks of training during the study. Lack of information with regards to training load or volume makes it hard to interpret the results as it is difficult to say what caused the improvement in each task; whether this was from the effect of training or being physically more mature. The Tanner (1962) method of determining secondary sex characteristics was used for measuring maturity status in this research and with a narrow age gap of 13.2 – 15.1 years of age it may have been difficult to partition maturity groups into early, on time and late maturing individuals with a subjective measure. The study does confirm that the variability of functional capacity could be equally accountable to the effect of maturity status as a result of training.

Training Load, Maturation and Injury Propensity

The American academy of paediatrics (2000) carried out a subject review on injuries in youth sport (9-15 years of age) and found that 45% of all injuries recorded over a 2 year period occurred in participants younger than 15 years of age. However, it is important to note that there are many factors that create a wide variation of injury incidence such as level of exposure to injury risks (i.e. contact sport), competition level and the definition of injury. The largest risk of adolescent injury is as a history of a previous injury (Junge et al. 2000). The

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aforementioned factors make it difficult to make comparisons in the literature as they often differ between studies. The review also showed that injury rates ranged from 0.6-19.1 per 1000 hours of training and that the injury rates also varied as a result of the differing factors. Maximising development time is important for adolescents in sport to increase their exposure to as many different permutations of the sport as possible (Dvorak and Junge 2000; Junge et al. 2000). However, it is equally as important to ensure that players stay fit to train and do not suffer from overtraining and as a result increase their likelihood of injury; i.e. possible repetitive strain or overuse injuries. Research investigating overtraining in youth sport is fairly sparse, however, Brink et al. (2011) warns of the dangers of high physical training load, as well as psychosocial factors that can lead to an increased likelihood of injury in adolescent footballers. There has been a recent increase in reported overuse injuries in adolescent football players (Agricola, et al. 2012) and one possible explanation could be increased prescribed training caused by early specialisation (Agricola, et al. 2014). To date there has been very little published research that has attempted to quantify training session time and injury data to examine the effect of an increased training load on injury propensity in adolescent sport. There have also been very few studies that have looked at the relationship between maturity and injury in elite adolescent football players. Most research in this area examines the impact of tournament play on injury rates and although injury rate during tournament play is important it would be beneficial to understand the degree to which injury propensity is affected by training session time over a longer period of time. Caine, et al. (2008) reviewed research that examined the incidence of injury on different sports. The author details that when the rate of injuries is shown as injuries per 1000 hours of athletic exposure, cross country running (10.9-15), American football (3.52-16.2) and football (2.43-17) are the sports that show the highest rate of injuries in youth participants. The studies critiqued however, used participants at various levels of competition and of varying age,

making it difficult to conclude what may be causing injuries; i.e. lack of training or too much training. One possible explanation for these sports being the most prevalent for adolescent injury is that they involve a high degree of contact during sprinting, jumping and pivoting movements. These activities are often involved in the mechanism of sports injury (Emery, et al. 2006). In agreement with these findings, adolescent football players are thought to be at increased risk of injury because of the immaturity of their neuromuscular systems (Schmikli, 1995).

Overuse injuries are becoming more common in adolescent sport as organised sports participation and early specialisation increases (Baker, 2003; Malina et al. 2010). An overuse injury can be defined as microtraumatic damage to the bone, muscle or tendon as a result of repetitive stress without allowing sufficient time to undergo the natural reparative process (Brenner, 2007). In an earlier study by Dalton, et al. (1993) the authors suggested that up to 50% of all injuries observed in paediatric sports medicine were related to overuse and that the increase in participation was linked to the number of overuse injuries reported. In addition, the authors state that overuse trauma is more problematic in adolescents as it occurs simultaneously with growth. As bones grow they are less able to cope with stress in comparison to fully developed adult bones (Maffulli, et al. 1992; Brenner, 2007). As well as this, the adolescent growth spurt is associated with increased muscle-tendon tightness and decreased physeal strength (Brenner, 2007). Bone mineralisation is also thought to occur later than linear bone growth and as a result bone can become temporarily more porous and prone to injury (Flaschmann, et al. 2000). Brenner, (2007) also suggests that injuries are more common around the time of PHV and some sports injuries are more prevalent if biomechanical problems are evident. There are few relevant studies available for adolescent athletes; however, overtraining is well documented in adults (Kellman, 2010). It can be

described as a series of psychological, physiological and hormonal changes that result in decreased sports performance that can lead to lack of motivation and enthusiasm to practise or compete.

Although not controlling for biological maturity, earlier research (Roy, et al. 1989; Brust, et al. 1992) examining injury incidence in adolescents of differing body size showed that lighter players were more likely to be injured than heavier players. In contrast, research in adolescent American football has shown that heavier players are more likely to be injured due to increased mass and in turn greater forces, placing stress on soft tissue and joints (Emery, et al. 2006). Le Gall, et al. (2006) conducted research that examined injury incidence in 233 players over 10 seasons at the National Football Institute in France. The researchers measured skeletal maturity to divide the participants into maturity groups of "on time", "early" and "late" maturing individuals. The findings of the study showed that there was no effect of maturity on injury incidence. However, the researchers observed that late maturers showed significantly higher rates of, what was defined as, major injury. Despite this, the authors state that biological maturity status did not significantly affect the overall injury incidence in the academy players. An injury rate per 1000 hours of exposure of 0.9-29.9 was recorded and this finding is in line with previous research (Price, et al. 2004). It can be assumed from these findings that whatever the maturity status of an individual, they are always susceptible to injury regardless of when they compete. One possible explanation for these findings could be that talent identification has favoured older, more physically desirable and mature players – as is often the case (Pittoli, et al. 2010) - meaning that late maturing individuals are underrepresented in the academy. A potential limitation to Le Gall's, et al. (2006) study is that training and match exposure was monitored and calculated as a team and not individually meaning that injury incidence is over or underestimated for each individual. Other previous

studies that have carried out similar research have either omitted exposure time (Volpi, et al. 2003; Price, et al. 2004) or used estimates such as the aforementioned research.

Summary

Previous research has shown there are many different factors that play a part in an adolescent footballer's physical development. The RAE (Musch and Grondin, 2001), growth and maturation (Bucheit and Mendez-Villaneuva, 2013; Malina, et al. 2000), anthropometric characteristics (Ali, et al. 2007; Stølen, et al. 2005) and subjective talent identification (Wolstencroft, et al. 2002) being some of these. As football becomes more lucrative and youth academy and elite player programmes become a more important commodity, information on the impact of systemic training programmes during adolescence is needed to guide clubs and national governing bodies. With evidence from the current research, stakeholders involved with long term player development programmes can make informed decisions about what is best for their young players with regards to volume of training, the impact of maturation on their performance, the physical attributes that may be most important for success in football, as well as information that could potentially enhance the talent ID process.

Chapter 2: Methodology

The studies that make up this thesis used the same methods of data collection throughout. These are as detailed in this chapter. Participants were given three attempts at each measure at every test date, with the exception of anthropometric measures and assessments of recovery capacity from high-intensity exercise (YYIRTL1). All testing was carried out on a standard indoor gym hall floor with participants wearing regular sports kit, unless stated otherwise (i.e. shorts, t shirt and trainers/running shoes).

2.1. Player grouping

The participants involved within the study chapters of this thesis were grouped based on year of birth (2000, 2001, 2002 and 2003). Year of birth was chosen as the grouping variable as the selection year at academy level and performance school level are different (January to December and March to February, respectively). Due to the difference in selection year, it was possible that an adolescent footballer could be training with an older age group within the Performance School, but a younger age group at academy level. For example, they could be born in the first quarter of the selection year at their club, but the fourth quarter within their year group in the Performance School programme.

2.2. Training session time and attendance

Sportsoffice

Sportsoffice is an online player management system that the Scottish Football Association (SFA) use to monitor training minutes and player attendance within the Performance Schools programme. The database is accessible by the head coaches at each Performance School and

updated by them on a regular basis. Access to the information was granted to the lead researcher and data were extracted and collated on a monthly basis.

Purpose built Microsoft Excel spreadsheet

In order for control groups to collect the same information as the Performance Schools, a purpose-built Microsoft Excel spreadsheet was created. The spreadsheet made it possible for control groups (who don't have access to Sportsoffice) to collect the same information as the Performance Schools – i.e. training minutes and player attendance. Spreadsheets were shared between coaches and the lead researcher on a monthly basis via email.

2.3. Anthropometric measures and estimate of maturity

Anthropometric measures were taken by the lead researcher and assistants. Anthropometric measurements were used to estimate approximate age at peak height velocity (PHV) using Mirwald's et al. (2002) multiple regression equation. The regression analysis was carried out in a purpose-built Microsoft Excel spreadsheet. Entering the test date, player's date of birth, stature, seated stature and mass into the spreadsheet provided each individual player's approximate age at PHV. Stature and seated stature were measured using a stadiometer (SECA 2013 Stadiometer). Seated stature was measured whilst seated on a purpose-built platform that was placed on the base of the same stadiometer (33cm wooden box). Body mass was measured using a set of calibrated scales (SECA Floor Scale). Participants removed their footwear when being measured for stature, seated stature and mass. Similar protocols for anthropometry have been used in previous research and are shown to be reliable and valid (Bucheit & Mendez-Villaneueva, 2013). As described by Mirwald, et al. (2002) maturity

offset is used as a relative indicator of somatic maturity and represents the time of maximum growth in stature during adolescence.

Stature

Participants were asked to remove their shoes and stand facing outwards from the stadiometer, on its base, during the assessment of stature. The gauge of the stadiometer was moved down until it rested flat on the participant's head, where the measure was then taken in centimetres (cm).

Seated Stature

Seated stature was measured with a similar method to stature, however, participants were asked to sit on a purpose-built (33cm) wooden platform that was placed on the base of the stadiometer. The participants were asked to ensure their back was resting flat against the stadiometer and that they were sitting up straight. The gauge was brought down to rest flat on the participant's head and the measure was then taken in cm.

Body Mass

Participants were asked to remove their shoes and stand, facing forwards, on a calibrated scale (SECA Floor Scale). Once the participant was standing still, the scale was allowed a moment to settle and the measure was taken in kilograms (kg).

2.4. Physiological test battery

Linear Speed

All participants performed a 20m sprint with split timings at 5m, 10m and 20m assessed using a Brower light gate system (Brower Timing TC-System). Participants initiated each sprint 0.5m behind the first light gate with self-selected recovery periods between each effort. A distance of 0.5m behind the gate was chosen so that participants would not disrupt the beam of the light gate before starting the assessment. It was also thought that 0.5m would not be a big enough distance to pick up any great speed prior to passing the first light gate.

Change of Direction (COD)

A change of direction test (figure 2) was carried out to best replicate agility and measure change of direction ability. The test used the Brower light gate system (Brower Timing TC-System) to measure the time to complete the test in seconds. The test required players to run from a marked point, 0.5m behind the first light gate, in a straight sprint for 10m, where they would turn over their right shoulder, sprint 10m and turn, with their foot planted at a marked point, and sprint 5m to finish through the light gate. Participants were measured turning over the right and left shoulders independently. The left and right turn times were highly correlated (r = .999) and therefore the mean of the best left and right total time was used in analyses.
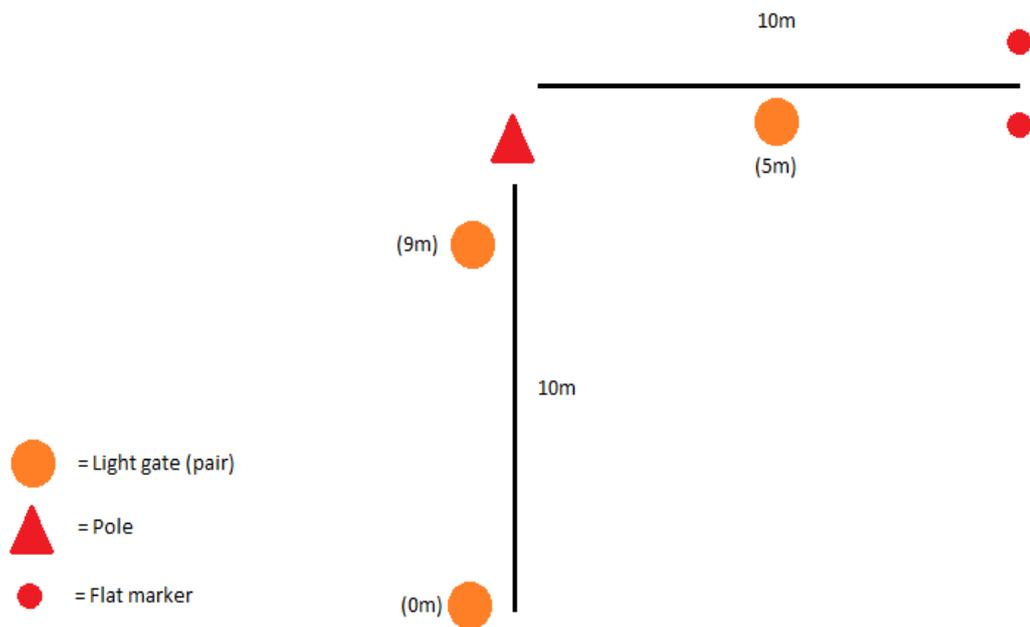
Figure 2. Diagram of Change of Direction Test (example of right turn).

<u>Lower Limb Power</u>

A squat jump (SJ) was used to measure lower limb power. The test measured the distance the participant was able to jump from the ground in cm. A "Just Jump" (Just Jump system) mat was used for this assessment. With the mat placed on a solid, flat surface the participants were asked to step on the mat, with their feet shoulder width apart, and place their hands on their hips. They would then bend their knees to enter a squat position – the depth of the squat is determined by the participant – and explode upwards, landing back on the mat. Participants were asked to keep their hands on their hips throughout the assessment.

Recovery Capacity from High-Intensity Exercise - YoYo Intermittent Recovery Test Level 1 (YYIRTL1)

The yoyo intermittent recovery test level 1 (YYIRTL1) test audio was played through a loud speaker as numerous participants completed the test simultaneously. The participants completed 2x20m runs between the start, turn and finish line when instructed by the test audio. Each 2x20m sprint was interspersed with a 10 second active rest period inside a designated 5m rest area. Participants were asked not to perform maximal exercise within 48 hours of taking part. Performance in the test was measured in distance covered in metres. Participants repeated the steps instructed by the test audio until they exited or completed the test. Participants who missed two signals, in total, on the audio were asked to leave the test. Participants were also asked to leave the test if they commenced running before instructed by the test audio, on more than one occasion.

Statistical Methods

The statistical methods adopted in the present thesis were used in an attempt to make an accurate inference about any present effects. The use of magnitude based inferences (MBI) (Hopkins, 2000) meant that the magnitude of any relationships or differences could be quantified (i.e. *trivial, small, moderate or large)*, rather than the traditional method of reporting a value as "significant" or "nonsignificant". MBI also allowed the findings to be interpreted in the context of confidence intervals (CI) – which indicate the likely range of the true value (Batterham and Hopkins, 2006). As well as providing an inference about magnitude, analysis of the type also holds statistical power when using smaller sample sizes and permits adjustment for covariates.

<u>2.5. Typical Error</u>

A sub-group of participants were used to calculate typical error (TE) for the 20m, COD and SJ assessments. The data were collected from 27 adolescent footballers (13.90±0.78 years of age), who were part of the SFA Performance School programme. Due to the participants training schedule, it was not possible to carry out repeated measures of the YYIRTL1 assessment. The TE used for the YYIRTL1 was taken from a study by Povoas, et al. (2015) that examined the validity and reliability of YoYo test scores in 9-16-year-old footballers.

Participants carried out three attempts of the 20m, COD and SJ assessments each, one day apart (for example, on Wednesday; T1, and again on Friday; T2). The best score in each test was used for the analysis.

T1 and T2 data were log transformed, to allow TE to be expressed as a percentage and to reduce risk of error from skewness. A delta (Δ) value was taken between T1 and T2 (*T2−T1*). TE was then calculated as:

$$\text{TE} = \left(\frac{\text{SD}\Delta}{\sqrt{2}}\right) \times 100$$

For 20m, COD and SJ assessments the TE was 1.70%, 2.40% and 4.50%, respectively. The TE reported by Povoas, et al. (2015), for the YYIRTL1, was 8.50%.

Chapter 3: Study 1

"The physiological characteristics of adolescent footballers selected for a systematic training regimen"

3.1. Introduction

In 2012 the Scottish Football Association (SFA) launched a new elite performance programme that would recruit young players from the ages of 12-16 years to engage in a systematic football training programme as part of their regular secondary school education. Seven schools were selected across Scotland; Kilmarnock, Glasgow, Motherwell, Falkirk, Edinburgh, Dundee and Aberdeen. Selection into the programme is structured according to the Scottish school year. The dates for the selection year run from the 1st of March that year to the 28/29th of February the following year. The goal of the programme is to improve the success rate of the national team in relation to qualification and competition in world class tournaments e.g. the European and World Cup. Elite programmes focusing on long term athlete development have become increasingly popular as national governing bodies look to standardise the development of their young players.

A common finding in youth football is that chronologically older players tend to be overrepresented in youth academies (Jimenez and Pain, 2008; Figueiredo, et al. 2009; Vandendreissche, et al. 2012; Reilly, et al. 2000). Previous literature suggests that these earlier born players can be significantly biologically more mature than players born later in the year (Malina et al. 2007), even within one year group. One reason posited for this overrepresentation is their ability to outperform less mature players in the physical aspects of the game (Meylan, et al. 2010). More pronounced physical attributes at a young age can often be mistaken for talent in football (Helsen, et al. 2000) and as a result, less physically mature but equally skilful players, can be left out (Matthys, et al. 2012; Vandendreissche, et al. 2012; Figueiredo, et al. 2009). The overrepresentation of older footballers in adolescent sport has been labelled the relative age effect (RAE). The RAE occurs when a larger number of players born in the earlier part of the selection year are present in greater numbers of the sport when

compared to the birth dates of the general population (Musch and Grondin, 2001; Boucher and Mortimer, 1994). Despite being a well documented phenomenon there is little evidence to suggest the effect is present in Scottish football. In an effort to avoid the RAE, and emphasise skill is as important as physical attributes, the SFA's new performance programme focuses on long term development. The talent identification process, however, is often subjective and opinion based, with pronounced physical attributes being mistaken for talent (Wolstencroft, et al. 2002).

It is imperative when assessing youth footballers that an account is made for maturation (Malina, et al. 2007; Stølen, et al. 2005), as each individual will physically develop at different rates. An established method of estimating an individual's maturity status is by using Mirwald's et al (2002) multiple regression equation. Using a set of anthropometric measures - stature, seated stature and mass – the time from peak height velocity (PHV) can be estimated ± 1 year (Mirwald, et al. 2002). The estimation is classified as "maturity offset", where negative and positive values denote pre-PHV and post-PHV, respectively. A player's PHV is where they experience their most rapid period of growth in stature. At this point in development the following authors have been able to demonstrate that this is where adolescents experience the largest improvements in sprint performance, change of direction ability, lower limb power and performance in intermittent field tests (Iuliano-Burns et al. 2001; Philippaerts et al. 2006 and Meylan, et al. 2014).

There were three aims in the present study. Firstly, to examine the birth date distribution of the Performance School cohort to establish if the RAE exists within the SFA performance school programme. Secondly, use a sub-population of the Performance School cohort to document the relationship between their anthropometric and physical characteristics. Finally, to analyse the difference between physical performance across the chronological year groups. The cohort of players is entirely unique in Scotland, in that they are selected as the "best

players" from cohorts of already highly trained youth players and entered into a full time training programme. These are areas that have never been examined in the Performance School population. It was hypothesised that the RAE would exist in the Performance Schools and that earlier born, biologically more mature players would physically outperform those born later in the selection year.

3.2. Methodology

Participants

A cohort of 344 highly trained youth football players aged 13.64 ± 1.14 years, who represent the SFA elite Performance School programme were included in the research and through their legal guardians provided consent to do so (Appendix A). Participants were given a participant information sheet (Appendix B) and also provided their consent to participate (Appendix A). Within the Performance School the players trained for football each day (Monday-Friday) as part of their regular school curriculum. The school programme provided the players with an additional 8-10 hours of extra football practise each week, in addition to the approximate 4.5 hours they received from training with their parent clubs. From this cohort a sub population of 132 players aged 13.38 ± 1.12 years was used to examine physical qualities. As part of their enrolment to the programme, players and parents/guardians provided personal information, including a date of birth and completed a physiological test battery within one month of the start of the school year. All player information was entered into the player management system, Sportsoffice. The system was accessible by the lead researcher. The study was granted ethical approval by the research ethics committee at Heriot-Watt University, Edinburgh.

Study overview

Dates of birth were provided by parents/guardians which were collated for each year group at all seven schools. Physical performance tests were carried out at the start of the school year, in August, for each age group in all Performance Schools at which point data was collected in nine different measures. These measures were – stature, mass, seated stature, 5m, 10m and

20m sprints, change of direction, squat jump (SJ) and the yo-yo intermittent recovery test level 1 (YYIRTL1). These tests were used to assess maturity offset, linear speed, change of direction ability, lower limb power and recovery capacity from high-intensity exercise, respectively. Each participant was given three attempts at each test (excluding anthropometrics and the YYIRTL1) and all attempts were recorded. All testing was carried out on an indoor standard gym hall floor. Physical performance data from three Performance Schools was chosen as a sub-group based on the reliability of the data collected, i.e. testing venue and personnel involved in data collection. Competing for time and facilities in the school environment made it difficult to collect physical performance data, with the necessary rigor, at each test date from every performance school. All testing was supervised by the lead researcher.

Anthropometric measures and estimate of maturity

Anthropometric measures were taken by the researcher and assistants in line with the protocol described in the methodology chapter (Chapter 1) of this thesis.

Birth date distribution

Participants were ascribed to a birth quartile group according to their date of birth relative to the school year. In Scotland, the school selection year runs from March 1st that year, to Feb $28/29^{th}$ the following year. The quartiles were therefore March, April, May – Quartile 1 (Q1); June, July, August – Quartile 2 (Q2); September, October, November – Quartile 3 (Q3) and December, January, February - Quartile 4 (Q4).

<u>Physical performance tests</u>

Linear speed, ability to change direction, lower limb power and recovery capacity from high-intensity exercise were assessed using the physiological test battery detailed in the methodology chapter (Chapter 1) of this thesis.

<u>Analysis</u>

Inferential statistics were used initially to examine any differences across birth quartiles and chronological age groups. Data are presented as Mean ± SD. A chi-square goodness of fit test was used in order to examine the RAE. A one-way ANOVA with post-hoc analysis (Tukey) was used to determine if differences were present for biological maturity, stature and mass. A linear regression model was used to examine the relationship between physical performance, in the 20m sprint, COD test, SJ, YYIRTL1 and maturity offset. Statistical significance was calculated at $p<.05$. Standardised beta coefficients (β), from the regression analysis, give an estimation of the contributions of each variable. Positive and negative β values represent an increase and decrease, respectively, in association with independent variables. Statistical analysis was performed using SPSS statistics software (PASW statistics 20). Due to the practical nature of the study effect sizes (Cohens d) and magnitude based inferences were also used. Effect sizes of 0.2, 0.5, and 0.8 were considered small, moderate and large respectively (Cohen's). Magnitude based inferences (MBI) (Hopkins, 2007) were used to explain the magnitude in difference between year groups regarding physical performance.

3.3. Results

RAE

There was a significantly ($p<0.05$) unequal birth date distribution observed in all year groups. For each year group there was a greater proportion of players born in Q1 than in any other quartile. The observed percentage of births was higher in Q1 of the performance school cohort than the expected distribution of the general population; based on birth records provided by the Scottish Government. For example, Q1 of the 2003 year group showed an observed representation of 50% in the performance school cohort when the expected distribution for the general population was 24%. In Q4 of the same year group there was an expected distribution of 25%, but only 10% of the performance school players cohort were born in this quartile (see Table 1).

Physical Performance and Chronological Age Groups

Using the chronological age groups, comparisons were made to show the magnitude of difference in performance between the year groups by factorial design (Table 2). The older age group in each comparison outperformed their younger counterparts in the 20m, COD, SJ and YYIRTL1. The year-to-year progression was observed to be greater as a function of the older age group in the YYIRTL1 and SJ with relative improvements of 47.9% and 15.6%, respectively. Performance in the 20m and COD were found to have smaller differences than the SJ and YYIRTL1 when comparing the oldest group (2000) with the youngest group (2003). The difference in these variables was observed as 3.8% and 1.7% for the 20m and COD, respectively.

Maturity offset

Maturity offset was significantly different between birth quartiles in the 2003, 2001 and 2000 age group (Table 1). The group of players born in 2001 in the first quartile showed an advanced maturity offset in comparison with those born in Q3 and Q4 ($p < .01$). This was also the case for players born in 2000 (Table 1). Large effect sizes (cohen's d) were found between Q1 and Q4 in the 2003 (d = 0.8), 2002 (d = 0.9), 2001 (d = 1.1) and 2000 (d = 1.1) year groups, with players born in Q1 showing an advanced maturity offset. A one-way ANOVA was used to examine the differences in stature and mass between the quartiles but there were no significant differences observed. However, small and trivial effect sizes were noted between Q1 and Q4 for stature and mass in the 2002 (d = 0.2 and 0.1 for stature and mass, respectively), 2001 (d = 0.5 and 0.7 for stature and mass, respectively) and 2000 (d = 0.5 and 0.3 for stature and mass, respectively) year groups (Table 4). These data suggest that players born in Q1 were taller and heavier than players born in Q4. Effect sizes in stature (d = 0.9) and mass (d = 1.1) between Q1 and Q4 in the 2003 age group demonstrated that players born in Q1 tended to be taller and heavier than those born in Q4.

Physical Performance and Maturity Offset

The linear regression model accounted for a statistically significant proportion of the variance in the 2003 and 2001 year groups ($R^2 = .188$, $p = .005$ and $R^2 = .213$, $p = .006$, respectively) for sprint ability over 20m ($\beta = -.434$, $p = .005$ and $\beta = -.462$, $p = .006$, respectively) (Table 5). The model also accounted for a statistically significant proportion of the variance in the 2003 and 2001 year groups ($R^2 = .097$, $p = .050$ and $R^2 = .156$, $p = .021$, respectively) with regards to COD ability in the 2003 ($\beta = -.312$, $p = .050$) year group and the SJ in the 2001 (β

= .395, p = .021) year group. The model, however, did not account for a statistically

significant proportion of the variance in any other measure of physical performance, in any

year group.

Table 1. The expected and observed birth date distribution per year (%) and Maturity offset values (Mean ± SD) within each year group, for the entire performance school cohort. A negative value indicates the period prior to PHV and a positive value indicates the period post-PHV

Year Group	n	x^2	Expected	Q1 vs	Observed	Expected	Q2 vs	Observed	Expected	Q3 vs	Observed	Expected	Q4 vs	Observed	Cohen's d Q1 vs Q4 (Maturity Offset)
2003	82	39.23**	24%		50% *-1.62±0.45*	25%		22% *-1.71±0.68*	27%		18% *-2.11±0.53* **A**	25%		10% *-2.03±0.49*	
			(N = 6310)		(N = 41)	(N = 6666)		(N = 18)	(N = 7185)		(N = 15)	(N = 6720)		(N = 8)	**0.8**
2002	75	34.05*	24%		45% *-0.94±0.71*	25%		29% *-1.13±0.47*	26%		12% *-1.50±0.58*	26%		13% *-1.49±0.53*	
			(N = 6233)		(N = 34)	(N = 6439)		(N = 22)	(N = 6808)		(N = 9)	(N = 6712)		(N = 10)	**0.9**
2001	100	25.28**	25%		42% *0.25±0.78* **B**	25%		29% *-0.36±0.75* **A**	26%		17% *-1.07±0.94* **A**	25%		12% *-0.55±0.68* **A**	
			(N = 6559)		(N =42)	(N = 6644)		(N = 29)	(N = 6828)		(N = 17)	(N = 6651)		(N = 12)	**1.1**
2000	87	28.29**	25%		49% *0.87±0.88* **B**	25%		20% *0.84±0.81*	25%		18% *0.24±0.62*	25%		13% *-0.43±0.81* **A**	
			(N = 6850)		(N = 43)	(N = 6835)		(N = 17)	(N = 6906)		(N = 16)	(N = 6739)		(N = 11)	**1.1**

*p<.05   **p<.01   **A** = significantly different to Quartile 1 **B =** significantly different to Quartile 4

Table 2. Magnitude based inferences (90% Confidence Intervals) on physical characteristics and performance measures between chronological year groups within the sub-population.

		Year Group				
Test		**2003 vs 2002**	**2001 vs 2003**	**2000 vs 2003**	**2000 vs 2001**	**2002 vs 2001**
20m	**Delta**	-1.10%	-3.90%	-3.80%	-3.80%	-2.00%
	Standardised mean ± SD	-0.23±0.33	-0.86±0.45	-0.83±0.49	-0.83±0.44	-0.58±0.58
	Clinical Inference	"Possibly Trivial"	"Likely Large"	"Likely Large"	"Likely Large"	"Likely Moderate"
COD	**Delta**	-2.30%	-4.30%	-1.70%	-1.70%	-2.00%
	Standardised mean ± SD	-0.53±0.42	-0.86±0.46	-1.35±0.59	-0.40±0.62	-0.46±0.69
	Clinical Inference	"Likely Moderate"	"Likely Large"	"Likely Very Large"	"Possibly Small"	"Possibly Small"
SJ	**Delta**	-0.90%	6.70%	15.60%	7.20%	7.40%
	Standardised mean ± SD	-0.08±0.41	0.55±0.37	1.24±0.42	0.60±0.49	0.68±0.60
	Clinical Inference	"Unclear"	"Likely Moderate"	"Likely Very Large"	"Likely Moderate"	"Likely Moderate"
YYIR TL1	**Delta**	7.30%	47.10%	47.90%	-14.70%	28.80%
	Standardised mean ± SD	0.17±0.48	0.96±0.46	0.98±0.54	-0.40±0.72	0.99±0.61
	Clinical Inference	"Unclear"	"Likely Very Large"	"Likely Very Large"	"Small"	"Likely Very Large"

Table 3. Stature and Mass of entire performance school cohort.

Year Group	Measure	Quartile 1	Quartile 2	Quartile 3	Quartile 4	Cohen's d Quartile 1 vs Quartile 4 STATURE
2003	Stature (cm)	151.6±8.1	149.2±5.6	148.4±7.3	144.4±4.3	0.9
	Mass (kg)	41.1±7.6	38.6±4.1	37.8±6.2	33.1±1.8	1.1
2002	Stature (cm)	154.8±8.8	152.3±7.9	153.3±6.2	153.1±4.1	0.2
	Mass (kg)	43.1±8.9	39.9±5.2	43.3±5.1	42.2±6.5	0.1
2001	Stature (cm)	165.2±9.4	163.0±9.9	159.4±8.1	160.1±12.9	0.5
	Mass (kg)	51.2±8.3	49.2±10.1	46.8±7.6	45.1±7.8	0.7
2000	Stature (cm)	167.3±9.9	169.4±8.4	170.2±8.2	163.1±5.7	0.5
	Mass (kg)	55.4±9.2	55.9±8.2	52.9±7.1	51.9±5.5	0.3

Table 4. Means and standard deviations of physical characteristics in the performance sub-population.

Year Group	Age (years)	Stature (cm)	Mass (kg)
2003 (N = 40)	11.79 ± .41	149.6 ± 6.8 **Ω μ** ∑	39.8 ± 5.9 ∑ **μ**
2002 (N = 35)	12.85 ± .42	153.7 ± 6.8 **¥ μ** ∑	41.5 ± 6.9 ∑ **μ**
2001 (N = 36)	13.86 ± .35	161.3 ± 8.8 **¥ Ω** ∑	47.9 ± 8.8 ∑ **Ω ¥**
2000 (N = 21)	14.85 ± .35	169.2 ± 8.3 **¥ Ω μ**	56.9 ± 8.5 **μ Ω ¥**

¥= significantly different to 2003 group

Ω = significantly different to 2002 group

μ = significantly different to 2001 group

∑ = significantly different to 2000 group

Table 5. Linear regression on maturity offset and physical performance in each year group within the sub-population.

Year Group	Test	Model Summary			ANOVA	Coefficients	
		R^2	*P*	*Durban-Watson*	*P*	*Standardised Beta*	*P*
2003 (n = 40)	**20m**	.188	.005	1.964	.005	-.434	.005
	SJ	.019	.395	1.817	.395	.197	.395
	COD	.097	.050	1.690	.050	-.312	.050
	YYIRTL1	.001	.867	1.646	.867	.032	.867
2002 (n = 35)	**20m**	.013	.531	2.617	.531	-.113	.531
	SJ	.001	.842	2.433	.842	-.036	.842
	COD	.005	.710	2.130	.710	.068	.710
	YYIRTL1	.020	.489	2.108	.489	.142	.489
2001 (n = 36)	**20m**	.213	.006	1.942	.006	-.462	.006
	SJ	.156	.021	2.462	.021	.395	.021
	COD	.001	.897	2.546	.897	.026	.897
	YYIRTL1	.084	.143	2.666	.143	.289	.143
2000 (n = 21)	**20m**	.084	.243	2.157	.243	-.290	.243
	SJ	.065	.308	2.508	.308	-.255	.308
	COD	.040	.460	1.632	.460	.199	.460
	YYIRTL1	.014	.667	1.660	.667	.118	.667

3.4. Discussion

The purpose of the present study was to establish whether the RAE existed within the SFA
Performance School programme. Additionally, the study aimed to investigate differences in
physical performance with regards to birth date distribution and maturity offset. The current
study found that the RAE was present in the Performance School programme and that players
born earlier in the selection year often displayed a significantly advanced maturity offset than
those born later. Despite this being the case, physical performance did not differ between the
players born at different times of the selection year. A key finding of the study was also that
there appears to be a larger scope for improvement in certain physical attributes (recovery
capacity from high-intensity exercise and lower limb power) than in others.

RAE in SFA Performance Schools

The current data confirmed the presence of the RAE within the Performance School
programme. In the current study, there was an uneven birth date distribution across all age
groups. The youngest players eligible for selection into the programme would be 11 and 12
years of age, making this the earliest opportunity to examine the recruitment policy in the
Performance Schools; similarly, Helsen et al (1998) noted the RAE was present in Belgian
soccer when recruiting players as young as six years old. With an overrepresentation and
underrepresentation of Q1 and Q4 players, respectively, when compared the general
population. It could be suggested, based on this evidence, that players have an increased
chance of selection into the programme if they were born earlier in the selection year. These
findings are in agreement with previous literature that cites skewed birth date distribution in
elite academies when compared to the general population (Vaeyens, et al. 2005). The present

study illustrated significant differences in the birth date distribution for all but one of the year groups (2002) (Table 1) and although the finding was not significant it can be seen that asymmetrical birth date distribution was present in this year group also with players born in Q1 (42%) differing from the expected general population (25%). Research has also been conducted to examine the existence of the RAE in adult football. Jimenez and Pain (2008) looked at the RAE in football in Spain and found that in senior squads the birth date distribution can be almost identical to that of the general population. It could be concluded from Jimenez and Pain's (2008) research that the advantages of being a player born earlier in the year within youth football are transient, as once the growth process is complete and players face selection for senior squads these differences no longer appear to exist (Jimenez and Pain, 2008). The problem remains, still, that talented younger born players are not progressing through elite youth academies and are being lost from the system entirely (Feltz and Petlichkoff, 1983 and Helsen, Starkes, and Hodges, 1998). It may be the case, however, that later born players who are selected for elite academies and programmes will develop more technically and tactically as they have had to compensate for their lack of physicality throughout their development. As a result, technically and tactically gifted later born players being selected for senior squads could be what is causing the absence of the RAE in senior football.

RAE and maturity offset

Due to the nature of youth football it is often the case that academy systems and elite programmes contain a greater number of players born earlier in the selection year that can also display an advanced maturity status compared to later born players (Augste and Lames, 2011 and Gil, et al 2014). In the present study, Cohen's d effect sizes were calculated to show

the size of the effect, based on whether it is a strong or weak effect, in maturity offset values between those born in Q1 and Q4 in each age group. Large effect sizes were recorded between Q1 and Q4 players in all age groups, with the largest effect size being seen in the 2000 and 2001 year groups (d = 1.1). These players are approximately 14 years of age and this is where you might expect to see the largest variation in biological maturity (Malina, et al. 2005). These findings suggest that maturity offset is a contributory factor in the presence of the RAE within this cohort of youth footballers.

Birth quartiles and anthropometry

The present study examined possible differences in anthropometric characteristics between birth quartiles. No significant differences were found with regards to stature and mass for the entire cohort but there were significant differences in maturity offset between some birth quartiles. Mirwald et al. (2002) developed an equation that indicates how many years an individual is from experiencing their peak height velocity (PHV). Negative values would show a player is pre-PHV and positive values shows they are post-PHV. Mirwald's et al (2002) equation uses stature, body mass as well as seated stature to estimate maturity status in relation to the growth curve. This may explain why there is no significant difference in stature and mass, but significant differences with regards to maturity offset. Despite there being no significant difference in anthropometry between birth quartiles, moderate and large effect sizes were found when comparing Q1 to Q4 in the 2003 (stature – d = .9, mass – d = 1.1) and 2001 (stature – d = .5, mass – d = .7) year groups. Within all year groups, players born in Q1 displayed an advanced maturity offset when compared with players born Q4. Significant differences, and correspondingly large effect sizes, in maturity offset between birth quartiles were noted in all year groups with the exception of the 2002 year group.

However, a large effect size (d = .9) was calculated when comparing Q1 to Q4. Perhaps most notable are the significant differences between Q1 and the rest of the quartiles in the 2001 year group. As the 2001 year group at this stage are approximately 14 years of age and are at the typical age of PHV (Philippaerts, et al. 2006 and Malina et al. 2004). The present study shows (Table 1) that Q1 of the 2001 age group is the earliest instance that a positive average maturity offset value is displayed. Youth footballers have been said to experience rapid improvement in physical attributes at the time of PHV, so it would be important to take into consideration for this year group. When players are selected for the Performance School programme they are guaranteed four years of the programme and, unlike club academy programmes, cannot be released (unless on the grounds of behaviour or application). It would appear that this is an attempt to allow players to develop technically and physically at their own rate – understanding that every individual is different. However, it is important to point out that players born in the last quarter of the selection year are still heavily outnumbered by those born in the first quarter (Table 1) and are at a serious disadvantage of being selected in the first place. Helsen et al (2000) and Reilly et al (2000) both discuss the dangers of the subjective selection of players for elite sport, as physical precocity can often be mistaken for talent and therefore draw the attention of scouts or coaches to taller, heavier, more mature young players. The selection process for the Performance School programme is entirely subjective and based on coach's/scouts opinions at trials and during games. It is possible that the Q4 players who have been selected for the programme in the present study are selected due to outstanding technical abilities as technical proficiency in young footballers appears to be homogeneous (Matthys, et al. 2012; Vandendreissche, et al. 2012 and Figueiredo, et al. 2009).

Maturity offset and physical performance

The second aim of the study was to investigate the impact that maturation had on physical performance. The current study measured linear speed, the ability to change direction (COD), lower limb power and recovery capacity from high-intensity exercise. These variables are all seen as desirable attributes for footballers and are frequently tested at both youth and senior level (Deprez, et al. 2015; Stolen, et al. 2005 and Little and Williams 2005). Previous literature that has examined similar factors has suggested that while the RAE causes overrepresentation of early born players, these early born players are also physically dominant in comparison to their later born counterparts (Baxter-Jones and Helms, 1994; Jimenez and Pain, 2008 and Helsen et al. 2000) and are often biologically more mature (Malina et al. 2007). The present study does not fully support these findings as there were no consistent differences found between players when physical attributes were examined in relation to maturity offset. Within the 2003 year group there were significant relationships between maturity offset and 20m sprint ability as well as COD ability meaning that these attributes were superior in relation to an advanced maturity offset. With regards to 20m sprint ability, however, maturity offset only accounted for 18% of the variation in performance and 9% with regards to COD ability. The findings were similar in the 2001 year group where significant relationships between maturity offset, 20m sprint ability and SJ showed that performance in these measures improved relative to an advanced maturity status. Although the present study did not measure it, it has been suggested that at the time of PHV adolescents will experience an increase in muscle mass (Meyers, et al. 2015). An increase in muscle mass in turn would improve force production and aid performance in the aforementioned attributes (Arruda, et al. 2015). These relationships, however, also accounted for a small variation in performance with 21% and 15%, respectively. It is possible these relationships exist in the

2001 groups as the players who make up this group are approximately 14 years of age and this is the typical age of the adolescent growth spurt (Malina et al, 2003) where youth footballers have been said to experience rapid improvements in physical performance (Philippaerts et al. 2006 and Meylan, et al. 2014). It is less clear why relationships, however weak, are present between maturity offset and physical performance are present in the 2003 group. As maturity offset does not appear to have a great or consistent effect on physical performance and players born in the initial months of the year are biologically more mature, it adds to the question of why the later months of the year are so underrepresented in the Performance School programme. Unlike club youth academies, the Performance School are able to select "the best, from the best". Clubs have already recruited the "best" players, in their opinion, and Performance School select from their cohort. With players representing Q4 likely underrepresented at club youth academy level and the Performance School programme only selecting the "best" players, late born players are at a further disadvantage. If only the most physically able Q4 players are being selected, finding an underrepresentation of them in the Performance School programme may not come as a surprise.

Chronological age and physical performance

Although it is important to account for maturation when assessing physical precocity in any youth sport (Bucheit and Mendez-Villaneuva, 2013; Malina, et al. 2000), meaningful inferences can also be made by looking at physical performance in chronological age groups. The most notable finding when comparing the oldest (2000) to the youngest group (2003) was that linear speed and change of direction appear to have a much smaller difference (1.7% and 3.8%, respectively) than lower limb power and YYIRTL1 (15.6% and 47.9%, respectively) (Table 5). This would suggest that there is a greater chance of developing lower

limb power and YYIRTL1, than linear speed and change of direction through football specific training. Sprint speed and ability to change direction have been accepted as important physical qualities and have been used to discriminate between elite and sub elite players (Brughelli, et al. 2008). As these attributes appear to be relatively fixed in comparison to other qualities, these two variables have the potential to inform future talent ID and also suggest that measures of YYIRTL1 and lower limb power may not be appropriate factors when identifying potential talent. Players are often selected for academies based on the premise that strength and conditioning staff can make them faster and more agile. Similarly, they may be rejected or released from elite academies due to being "unfit". The current study used a surrogate measure of recovery capacity from high-intensity exercise by recording distance covered in the YYIRTL1. The results would suggest that players can almost double their endurance capacity in the intermittent field test through football specific training. It can also be proposed that if clubs or academies desire fast and agile players then they should test for these attributes and select the players who already possess these qualities, as they are less likely to change over time or with training.

Limitations

A limitation to the study is that although the Performance School programme is run across Scotland in every region and should provide a national perspective of elite level of Scottish youth football but does not necessarily contain the "best" players. Players need to apply in order to be selected in the first place so the programme still contains an element of self-selection. Overcoming this limitation would involve implementing the same test battery across the country, at different levels of the game (Performance School, non-Performance School, professional youth and grassroots clubs), in order to gain a true national perspective.

It would be extremely difficult to carry out such a project due to time and financial constraints, however, similar research questions will be investigated later in this thesis. Also, due to the nature of the RAE, the number of players born in the final quarter of the selection year was low in both the anthropometric and physical performance comparisons. It would have also been beneficial to have physical performance data for the entire Performance School cohort, making for stronger statistical analysis.

Conclusion

In conclusion, the RAE does exist in the SFA Performance School programme. Presence of this phenomenon confirms that players born earlier in the selection year are overrepresented in the programme when compared to the general population and that players born later in the selection year are underrepresented. Despite these earlier born players sometimes being physically taller, heavier and biologically more mature, these differences did not consistently affect measures of physical performance. Despite some significant differences being observed between measures of physical performance and maturity offset, the relationship accounted for a relatively small proportion of the variance in all cases, meaning that maturity status did not have any great impact on physical performance. It would be worthwhile for coaches and scouts to focus on the technical qualities of young players when identifying talent as these are independent of maturity (Vandendriessche et al. 2005). Furthermore, if fast and agile players are desirable when selecting for the programme, these attributes could be tested during talent ID as these qualities appear to be fixed and don't alter much with football specific training.

Chapter 4: Study 2

"An examination of within-season change in the physical fitness of adolescent footballers"

4.1. Introduction

The SFA Performance School programme is an individual player programme that focuses on improving technical skill by increasing young players contact time with the ball. Performance School sessions focus on mastering techniques such as passing and dribbling; however, football specific skill is difficult to quantify and measure and therefore observed changes in technical ability can often be subjective (Matthys, et al. 2012, Vandendreissche, et al. 2012 and Figueiredo, et al. 2009). To effectively measure the progress in technical skill for players in the programme one would need to design suitable field tests that examine each skill. Unfortunately, there are no valid and reliable tests available that can replicate some of the specific demands of football (e.g., game awareness). The application of a more objective measure, may be more appropriate to assess physical capacity to determine progression of the players in the programme.

Measuring physical capacity is certainly more common in football, than assessment of skill, and attributes such as sprint speed, ability to change direction, lower limb power and recovery capacity from high-intensity exercise are frequently examined in both adult and youth football (Iuliano-Burns et al. 2001; Philippaerts et al. 2006 and Meylan, et al. 2014). While the physical characteristics and capacity of adolescent football players is of interest to researchers and football coaches, measuring them can often be problematic due to the many confounding factors, such as the Relative Age Effect (RAE) and biological maturation (Malina, et al. 2004).

One confounding factor that is regularly reported as impacting on an adolescent's physical performance is biological maturation (Malina et al. 2007 and Meylan, et al. 2010). Current literature suggests that biological maturity can play an important role in adolescent sport,

(Philippaerts et al. 2006; DiFiori, et al. 2014 and Meylan, et al. 2014) however, little is known about the physiological impact of a systematic training regimen on youth and adolescent footballers with regards to the rate of physical progression.

The current practise in selection for Performance School programme appears to be based on anthropometric characteristics, which are influenced by biological maturation, as well as the date that a player is born in the selection year. These variables can, therefore, be a confounding factor in the development of adolescent footballers. It was evident in Chapter 3 that the chronologically older groups outperformed their younger counterparts in all measures of physical performance. Despite a conscious effort being made by the SFA to avoid the RAE, it was found to be present in the Performance School population, resulting in a selection bias that benefits players born earlier in the selection year. Although these earlier born players were taller, heavier and had an advanced maturity offset there was no difference in physical performance within the year groups. The research in Chapter 1 also identified that some physical attributes appear to be relatively stable between the year groups (e.g. sprint speed and ability to change direction). Following on from these initial findings it is now possible to examine the rate of change in physical performance across the year groups in an attempt to explore the factors that might be contributing towards rate of physical progression.

The aim of the present study was to examine the physiological impact of the training programme, with regards to change in physical performance. It became apparent that certain variables were contributing towards change in physical performance and so the study also examined to what extent baseline fitness, progression in maturity offset and training session time had an impact on change in physical performance over time from baseline. It was hypothesised that progression in maturity offset would make the largest contribution and best explain the rate of change over time from baseline.

4.2. Methodology

Participants

A cohort of 88 trained youth football players aged 13.36 ± 1.15 years, who had been selected into the SFA Elite Performance School programme, took part in the study following the consent by their legal guardians (Appendix A). Participants were given a study overview (Appendix B) and also provided written informed consent (Appendix A). Each participant completed football specific training five days per week (Monday to Friday) as an integrated aspect of their school curriculum. Players were also instructed not to alter any aspect of the training that took part outside the Performance School programme. The players trained independently in their chronological year groups (2000; n = 12, 2001; n = 21, 2002; n = 25, 2003; n = 30) for approximately 3 hours and 41 minutes each week, which was in addition to evening sessions at their registered clubs.

All player information was entered into the player management system, Sportsoffice (The Sports Office, Wigan), and was accessible by the lead researcher. The study was granted ethics approval by the research ethics committee at Heriot-Watt University, Edinburgh.

Study Overview

Dates of birth were provided by the parents/guardians and were collated for each year group. Physical performance tests were carried out at the start of the school year in August (T1 – "Baseline fitness") and the end of the school year in May/June the following year (T2). At both time points players were assessed for anthropometry (stature, mass and seated stature),

linear speed (20m), change of direction (COD), lower body power (squat jump; SJ) and using a proxy measure of recovery capacity from high-intensity exercise (Yo-Yo intermittent recovery test level 1; YYIRTL1). Each participant was given three attempts at each test (excluding anthropometry and the YYIRTL1) with the best score being used for subsequent analysis. All testing was carried out in an indoor facility.

Training session time and number of sessions missed for each player were entered into Sportsoffice at the end of each week by the head coaches at the Performance Schools.

Anthropometric measures and estimate of maturity

Anthropometric measures were taken by the lead researcher and assistants in line with the protocol described in the methodology chapter (Chapter 2) of this thesis.

Physical performance tests

Linear speed, ability to change of direction, lower limb power and YYIRTL1 performance were assessed using the physiological test battery detailed in the methodology chapter (Chapter 2) of this thesis.

Analysis

The statistical approach undertaken in the present study was designed to examine the rate of progression in different measures of physical capacity, both as an entire group, and within separate year groups. It was important to use partial correlations to determine relationships, in the variables of interest, as it was possible to do so while controlling for the effects of other

confounding variables. A means comparison was not appropriate in the present study as the study did not set out to determine physiological differences across the age groups. Moreover, it was not possible to control for other confounding factors using a means comparison. There are already several existing pieces of literature that examine physiological differences across chronological and biological maturity groups (Figuerido, et al. 2010; Vadendriessche, et al. 2012 and Gil, et al., 2014), but few have attempted to clarify what factors contribute towards any change in physical performance.

Data are reported as mean ± SD and were calculated for performance in the 20m, COD, SJ and YYIRTL1 with each year group at T1 and T2. Change over time from baseline was calculated as the delta value between T1 and T2. Negative delta values were considered an improvement in score for the 20m and COD assessments, while positive delta values were considered an improvement for the SJ and YYIRTL1 assessments. The magnitude of the effect of the predictors were calculated using partial correlations. Partial correlations were used to find unique relationships between two variables while controlling for variables that may confound the relationship. For example, it was possible to show the relationship between change over time from baseline and training session time, while controlling for progression in maturity offset and baseline fitness. Confidence intervals (CI) (90%) were calculated using Hopkins (2007) confidence limits and clinical chances Microsoft Excel spreadsheet. A scale of <0.1, trivial; 0.1-0.3, small; 0.3-0.5, moderate; 0.5-0.7, large; 0.7-0.9, very large and >0.9, nearly perfect, was used to interpret the magnitude of the correlation coefficients. Further to this, magnitude based inferences were subsequently applied to the correlation coefficients and interpreted in the context of the confidence intervals using Hopkins (2007) confidence limits and clinical chances spreadsheet. Statistical analysis was performed using SPSS statistics software (PASW statistics 20) and Hopkins (2007) confidence limits and clinical chances, Microsoft excel spreadsheet.

4.3. Results

Descriptive data are presented in Table 6. Partial correlations showing the relationship between baseline and change over time from baseline, while controlling for progression in maturity offset and training session time, frequently explained the largest proportion of the variance and subsequently showed the greatest effects (Table 7). Of the three variables that could potential influence the rate of physical progression, baseline fitness consistently demonstrated the largest associations with physical progression. The 2000 group showed trivial, *small* and *moderate* effects for the 20m, COD and SJ, respectively. The 2001 group showed *small, small, moderate* and *small* effects for the 20m, COD, SJ and YYIRTL1, respectively. *Unclear, large, moderate* and *small* effects were found for the the 20m, COD, SJ and YYIRTL1, respectively, in the 2002 group. The 2003 group showed *trivial, small, moderate* and *small* effects for the 20m, COD, SJ and YYIRTL1, respectively.

Partial correlations showing the relationship between progression in maturity offset and change over time from baseline, while controlling for baseline and training session time, are shown in Table 8. Progression in maturity offset did not affect change over time from baseline as expected and magnitudes were often *unclear, trivial* or *small*. Most notably, the 2001 group (who were approximate age of PHV at the time of the study) *showed unclear, moderate, moderate* and *trivial* effects for the 20m, COD, SJ and YYIRTL1, respectively.

Partial correlations showing the relationship between training session time and change over time from baseline, while controlling for baseline and progression in maturity offset are shown in Table 9. In a similar pattern to progression in maturity offset, the effect of training session time on change over time from baseline often reported *unclear, trivial* or *small*

effects. The most notable effect was seen for 20m in the 2000 group which displayed a *moderate* effect.

Partial correlations were also calculated when all the participant's data were grouped together. Again, the relationship between baseline and change over time from baseline displayed the largest effects; *trivial, small, moderate* and *small* for the 20m, COD, SJ and YYIRTL1, respectively (Table 7). The relationship between progression in maturity offset (Table 8) and training session time (Table 9) with change over time from baseline were all *trivial* or *unclear*, with only one exception; the relationship between change over time from baseline in SJ and progression in maturity offset was noted as *small* (Table 8).

Table 6. Mean±SD for physical measures at Time 1 and Time 2, as well as, Mean±SD for change over time from baseline.

| Physical Measure | Year Group | Physical Performance | | Change over time from baseline |
		Mean ± SD (T1)	Mean ± SD (T2)	Mean ± SD
Maturity Offset	*2000*	0.82±.95	1.59±1.02	1.29±1.90
	2001	-0.51±.66	0.22±.69	0.81±.21
	2002	-1.36±.56	-0.55±.64	0.78±.17
	2003	-1.90±.49	-1.20±.96	0.72±.20
20m (seconds)	*2000*	3.23±.14	3.19±.16	-0.04±.11
	2001	3.47±.14	3.39±.14	-0.07±.13
	2002	3.51±.13	3.47±.17	-0.04± .13
	2003	3.57±.18	3.52±.19	-0.04±.11
COD (seconds)	*2000*	5.99±.22	5.87±.29	-0.13±.28
	2001	6.16±.23	6.22±.28	0.06±.24
	2002	6.26±.31	6.07±.23	-0.18±.28
	2003	6.45±.29	6.20±.89	-0.26±1.00
SJ (cm)	*2000*	47.07±4.58	46.41±4.28	-0.66±2.88
	2001	40.66±4.99	43.10±6.02	2.40±6.24
	2002	38.37±4.07	40.73±3.41	2.36±3.13
	2003	37.93±4.44	37.73±4.07	-0.20±4.14
YYIRTL1 (m)	*2000*	3128±708	3356±541	228±354
	2001	2727±622	2806±698	79±668
	2002	2086±648	2495±598	408±443
	2003	2068±652	2624±720	556±589

Table 7. Partial correlations (90% confidence intervals) showing the relationship between change in 20m, COD, SJ and YYIRTL1 performance and baseline, in each year group and the entire group when controlling for progression in maturation and training session time.

	"Baseline"			
Group	**20m**	**COD**	**SJ**	**YYIRTL1**
2000 (n = 12)	-0.28 -0.68 to 0.88 Possibly trivial	-0.47 -0.79 to 0.04 Possibly small	-0.35 -0.18 to 0.72 Possibly moderate	**VOID**
2001 (n = 21)	-0.37 -0.65 to 0.00 Possibly small	-0.36 -0.73 to 0.17 Possibly small	-0.56 -0.83 to -0.08 Likely moderate	-0.42 -0.76 to 0.10 Likely small
2002 (n = 25)	0.06 -0.28 to 0.39 Unclear	-0.74 -0.86 to -0.54 Possibly large	-0.57 -0.76 to-0.29 Possibly moderate	-0.40 -0.65 to -0.07 Possibly small
2003 (n = 30)	-0.16 -0.44 to 0.15 Likely trivial	-0.47 -0.68 to 0.19 Likely small	-0.54 -0.73 to -0.28 Possibly moderate	-0.21 -0.49 to 0.10 Possibly trivial
All (n = 88)	-0.15 -0.32 to 0.03 Possibly trivial	-0.45 -0.58 to -0.30 Likely small	-0.46 -0.58 to -0.03 Possibly moderate	-0.42 -0.57 to -0.25 Likely small

Table 8. Partial correlations (90% confidence intervals) showing the relationship between change in 20m, COD, SJ and YYIRTL1 performance and progression in maturity offset, in each year group and the entire group when controlling for baseline and training session time.

	Progression in Maturity Offset			
Group	**20m**	**COD**	**SJ**	**YYIRTL1**
2000 (n = 12)	0.68 0.27 to 0.88 Likely moderate	-0.09 -0.56 to 0.43 Unclear	-0.04 -0.53 to 0.47 Unclear	**VOID**
2001 (n = 21)	-0.08 -0.44 to 0.30 Unclear	-0.60 -0.85 to -0.14 Possibly moderate	0.46 0.11 to 0.71 Likely moderate	-0.22 -0.55 to 0.16 Trivial
2002 (n = 25)	0.20 -0.15 to 0.50 Possibly trivial	0.18 -0.17 to 0.49 Possibly trivial	0.06 -0.28 to 0.39 Unclear	-0.09 -0.41 to 0.22 Unclear
2003 (n = 30)	0.03 -0.28 to 0.33 Unclear	-0.04 -0.34 to 0.27 Unclear	-0.13 -0.42 to 0.18 Unclear	-0.38 -0.61 to -0.08 Possibly small
All (n = 88)	0.25 0.08 to 0.41 Possibly trivial	-0.03 -0.22 to 0.14 Unclear	0.18 0.00 to 0.35 Likely small	-0.23 -0.40 to 0.04 Likely trivial

Table 9. Partial correlations (90% confidence intervals) showing the relationship between change in 20m, COD, SJ and YYIRTL1 performance and training session time, in each year group and the entire group when controlling for baseline and progression in maturity offset.

	Training session time			
Group	**20m**	**COD**	**SJ**	**YYIRTL1**
2000 (n = 12)	0.59 0.13 to 0.84 Possibly moderate	0.22 -0.31 to 0.65 Unclear	-0.04 -0.53 to 0.47 Unclear	**VOID**
2001 (n = 21)	-0.15 -0.44 to 0.23 Possibly trivial	0.31 -0.31 to 0.65 Possibly small	-0.25 -0.57 to 0.13 Possibly small	0.05 -0.33 to 0.41 Unclear
2002 (n = 25)	0.25 -0.09 to 0.54 Possibly trivial	0.09 -0.25 to 0.41 Unclear	0.09 -0.25 to 0.41 Unclear	0.47 0.16 to 0.70 Likely small
2003 (n = 30)	0.31 0.00 to 0.56 Possibly small	-0.05 0.35 to 0.26 Unclear	-0.04 -0.34 to 0.27 Unclear	-0.37 -0.61 to 0.07 Possibly small
All (n = 88)	0.16 -0.02 to 0.33 Possibly trivial	0.09 -0.08 to 0.27 Possibly trivial	-0.07 -0.24 to 0.11 Unclear	-0.01 -0.20 to 0.18 Unclear

4.4. Discussion

The study aimed to assess which variable of interest contributed the largest amount to change over time from baseline; baseline fitness, progression in maturity status or training session time. The current study demonstrated that baseline fitness was the largest contributing factor to change over time from baseline, frequently explaining the largest proportion of the variance, while controlling for other confounding variables. Maturity had the greatest impact in the 2001 age group where players were at typical age of PHV (T1; -0.51±.66 and T2; 0.22±.69), however, moderate effects were only observed for COD and SJ.

Baseline fitness and change over time from baseline

Having assessed the contribution of three different variables towards change over time from baseline (progression in maturity offset, training session time and baseline fitness), baseline fitness appeared to frequently explain the largest proportion of the variance in all groups (Table 7), which was in contrast to the other measured variables. Baseline fitness explained the largest proportion of the variance with regards to change over time from baseline in at least two measures of physical performance in each age group. In the 2001 group in particular, it accounted for the largest proportion of the variance in three measures; *small*, *moderate* and *small* effects for the 20m, SJ, and YYIRTL1, respectively. During the test period the 2001 group were aged 14 years old, which is approximate age at PHV. It was expected, particularly at this age (approximately 14 years), that maturity would be the contributing factor in change in physical performance, however this is not the case in the present study. Baseline was also able to account for the largest proportion of the variance, and displayed moderate effects, for change in SJ for all age groups. Improvement in SJ

performance is met with some scepticism, however, as the measure has been shown previously to be driven by learning effects (Markovic, et al. 2004; Kotzamanidis, et al. 2005). Moreover, it is possible that improvements in SJ are a product of increased muscle mass as a result of training and maturation, or equally, could be due to neuromuscular adaptation (Malina, et al. 2004; Tonson, et al. 2008). Unfortunately, muscle mass was not measured in the current study, so it is not possible to attribute any change to increased muscle mass at present.

Partial correlations and magnitude of effects were also calculated for the entire group together. Grouping players together not only increased the number of participants in the analysis and tightened the confidence intervals, but provided an indication of which three variables measured (baseline, maturity, training) contributes the most to a youth player's change in physical performance in a broad group that spans PHV. When players data are grouped together baseline accounted for the largest proportion of the variance in COD (*small*), SJ (*moderate*) and YYIRTL1 (*small*).

The data indicates that the lower a player's baseline measure, the more likely that player is to progress physically – fitness training favours the less fit. These data have implications on training structure and periodisation for systematic training programmes. Based on this evidence coaches should be cautious when discounting players based on physical performance, as those with the lowest baseline fitness have the greatest potential for change. The lack of contribution from progression in maturity offset and training session time would suggest that it is not physical growth or the amount of training a player carries out that has the largest impact on their rate of change over time. Instead, it appears to be at what point they started – their baseline. Wrigley et al. (2014) conducted similar research comparing the rate of progression in academy vs non-academy adolescent footballers, of a similar age to the present study. The research involved similar measures, including an assessment of linear

speed, agility and lower limb power and the analysis carried out also used baseline fitness as a covariate. The authors found that systematic football training as part of a youth academy could accelerate physical development – independent of baseline fitness or change in maturity status – when compared to non-academy youth footballers. The findings in the current study are not in agreement with Wrigley et al. (2014) in this instance, as baseline fitness appears to be the largest contributing variable to change over time from baseline. It is important to note, however, that a control group was not used in the present study, so no comparison with age matched controls are presented.

Understanding the findings in the present study could inform training prescription and indicate where time and resources are best used. Also, care must be taken when attempting to understand and interpret physical test results, as lower baseline fitness results appear to infer a greater opportunity for change with regards to physical progression. Coaches may view players with lower baseline fitness results as inferior and disregard them during the initial selection process, however, these players appear to have the greatest scope for improvement. When discussing any change in physical performance it is imperative that a starting point is accounted for; and to date literature surrounding this topic in a youth and adolescent sporting population is scarce.

Progression in maturity offset and change over time from baseline

Progression in maturity offset was expected to have a meaningful impact on change in physical performance over time from baseline. In the present study, progression in maturity offset was only able to explain a small proportion of the variance in each measure of physical performance in each age group, and when the participants were grouped together (Table 8).

Valente dos Santos, et al (2012) conducted research assessing the contribution of maturity status in predicting functional capacity. Although the authors employed a different method of quantifying maturity status (skeletal) from the present study, they found that maturity status assessed at baseline significantly predicted functional capacity over a study period of 3-5 years, where players were assessed annually. Maturity status is often attributed as being a confounding factor in physical performance in youth and adolescent footballers (Bucheit and Mendez-Villenueva, 2014 and Carling et al. 2012). Malina et al (2004) also found that maturity status was the primary contributor to variation in performance in a shuttle run test during their research. However, research examining the influence of maturity status on physical capacity is often carried out with only one time point. As a result, existing literature is often unable to examine what is contributing to any changes in physical capacity over time. Early studies (Soares and Matsudo 1982 and Berg, et al. 1985) examining change in physical performance are available but do not account for maturation and were carried out over short test periods (9 and 12 weeks, respectively). The present study was designed to examine rate of change in physical performance, carrying out physical assessments at the start and end of an entire competitive season, over a 10-month period. The data confirmed that progression in maturity offset did not influence change over time from baseline. Progression in maturity offset was rarely identified as the largest contributing variable, however, it was noted as having a *moderate* effect in the 2001 group with regards to COD and SJ. At the time of data collection, the 2001 group would have been approximately 14 years of age – typical age at PHV (-.51 and .22 at T1 and T2, respectively) (Mirwald, et al. 2002). Existing literature has shown that at the time of PHV, adolescents can experience accelerated improvement in football specific field tests such as linear sprints, measures of agility (Philippaerts, et al. 2006) and recovery capacity from high-intensity exercise (Naughton, et al. 2007). Despite progression in maturity offset explaining the largest proportion of the variance to change over

time in the SJ (*moderate*) and COD (*moderate*) test on this occasion, baseline fitness was frequently able to explain the largest proportion of the variance in other measures (Table 7). In this instance, progression in maturity offset is not contributing towards change over time from baseline.

Training session time and change over time from baseline

Training session time was noted as having little impact on change over time from baseline in the present study. Previous literature investigating the relationship between training and match load and changes in fitness in professional youth footballers found that there was no significant change in fitness over a six-week study period when assessing lactate threshold using a treadmill protocol (Akubat, et al. 2012). Akubat, et al. (2012) did, however, indicate that percentage change in lactate threshold was significantly correlated to, weekly reported, individualised training impulse (Banister's TRIMP, 1991) for the adolescent population. It is important to note, however, that having indivualised TRIMP values in the current setting is unrealistic. Training session time was the only logistically feasible method for collecting information on training in the present study – something that has been neglected in previous research (Wrigley, et al. 2014) that examines physiological change in adolescent footballers. In Malina's, et al (2004) study, the researchers examined the contribution of training history on measures of physical capacity in youth footballers aged 13-15 years. The authors suggested that although training history was not the largest contributor to physical capacity it was still a significant contributor with regards to recovery capacity from high-intensity exercise. Valente dos Santos, et al (2012) however, did find that scores in measures of functional capacity significantly improved as a result of training session time. The

assessments of functional capacity used by Valente dos Santos, et al (2012) were not dissimilar to the current study: sprint test, lower limb explosive power, agility and aerobic endurance. Although the present study did not note training history, training session time data were collected and it was found that volume of training did not often explain the largest proportion of the variance or present clear effects. With training session time unable to frequently explain the largest proportion of the variance, it may be appropriate to suggest that the amount of training carried out by the young footballers in the current study is not having an overwhelming impact on their rate of change with regards to physical performance. It may also propose that measuring training session time alone is not a sensitive enough method when assessing rate of change over time and other methods such as quantifying training intensity may be more appropriate. In the present study, training session time showed a *moderate* effect on change over time from baseline in the 20m for the 2000 group. However, it is important to note that only the training session time for the Performance School was available for the participants. The players involved in the study, as well as being part of the Performance School training programme, also train with their parent clubs in the evening but this training session time was not available for analysis.

Limitations

Despite providing worthwhile findings and important practical messages, the present study had potential limitations. Firstly, the 2000 group had to be excluded from any analysis involving the YYIRTL1. Due to players in the 2000 group being able to complete the test, it was not possible to give them the chance to show any progression from T1 to T2. The YYIRTL1 remained a difficult enough measure for other year groups, however, and had been

used extensively at all testing dates, making it difficult to change the assessment at any point. Doing so would have made it impossible to compare previously collected and analysed data. Secondly, it was only possible to collect training session time data throughout the test period. Due to the programme having few full-time members of staff with relevant experience, it was not possible to accurately collect any data that would note training intensity. As well as this, only training session time for the Performance School was available and no training session time was obtained from parent clubs, making it impossible to create a full picture of the training the players are carrying out on a daily basis.

Quantifying training intensity for the cohort used in the current study would be of interest for future research. Measuring training intensity may provide a more sensitive measure for assessing physical change over the course of a competitive season (Impellizzeri, et al. 2006). One proposed method of doing this would be to collect training load and using training session time multiplied by rating of perceived exertion (RPE); a method that is frequently used in quantifying training load (Impellizzeri, 2004) that could realistically be collected within the programme. Similar methods of quantifying training load in adolescent populations have been used in other sports, such as rugby (Hartwig, Naughton and Searl, 2008).

Conclusion

The initial aim of the study was to assess the impact of the SFA Performance School programme with regards to change in physical performance in the 20m, COD, SJ and YYIRTL1. The present study also assessed the contribution of baseline fitness, progression in maturity offset and training session time to the change in physical performance over time

from baseline (T1-T2). Having assessed the variables of interest, it is apparent that baseline fitness explained the largest proportion of the variance, as well as showing the largest effects, in all year groups and when the players were analysed as one group. Previous literature frequently reports maturity as a confounding factor in physical performance during adolescence (Valente dos Santos, et al. 2012; Carling et al. 2012 and Bucheit and Mendez-Villenueva, 2014), however, in the present study maturity did not impact change in physical performance when assessed over an entire competitive season; particularly in comparison to baseline fitness.

It could be suggested, as highlighted by the current findings, that baseline fitness is accounted for when assessing any change in physical performance. Coaches should be careful during the player recruitment process that they are not disregarding players who possess poorer baseline fitness measures, as they appear to have the greatest opportunity for change. It would be of interest in future to conduct similar research that quantifies training intensity and assess its contribution towards change in physical performance.

Chapter 5: Study 3

"An examination of individual physiological response to training stimulus".

5.1. Introduction

It is common practice in football academies to conduct physiological assessment on youth and adolescent footballers (Stølen, et al. 2005; Chamari, et al. 2004; Abernathy and Bleakley, 2007; Bucheit and Mendez-Villaneuva, 2013). The data from these assessments are subsequently used to differentiate between elite and non-elite youth players, to monitor the response to training or as a tool for talent identification and player recruitment (Vaeyens, et al. 2006, Buchheit, et al. 2012). The physiological assessments used in this thesis are consistent with measures of anthropometry, agility or change of direction, sprint speed, power and aerobic fitness (Reilly, et al. 2000) used in the existing literature.

The use of physiological assessment has been cited as a potential mechanism to identify youth footballers who will be successful in progressing to a higher level in the sport (le Gall, et al. 2010). However, Vaeyans et al. (2005) suggests that although young players may exhibit desirable attributes such as speed, agility, power and aerobic fitness, the player may not retain these during stages of growth and maturation. It is important for coaches to understand the impact of the training stimulus they are providing for their players, as an understanding of physiological response to training stimulus could inform changes in periodisation, training prescription and ultimately further individualise training for young players.

Caution should be applied when ranking players based on physiological assessment at young ages. For example, who is the fastest, most agile or fittest, as this method of ranking has been shown to vary considerably during adolescence and be an unstable way of assessing young footballers (Buchheit and Mendez-Villanueva, 2013). Fitness reports are often a way of tracking a player's progress within an academy or long-term development programme. Fitness reports often contain player rankings and individual comparisons with the rest of a

group, however, if player ranking is unstable and can change over the course of one season (for example) they may be misleading for coaches who attempt to use the ranking as an assessment tool.

Individualised athlete development has been acknowledged previously (Foster, 1998; Balyi and Hamilton, 2004); however, research suggesting the most effective way to implement it in practice is limited. The importance of assessing real change in a physiological setting has been discussed by Atkinson and Batterham (2015), who emphasised that an understanding of true individual difference is necessary before attempting to identify "responders" and "non-responders" in a population. Scharhag-Rosenberger, et al. (2012) and Astorino and Schubert (2014) conducted research that examined individual response to training stimuli and also suggested that being able to identify "responders" and "non-responders" is an important aspect in altering and individualising training. Perhaps most importantly, athletes who are labelled as "non-responders" can subsequently become "responders" following changes in training stimulus (Bonafiglia, et al. 2016). Understanding the individual response to training is important with regards to athlete development and is in contrast with development at a group level. The present study offers individual analysis of a unique group of youth footballers, who train every day as part of a systematic training programme, where the analysis also benefits from population based typical error and thresholds for a meaningful change. Typical error can be defined as the variation in a subject's test values from measurement to measurement.

Data presented in chapter 4 of this thesis demonstrated that, in comparison to other factors, baseline fitness explained the largest proportion of variance with regards to change in physical performance across one season, suggesting that training appears to be more advantageous to those with less developed physical attributes. Knowing that training is more beneficial for those with less pronounced physical attributes, it would therefore be

appropriate to examine if there is any change in the rank order over time and, during the same period, determine the percentage of players within each group that respond to the prescribed training stimulus.

The present study had two main objectives. Firstly, to assess the stability of player ranking, based on physiological assessment over one competitive season. Secondly, to examine the proportion of the year groups that either progress, remain stable or regress with regards to change in 20m, COD, SJ and YYIRTL1 performance, following one competitive seasons training in the Performance School programme.

5.2. Methodology

Participants

The same group of 88 trained youth football players from chapter four of this thesis (aged 13.36 ± 1.15 years), who had been selected into the SFA Elite Performance School programme participated in the study following consent provided by their legal guardians (Appendix A). Participants were given an overview of the study (Appendix B) and provided written informed consent (Appendix A). Each participant completed football specific training five days per week (Monday-Friday) as an integrated component of their school curriculum. Players were also instructed not to alter any aspect of their training undertaken outside the Performance School programme. The players trained in chronological year groups (2000; n = 12, 2001; n = 21, 2002; n = 25, 2003; n = 30) for approximately 3 hours and 41 minutes each week, which was in addition to evening sessions at their registered clubs.

All player information was entered into the player management system, Sportsoffice (The Sports Office, Wigan), and was accessible by the lead researcher. The study was granted ethics approval by the research ethics committee at Heriot-Watt University, Edinburgh.

Study Overview

Dates of birth were provided by the parents/guardians and were collated for each year group. Physical performance tests were carried out at the start of the school year in August (T1 – "Baseline fitness") and the end of the school year in May/June the following year (T2). At both time points players were assessed for linear speed (20m), change of direction (COD), lower body power (squat jump; SJ) and recovery capacity from high-intensity exercise using a field based, proxy measure (Yo-Yo intermittent recovery test level 1; YYIRTL1). Each participant was given three attempts at each test (excluding anthropometry and the YYIRTL1) with the best score used for subsequent analysis. All testing was carried out in an indoor facility.

Physical performance tests

Linear speed, ability to change direction, lower limb power and YYIRTL1 performance were assessed using the physiological test battery detailed in the methodology chapter (Chapter 2) of this thesis.

<u>Analysis</u>

Using a commercially available spreadsheet Hopkins' (2012), the ranking stability of players between T1 and T2 was assessed using performance on 20m, COD, SJ and YYIRTL1 fitness tests. Intra-class correlation coefficients (ICC's) of these data are presented as well as 90% confidence intervals (Table 1). ICC's are able to determine the extent to which a score maintains its position in a sample after repeated measures. Bucheit and Mendez-Villanueva (2013) used a similar method of analysis with the following thresholds; >.99 *extremely high*, .99-.90 *very high*, .90-.75 *high*, .75-.50 *moderate*, .50-.20 *low*, <.20 *very low* whereby an ICC of >.70 is considered to reflect high stability in a ranking and is the convention adopted in the present study.

The threshold for the smallest worthwhile change (SWC) differed depending on the physical measure and year group under assessment. The threshold for the SWC was calculated as:

$$SWC = \text{Pooled between} - \text{player standard deviation} \times 0.2$$

Typical error (TE) was calculated for 20m, COD and SJ using Hopkins' (2000) Microsoft Excel spreadsheet and repeated measures taken during data collection. T1 and T2 data were log transformed, to allow TE to be expressed as a percentage and to reduce risk of error from skewness. A delta (Δ) value was taken between T1 and T2 (*T2−T1*). TE was then calculated as:

$$\text{TE} = \left(\frac{\text{SD}\Delta}{\sqrt{2}}\right) \times 100$$

and expressed as a percentage. For 20m, COD and SJ the TE was 1.7%, 2.4% and 4.5%, respectively. The TE used for the YYIRTL1 was taken from a study by Povoas, et al (2015) that examined the validity and reliability of YoYo test scores in 9-16-year-old footballers, as there were no repeated measures for YYIRTL1 at T1 or T2 in the present study. The reliability score was reported as 8.5% by Povoas, et al (2015). TE was used in the analysis to ensure that any change in physical performance was categorised as a worthwhile change. In that, it was out with the variation in a player's value from measurement to measurement. A commercially available spreadsheet (http://www.sportsci.org/) was used to calculate the percentage of the year groups that had responded, remained stable or regressed following one competitive seasons training, based on a change in physical performance variables. The data are presented as percentages of the total number of participants in each group (Figure 3A – 3D). In this instance, a player was considered a "responder" or "regressed" if there was a >75% benefit or >75% of decrement, respectively, that change in 20m, COD, SJ and YYIRTL1 performance was a worthwhile change. A player was considered "stable" if the percentage chance of change was between the threshold for responder and regressed (e.g. a trivial change).

5.3. Results

Ranking stability

Table 10 shows that the ICC for 20m sprint was >.70 for only the 2000 (0.73) and 2003 (0.88) groups, suggesting that linear speed was relatively stable when ranked. Conversely, the ICC's shown for COD were reported as <.70 for all year groups. The SJ, across all year groups, apart from the 2000 group (.82), had an ICC of <.70 (Table 10), suggesting that this variable had *moderate* relative reliability over one competitive season in adolescent footballers. Although the YYIRTL1 showed an ICC of <.70 in the 2003 group (.65), ICC's of >.70 were reported as stable for all other year groups; .76 and .78 for the 2002, 2001 groups, respectively.

Individual responders

The percentage of players who responded, remained stable or regressed following the season's training are displayed in Figures 3A-3D The number of responders appeared to be lower for the 20m (Figure 3A) and COD (Figure 3B), in comparison to the SJ (Figure 3C) and YYIRTL1 (Figure 3D) which had a higher percentage of responders in each year group. For example, the highest percentage of responders was 8% (2000 group) and 10% (2001 group) for 20m and COD, respectively. By comparison, the 2002 group displayed as many as 16% and 56% as responders in the SJ (Figure 3C) and YYIRTL1 (Figure 3D), respectively. These data would suggest that there is greater potential for improvement in measures

assessing lower limb power and recovery capacity from high-intensity exercise, than linear speed and change of direction ability.

Conversely there seems to be an opposite effect with regards to the percentage of players who regress following one season's training. There are greater percentages of players regressing in the 20m (Figure 3A) and COD (Figure 3B) (for example, 16%; 2002 group and 17%; 2003 group, respectively), compared to the number of players regressing in the SJ (Figure 3C) and YYIRTL1 (Figure 3D) (for example, 33%; 2000 group and 19%; 2001 group, respectively).

Table 10. The table displays the intra-class correlation coefficient (ICC) with regards to stability in the ranking of players. Confidence intervals (90%) (CI) are also shown.

Physical Measure		2000	2001	2002	2003
20m	*ICC* *CI*	0.73 (0.61 to 0.92) Moderate	0.58 (0.28 to 0.78) Moderate	0.68 (0.44 to 0.82) Moderate	0.88 (0.78 to 0.93) High
COD	*ICC* *CI*	0.47 (0.01 to 0.77) Low	0.60 (0.31 to 0.79) Moderate	0.48 (0.17 to 0.70) Low	-0.15 (-0.43 to 0.16) Very Low
SJ	*ICC* *CI*	0.82 (0.57 to 0.93) Moderate	0.61 (0.30 to 0.80) Moderate	0.67 (0.44 to 0.82) Moderate	0.54 (0.29 to 0.72) Moderate
YYIRTL1	*ICC* *CI*	**VOID**	0.78 (0.58 to 0.90) High	0.76 (0.58 to 0.87) High	0.65 (0.43 to 0.79) Moderate

Figure 3A – Figure 3B Percentage of those who responded, were stable or regressed from T1 to T2 in 20m, COD, SJ and YYIRTL1.

Figure 3A — **20m**

Figure 3B — **COD**

Figure 3C — **SJ**

Figure 3D — **YYIRTL1**
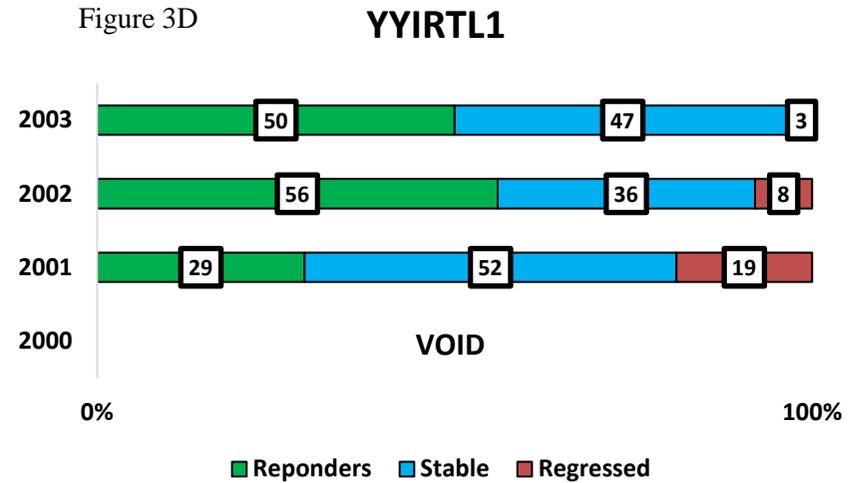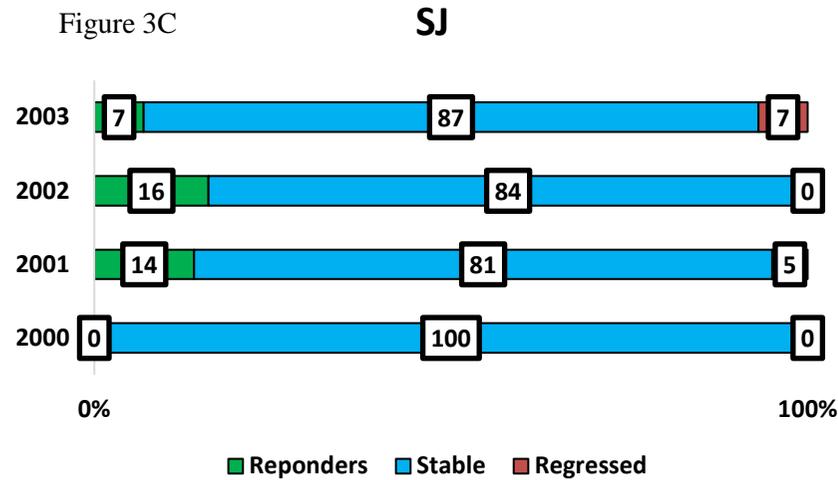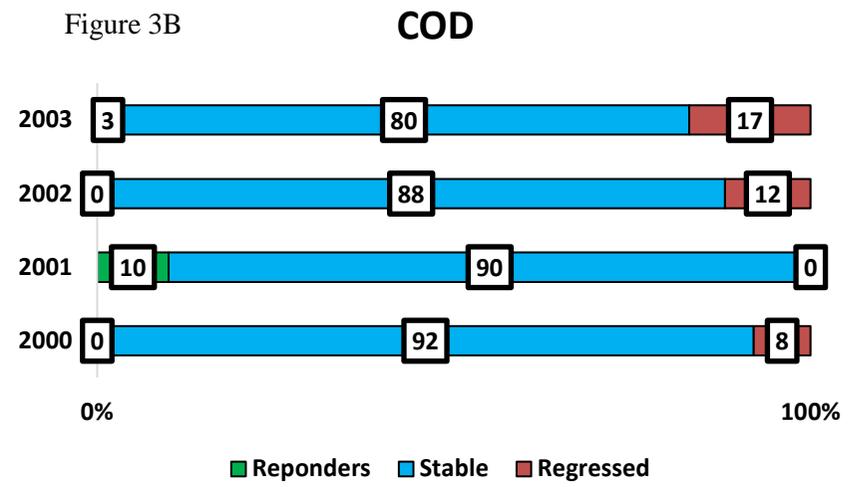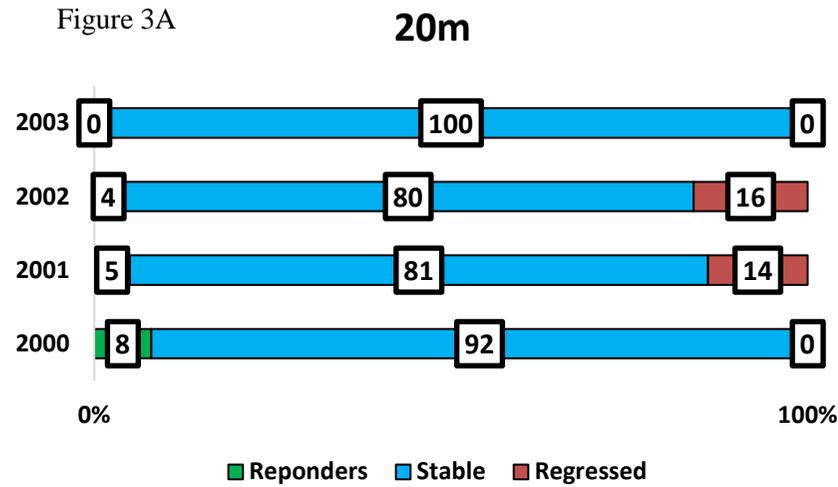
5.4. Discussion

Firstly, the purpose of the present study was to determine the stability in the ranking of players, by physical performance, over the course of one competitive season. Secondly, the study aimed to establish the percentage of players within each year group that either responded, remained stable or regressed following one season's training, with regards to change in 20m, COD, SJ and YYIRTL1 performance. The current study was able to establish that stability in ranking differs depending on age group and measure of physical performance and that there appears to be greater potential for improvement in physical performance in assessments measuring lower limb power and recovery capacity from high-intensity exercise than assessments of linear speed and change of direction ability.

Stability of ranking

The first aim of the present study was to determine the stability of ranking adolescent footballers over the course of one competitive season. Players were ranked based on their performance in each of the variables: 20m, COD, SJ and YYIRTL1 across a nine-month period. Data in the present study suggested that stability in ranking differs depending on both the year group and measure of physical capacity and that the ranking of some variables appear to be more stable than others - the 20m sprint and YYIRTL1 were reported as most frequently stable (ICC >.70) (Table 10). Moreover, studies have shown there are some physical traits that can be used to determine a young player's likelihood of progression to a higher standard of play (le Gall, et al. 2010). Research examining the stability of ranking in adolescent athletes is limited and the vast majority of existing studies involve sedentary

populations (Maia, et al. 2003; Abbot and Collins, 2002). One report that examined a similar population to the present study was carried out by Buchheit and Mendez-Villanueva (2013). The authors sought to assess the short-term reliability (relative to age and maturity) and long-term stability (over a 4-year period) of anthropometric and physical performance measures in adolescent footballers. The study comprised of 80 participants (14.5±1.5 years) from an elite soccer academy who carried out a similar volume of training to the current study's participants (~14 hours per week). During the study the participants were assessed using 40m sprint test (with 10m split times taken), the countermovement jump (CMJ) and an incremental field running test, as well as having anthropometric measures taken to estimate maturation status (maturity offset). The authors observed large inter-individual differences over a four-year period with regards to anthropometric and physiological measures, presenting ICC's of 0.66 to 0.96 for the 10m sprint test and body mass, respectively, suggesting that measures of physical performance in an adolescent population can be unstable. The findings in the present study are in agreement with Buchheit and Mendez-Villanueva's (2013), as they demonstrated varying levels stability over the course of a season depending on the year group and measure of physical capacity. The ICC's reported in the present study for 20m sprint, SJ and YYIRTL1 are similar to those reported by Bucheit and Mendez-Villanueva (2013) for 10m sprint, CMJ and an intermittent field running test (measures of physical capacity that are comparable between the studies). The authors reported a range in ICC's of 0.50-0.80, 0.50-0.80 and 0.73-0.91 for the 10m sprint, CMJ and intermittent field running test, respectively. The present data showed ICC's of 0.58-0.88, 0.54-0.82, 0.65-0.87 for 20m sprint, SJ and YYIRTL1, respectively (Table 10). Both sets of data suggest that the use of some measures of physical capacity during talent identification and certain stages of athlete development may be questionable. Although the studies report similar findings, it is important to note some differences in the study design and also that the

ICC's reported were in relation to long-term stability, which the present study did not measure. Buchheit and Mendez-Villanueva (2013) used a small sample of 10 participants to assess long-term stability of ranking players, however, these measures were conducted over a 4-year period. In contrast, the present study used data based on only one competitive season but both sets of data suggest that caution should be taken when using measures of physical capacity to identify talent or rank adolescent footballers (i.e. "fittest" or "fastest") within academies. It is important to recognise that physical performance in adolescent footballers can vary during growth and maturation and it could be suggested that, due to a coach's perception of a player, ranking players based on physical prowess could be detrimental to their chance of progressing through an academy or systematic training programme and succeeding in the sport.

Participants in the present study were part of a systematic training programme at a time when they were also experiencing adaptations with regards to growth and maturation (approximately 12-16 years of age). Vaeyens, et al. (2008) found that young footballers with desirable attributes for football did not necessarily maintain these throughout the maturation process. Some reasons posited for this unpredictability include periods of rapid growth that impact on co-ordination ("adolescent awkwardness") (Malina, et al. 2004), learning effects (Markovic, et al. 2004; Kotzamanidis, et al. 2005) that take place as young players repeat physical tests and coping strategies (Malina, et al 2004; Reeves, et al. 2009), such as pacing, during an intermittent field test. Therefore, it seems that great care must be taken in conducting any physical testing for talent ID and player development within academies as a young player's physical capacity may be unpredictable throughout adolescence. How well adolescent players are able to perform physically pre-PHV may also contribute to the unpredictability, as improvements may not be expected in athletes who already possess high levels of physical performance (Philippaerts, et al. 2006). It could also be suggested that it is

not the data collection (which might be useful in monitoring progression) that is the problem, but the way that physical test data are applied and interpreted. Moreover, it is not necessarily the act of ranking adolescent footballers that is the problem, but how the ranking is used; for example, if a player's selection or deselection from an academy or programme depends on it.

Individual responders

The second aim of the current study was to determine the percentage of players within each age group that either responded, remained stable or regressed, with regards to a change in physical performance in the 20m, COD, SJ and YYIRTL1 assessments, over one competitive season's training. The data presented in Figures 3A – 3D, show that the number of players who responded, remained stable or regressed differs depending on year group and the measure of physical performance. For example, the response was higher than any other measure of physical performance, with regards to change in performance, in the YYIRTL1, with up to 50% (15 players) and 56% (14 players) of the group in 2003 and 2002 groups respectively, being highlighted as having responded (Figures 3A – 3D). The data also showed that a smaller number of players were responders in the 20m and COD assessments.

In an attempt to examine changes in VO_2 max, lactate threshold and submaximal heart rate, Bonafiglia, et al. (2016) conducted an experiment on a cohort of 21 recreationally active participants who completed three different cycling protocols. Although the authors stated that improvement was observed across all variables at a group level, they also highlighted a much greater diversity in the outcome as a consequence of analysing individual results and a number of non-responders were observed. One of the most important findings from Bonafiglia's et al (2016) study was that participants who did not respond to endurance training, responded to sprint interval training and vice versa. Suggesting that the number of

non-responders in a group can be reduced by altering the training stimulus. It could be suggested, therefore, that a non-response could be indicative of an insufficient training load or training protocol, as further loading has been shown to turn non-responders into responders (Montero and Lundby, 2017). It is important to note that the study by Bonafiglia, et al. (2016) recruited a rather different cohort (recreationally active volunteers) to the present study. Worthwhile changes in physical capacity of highly trained athletes tend to be smaller because they already possess a high level of physical prowess (Laursen and Jenkins, 2002; Lundby and Robach, 2015). It should also be noted that Bonafiglia, et al. (2016) only measured the participant's initial response to training (after 3 weeks of the intervention), so were unable to suggest whether a response would continue over a longer period of time. However, the research provides support to the current study's findings, as some players in the present study were identified as having regressed, as well as high number of players in each age group being identified as stable. Considering individual responders and non-responders in a group setting is important for athlete development. Data that demonstrate training cannot be a homogenous approach may dictate training prescription. Although non-responders can be present within groups, individualised training can be effective in finding a method of training that players respond to more favourably (Bonafiglia, et al. 2016). Bouchard, et al. (2012) and Sisson, et al. (2009) have made similar suggestions with regards to adapting training interventions to better suit the individual. However, both of the aforementioned studies involved subjects from sedentary populations and although support the idea of assessing individuals, are not strictly comparable with the present study.

Further studies (Bacon, et al 2013; Hautala, et al. 2006) that examine an individual response to different training stimuli are available but there is a lack of existing literature assessing the response to systematic training in adolescent sport. For example, a study (Wrigley, et al. 2014) examining the rate of physical development in adolescent footballers reported that

academy players, who trained and competed at a higher level, developed physically at a greater rate than players who were not part of a systematic training regimen. However, the rate of physical development was assessed at a group level and not by assessing individual responses. One possible explanation for the paucity of research in this area is that methods attempting to group athletes as responders, stable or players who have regressed, are a fairly recent alternative method of interpreting data (Bonafiglia, et al. 2016; Gurd, et al. 2016; Ross, et al. 2015). One study carried out a meta-analysis of studies that examined young adults (ranging from 20.6±1.6 - 23±5 years of age), although still in a recreationally active population and reported a similar percentage of responders for VO_2 max as the YYIRTL1 in the present study (Gurd, et al. 2016). A difficulty also arises in that the definition of responders is not standardised, with some studies defining responders as $1.5 \times TE$. Following a sprint interval training intervention, 22% of participants were labelled responders with regards to VO_2 max. With regards to YYIRTL1 – an assessment being used to measure recovery capacity from high-intensity exercise - the percentage of responders in the younger age groups was; 56% (14 players) and 50% (15 players) in the 2002 and 2003 groups, respectively, compared to 29% of the 2001 group (6 players). One reason posited for this may be that the initial impact of entering into a full-time training regimen was being exhibited over the first 2 years of the programme and thereafter the percentage of players who improved in the YYIRTL1 assessment reduced. The number of responders with regards to the YYIRTL1 then decreased to 29% (7 players) in the 2001 group (year 3 of the programme). With regards to responders in the 20m and COD assessments, the present study reported a low percentage in each group for both measures of physical capacity. No player in the 2003 group was identified as having responded with regards to change in 20m sprint performance. The percentage of responders was consistently low across all age groups; 4% (1 player), 5% (1 player) and 8% (1 player) for the 2002, 2001 and 2000 group, respectively. The percentage

of responders for COD was also low in each year group and there were only responders in the 2001 and 2003 groups. The data in the present study with regards to YYIRTL1, 20m and COD are somewhat concurrent with the findings presented in Chapter 3 and 4 of this thesis. In chapter 3 the findings would suggest there was greater room for improvement in the YYIRTL1 when comparing the chronologically youngest group to the oldest group, similar to that observed in the 2003 and 2002 groups in the current study (50.0%; 15 players, and 56.0%; 14 players, respectively). The results in the previous chapters also suggest that 20m sprint ability and COD appear to be fairly fixed attributes, with less room for improvement in these measures of physical capacity, consequently little change in performance was expected. With 3% (1 player) of the 2003 group for COD and low responders in the 2000 year groups for the COD (0 players) and 20m (1 player), respectively, these findings suggest that COD and 20m attributes may be fixed and static, with little opportunity for improvement, based on the current training stimulus. Furthermore, 14% (3 players) and 16% (4 players) of the group were shown to regress with regards to change in 20m performance in the 2001 and 2002 group, respectively. It is possible that performance in linear sprinting was affected by growth and maturation in these age group (typical age at PHV), which can cause a loss of co-ordination and cause "adolescent awkwardness" (Malina, et al. 2004). Although, if a loss of co-ordination was the cause for a lower level of performance in the 20m sprint, the same might have been expected for COD in the same groups; however, only 12% (3 players) of the 2002 group were identified as having regressed and no players in the 2001 group had regressed with regards to COD (Figure 3B). The data showing the percentage of responders with regards to the SJ assessment are inconclusive. It is possible that larger numbers of responders in the 2001 to 2002 group (14%; 3 players, and 16%; 4 players, respectively) was caused by a learning effect in the assessment, or perhaps their proximity to PHV. Previous literature carried out using jump assessments have citied the learning effect as an issue that

impacts on the reliability and validity of the measures (Markovic, et al. 2004; Kotzamanidis, et al. 2005). Jump assessments may also be more sensitive to short-term change in performance and are often used for daily assessment of neuromuscular function (Byrne, et al. 2004). It is also possible that the sudden increase in the number of responders between the age groups was caused by an increase in muscle mass, having participated in a systematic training programme (Tonson, et al. 2008; Meylan, et al. 2014). However, the present study did not involve any measures of muscle mass, therefore it is not possible to substantiate this as the sole reason.

Limitations

Although the findings of this work provide some interesting and important practical messages, the present study did have some limitations. Similar to the previous chapter, any analysis involving the YYIRTL1 and the 2000 group had to be discarded due to players in this group being able to complete the test. Completing the test at each time point did not provide an opportunity to show any progression or regression in the measure. It may have been beneficial to assess the stability in measures of physical capacity over a longer period. Doing so, may contribute to the understanding of what measures of physical capacity are most relevant through the development of a young athletes. For example, at stages of talent ID and player recruitment or when deciding on the retention or release of players from clubs and development programmes, it is important to understand the potential for progression in physical prowess as well as the dangers of relying heavily on the ranking of adolescent athletes during these processes.

Any future research could benefit from analysing stability over a longer study period. Since such an approach would allow a better understanding of the fixed and plastic nature of some physical attributes that may indicate potential in adolescent footballers. The coach's perception of players labelled as responders, stable and those who have regressed, could add an interesting qualitative aspect to the present study, as ultimately a coach's perception of a player may determine the likelihood that they progress within an academy or player development programme. A sound understanding, from coaches, of the labels and their limitations would be necessary if such research was to take place.

Conclusion

In conclusion, the present study has shown that there were varying levels of response to the training stimulus, depending on year group and the variables related to physical performance. The present study demonstrated that the stability of ranking players by physical performance in the 20m, COD, SJ and YIIRTL1 varies depending on the physical measure and year group. Some measures of physical performance appear to be more stable than others, with COD performance in the 2003 group shown to be unstable (ICC <.07), but 20m sprint in the 2000 and 2003 group shown to be stable (ICC>.07), suggesting that player ranking is more likely to stay the same between time points in some measures of physical performance than others. Higher percentages of responders were noted in the YYIRTL1 and SJ assessments, compared to the 20m and COD. The findings in this chapter support the findings in chapter 3 of this thesis, as it appears that there is greater potential for improvement in measures of recovery capacity from high-intensity exercise and lower limb power, than measures of linear speed and COD ability. The data suggests that there are players in each age group who are not

responding, or are regressing, following one competitive season's training in the Performance School programme and that response to the prescribed training in the present study is variable in some aspects of physical capacity. The aspect of fitness that appears to improve most over one competitive season is recovery capacity from high-intensity exercise, with up to 56% of the 2002 group making a worthwhile improvement in the YYIRTL1. However, the remaining measures of physical performance appear relatively stable and despite the apparent effect, the ranking of the players does change. Changes in ranking order over one competitive season could raise an issue for coaches if they are using measures of physical performance as an assessment tool. The findings in the present study are also in agreement with some existing literature (Buchheit and Mendez-Villanueva, 2013) that suggests care must be taken when attempting to rank adolescent athletes by physical performance, as physical performance can be unpredictable throughout adolescence. Although it could be argued that coaches can use player ranking at one time-point to motivate adolescent players into improving and competing with their teammates, the unstable ranking of players calls into question the usefulness of carrying out some physical assessments with adolescent footballers. Ranking adolescent players could be particularly detrimental to player development if their selection or deselection from academies or systematic training programmes is based on their rank within a group.

Chapter 6: Study 4

"Differentiating between adolescent footballers competing and training at different levels in youth football"

6.1. Introduction

Adolescent footballers in Scotland have the opportunity to participate in football at different levels. The level that an adolescent footballer participates is often dependent on their technical (Bradley et al. 2011; Carling and Bloomfield, 2010) and physical attributes (Reilly, et al. 2000), but also on their desire to compete as some adolescent footballers participate only for enjoyment (Zuber and Conzelmann, 2014). The creation of the Performance School (PS) programme provided another level of development to Scottish adolescent football that was not widely available prior to 2012. Existing grassroots (GR) and professional youth (PY) academies typically involve one to three evening(s) of organised football specific training per week. For the players selected into the Performance School the programme provides a systematic training regimen alongside PY and GR training. A player involved in the PS programme would, for example, be involved in five structured football-specific sessions as part of their school curriculum as well as training with their parent club in the evening. PY and GR clubs often demand less time commitment as players take part in less structured football sessions per week. Given that the purpose of the PS programme is, ultimately, to raise the standard of the game at the national level from home developed players, it would be of interest to examine the impact that the programme is having on the adolescent players enrolled in it, compared to players who are not. The PS programme contains players who compete at the same level as PY players, despite them having different volumes of training. Players involved at a GR club train and compete at, presumably, a lower level than the PS and PY groups.

As discussed previously in this thesis, a selection bias is frequently observed in elite academies in favour of players who are born in the earlier parts of the selection year (see chapter 3), who are biologically more mature and with greater physical prowess (Jimenez and

Pain, 2008; Figueiredo, et al. 2009; Vandendreissche, et al. 2012; Reilly, et al. 2000). It has also been acknowledged that elite and sub-elite players can be differentiated using some measures of physical capacity (Reilly, et al. 2000). Reilly, et al. (2000) concluded that sprint speed and agility were discriminating factors in adolescent players who progressed onto a higher level of play. However, caution must be used when attempting to select players based purely on anthropometric or physical characteristics, as such methods can often prematurely disregard young footballers who have the potential to excel in the future (Williams and Reilly, 2000; Unnithan, et al. 2012). Unnithan, et al. (2012) further suggests that assessing physical prowess in adolescence merely provides an indication of current performance levels and not of future potential. As a consequence, authors have cited the importance of long term development programmes in football and suggest that they ultimately lead to increased footballing expertise (le Gall, et al. 2010; Meylan, et al. 2010). The PS programme has only recently been established in Scotland and the physiological impact of the programme remains unknown, as longitudinal data have not been collected throughout the programme. It would be beneficial to understand what, if any, physiological impact the additional structured football sessions are having in comparison to age matched controls who are exposed to different levels of competition and volumes of training.

There were two aims to the present study. Firstly, to examine the physiological profiles between players representing three levels of training and competition; PS, PY and GR, in an attempt to differentiate between the physical attributes of players at each level of training and competition. Secondly, to determine the rate of physical progression across the different groups and whether this was affected depending on the level of training and competition.

6.2. Methodology

Participants

Three separate cohorts of youth football players representing the PS programme (n = 88; aged 13.36 ± 1.15), PY clubs (n = 52; aged 13.58 ± 1.28) and GR club (n = 35; aged 13.39 ± 1.22), respectively, took part in the study following the consent by their legal guardians. Participants were given a study overview and also provided written informed consent. Participants from the PS programme completed football specific training five days per week (Monday-Friday) as an integrated aspect of their school curriculum. Players were also instructed not to alter any aspect of the training that took part outside the Performance School programme. The players trained in chronological year groups at both PS and club programmes. PS players trained for approximately 3 hours and 41 minutes each week, which was in addition to evening sessions at their registered clubs. Players involved at PY clubs trained with their registered club, as normal (approximately 2 hours 49 minutes each week). Given that the PS players compete at the same level as the PY players, it would be fair to assume they would carry out a similar training session time, per week, at their parent clubs as the PY group; bringing the PS approximate training session time to 6 hours 30 minutes per week, approximately. GR players, similarly to PY player, trained as normal at their registered club. The GR club trained for approximately 2 hours 4 minutes per week. Within the present youth football structure in Scotland, PS and PY players often compete in the same structure, whereas GR would compete at, presumably, a lower level of competition.

Information for the PS players was entered into the player management system, Sportsoffice (The Sports Office, Wigan), by the head coach and was accessible by the lead researcher. A Microsoft Excel workbook was created by the lead researcher and distributed to both PY and

GR club coaches. The workbooks were completed by club coaches and shared between the

lead researcher and club coach on a monthly basis. Workbooks were used to collate training

minutes, game minutes and session attendance for players at PY and GR clubs. The study

was granted ethics approval by the research ethics committee at Heriot-Watt University,

Edinburgh.

Study Overview

Dates of birth were provided by the parents/guardians and were collated for each year group.

Physical performance tests were carried out at the start of the school year in August (T1 –

"Baseline fitness") and the end of the school year in May/June the following year (T2) with

all groups. At both time points players were assessed for anthropometry (stature, mass and

seated stature), linear speed (20m), change of direction (COD), lower body power (squat

jump; SJ) and using a proxy measure of aerobic capacity (Yo-Yo intermittent recovery test

level 1; YYIRTL1). Each participant was given three attempts at each test (excluding

anthropometry and the YYIRTL1) with the best score being used for subsequent analysis. All

testing was carried out in an indoor facility.

Anthropometric measures and estimate of maturity

Anthropometric measures were taken by the lead researcher and assistants in line with the

protocol described in the methodology chapter (Chapter 2) of this thesis.

Physical performance tests

Linear speed, ability to change of direction, lower limb power and YYIRTL1 performance were assessed using the physiological test battery detailed in the methodology chapter (Chapter 2) of this thesis.

Analysis

Mean±SD was calculated for 20m, COD, SJ, YYIRTL1, stature, mass and maturity offset in the PS, PY and GR groups at T1 (Table 11) and T2. Changes in maturity offset and change in physical performance (in 20m, COD, SJ and YYIRTL1) over time from baseline were also calculated (T1-T2). Change over time from baseline was analysed within each group using an ANCOVA, with baseline fitness (T1) as the covariate. Controlling for baseline fitness made it possible to determine the impact of physical performance at T1 on change over time from baseline. Standardised thresholds of *small, moderate*, and *large* (0.2, 0.6 and 1.2, respectively) (Hopkins, 2007) effects were derived from between-subject standard deviation of T1 values and used to identify the magnitude of relationships between groups. A commercially available, purpose built, Microsoft Excel spreadsheet (Hopkins, 2007) was used to calculate the magnitude based inferences (MBI) that show the magnitude of difference in physical performance at T1 (Table 12) as well as the magnitude of difference in rate of progression from T1 to T2 (Table 13) between the PS, PY and GR groups. Further to this, magnitude based inferences were subsequently interpreted in the context of the confidence intervals using Hopkins (2007) confidence limits and clinical chances spreadsheet. Change over time from T1 to T2 is shown in Figures 4A-4D Statistical analysis

was performed using SPSS statistics software (PASW statistics 20) and Hopkin's (2007) confidence limits and clinical chances, Microsoft Excel workbook.

6.3. Results

Descriptive data are presented in Table 11. The PS population were identified as having carried out the greatest training session time (17,640±1479 minutes) of the three groups. A *large* effect was found between the PS and both PY and GR groups with regards to training session time (Table 11). Table 12 shows the magnitude of difference in physical performance (20m, COD, SJ and YYIRTL1) at T1 between the three groups; PS, PY and GR. 20m sprint was the only measure of physical performance that was able to consistently differentiate between levels of competition; *moderate* effects were found between PS and GR, as well between PY and GR, but the effect between PS and PY was *trivial*. The PS group often possessed the greatest physical ability in 20m, COD and SJ out of the three groups at T1, with *moderate* effects for 20m and COD presented between the PS and GR groups. However, only *trivial* and *small* effects were identified between the PS and PY groups, suggesting that the PS and PY groups do not differ greatly in terms of physical performance in the 20m, COD or SJ. However, the PS group did outperform both PY (*moderate effect)* and GR (*moderate effect*) groups at T1 in the YYIRTL1. The effect shown between PY and GR was *Trivial.* The data suggest that an advanced YYIRTL1 score is suggestive of a higher training session time.

Table 13 shows the magnitude of the difference in change in physical performance (T1 to T2) over one competitive season between the three groups; PS, PY and GR. All effects shown for change in physical performance from T1 to T2 were *unclear*, *trivial* or *small*, suggesting that players in each group developed at the same rate, with regards to change in physical

performance, despite having largely different volumes of training. Figure 4A-4B illustrates

the change in physical performance from T1 to T2. The data shows the rate of change in

physical performance over one competitive season and demonstrates that none of the changes

were large enough to alter the order of physical performance between the groups. For

example, PY perform greatest in 20m (Figure 4A), then PS, followed by GR at T1; the same

order is present at T2. Similar patterns of change in physical performance are present for

COD (Figure 4B), SJ (Figure 4C) and YYIRTL1 (Figure 4D).

Table 11. Mean±SD for 20m, COD, SJ, YYIRTL1 performance at T1 and Training session time from one competitive season as well as age, stature, mass and maturity offset within each of the groups at T1.

Physical Performance (T1)

Assessment	Performance School (n = 88)	Professional Youth (n = 52)	Grassroots (n = 35)
Age (years)	13.4±1.2	13.6±1.3	13.4±1.2
Stature (cm)	155.2±9.6*	160.5±9.6	156.1±12.1*
Body Mass (kg)	43.0±8.4*	47.7±10.7	43.1±11.1*
Maturity Offset	-1.1±1.1*	-0.5±1.3	-0.9±1.3*
20m (s)	3.5±0.9	3.5±0.2	3.7±0.2
COD (s)	6.3±.3	6.4±0.4	6.5±0.3
SJ (cm)	39.9±5.4	38.9±6.2	36.5±6.2
YYIRTL1 (m)	2375±758	1752±535	1632±494
		Training session time	
Minutes Trained	17,640±1479	5976±1382 **L**	4970±1936 **LS**

L = Large difference compared with PS   **S** = Small difference compared with PY   *significantly different to PY group ($p<0.05$)

Table 12. Magnitude Based Inferences with mean differences (90% CI) are presented showing the size of the effects between the different groups with regards to physical performance in the 20m, COD, SJ and YYIRTL1 assessments at T1.

Physical Performance Comparisons

_20m_

Performance School & Pro-Youth	**Performance School & Grassroots**	**Pro-Youth & Grassroots**
-0.03	0.21	0.22
(-0.05 to -0.02)	(0.11 to 0.26)	(0.13 to 0.31)
Likely trivial	Likely Moderate	Very likely moderate

COD

Performance School & Pro-Youth	**Performance School & Grassroots**	**Pro-Youth & Grassroots**
0.10	0.25	0.15
(0.07 to 0.13)	(0.18 to 0.34)	(0.11 to 0.21)
Very likely small	Likely moderate	Most likely small

_SJ_

Performance School & Pro-Youth	**Performance School & Grassroots**	**Pro-Youth & Grassroots**
0.11	3.47	-2.36
(-2.80 to 0.58)	(0.28 to 4.40)	(-3.10 to -1.60)
Trivial	Likely small	Very likely small

YYIRTL1

Performance School & Pro-Youth	**Performance School & Grassroots**	**Pro-Youth & Grassroots**
-623	-743	-120
(-850 to -390)	(-1000 to -470)	(-360 to 120)
Likely moderate	Very likely moderate	Trivial

Table 13. Magnitude Based Inferences with mean differences (90% CI) are presented showing the size of the effects between the different groups with regards to change in physical performance in the 20m, COD, SJ and YYIRTL1 assessments from T1 to T2.

Change in Physical Performance (T1 to T2) Comparisons

Change in 20m Performance

Performance School & Pro-Youth	**Performance School & Grassroots**	**Pro-Youth & Grassroots**
0.06	0.10	0.04
(-0.09 to -0.04)	(-0.15 to -0.06)	(-0.08 to 0.01)
Trivial	Likely small	Trivial

Change in COD Performance

Performance School & Pro-Youth	**Performance School & Grassroots**	**Pro-Youth & Grassroots**
-0.02	-0.10	-0.09
(-0.11 to 0.15)	(-0.05 to 0.25)	(-0.08 to 0.25)
Unclear	Possibly small	Trivial

Change in SJ Performance

Performance School & Pro-Youth	**Performance School & Grassroots**	**Pro-Youth & Grassroots**
-0.72	-0.92	-0.21
(-0.55 - 2.00)	(-0.56 to 2.4)	(-1.30 to 1.70)
Trivial	Trivial	Unclear

Change in YYIRTL1 Performance

Performance School & Pro-Youth	**Performance School & Grassroots**	**Pro-Youth & Grassroots**
-8	393	401
(-150 to 160)	(-550 to -230)	(-570 to -240)
Unclear	Very likely small	Very likely small

Figures 4A-4D Physical performance at T1 and T2 in the 20m, COD, SJ and YYIRTL1 for each age group.

20m — Figure 4A

COD — Figure 4B

SJ — Figure 4C

YYIRTL1 — Figure 4D
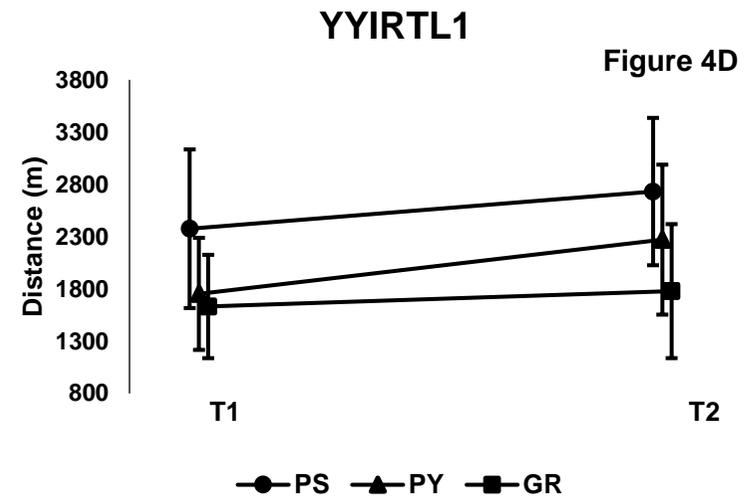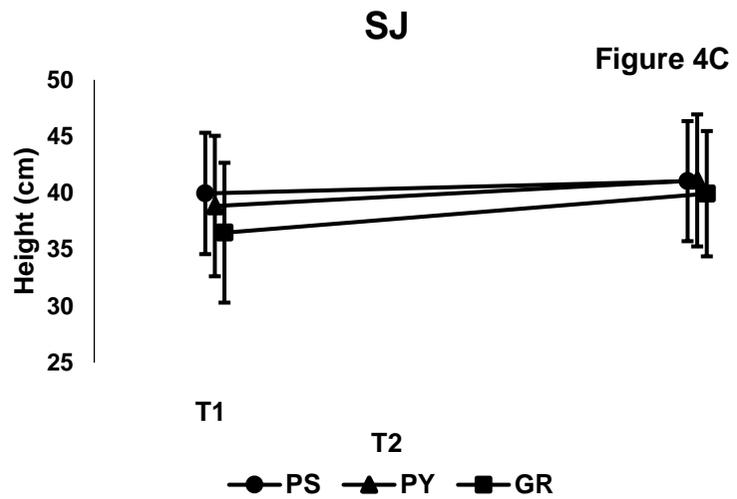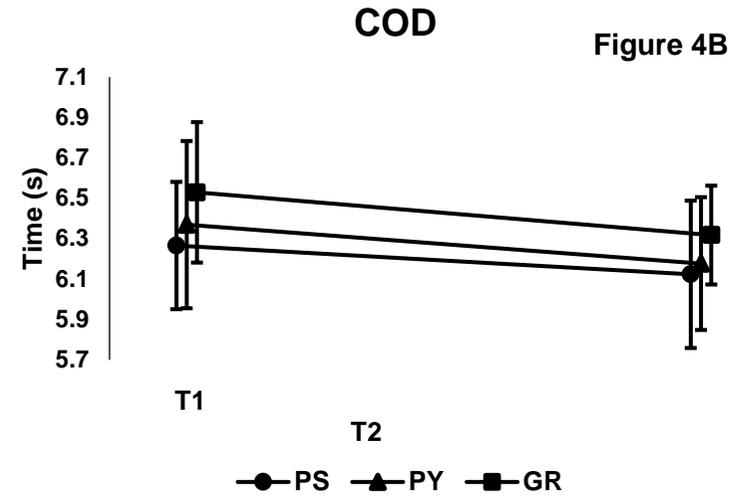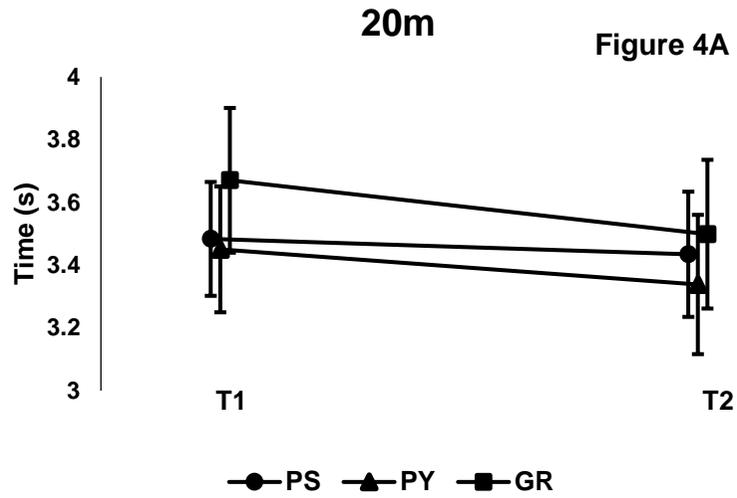
6.4. Discussion

Data from the current study suggest that 20m sprint was the only physical attribute that was able to consistently differentiate between players competing at different levels, with *moderate* effects found between PS and GR as well as PY and GR, but only a *trivial* effect between PS and PY. As well as this, YYIRTL1 was the only measure of physical performance that was able to distinguish between players at different volumes of training (PS and PY, *moderate;* PS and GR, *moderate*). However, the results also indicate that despite the PS group undertaking a greater training session time than both PY and GR groups (*large* effect in comparison to PY and GR; *small* effect between PY and GR), the training stimulus prescribed to PS players, over one competitive season, does not appear to accelerate physical performance.

Physical Performance

It is often cited in the literature that adolescent players who train and compete at a higher level in football possess greater physical attributes (Reilly, et al. 2000; le Gall, et al. 2010 and Meylan, et al. 2010; Meylan, et al. 2014). Reilly et al. (2000) carried out a study involving 31 (16 "elite" and 15 "sub-elite") adolescent footballers (aged 15-16 years), where the authors attempted to distinguish between playing standards based on measures of physical performance. The authors used similar measures of physical performance to the present study, including sprint speed, agility, lower limb power and VO_2 max. With regards to physical performance the greatest differentiating factors between "elite" and "sub-elite" players in the study were sprint speed and agility. The present study supports some of the

findings in Reilly's et al (2000) research; for example, 20m sprint was identified as the only measure of physical performance that was consistently able to differentiate between levels of competition in the present study. COD (or agility) was seen to have a *moderate* effect between PS and GR, but only a *small* effect was noted in other comparisons (Table 12). In chapter 3 of this thesis 20m and COD performance were identified as fairly fixed attributes that may be appropriate for use in player recruitment and talent ID. Data in the current study agree with previous chapters of this thesis, that 20m and COD performance may be suitable during talent ID and player recruitment.

The present study also indicated that performance in the YYIRTL1 (used as a proxy measure of aerobic capacity) was reflected of the higher training session time carried out by the PS group. Furthermore, Wrigley, et al. (2014) found that non-academy players were outperformed by academy players in measures of sprint speed, agility, repeated sprint and aerobic capacity (measured using distance covered in a yo-yo test). Findings in the present study are similar to Wrigley's et al. (2014) research as *moderate* effects were identified for 20m, COD and YYIRTL1 between the PS and GR groups. le Gall, et al. (2010) conducted research that examined the physical characteristics of adolescent footballers who progressed to a higher standard of play following involvement in a systematic training programme at youth level in France. The research involved 161 participants (aged 13.4 – 15.5 years) and data was collected over an 11-year period. The authors identified that players who were successful in progressing to higher levels of play (professional or international football) were biologically more mature, had greater anaerobic power, were faster in a 40m sprint and had greater jump performance compared to those who either dropped out the sport or played at an amateur level upon leaving the programme. Although le Gall, et al. (2010) suggest that these differences were significant, the present study was able to qualify the magnitude of difference between the groups of players involved, where le Gall, et al. (2010) did not. The present

study does, however, agree that sprint speed appears to be a differentiating factor between level of training and competition in youth footballers.

Malina et al. (2005), however, has suggested that physical characteristics and physical prowess are not associated with results in football skill tests in adolescents and suggest that skill level should be held in higher regard than physical performance at a young age. Moreover, literature involving other sports also serves as a warning on the use of measures of physical performance in the differentiation of adolescent athletes. Research carried out with young Australian Rules Football (Pyne, et al. 2005) and American Football players (Sierer, et al. 2008) noted that there were no substantial differences in physical prowess between players who had sustained periods of success in the sport or those who were selected or not-selected in drafts.

Change in physical performance

Change in physical performance was assessed as the difference in 20m, COD, SJ and YYIRTL1 between T1 and T2, over the course of one competitive season and was shown not to differ between any of the groups; *unclear*, *trivial* and *small* effects were found between PS, PY and GR groups in all measures of physical performance.

Existing literature that examines change in measures of physical performance considered important for success in football (speed, agility, lower limb power and aerobic capacity) is limited. Previous literature on the topic is often aimed at explaining the physiological response to prescribed training loads, such as small sided games (Rampinini et al. 2007; Hill-Haas, et al. 2009). Wrigley, et al. (2014), however, conducted research involving academy (n = 27) and non-academy (n = 18) youth footballers in England. The players involved in the

research were of similar ages to players in the present study (12-16 years of age) and comparable measurements of physical performance were used, including 20m sprint, countermovement jump, agility and intermittent endurance capacity (YYIRTL2). The authors also used a similar method of analysis, in which they used baseline fitness as a covariate. Despite the similarities in the analysis, the present study does not support Wrigley's et al. (2014) findings. The authors reported that being part of an academy structure, and long-term development programme, accelerated the rate of physical development in adolescent footballers compared to non-academy, age-matched, footballers. One of the advantages of Wrigley's et al. (2014) study is that the researchers were able to collect data over a three-year period, whereas data in the present study was only collected over one competitive season. However, the current study was able to present training session time data; something that the aforementioned study did not do. Without training session time data in Wrigley's et al. (2014) study, it is difficult to establish whether training session time (or other factors) plays a meaningful role in player development. It is possible that the academy players in Wrigley's et al. (2014) study carried out a greater training session time than the PS and PY groups in the present study or that the non-academy players carried out a lower training session time than the GR group, meaning that differences in rate of change in physical performance are less pronounced in the present study. It may, however, be the case that if the period of data collection in the present study was longer then similar results might be evident. Other studies have shown that annual training session time is able to significantly predict functional capacity over a five-year study period (Valente dos Santos et al. 2012). Again, however, the authors only state significant differences and do not quantify the magnitude of these differences, meaning they are unable to make an inference about the practical significance of the effect. Akubat et al. (2012) attempted to examine the relationship between training and match load monitoring and changes in fitness in professional youth soccer players. Only nine

participants (17 ± 1 years) were used in the study and lactate threshold was measured using a motorised treadmill protocol, before and after a six-week study period. The authors found that by quantifying training load using an individualised training impulse (iTrimp), a correlation was identified between mean weekly iTrimp and percentage change in lactate threshold. It could be suggested that quantifying intensity (rather than only volume) of training is important and something to be considered in future when assessing change in physical performance in adolescent youth footballers.

The results of the present study show that change in physical performance did not differ between the respective groups of adolescent footballers over the course of one competitive season. Moreover, if a higher volume of football specific training (*large* effect between PS, PY and GR; Table 11) does not accelerate the rate of physical development it may be important to explore other potential benefits of systematic training in adolescent footballers. For example, identifying any changes in technical skill over a similar period to the present study. However, as discussed previously in this thesis, there are many issues with quantifying technical skill in footballers (Matthys, et al. 2012, Vandendreissche, et al. 2012 and Figueiredo, et al. 2009). If the same rate of physical progression is available from a lower volume of training, then finances, time and resources may be better placed elsewhere.

<u>Limitations</u>

Despite providing some worthwhile and interesting findings surrounding progression in physical performance, the present study did have some limitations. Firstly, the same as in previous chapters, a group of participants in the PS group had to be excluded from any analysis involving change in YYIRTL1 performance as they were able to complete the test. As some participants completed the YYIRTL1 assessment at T1 and T2, it did not provide them with the opportunity to show any progression. In the present study, any analysis carried out involving the YYIRTL1 was conducted with 66 participants, instead of 88.

Secondly, it would have been useful to examine change in physical performance over a longer period of time in line with some of the previous literature. Doing so could provide a better indication of the physiological impact that systematic training has on adolescent footballers over, for example, the full four-year period of the PS programme.

Other than potentially extending the study period in future research, it may also be appropriate to quantify training intensity, rather than only reporting training session time. Quantifying training intensity at different levels of training and competition may allow for a better understanding of training prescription and periodisation in adolescent footballers. For example, provide an understanding of what intensity is required to benefit certain aspects of fitness. Finally, for future research it may be appropriate to consider an intervention study in which PS players are prescribed with a specific programme to develop speed or agility, for example, and are compared with age matched control groups who are not.

Conclusion

In conclusion, the present study indicates that only 20m sprint ability (T1) was able to consistently discriminate between the higher and lower levels of competition in adolescent footballers (PS and GR; *moderate*, PY and GR; *moderate*). As well as this, YYIRTL1 was the only measure of physical performance (T1) that was suggestive of a greater training session time (PS and PY; *moderate*, PS and GR; *moderate*). The findings also indicate that despite the PS group carrying out a higher training session time than both PY and GR groups, rate of change in 20m, COD, SJ and YYIRTL1 did not differ between the groups; *unclear*, *trivial* and *small* effects found in all comparisons (Table 13). If physical performance is not accelerated by taking part in systematic training during adolescence, it would be beneficial to understand what benefits, if any, a rigorous training regimen does have – i.e. technical or tactical benefits.

Chapter 7: General Discussion

General Discussion

The SFA Performance School programme was launched in 2012 and was designed to provide the best youth footballers in Scotland the opportunity to take part in a 4-year systematic training programme and takes boys from 12-16 years of age (approximately). The overall aim of the programme is to improve the success rate of the senior national team in relation to qualification and competition in world class tournaments e.g. the European and World Cup. Elite programmes focusing on long term athlete development have become increasingly popular as national governing bodies look to standardise the development of their young players. As the programme is relatively new, the training provided through the programme has yet to be examined for its impact on those selected to participate.

The overarching aim of this thesis was to examine the physiological response to a systematic training programme in adolescent footballers. As mentioned previously, the physiological impact of systematic training on adolescent footballers in Scotland is an area that, to date, has not been investigated.

Given that one of the purposes of the Performance School programme was to focus on long-term athlete development and avoid the Relative Age Effect (RAE), it was appropriate to firstly analyse the physical characteristics and birth date distribution of the young players who were currently enrolled in the programme. Study 1 examined the distribution of birth dates across each of the age groups in comparison to the general population. The study also sought to determine whether physical prowess differed depending on time of birth within the selection year. Existing literature has suggested that it is common to find an overrepresentation of chronologically older players in youth academies and development programmes (Jimenez and Pain, 2008; Figueiredo, et al. 2009; Vandendreissche, et al. 2012;

Reilly, et al. 2000). Authors have also stated that one of the reasons posited for the overrepresentation is that earlier born players tend to be significantly taller, heavier and biologically more mature than those born later in the selection year (Malina et al. 2007). In addition, these advanced physical characteristics mean that more mature players can often outperform their less mature counterparts in the physical aspects of the game (Meylan, et al. 2010). Pronounced physical attributes can often be mistaken for talent and, thus, less physically mature but equally skilful players can be disregarded (Matthys, et al. 2012; Vandendreissche, et al. 2012; Figueiredo, et al. 2009).

The results of Study 1 showed that the RAE was present within all year groups of the Performance School programme, despite one of the aims of the programme being to avoid it. In addition, the study also demonstrated that players born earlier in the selection year were taller, heavier and biologically more mature than their later born counterparts. In spite of the differences in physical stature, these characteristics were not borne out in relation to physical performance. Such findings indicate that there are issues with player recruitment and talent ID, as players appear to be selected based on their physical appearance i.e. stature and mass. Selecting players based on such attributes could result in talented, later born players, being missed.

The findings in Study 1 support previous research that has shown the RAE is frequently evident in sport academies during adolescence (Jimenez and Pain, 2008; Figueiredo, et al. 2009; Vandendreissche, et al. 2012; Reilly, et al. 2000). However, Study 1 was not in agreement with other existing literature that suggests biologically more mature players with advanced physical characteristics are often able to outperform their less mature counterparts (Meylan, et al. 2010). Such findings were not present in Study 1 and it was highlighted that despite differences in biological maturity, there were no differences in physical capacity between those born at the start and end of the selection year. Findings such as these, have

important implications. Firstly, there appears to be a fundamental issue during player recruitment that results in young players with advanced physical characteristics, i.e. stature and mass, being selected ahead of shorter and lighter players. It is possible that coaches are mistaking the impact of advanced physical characteristics for talent – a finding that has been presented previously by Matthys, et al. 2012. Secondly, if players born at the end of the selection year are as physically capable as the biologically more mature players born at the start it is not clear why there is such a great underrepresentation of later born players in the programme.

Sessions within the Performance School programme are aimed primarily at improving technical skills such as passing and dribbling. However, technical skill is difficult to quantify and measure, meaning observed changes in technical skill can often be subjective (Matthys, et al. 2012, Vandendreissche, et al. 2012 and Figueiredo, et al. 2009). It was therefore appropriate to apply a more objective measure to determine the progression of the players in the programme. Study 2 aimed to examine the physiological impact of the systematic training programme, with regards to rate of change in physical performance. It became apparent that certain variables were contributing to change in physical performance and so the extent to which baseline fitness, progression in maturity offset and training session time impacted change in physical performance were examined. Biological maturity is frequently cited as impacting on an adolescent footballer's performance (Malina et al. 2007 and Meylan, et al. 2010) and was therefore expected to influence change in physical performance, more so than baseline fitness or training session time.

It was found in Study 2 that baseline fitness made the largest contribution to change in physical performance over time. It was also noted from Study 2 that maturity offset did not contribute to a significant degree to changes in physical performance. The findings also

highlight the importance of the effects of baseline fitness when assessing changes in physical performance. These data emphasise that coaches should use caution during the player recruitment process not to disregard players who possess poorer baseline measures; as those with the lowest baseline measures appear to have the greatest capacity for change. Previous literature often reports maturity as a confounding factor in physical performance during adolescence (Valente dos Santos, et al. 2012; Carling et al. 2012 and Bucheit and Mendez-Villenueva, 2014), however, in Study 2 maturity had little impact on the change in physical performance when assessed over an entire competitive season; particularly in comparison to baseline fitness. It could be suggested that coaches and scouts consider baseline fitness when recruiting players for systematic training programmes, since it appears that players with lower baseline fitness measures have the greatest capacity for change in physical performance. The results in Study 2 indicate that players with lower levels of baseline fitness appear to have the greatest potential for change and therefore caution should be used when selecting young players based on physical performance. The findings also suggest that the players with lower baseline fitness measures appear to benefit most from the training stimulus being provided in the Performance School programme. If players with lower levels of baseline fitness are benefitting most, it could be argued that training is more suited to them and that players with the highest levels of fitness (in 20m, COD, SJ and YYIRTL1) need to work at a greater intensity in order to improve physically – something they are not able to do due to the homogeneity of the training that is prescribed. It could therefore be suggested that groups who are closer together, in terms of physical prowess, should be chosen to train together to allow for a high intensity of training for all players.

Physiological assessments have been used previously as a mechanism for identifying players who will be successful in progressing to a higher level of play (le Gall, et al. 2010). Study 3 aimed to assess the stability in ranking players based on physiological assessment. Understanding the stability of player rankings is important, particularly if coaches are going to use them as an assessment tool. Having examined changes in physical performance at a group level, it was now possible to determine the percentage of players in each group either progressed, remained stable or regressed on an individual level with regards to change in physical performance following an entire season's training. Understanding individual response to training is an important aspect of long-term athlete development (Scharhag-Rosenberger, et al. 2012; Astorino and Schubert, 2014) and can be used to further individualise training and inform periodisation.

The results in Study 3 expanded and provided greater detail on the findings from Study 1 and 2, by inducing that rank order in 20m sprint was the most likely attribute to remain the same between time points. Furthermore, the data also highlighted that some measures of physical capacity appear to be more stable than others, and that this was dependent on the physical measure and year group. With regards to those who responded, remained stable or regressed in relation physical performance the results indicated that response was highest in the YYIRTL1 and SJ assessments, supporting findings in Study 1. Varied response to training and unstable ranking of players call into question the usefulness of carrying out certain physical assessments with adolescent footballers, particularly if they are going to be used as a selection tool.

The findings in Study 3 further the idea that caution should be exercised when attempting to use physical performance to rank adolescent players, as rank order can be unstable. The unstable ranking of players calls into question the usefulness of carrying out some physical assessments with youth and adolescent footballers, especially if their selection is based on

their rank within a group. The findings in Study 3 are consistent with those in Study 1, as 20m and COD performance in Study 3 were found to have a low percentage of responders within each age group. It may therefore be appropriate to test these attributes during the talent ID process, if speed and agility and desirable attributes.

Finally, Study 4 aimed to examine the differences in both physical characteristics and rate of change in physical performance between groups of adolescent footballers who participate in different levels of training and competition. As this relatively new level of systematic training has been introduced to Scottish youth football, it is important to understand the differences in rate of change in physical performance between players who are enrolled in the programme compared to those who are not. It has been previously acknowledged that measures of physical performance can be used to differentiate between "elite" and "sub-elite" adolescent footballers (Reilly, et al. 2000). Wrigley, et al (2014) found that taking part in a systematic training programme for football accelerated physical development when compared with age matched controls. However, little other research that examines the differences in rate of change between groups who train and compete at different levels in youth football is available.

The results place into context the potential effectiveness of the SFA programme when comparing the cohort to age-matched groups with regards to physical prowess and change in physical performance. The results indicate that 20m sprint performance was the only physical attribute that was able to consistently differentiate between levels of competition in adolescent footballers. While interestingly, in a programme that focuses mainly on skill development, YYIRTL1 performance was the only attribute that was suggestive of an increased training session time. With regards to change in physical performance, there were no differences present between the groups, meaning that regardless of training session time or

level of competition all groups change at the same rate. It is appropriate, therefore, to assess what other impact the systematic training regimen is having if participating does not accelerate physical development. Other areas of interest may surround improvements in technical skill or tactical awareness, although these can be difficult to quantify and measure. Despite carrying out an additional 40-50% of additional training, the Performance School players did not progress at a greater rate, in four measures of physical performance, than players who were training with Professional Youth academies or Grassroots clubs. If taking part in a higher volume of training does not accelerate physical development in youth footballers, it would be beneficial to understand what benefits do arise from being part of a systematic training programme during adolescence. It is possible that there may be benefits in the form of technical skill or tactical awareness.

Limitations and the future directions of the current research

The studies in this thesis did have some limitations, despite presenting worthwhile findings for both theoretical and applied practise. The first possible limitation that encompasses all the studies in this thesis was that players need to apply to be selected for the Performance School programme. As the programme contains an element of self-selection, it is not possible to say that the players within the programme are "the best" players available. Moreover, a national perspective of the elite level youth football in Scotland is hard to create.

In Study 1, only a small number of players were available for analysis with regards to the RAE and both anthropometric and physical performance comparisons. Due to the nature of the RAE, it is expected that there will be fewer players born in the final quarter of the year. A limitation that was evident in Studies 2, 3 and 4 was that players in the 2000 group were able to complete the YYIRTL1 at each test date. Being able to complete the assessment

meant that players weren't given the opportunity to show progression in the measure. As a result, players in the 2000 year group were removed from any analysis involving the YYIRTL1.

It is important to consider the study period used when assessing stability of ranking in players based on physical performance and change in physical performance, as was carried out in Study 3 and 4 of this thesis. A longer study period could have provided a better idea of how stable player ranking is over, for example, the entire four years of the Performance School programme. Doing so, may contribute to the understanding of what measures of physical performance are most relevant throughout the development of young athletes. For example, at stages of talent ID and player recruitment or when deciding on the retention or release of players from clubs and development programmes, it is important to understand the potential for progression in physical prowess as well as the dangers of relying heavily on the ranking of adolescent athletes during these processes. It is also possible that greater change in physical performance would have been evident if studied over a longer period and findings similar to Wrigley's et al. (2014) study may have been present; showing that players involved in a systematic training programme experience accelerated physical development when compared to those who are not.

There are a number of directions that the current research could go in the future. It would be interesting to conduct similar research that aimed to quantify training load. It was evident in Study 2 of this thesis that training session time did not contribute greatly to change in physical performance, particularly when compared to baseline fitness. However, previous research that has quantified training load using an individualised training impulse (iTrimp) has shown that there is a relationship between iTrimp and improvements in physical

performance when assessing lactate threshold. iTrimp may be unrealistic to implement in programmes without appropriate staffing, however simpler methods (training session time $\times$ rating of perceived exertion) of quantifying training load are available and have been deemed reliable and valid by other researchers (Buchheit, et al. 2013; Hill-Haas, et al. 2011; Impellizzeri, et al. 2004). Understanding the appropriate training load to prescribe during adolescent player development would be beneficial for coaches and is an area of research that remains relatively unexamined. For example, if three training sessions per week provides the same change in physical performance as five training sessions per week, then resources and time could be better distributed.

Another direction for the current research could be to combine physiological assessment with a qualitative measure that examines coach's perception of players within a systematic training programme. Ultimately, a coach's perception of a player will determine the likelihood that they progress within an academy or player development programme. Larkin and O'Connor (2017) researched coach's perceptions of key attributes during player recruitment and concluded that a multifaceted approach, considering physical performance, technical skill and psychological attributes should be adopted when recruiting adolescent football players. Therefore, future studies may wish to track the short and long-term success of adolescent footballers in systematic training programmes and examine if any specific attributes (physical, technical or psychological) are indicative of such success. With regards to the RAE, for example, previous literature exists that suggests psychological disparities as well as relatively older players being able to display higher perceptions of confidence could play a role in selection and retention of young athletes (Musch, et al. 2001; Harter, 1978). Existing research, however, was not conducted in football and is dated.

Finally, an interesting avenue for the current research would be to conduct a follow up study with players who were enrolled in the Performance School programme. A follow-up study could be conducted in, for example, five or 10 years and could take on a number of forms. One example could be to examine the career path of the players who were born earlier and later in the selection year, with regards to long-term success in football. Another potential follow-up study might assess any relationships between physical performance in adolescence and progression into, or long-term success, in senior football.

Conclusion

Football associations and governing bodies are beginning to implement player development strategies at an earlier age in an attempt to standardise the development of their young players (Miller, et al. 2015). The rewards for success or even qualification in major tournaments, such as the World Cup and European Championship, could be one explanation for the increasing focus on youth development (Smolianov, et al. 2015). The studies in this thesis attempt to examine some of the factors that impact on the physical development of young footballers. Among the many contributing factors to physical development in young footballers, the current thesis presented studies that examined the RAE and issues surrounding player recruitment, as well as the impact of maturation, volume of training and baseline fitness on physical performance and change in physical performance.

The findings presented in this thesis indicate that there is an issue during the player recruitment and talent ID phase of the Performance School programme, as highlighted in Study 1 with presence of the RAE. Furthermore, Study 2 showed that once players are selected into the programme, the players who have the lowest baseline fitness are benefiting

the most physically from the prescribed training. Study 3 extended the findings in Study 2, showing that player rankings, by physical performance, during adolescence can be unstable; suggesting that great care must be taken when using measures of physical performance with adolescent players, particularly if their selection or de-selection depends on their rank within a group. Findings in Study 4 demonstrated that regardless of training session time, adolescent footballers training and competing at different levels in Scotland, do not differ with regards to change in physical performance over one competitive season. Understanding that there are no physical benefits from systematic training in adolescence is important. If no physical benefit is present then it might be the case that players are benefiting technically or tactically, however, these attributes are hard to quantify. It is apparent that more research needs to be conducted to examine exactly what the benefits of a systematic training regimen are for adolescent footballers.

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Appendix A

INFORMED CONSENT FORM

The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that Heriot-Watt University has approved all procedures. Please tick the boxes below to show you are in agreement with the statement.

☐ I have read and understood all information provided and this consent form.

☐ I have had an opportunity to ask questions about my participation.

☐ I understand that I am under no obligation to take part in the study.

☐ I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing.

☐ I understand that all the information I provide will be treated in strict confidence.

☐ I am happy to have blood taken, via a finger prick, to test blood lactate levels.

☐ I agree to participate in this study.

Your name

_____

Your signature

_____

Parent/Guardian signature

_____

Signature of investigator

_____

Date

_____

Appendix B

Participant Information Sheet

"The physiological impact of a systematic training programme on adolescent footballers"

1.   Invitation

You are being invited to take part in this research study. The criteria for your selection are that you currently train and play football with either a professional youth club or a recreational boy's club team.

Before you decide whether or not to take part, it is important for you to understand why the research is being carried out and what it will involve. Please take time to read the following information sheet carefully, and discuss it with others if you wish. Ask us if there is anything that is not clear, or if you would like more information. Take time to decide whether or not you wish to take part.

2.   What is the purpose of the study?

The aim of the study is to assess the impact that different training session times, at different levels of competition, have on physical prowess in youth footballers.

3.   Do I have to take part?

Your participation in the study is entirely voluntary and you are under no obligation to take part if you do not see fit. Should you decide to participate you will be asked to sign a consent form to say that you understand what is involved. However, you are also free to leave the study at any point if you do not wish to continue. You are not required to give a reason for withdrawing.

4.   What will happen to me if I take part?

You will undergo a battery of fitness tests on two separate occasions. The battery of tests will involve measuring height and weight, sprint speed, change of direction, jump height, and

recovery capacity from high-intensity exercise. Your training minutes, game minutes and sessions missed through injury will be logged over a 6 month period. Every 6 weeks (over the 6 month test period) after the initial test date you will undergo a 6 minute sub maximal yoyo test. Your heart rate will be measured using a heart rate monitor and your blood lactate will be measured, via a finger prick, at each of these 6 week test dates.

5.   What are other possible disadvantages and risks of taking part?

All procedures have been risk assessed and their no risks to your health. Your data will also be anonymous and will be kept secure at all times. You will not be identified in any report or publication.

6.   What happens when the research study stops?

If you wish you will be kept informed of the progress of study and informed of the overall results. Results may be published in a scientific journal or presented at a scientific conference. The data will be anonymous and you will not be identified in any report or publication. Participants will be offered a copy of their results should they wish to see them.

7.   What if there is a problem?

If you have a concern about any aspect of this study, you should ask to speak with the researchers who will do their best to answer your question.

8.   Will my taking part be kept confidential?

All the information about your participation in this study will be kept confidential. Only the investigators will have access to your name and contact details which will be kept on a password protected computer. The information you provide will be anonymous and transcripts will be either kept on password protected computers or in locked filing cabinets. Yes. All the information about your participation in this study will be kept confidential.

9.   Contact for further information

You are encouraged to ask any questions you wish, before, during or after the study. Should you have any queries or concerns at any time please contact Michael King (07854015044, mk443@hw.ac.uk).