

THE UNIVERSITY OF WOLVERHAMPTON

**Selection Biases Within an English Football Academy:
Implications of the Elite Player Performance Plan**

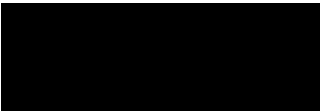
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Philosophy by

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Abstract

The Elite Player Performance Plan (EPPP) was introduced in 2011 in order to enhance the youth football academy system in England. Previous literature demonstrates that relative age and biological maturation are responsible for selection biases within youth football, where both factors exert an influence on anthropometry and physical performances. However, there is limited research that has examined the aforementioned factors over a prolonged period of time, and especially within academies operating under the EPPP. Therefore, the general aim of this thesis was to investigate relative age, biological maturity, anthropometric and physical performance characteristics of male youth players from an English football club, as they progressed through the developmental pathway, under the EPPP framework.

The findings from Chapter 3 revealed that selection within the investigated club was heavily overrepresented by relatively older and earlier maturing players, and this persisted since the EPPP was introduced. Subsequently, Chapter 4 identified that biological maturity, anthropometry and physical performances distinguished players that were retained across the developmental pathway, in an age group dependent manner. Chapter 5 provided estimates for when the development of anthropometric and physical performance characteristics initiate, peak and plateau, according to somatic maturity. Finally, Chapter 6 demonstrated that a bio-banding intervention may influence the decision-making process adopted by academy coaches' regarding player selection and retention.

In summary, the investigations conducted within this thesis provide novel and contemporary knowledge that can be used to enhance practice within the current club. Specifically, the findings from this thesis highlight that relative age, biological maturity, anthropometry and physical performances influence player selection and retention within this academy, suggesting that policies (e.g. the EPPP) require careful evaluation so that inappropriate selection biases can be nullified. Further studies are required to corroborate and extend these findings on a wider scale through robust methodological approaches.

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Thesis Publications

1. Relative Age, Maturation, Anthropometric and Physical Performance Characteristics of Elite Football Players: Observations from a Top Categorised Academy - **Chapter 3**

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2. The Influence of Birth Quartile, Maturation, Anthropometry and Physical Performances on Player Retention: Observations from an Elite Football Academy - **Chapter 4**

Patel, R., Nevill, A., Smith, T., Cloak, R., & Wyon, M. (2020). The influence of birth quartile, maturation, anthropometry and physical performances on player retention: Observations from an elite football academy. *International Journal of Sports Science & Coaching*, 15(2), 121–134. <https://doi.org/10.1177/1747954120906507>

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List of Abbreviations

FIFA	International Federation of Association Football
EPL	English Premier League
UEFA	Union of European Football Associations
FFP	Financial Fair Play
The FA	The Football Association
FL	Football League
EPPP	The Elite Player Performance Plan
U	Under
RAE	Relative age effect
PMA	Performance Management Application
min	Minute
s	Seconds
km	Kilometres
km/hr	Kilometres per hour
kg	Kilograms
cm	Centimetres
yr	Year
cm/yr	Centimetres per year
kg/yr	Kilograms per year
Hz	Hertz
HR _{max}	Maximal heart rate
ISAK	International Society for the Advancement of Kinanthropometry

PHV	Peak height velocity
GP	Grulich-Pyle
TW	Tanner-Whitehouse
KR	Khamis-Roche
CMJ	Countermovement jump
m	Metres
GPS	Global positioning system
VO ₂ max	Maximum oxygen uptake (mL·kg ⁻¹ ·min ⁻¹)
3G	Third generation (artificial playing surface)
APHV	Age at peak height velocity
YPHV	Years from/to peak height velocity
Yo-Yo IR1	Yo-Yo Intermittent Recovery Level 1
Yo-Yo IR2	Yo-Yo Intermittent Recovery Level 2
Sqrt	Square root

Chapter 1 – General Introduction

1.1 Background and rationale

In the past half-century, the England national football team has failed to consistently achieve success in major international competitions (King, 2014), corresponding to an average of 10th position since the International Federation of Association Football (FIFA) World Ranking was established in 1993 (FIFA, 2018). The shortcomings of the national team have received much attention within the English media, where the underlying causes have been attributed to players and management, for example (Wilson, 2016; Hayward, 2016).

However, it has been suggested that the failings are largely multifaceted, where it is argued that factors such as culture, the quality of coaching facilitating player development, and the quality and quantity of players available for national team selection are key (King, 2014). The number of English players representing teams in the top tiers of English football, particularly the English Premier League (EPL), has diminished in recent years; a report from the Union of European Football Associations (UEFA) indicates that the EPL has the highest percentage of foreign players, with the English Championship having the sixth most (Sky Sports, 2017). Player migration can be associated with undesirable outcomes for English football, whereby the recruitment of more foreign players may consequently provide less opportunities for English players, which may eventually lead to a state of dependent development (Maguire and Pearton, 2000; Littlewood et al., 2011). This appears compounded by the increasing financial expenditure for non-English players during a recent transfer window by EPL clubs (Deloitte, 2018; Guardian Sport, 2017), instead of investing in 'home-grown' players. Despite progressive increases in revenues generated by clubs (Georgievski and Žeger, 2016), excessive expenditures, for foreign players in particular, may

heighten the risk of financial instability, even resulting in administration (Beech et al., 2010).

In a bid to prevent clubs overspending and the risk of long-term financial problems, the European governing body for football, UEFA, established the Financial Fair Play (FFP) regulation in 2010 (UEFA, 2015). A further aim of this regulation was to encourage the allocation of financial resources to youth development in a bid to enable clubs to be self-sustaining. In addition, the governing body for English football, The Football Association (FA), recognised limitations in the developmental pathway of young footballers and proposed new rules to increase the number of 'home-grown' and club trained players (The FA, 2015b). This included: a change in the definition of a home-grown player, a reduction in the number of non-home-grown players permitted within a first team squad, and the requirement that at least two of these home-grown players are also club trained (The FA, 2015b).

In England, a major overhaul in the long-term youth development strategy was implemented by the EPL and other key stakeholders to create a world leading Academy System. This strategy has the primary aim of enhancing the number and quality of home-grown players being produced by EPL and Football League (FL) clubs to represent their respective senior teams, and subsequently the England national team. The Elite Player Performance Plan (EPPP) (Premier League, 2011) was introduced in 2011 as a result. This comprised a comprehensive modernisation of the Academy System in which detailed processes and criteria were formulated to enhance the efficiency of youth development strategies for clubs within the United Kingdom (Premier League, 2011). This included a new classification system, where individual clubs would be audited by the EPL and awarded a categorisation from 1 to 4 - with 1

being the highest quality - for demonstrating key criteria necessary for creating a high-quality environment in various disciplines such as coaching, education, recruitment, sport science and medicine.

A seemingly key strategy for academies is the recruitment of talented players from a young age and subsequently nurturing them through the developmental pathway for senior team representation. In England, players can be formally registered to an academy starting from the Under 9 (U9) group (Premier League, 2011). Whilst the individual philosophy of a club may influence the particular profile of a player they seek to recruit and retain, it is clear that predictors of football talent are multifactorial (Williams and Reilly, 2000). Accordingly, the literature has documented that individuals selected by academies are distinguished by superior attributes compared to peers at lower playing levels which includes: anthropometry, physical and technical performances and psychological skills (Gil et al., 2014; Figueiredo et al., 2009; Coelho et al., 2010; Reilly et al., 2000b). Indeed, these factors are important for match success (Reilly, 2006; Stølen et al., 2005). Consequently, it seems logical that academies would use multifactorial competencies to maximise the effectiveness of their recruitment or selection strategies (Vaeyens et al., 2006; Unnithan et al., 2012; Sarmiento et al., 2018).

In practice, the selection process in youth football operates in a biased manner, particularly for academies (Meylan et al., 2010; Unnithan et al., 2012). Despite young players being categorised by their chronological age (CA) into groups to promote fairness, there can be marked differences between individuals within these age groups (Malina et al., 2004a; Musch and Grondin, 2001), and these seemingly contribute to selection biases (Cobley et al., 2009; Meylan et al., 2010). Specifically, academies

select a greater proportion of players born towards the start of their respective selection year (Mujika et al., 2009; Grossmann and Lames, 2013) - this is known as the relative age effect (RAE) (Barnsley et al., 1992; Musch and Grondin, 2001; Cobley et al., 2009). Additionally, academies also favour the selection of players that are advanced in biological maturity (Malina et al., 2000), and this factor also appears to be a stronger determinant of selection than birth date (in U12 to U17 groups) (Johnson et al., 2017). Both selection biases (explained further in **Chapter 2**) can be aligned with the maturation-selection hypothesis (Cobley et al., 2009); that is, players demonstrating superior anthropometric (body size) and physical performance characteristics are favoured (Sierra-Diaz et al., 2017). Consequently, academies may overlook relatively younger and/or later maturing players despite the possibility that these individuals may have a greater likelihood of achieving professional status compared to relatively older and/or earlier maturing players (Ostojic et al., 2014; Skorski et al., 2016). The systematic discrimination of players due to temporarily inferior physical attributes can result in the premature dropout of relatively younger and/or later maturing players (Helsen et al., 1998; Malina et al., 2000), thereby restricting the talent pool that academies can select from. Consequently, there is a need for contemporary research to be conducted within academy football to examine selection strategies throughout the entire developmental pathway, where relative age and biological maturity should be considered. Through applied research, a greater understanding of the impact of the EPPP framework can be determined, thereby elucidating areas where beneficial changes can be made to current practice.

Despite relative age effects being investigated extensively within youth football, there is limited research relating to the prevalence of this phenomenon in UK-based academies (Sierra-Diaz et al., 2017). Given that the EPPP has resulted in substantial

changes to academies' operating procedures, including recruitment and reputation advantages for the highest categorised academies (Premier League, 2011), a clear understanding of how this may have impacted selection strategies is of interest to researchers, practitioners and policymakers that are involved in English youth football. Additionally, as biological maturity exists as a separate but related selection bias (Johnson et al., 2017), and exerts a considerable influence on attributes (e.g. physical performance) that predict football performance (Meylan et al., 2010; Malina et al., 2004b), it is essential that this factor is also considered. The existing literature have adopted a broad range of methodological approaches to investigate the prevalence of relative age (Sierra-Diaz et al., 2017) and maturation-related selection biases (Meylan et al., 2010). However, these studies have typically adopted cross-sectional designs or have not taken into account repeated measures over an entire season (Deprez et al., 2013; Deprez et al., 2012; Lovell et al., 2015; Fragoso et al., 2015; Carling et al., 2009), which may limit the scope of the findings given that developmental changes are highly variable around adolescence (Malina et al., 2004a).

Previous literature demonstrates consistently that due to selection biases within football academies, the characteristics of players selected into these highly selective cohorts are largely homogenous, at least with regards to anthropometry, physical performances and biological maturity (Deprez et al., 2013; Deprez et al., 2012; Fragoso et al., 2015; Hirose, 2009; Lovell et al., 2015). However, individual variability in biological maturation processes (i.e. timing and tempo) are evident and may lead to considerable differences in anthropometry and physical performances for individuals within the same age group (Malina et al., 2004a). The penchant for youth teams to select players based on anthropometry and physical performances is deemed inappropriate (Williams and Reilly, 2000), particularly as late maturing players catch-

up and can even surpass their earlier maturing peers for these characteristics (Lefevre et al., 1990). Whilst previous research has typically examined the influence of relative age, biological maturity, anthropometry and physical performances on selection into academies (or high-level teams) (Meylan et al., 2010; Sierra-Diaz et al., 2017), the impact of these factors on retention/dropout for each age group throughout the developmental pathway, particularly for entry to the senior team, remains largely unknown (Deprez et al., 2015e; le Gall et al., 2010).

Predictors of talent in football are considered multifaceted (Huijgen et al., 2014; Reilly et al., 2000b), yet can be influenced by social and environmental factors, as well as biological maturation (Williams and Reilly, 2000). The relationship between biological maturation on numerous indicators of football performance has previously been established, where players advanced in biological maturity demonstrate superior anthropometry and physical performance characteristics (Meylan et al., 2010). Therefore, it is useful for practitioners to consider these characteristics in relation to biological maturity, thereby providing valuable information that could be used for talent identification and development purposes (Cumming et al., 2017; Lloyd and Oliver, 2013). Previous research has revealed that peak development of anthropometry and physical performances coincide with the timing of peak height velocity (PHV), and that development of these typically plateau during the post-PHV period (Beunen and Malina, 1988; Philippaerts et al., 2006). Whilst these findings are useful, drawbacks within the methodological approaches of these studies provide a rationale for a contemporary investigation to corroborate and extend previous findings. Specifically, the restriction to only one measurement per season (i.e. annually) for individual players is unlikely to accurately account for developmental changes that occur within a season (Malina et al., 2004a). Therefore, there is a need for a contemporary

approach to examine developmental changes of anthropometry and physical performances, according to somatic maturity, to identify when development of these factors initiate, peak and plateau.

Whilst previous literature has offered solutions to counteract selection biases, these have often focussed on mitigating the influence of relative age (Sierra-Diaz et al., 2017; Cobley et al., 2009). However, as biological maturity is a stronger determinant of selection into academies (from U12 to U17) compared to birth date (Johnson et al., 2017), this selection bias requires primary consideration for the majority of age groups along the developmental pathway within academies. Qualitative evidence obtained from coaches within youth football indicate that they have a role in the selection and retention of players, where organisational pressures (e.g. selecting players to win) are responsible, at least partly, for perpetuating selection biases in youth football (Hill and Sotiriadou, 2016). Therefore, attempts to reduce selection biases in youth football appear reliant on altering the decision-making process adopted by talent selectors (e.g. coaches). Bio-banding has recently emerged as a potential strategy to enhance talent identification within youth sports (Cumming et al., 2017), though at present, there is a lack of empirical evidence to support the implementation of this approach. Thus, there is a need to investigate the potential benefits of bio-banding as a strategy to mitigate the maturation-related selection bias within academy football; specifically, to determine whether it can alter the decision-making process adopted by talent selectors.

In summary, the current literature demonstrates that whilst there is a considerable body of research that has sought to investigate selection biases within male youth football, the implementation of the EPPP represents a significant policy change within

UK-based academies, thereby justifying contemporary research to establish the impact on applied practice. Furthermore, several methodological drawbacks of previous studies, including the use of only measure per season and/or relatively short investigation periods, highlight areas where contemporary research can adopt a different methodology to corroborate and extend previous findings.

1.2 Thesis Organisation

The main focus of this thesis is to gain a greater understanding of how relative age, biological maturity, anthropometric and physical performance characteristics of youth players have impacted applied practice within academy football, since the EPPP was introduced.

A brief outline of each chapter in this thesis is described as follows:

Chapter 2 involves a review and critical analysis of the current literature regarding pertinent themes within this thesis including: the EPPP, anthropometry, biological maturation, the relative age effect, physical performance and retention/dropout.

Chapters 3-6 consist of original investigations that were conducted to meet the specific aims of objectives of this thesis (see **Section 2.10**):

- Chapter 3 investigates the prevalence of selection biases in all age groups within an English professional football club and establishes between-quartile differences for somatic maturity, anthropometry and physical performance characteristics.

- Chapter 4 investigates if birth quartile, somatic maturity, anthropometry and physical performance characteristics distinguish players retained along the developmental pathway between U11 to U21 groups.
- Chapter 5 establishes growth curves of anthropometric and physical performance characteristics, according to somatic maturity, to estimate when development of these initiate, peak and plateau.
- Chapter 6 investigates coaches' experiences of a bio-banding intervention to determine if this approach has any practical applications for reducing the maturation-related selection bias.

Chapters 3-5 use large cohorts of players through mixed-longitudinal designs and quantitative analysis; Chapter 6 uses a qualitative approach with a sample of coaches and a sub-sample of players for a bio-banding intervention.

Chapter 7 discusses the findings of this thesis according to the specific aims of this thesis (see **Section 2.10**). Additionally, this chapter addresses the research limitations, recommendations for future research, overall conclusions and practical applications of this thesis.

Finally, references that were used throughout this thesis and appendices are subsequently provided.

Chapter 2. Review of Literature

2.1 The Elite Player Performance Plan

Together, the EPL and other key stakeholders introduced The EPPP in 2011 in an attempt to create a world-leading Academy System with the primary aim of producing more and higher quality 'home-grown' players capable of representing the England national team (Premier League, 2011). This was achieved by establishing a comprehensive framework that provided incentives for clubs to invest in their respective youth development infrastructure. According to the EPPP framework, clubs are required to demonstrate fulfilment of certain criteria across the entire multi-disciplinary provision, where regular audits take place to categorise each club on the basis of their ability to provide an high-quality environment catering to holistic youth development (Premier League, 2011). Consequently, a number of changes were mandated which sought to bridge the gap between other elitist domains within the UK (e.g. music, dance and cycling) and youth football development systems across Europe (e.g. Holland, France and Spain) (Premier League, 2011).

Perhaps the most significant change under the EPPP is the creation of the categorisation system. This has several implications for individual clubs that vary in categorisation. For example, for a top categorised academy (Category 1), players in the Foundation Phase (U5 to U11) would be expected to receive 4 hours coaching per week, rising to 8 hours. In the Youth Development Phase (U12 to U16), this corresponds to 12 hours per week, rising to 16 hours. Finally, players in the Professional Development Phase (U17 to U21/23) would complete 16 hours per week in a full-time capacity (Premier League, 2011). This access to coaching differs substantially from a Category 3 academy (approximately half the total time of a Category 1 academy) (Premier League, 2011), and would appear to impact

developmental opportunities for players across academies. Additionally, Category 1 academies are permitted to adopt recruitment strategies on a national scale, thereby providing them with a greater scope to identify the most talented players within the country (Premier League, 2011).

The EPPP also recommends that academies employ specialist staff to contribute towards a multidisciplinary team that support the club philosophy (Premier League, 2011). Specifically, the appointment of sports science and medical provision enables the implementation of monitoring strategies that are considered central to the efficacy of applied practice (Premier League, 2011). This involves players from the Youth Development and Professional Phases performing standardised fitness testing at multiple points per season, in which birth date, anthropometry, physical performance characteristics and estimations of biological maturity are obtained (these are addressed below in **Sections 2.3 to 2.8**) The practical applications of this information are broad, and include benefits for: player recruitment (Williams and Reilly, 2000), strength and conditioning provision (Bergeron et al., 2015), guiding and evaluating training prescription (Svensson and Drust, 2005; Johnson, 2009) and enabling performance benchmarking relative to chronological age and biological maturity (Cumming et al., 2017; Jones et al., 2000). However, it is important to note that other predictors of performance (e.g. technical, tactical and psychological skills) are not currently mandated under the EPPP testing battery (Premier League, 2011), but are still important for researchers and practitioners to consider (Williams and Reilly, 2000; Larkin and O'Connor, 2017; Vaeyens et al., 2006).

In light of the EPPP, and the permutations for applied practice that have ensued, there are several areas of research that were proposed (within the EPPP documentation)

that seek to inform best practice (Premier League, 2011). For example, suggested areas of research included investigations of the relative age effect, physical performance, biological maturity and dropout. Given the importance of these research areas in relation to the EPPP, this thesis will now address these, and associated factors, in the context of current literature.

2.1.1 Monitoring of Football Players

As highlighted in the previous section, the implementation of fitness testing batteries can have a range of useful applications within applied practice including training prescription and talent identification, as well as feedback and motivation for the player (Barker and Armstrong, 2011). By conducting fitness testing at regular intervals throughout the season, including a baseline measure at the start of the season, it is possible to assess progress and/or seasonal variability, where performances are expected to improve as a result of regular training and match exposure (Dragijsky et al., 2017; Walker and Turner, 2009). Moreover, it is important that monitoring is conducted regularly throughout a season, especially when concerning youth players (i.e. in Youth Development and Professional Development Phases), due to sporadic changes that can occur over a short period of time due to growth and maturation processes (Malina et al., 2004a). Inter-individual variability in these processes (described further in **Sections 2.2** and **2.3**) has been shown to both positively and negatively influence physical and technical performances (Malina et al., 2005; Malina et al., 2004b), thereby highlighting the need to continually monitor the current status and competencies of the individual.

The implementation of a fitness testing battery requires thorough deliberation of each component to ensure that they are valid and reliable. Validity is deemed to be the most

important consideration of a fitness testing battery; it concerns the extent to which a test effectively measures the variable of interest (Baechle and Earle, 2008) and is typically ascertained through correlation analysis (with a 'gold-standard' indicator) (Svensson and Drust, 2005). Reliability refers to how repeatable a test is or the level of consistency that is observed over repeated tests, where a test with low reliability (i.e. high measurement error) is said to offer little value (Baechle and Earle, 2008). There are several factors that contribute to measurement error and thus the reliability of each testing component, these include: intrasubject variability, concerning an individual player; intrarater reliability, concerning an individual obtaining measures; and interrater reliability, concerning all individuals involved in obtaining measures (Baechle and Earle, 2008). These sources of measurement error pose issues for fitness testing batteries and require consideration for all those involved.

To this end, the EPPP has mandated standardisation of the testing protocol, which includes the use of equipment, testing environment, seasonal timings and anthropometric and physical performance tests (Premier League, 2011) (see **Section 2.6** for more information). Whilst it is recognised that the greatest level of control and standardisation would involve conducting testing within a laboratory-based environment, the use of sport-specific field tests offer greater ecological validity and practicality (Bergeron et al., 2015; Svensson and Drust, 2005) and are therefore favoured within applied settings (Turner et al., 2011). However, it is important to recognise that field tests do not typically provide information relating to the specific physiological mechanisms underpinning performance; laboratory tests are required for this information (Svensson and Drust, 2005). Nevertheless, in order to justify the implementation of field tests, it is important to understand the demands of football and identify the key variables that warrant monitoring.

2.1.2 *Physical Requirements of Football*

Football consists of an activity profile that can be classed as intermittent, with changes in activity occurring approximately every 4 to 6 s (Stølen et al., 2005; Bangsbo et al., 2006; Ekblom, 1986). The physiological demands of football require contribution from both aerobic and anaerobic energy systems throughout the game, where the former is heavily taxed due to the need to perform a multitude of actions repeatedly over the duration of a game (typically 80-90 min) (Bangsbo et al., 2006; Ekblom, 1986). Time-motion analysis indicates that professional senior players typically cover approximately 10-12 km per game (Stølen et al., 2005), where distances covered by youth players typically increase per age group from around 5.8 km in U11 players (Goto et al., 2015) to 8.9 ± 0.9 km in U18 players (Buchheit et al., 2010). Furthermore, players typically demonstrate an average work intensity of around 80-90% HR_{max} during matches (Stølen et al., 2005).

The anaerobic energy system is heavily taxed during brief intense actions – corresponding to around 150-250 actions per game - as well as during intense periods of play (Bangsbo et al., 2007; Bangsbo et al., 2006). Moreover, these anaerobic activities typically contribute to defining moments during a game, which may include sprinting or jumping duels with an opponent to win the ball (Stølen et al., 2005; Reilly, 2006; Faude et al., 2012).

Positional differences in match-running performance are evident in senior (Mohr et al., 2003) and youth football (Buchheit et al., 2010), where field-based tests show moderate to large correlations with match-running performance, despite correlation magnitudes varying according to position and performance metric (Buchheit et al.,

2010). Players that demonstrate superior physical outputs during a match, such as total distance and high-speed running, are preferentially selected for higher levels (Goto et al., 2015; Mohr et al., 2003).

There are also anthropometric requirements of football, which can typically be related to playing position. Specifically, superior height for goalkeepers, central defenders and central attackers can provide advantages for success (Reilly et al., 2000a); for example, winning aerial duels and making saves. Whilst some research indicates that there is heterogeneity in body size between playing positions in senior and youth teams (Reilly et al., 2000a; Lago-Penas et al., 2011), other evidence from senior players demonstrates a homogenous profile (Hencken and White, 2006). However, it should be noted that within-position variances exist (Hencken and White, 2006) and appear to reflect different requirements of sub-positions (e.g. lateral and central defenders) (Lago-Penas et al., 2011).

Evidently, it is important that football players are able to maximise performance through development of physical characteristics, particularly with regards to lower limb explosive strength and maximal aerobic power (Buchheit et al., 2010). Indeed, the EPPP testing battery includes numerous components of physical performance (see **Section 2.6**) that are advocated for optimising training prescription (Turner et al., 2011), and thus highlight the necessity of regular monitoring within applied practice (Bergeron et al., 2015). Additionally, it can be considered important to monitor anthropometry, given that factors such as superior height, low body fat and enhanced muscle mass may contribute to team success, playing position allocation and enhanced physical performance (Lago-Penas et al., 2011; Lago-Peñas et al., 2014;

Deprez et al., 2015b). Finally, given that biological maturity exerts an influence on anthropometry and physical performances (Malina et al., 2004a), this factor should also be included within fitness testing batteries conducted with youth players (Meylan et al., 2010). To monitor anthropometry, biological maturity and physical performances, a number of approaches are currently used and advocated as part of the EPPP testing battery. This thesis will now take a closer examination of these specific components as well as their relationship to selection biases.

2.2 Anthropometry

Growth is referred to as a biological process that occurs most significantly during prenatal to postnatal life, until around 20 years of age, where the growth of biological tissue and systems result in an increase in body mass and stature (Malina et al., 2004a). Systemic growth of the human body during the postnatal period has previously been identified with four growth curves of different biological systems known as Scammon's curves – this entails neural, genital, lymphoid and general curves (Malina et al., 2004a; Harris et al., 1930) (see **Figure 2.1**). The general curve is characterised by growth of the body and its parts, including body size, muscle mass, the heart and blood vessels, as well as skeletal, respiratory, digestive and urinary systems (Malina et al., 2004a). The general curve also comprises four stages: stage one demonstrates rapid growth during infancy and early childhood; stage two, consistent growth during middle childhood; stage three, rapid growth at the adolescent growth spurt which entails peak height velocity (PHV); stage four, a progressive decrease and eventual cessation of growth at the start of adulthood (Malina et al., 2004a). The growth curves demonstrate (albeit in a simplified manner) that growth of different systems of the body occur continuously during the postnatal period (until full maturity is attained), but vary

with regards to the timing and tempo (Malina et al., 2004a). To obtain growth curves, it is suggested that regular measurements are obtained in a longitudinal manner, thereby enabling the growth velocities (and PHV) of an individual to be determined (Malina et al., 2004a). Indeed, it has previously been demonstrated that the rates of growth in body size vary from infancy to adulthood (Tanner et al., 1966) (see **Figure 2.2**). Additionally, growth data can be used for comparing individuals (as well as samples) with reference data through a percentile approach (Malina et al., 2004a) (see **Figure 2.3**).

Systematic measurements of the human body can be referred to as anthropometry (Malina et al., 2004a). There are many measures that can be obtained through anthropometry, though the basic measurements typically obtained are body mass, stature or standing height, and sitting height (Stewart et al., 2011). To facilitate the measurement of anthropometry, international standards have been implemented by The International Society for the Advancement of Kinanthropometry (ISAK) (Stewart et al., 2011). The measurement of body mass is simple and only requires a weighing scale. There is diurnal variation associated with body mass of around 1 kg in children and 2 kg in adults (Stewart et al., 2011). Thus, it is recommended that body mass measurements are obtained in the morning twelve hours after food and after voiding. In light of issues associated with obtaining nude body mass from subjects, it is sufficient for the subject to be wearing minimal clothing for measurement. The measurement of stature requires a stadiometer and is also subject to diurnal variation, where a loss of around 1% in stature is common from the morning to the evening, though this can be reduced by using the stretch stature technique (Stewart et al., 2011). The measurement of sitting height requires a stadiometer and anthropometric

box and is also performed using the stretch stature technique. These basic measurements can be used in applied settings to monitor the tempo of an individual's growth over a period of time. Another practical use of anthropometry is the ability to derive estimations of somatic maturity, though assessment of maturity is not only confined to somatic methods (Lloyd et al., 2014a). Indeed, assessment of other biological systems operating within the body is common and the most widely used methods to assess biological maturity will now be addressed.

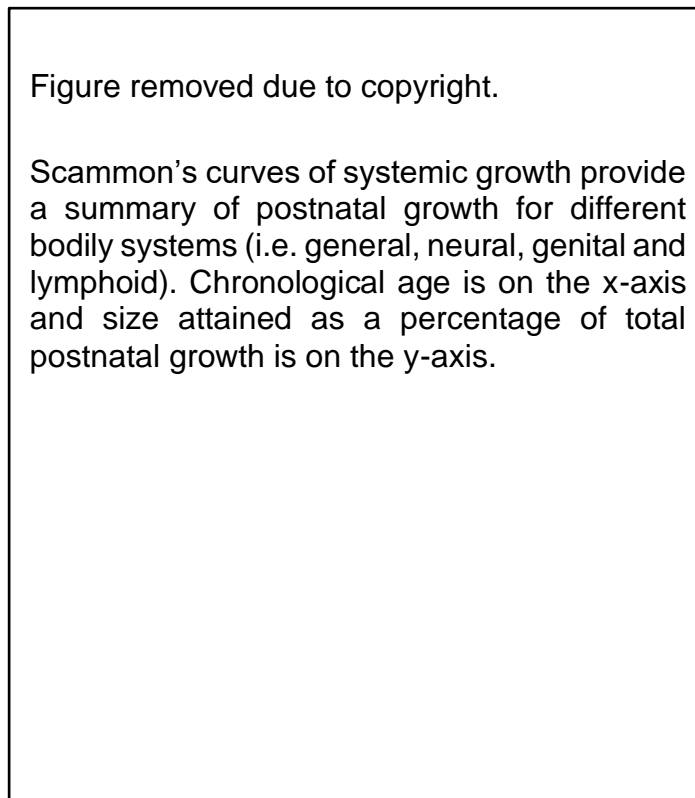


Figure 2.1 Scammon's curves of systemic growth demonstrating general, neural, genital and lymphoid curves (Taken from Malina et al. (Malina et al., 2004a)).

A)

Figure removed due to copyright.

Panel A depicts velocity curves for height (stature) gain in males and females during the postnatal period. Chronological age is on the x-axis and height gain (cm/yr) is on the y-axis.

B)

Figure removed due to copyright.

Panel B depicts velocity curves for weight (body mass) gain in males and females during the postnatal period. Chronological age is on the x-axis and weight gain (kg/yr) is on the y-axis.

Figure 2.2 Typical individual growth velocity curves for (A) stature and (B) body mass in girls and boys (Taken from Tanner et al. (Tanner et al., 1966)).

Figure removed due to copyright.

Growth chart depicting reference data for boys stature (height) and weight (body mass) between 2 and 20-years-of-age, which includes stature-for-age and weight-for-age percentiles (i.e. 3rd, 10th, 25th, 50th, 75th, 90th and 97th). Chronological age is on the x-axis; height (inches and cm) and weight (pounds and kg) is on the y-axis.

Figure 2.3 Growth chart depicting stature and body mass at each age interval from 2 to 20-years-of-age in boys with percentiles (Taken from Centers for Disease Control and Prevention (National Center for Health Statistics, 2000)).

2.3 Biological Maturation

Maturation can be defined as the process of becoming mature or progressing to an adult-like state, whereas maturity refers to the extent to which an individual has progressed towards this state (Malina et al., 2004a). Biological processes within the human body are governed by different biological systems including skeletal, sexual and somatic systems. These systems can differ in the timing and tempo at which they occur; timing relates to when a process occurs and tempo relates to the rate at which a process occurs (Malina et al., 2004a). Importantly, the timing and tempo of these maturation processes can vary considerably for individuals of the same/similar chronological age (CA) which means that marked differences can be observed between individuals - in the level of maturity attained - at any given time point (Malina et al., 2004a). Whilst CA is easily determined, it is more problematic ascertaining an individual's biological maturity status. Typically, biological maturity is expressed relative to CA, thereby allowing individuals to be classified and differentiated by their maturity status (Malina et al., 2004a). Individuals that are biologically advanced in comparison with their CA can be referred to as 'early maturers', those demonstrating normal maturity for their CA are termed 'average maturers', whereas those who are delayed in maturity for their CA are deemed 'late maturers' (Malina et al., 2004a). Given that biological maturity is associated with changes in growth and performance, which can occur with large variability between individuals of the same age (Malina et al., 2004a), the assessment and understanding of biological maturity can be considered fundamental for many applications in youth sport (Lloyd et al., 2014a; Malina et al., 2015). An individual's maturity status is typically derived through the aforementioned biological systems (i.e. skeletal, sexual and somatic), where different methods exist for each approach.

2.3.1 *Skeletal Maturity:*

Assessment of skeletal age or maturity is an invasive approach which involves determining the progress of the skeleton from cartilage (during the prenatal period) to fully developed bone in adulthood, thus making the skeleton an appropriate indicator of maturity (Malina et al., 2004a). Specifically, maturation of the skeleton varies between different types of bone within an individual and between individuals too (Malina et al., 2013). For example, the hand-wrist is the most common site to assess skeletal maturity as there are multiple bones types and the pattern of maturation in these is fairly predictable (Manzoor Mughal et al., 2014), thus making it an ideal site for assessment. Specifically, the hand-wrist site is comprised of long bones (large: radius and ulna; small: metacarpals and phalanges) and carpal or round bones (hamate, capitate, trapezoid, trapezium, triquetral, lunate and navicular), where full maturity of the former is attained in late adolescence, whereas the latter is attained at around 13 to 14-years-of-age (Tritrakarn and Tansuphasiri, 1991; Malina et al., 2004a). Once a hand-wrist radiograph of the individual is made, comparisons of the degree of ossification present at the anatomical site are made with reference images, written descriptions or both – depending on the method utilised (Malina et al., 2004a). Subsequently, skeletal age of the individual is derived, typically in accordance with their CA. For example, skeletal age can be expressed as a difference (skeletal age minus CA) or ratio (skeletal age/CA) (Malina et al., 2015). Although, it must be noted that even within the same CA group, skeletal age can range from seven to nine times the range of the CA within that group (Malina et al., 2004a) - this highlights the large inter-individual variability associated with skeletal maturity. To facilitate the assessment of skeletal maturity, three methods are commonly used that utilise the hand-wrist site: Gruelich-Pyle (GP) (Greulich, 1959); Tanner-Whitehouse (TW)

(Tanner, 2001; Tanner and Healy, 1975; Tanner, 1962b); and Fels (Roche et al., 1988).

2.3.1.1 The Gruelich-Pyle method

This method can also be referred to as the atlas or inspectional method (Malina et al., 2004a) and is based on the original work of Todd (Todd, 1937). It involves a hand-wrist X-ray of the individual, which is subsequently compared to standard X-ray plates of differing maturity at set chronological ages, where all 30 bones of the hand-wrist are assessed. The skeletal age of the individual is subsequently recorded as the standard X-ray plate that matches the best. However, a key limitation with this approach is that it does not account for the individual variability of development that occur between different bones (Lloyd et al., 2014a). Instead, it has been suggested that a more appropriate way to use the GP method is to rate the skeletal maturity of each individual bone that is observed in the X-ray in the same manner as previously described (Malina et al., 2013). Once all individual bones have been rated, the median skeletal age of all these bones is used to determine the individual's overall skeletal age. The reference values used to develop the GP method were from white North American families of high socioeconomic status in the 1930's.

Assessments using GP method have been adopted in a limited number of studies investigating youth footballers, which includes samples from Asia (Tritrakarn and Tansuphasiri, 1991) and Europe (France) (Carling et al., 2012; Carling et al., 2009; Le Gall et al., 2010; Le Gall, 2007). In the study of Asian players, assessments of skeletal age were used for age determination purposes, whereby more than half of the players investigated were deemed to be over the age limit (16 years of age) and a third

reported to be skeletally mature (Tritrakarn and Tansuphasiri, 1991). This study also indicated that complete maturation of the carpals was attained by all players, highlighting that these particular bones offer little value in determining maturity from middle to late adolescence. The latter studies conducted with French youth football players have used skeletal age to compare differences between birth quartiles, playing levels as well as exploring differences in maturity with regards to anthropometric and physical performances characteristics and injury incidence. Of these studies, Le Gall et al. reported that 63.5% of players were identified as normal or average maturers, with just 12.0% and 24.5% of players identified as late and early maturers, respectively (Le Gall, 2007). Carling et al. reported no significant differences in skeletal age across birth quartiles and playing status, suggesting a relatively homogenous profile of players that were observed throughout the study period (Carling et al., 2009). The other study observed that international U15 and U16 players were less mature than amateur peers (Le Gall et al., 2010), suggesting that other factors other than biological maturity are related to attaining a high playing level. The final study demonstrated that the majority of players on entry into the academy for a decade were average maturers (62%), with early and late maturers representing 22% and 16%, respectively (Carling et al., 2012). The four studies conducted in Europe involved participants from the same organisation, where the same assessor conducted all assessments of skeletal maturity and intra-measurer reliability was high. However, the study conducted in Asia did not report key information relating to the methodology, including who was involved in the assessments of skeletal maturity (Tritrakarn and Tansuphasiri, 1991). All of the aforementioned studies conducted assessments of skeletal maturity on samples of youth players that appear to differ considerably from the reference sample that the GP

method is based on, and thus requires acknowledgement when interpreting the findings.

2.3.1.2 The Tanner-Whitehouse method

This method requires matching the features of 13 or 20 individual bones (of the hand-wrist site) to specific written criteria as each individual bone progresses from immaturity to complete maturity, with images of the written criteria used as a supplementary guide (Malina et al., 2004a; Tanner, 1962b). The rationale behind this method was to develop a maturity scale that did not directly relate to chronological age, as per the GP method (Greulich, 1959), thereby enabling maturity scores to define specific population norms in which comparisons of individuals can be compared against (Cameron, 1993). Individual bones are assessed and scored on a scale from 0 (immaturity) to 1000 (maturity), subsequently a cumulative score is used to derive a skeletal age value. The first Tanner-Whitehouse (TW) method was developed using a cross-sectional sample of British children (Tanner, 1962b). However, since the original TW method was established, there have been revisions, resulting in the formation of the TW2 method (Tanner and Healy, 1975) and TW3 method (Tanner, 2001), both of which consider different bones to the original TW method and provide separate maturity scores for the carpal and long bones, where the former attains maturity at around 13 years of age (Malina et al., 2004a). Furthermore, the most recent revision (TW3) includes reference values from British, Belgian, Italian, Spanish and Argentinian, American and Japanese samples. An important consideration for this method, particularly when comparing studies, is the observation that a lower skeletal age is associated with TW3 in comparison with TW2 for the same maturity score (Malina et al., 2007a). Finally, the TW3 method is deemed to be limited by the

subjective nature in which assessments of maturity are determined (Lloyd et al., 2014a).

Derivatives of the TW method have been used in several studies of youth footballers in samples from Asia (Japan) (Hirose and Hirano, 2012) and Europe (Spain, Belgium and Portugal) (Malina et al., 2007a; Fragoso et al., 2015; Vaeyens et al., 2006). The study of Japanese youth players compared differences between the TW3 method and the Japanese standardised skeletal age method (Hirose and Hirano, 2012); they found a clear discrepancy between both methods, in an age group dependent manner. Similarly, research conducted in Spanish youth players found only moderate concordance between TW3 and Fels methods (Malina et al., 2007a); this study also reported that players had skeletal ages in advance of their CA (i.e. earlier maturing), and this favourable selection of early maturers increased with age. Fragoso et al. used the TW3 method and observed that players born in Q1 and Q2 tended to have a skeletal age in advance of their chronological age, though the standard deviations for all birth quartiles overlapped, suggesting a relatively homogenous cohort of players with regards to biological maturity (Fragoso et al., 2015). Vaeyens et al. used the TW2 method to assess skeletal maturity but only used this measure as a covariate within analysis and thus did not report the maturity composition of players observed (Vaeyens et al., 2006). All the aforementioned studies used a single measurer to perform assessments of skeletal maturity, except for the study by Hirose et al. – this used two measurers and inter-measurer reliability was high (Hirose, 2009). Additionally, the studies by Malina et al. (Malina et al., 2007a) and Fragoso et al. (Fragoso et al., 2015) reported high reliability for their single measurer, though corresponding information was not reported by Vaeyens et al. (Vaeyens et al., 2006).

The aforementioned studies using the TW3 method appear to demonstrate a relatively close affinity with the reference samples, apart from the study by Fragoso et al. which investigated Portuguese players (Fragoso et al., 2015). Despite the TW3 method including a broad reference sample, which offers an advantage for researchers within the corresponding countries, there still needs to be consideration for regional differences that may exist within the same country, as well as secular changes (Takai and Akiyoshi, 1983).

2.3.1.3 The Fels method

This method derives skeletal maturity through several recognised indicators assessed via a grading system with specific criteria (Roche et al., 1988). The average number of bone indicators to be assessed at any given age (for a male) are 51, with most operating as two or three-grade indicators (i.e. absent, incomplete, complete) (Chumela et al., 1989). Each bone is graded by matching images with described criteria, where shapes of each carpal bone and the epiphyses, along with the diaphysis of the ulna and radius, as well as the metacarpals and phalanges of the first, third and fifth digits are assessed (Malina et al., 2004a). In addition, the degree to which the pisiform and adductor sesamoid are present is also determined. Finally, the ratios of widths of the epiphysis and metaphysis of each long bone are calculated. Once grading and ratios have been finalised, specialist computer software can be used to derive an estimate of skeletal age along with standard error, which is typically around 0.3 years (Chumela et al., 1989) - this represents a strength of this method in comparison to the other methods of assessing skeletal maturity. It is also reported that skeletal maturity can be assessed with the Fels method is less time than the GP method (Chumela et al., 1989), thereby offering a practical advantage. This method

was developed using participants of the Fels Longitudinal Study, which mainly represents middle class children from America (Ohio) between the 1930s and 1970s (Roche et al., 1988).

The Fels method has been adopted most frequently within studies of youth football players, compared with the GP and TW methods, which includes samples from Europe (Spain, Portugal and England) (Coelho et al., 2010; Figueiredo et al., 2011; Figueiredo et al., 2009; Valente-dos-Santos et al., 2012a; Valente-dos-Santos et al., 2014b; Valente-dos-Santos et al., 2012c; Malina et al., 2007a; Johnson, 2009) and South America (Brazil) (Teixeira et al., 2015). Apart from a study comparing the Fels and TW3 methods (Malina et al., 2007a), all studies investigated skeletal age in relation to anthropometry, physical and technical performances, injury incidence and/or playing level. In general, these studies also reported that the samples investigated tended to be advanced in maturity. All the aforementioned studies utilised a single measurer for the assessment of skeletal maturity, except for a study of Portuguese players (Coelho et al., 2010) which used two measurers, and two other studies with Portuguese players which did not report this information (Valente-dos-Santos et al., 2012a; Valente-dos-Santos et al., 2012c). All other studies, apart from a study investigating the relationship between skeletal maturity and playing level (Figueiredo et al., 2009), also reported information relating to inter and/or intra-measurer reliability, where high reliability was observed. However, due to the reference sample for the Fels method being based on American children, the aforementioned studies appear to lack congruence which may limit the inferences made for skeletal maturity.

2.3.2 *Summary of Assessing Skeletal Maturity*

Though the assessment of skeletal maturity is often considered the optimal approach to assess biological maturity (Lloyd et al., 2014a), there are several limitations with this invasive approach. Indeed, whilst there are concerns regarding exposure to radiation, the risks appear to be minimal (Malina et al., 2015). Yet, in consideration of the ethical difficulties associated with adopting this invasive approach, other studies have sought to adopt alternative methods to derive skeletal maturity, including the use of magnetic resonance imaging (Bolívar et al., 2015; George et al., 2010). More recently, dual-energy X-ray absorptiometry demonstrated similar accuracy to standard X-rays, where the former has a 10-fold lower radiation exposure than the latter (Romann and Fuchslocher, 2016). Despite this, the greater time and cost of dual-energy X-ray absorptiometry is a severe limitation. Still, the most substantial limitations of assessing skeletal maturity relate to the expense, need for specialist equipment and assessors, and time required to conduct and interpret the assessments (Lloyd et al., 2014a; Malina et al., 2015). Given the lack of concordance between specific methods to assess skeletal maturity (Hirose and Hirano, 2012; Malina et al., 2007a), it must be acknowledged that different methods to assess the same biological system (skeletal age) cannot be used interchangeably. The variability between methods can be related to differences in grading criteria to determine the degree of maturity as well as the reference populations the methods were derived from, which can differ greatly from the samples of players that have subsequently been assessed. Moreover, it must be noted that due to variability in the maturation of different bones/anatomical sites during postnatal life, there is a need to consider the suitability of specific sites in assessing skeletal maturity, which can pose an issue for longitudinal studies. The knee appears to be a useful site during infancy and early childhood, the hand-wrist appears

appropriate from late childhood throughout adolescence, and the clavicle is suggested for individuals at late adolescence to adulthood (Manzoor Mughal et al., 2014; Malina et al., 2004a). Finally, all methods of assessing skeletal maturity are subject to measurement error which can pose problems when attempting to classify individuals into groups (i.e. early, average and late maturers) (Malina et al., 2004a). To account for this issue, a broad range of ± 1 year is typically used for the classification of individuals based on their maturity status (Malina et al., 2007a), where this broad range appears more appropriate for GP and TW methods as both do not provide error estimates. On the other hand, standard error reported for the Fels method is around 0.3 years (Chumela et al., 1989), suggesting that narrower ranges (e.g. 3 months) of classification are appropriate with this method. The aforementioned considerations and limitations associated with the assessment of skeletal maturity should be acknowledged, and owing to these drawbacks, the assessment skeletal maturity in applied settings is likely to be considered largely impractical.

2.3.3 *Sexual Maturity:*

Sexual maturation is a continuous process that concludes when full sexual maturity is attained. In males, the biological development that takes place from childhood to adulthood is typified by drastic changes in primary (e.g. testes and penis) and secondary (e.g. pubic and facial hair) sexual characteristics due to maturation of the reproductive system (Malina et al., 2004a). Due to this range of associated indicators, assessments of sexual maturity can be made. However, it must be noted that as this approach requires assessing the development of the genitals and/or pubic hair, it is deemed an invasive method (Malina et al., 2004a). Moreover, unlike the assessment of skeletal maturity, this method only relates to the period around puberty, and is

therefore deemed to have limited use (Lloyd et al., 2014a). Individuals can also be classified by their sexual maturity status (within the same CA group only), where specific stages of either genital or pubic hair development can be utilised (Malina et al., 2004a). As it can be problematic to ascertain when a specific stage is attained and for how long the individual remains in that stage, it is recommended that measures are obtained at relatively short intervals (e.g. 3 to 6 months) to enhance accuracy (Malina et al., 2004a). Given that there are various sexual characteristics subject to biological development, several methods that can be used to assess sexual maturity.

Assessments of pubertal stage is most commonly used and involves categorising the current developmental status of a particular sex characteristic into stages from 1 (prepubescent or immature) to 5/6 (pubescent or mature) (Malina et al., 2004a). To facilitate this assessment, criteria for genital and pubic hair development have been documented by Tanner (Tanner, 1962a); this process involves a trained paediatrician performing a direct observation of the individual and making comparisons with discrete reference stages (Malina et al., 2004a). However, due to the invasive nature of this approach, self-assessments have also been validated as a viable tool to determine sexual maturity (Matsudo and Matsudo, 1994; Leone and Comtois, 2007), though limitations exist with this approach given that individuals may under/overestimate their status (Leone and Comtois, 2007). On the other hand, sexual maturity has also been assessed less commonly through the estimation of testicular volume, via the size of the testes (Prader, 1966). Specifically, this process involves matching the individual's testes against ellipsoid models of a known volume (from 1 to 25 ml), where a volume equal to or over 4 ml typically indicates the start of puberty (Malina et al., 2004a). However, unlike assessments of pubertal stage, which can be obtained through self-

reporting of the individual, estimations of testicular volume should be obtained from a trained assessor (Malina et al., 2004a).

Studies that have adopted the assessment of pubertal stage have typically used a clinician to perform the assessment, and have been carried out in samples of youth football players across Europe (Portugal, England, Denmark and Italy) (Figueiredo et al., 2011; Figueiredo et al., 2009; Forbes et al., 2009a; Forbes et al., 2009b; Sproviero et al., 2002; Hansen et al., 1999; Malina et al., 2005; Malina et al., 2004b; Malina et al., 2007b). Similarly, studies utilising assessments of testicular volume (by a trained endocrinologist) have been conducted in Europe (Denmark) (Hansen et al., 1999; Hansen and Klausen, 2004; Strøyer et al., 2004). In general, these studies have sought to investigate associations between sexual maturity and anthropometry, physical and technical performances, and/or playing level. It was observed that physical performances were better for players advanced in sexual maturity, with stage of pubic hair a positive predictor for jump, sprint and aerobic endurance performance in 13-15-year-old boys (Malina et al., 2004b). Similarly, sexual maturity was also a positive predictor for soccer-specific skills (Malina et al., 2005), albeit to a lesser extent than physical performance variables as per the previous study (Malina et al., 2004b) – this highlights a stronger relationship between maturity and physical performances. On the other hand, Figueiredo et al. observed that stage of pubic hair was not a predictor for physical performance or soccer-specific skills in 11-14-year-old boys (Figueiredo et al., 2011); it was suggested that the limited range of sexual maturity in their sample of players may have been responsible for the discordance with a previous study (Malina et al., 2004b). Alternatively, the authors proposed that it may reflect issues with the limited number of classifications when ascribing players by their sexual

maturity (Figueiredo et al., 2011), where a lack of sensitivity could make it difficult to observe meaningful differences. It was also observed that higher skilled players (soccer-specific skills) tended to be advanced in sexual maturity (Malina et al., 2007b), though as some of these tests included dribbling (i.e. running), it was suggested that the relationship between sexual maturity and sprint performance (Malina et al., 2004b) was at least partly responsible. In all of the aforementioned studies that used pubertal stage for assessment, a trained physician conducted the measurement, except for two studies from England where maturity status was self-reported (Forbes et al., 2009a; Forbes et al., 2009b). None of the above studies assessing sexual maturity reported measurement reliability, suggesting this approach is particularly problematic for obtaining such information.

2.3.4 Summary of Assessing Sexual Maturity

The assessment of sexual maturity has been adopted in the literature to a lesser extent than skeletal maturity, seemingly due to other important considerations that restrict its use within applied research. For example, the need for trained clinicians to perform assessments and the potential reluctance for consent and assent from the parent/guardian and the individual being assessed (Lloyd et al., 2014a) make this approach unsuitable in non-clinical domains. In addition, the potential for misclassification of specific stages may limit its application, particularly when determining individuals that have achieved full sexual maturity (Matsudo and Matsudo, 1994). Additionally, despite some studies adopting self-assessments (Forbes et al., 2009a; Forbes et al., 2009b), these appear liable to inaccuracy (Leone and Comtois, 2007). Finally, assessments of sexual maturity are aligned with discreet classifications around the period of puberty, thereby limiting its use outside of this phase – this is a

considerable drawback for utilisation within longitudinal studies as well as applied practice. Therefore, the associated limitations with assessing sexual maturity can be deemed inappropriate in most applied settings.

2.3.5 Somatic Maturity:

In contrast to the aforementioned invasive methods of assessing biological maturity, somatic methods offer a non-invasive alternative. Anthropometric measurements are obtained and can be subsequently used to derive several indicators of maturity including growth rate, age at peak height velocity (APHV) and percentage of predicted adult height attained. As mentioned in **Section 2.2**, through longitudinal measurements, it is possible to plot distance and velocity curves, thereby allowing the actual timing of age at PHV and the tempo of growth to be ascertained (Malina et al., 2004a). Research conducted in a sample of British boys demonstrated that peak height velocity occurs at around 14.1 ± 0.13 years, corresponding to increases of 10.3 ± 0.22 cm.year (Tanner et al., 1966). However, determination of growth curves is limited by the need to obtain repeated measures over an extended period of time. Moreover, the detection of PHV retrospectively means that any potential impact of this information on applied practice is severely restricted. In light of these limitations, other approaches have been developed which enable the estimation of these indices through anthropometric measures and predictive equations. There are several commonly used methods to estimate somatic maturity which include equations developed by: Khamis-Roche (Khamis and Roche, 1994); Mirwald et al. (Mirwald et al., 2002); and Sherar et al. (Sherar et al., 2005).

2.3.5.1 *The Khamis-Roche method*

The Khamis-Roche (KR) method is used to predict adult height for an individual by using a predictive equation based on anthropometric measures. It was developed in light of previous methods that necessitated the assessment of skeletal age, which the authors deemed not readily available, particularly on a broad scale for all those involved in child development (Khamis and Roche, 1994). Instead, the KR method uses the heights of an individual's biological parents, expressed as mid-parent height, to provide an estimation of the adult height the child is likely to attain along with 50% and 90% error bounds (Khamis and Roche, 1994). The equation requires the child's current height and body mass, along with mid-parent height to derive the percentage of predicted adult height attained, which is used as an indicator of maturity. For example, an individual identified as having attained 85% of their predicted adult height is further ahead in somatic maturity compared to another individual at 75% of their predicted adult height. The equation can be used confidently for males aged 4.0 to 17.5 years with an average 90% error bound corresponding to approximately 5.3 cm (Khamis and Roche, 1994). However, it is recognised that the measurement of (both) biological parents is not always possible, in which case self-reported measures may be used, yet are prone to inaccuracy (Bowman and DeLucia, 1992; Cizmecioglu et al., 2005). Accordingly, adjustments to the equation have been proposed to account for the inaccuracies associated with self-reported measures of height (Epstein et al., 1995). The ability to determine current height as a percentage of predicted adult height can be particularly useful for distinguishing individuals (within the same CA group) that are tall because of a genetic predisposition from those that are tall due to advanced maturity (Malina et al., 2004a). The data used in the development of this method is from the Fels Longitudinal Study, where the reference population predominantly

represents middle class children from southwestern Ohio between the 1930s and 1970s (Roche et al., 1988).

Studies utilising the KR method within investigations of youth football players include a sample from Europe (Spain) (Bidaurrezaga-Letona et al., 2015a) and one in an unreported sample (Gil et al., 2014). The former study used the KR method to categorise players as early and late maturers and found that improvements for jump and running performance differed for both groups (Bidaurrezaga-Letona et al., 2015a). The latter study demonstrated that selected outfield players were at a similar percentage of predicted adult stature (maturity) compared to non-selected players, though the former also had significantly superior physical performances yet a lower predicted height. On the other hand, selected goalkeepers tended to show anthropometric advantages as well as a higher predicted height than non-selected goalkeepers (Gil et al., 2014). Both studies used a single measurer to obtain anthropometric values; the study using a Spanish sample reported good reliability for measurements (Bidaurrezaga-Letona et al., 2015a), whereas this was unreported in the other study (Gil et al., 2014). Moreover, the method used to derive parental height (i.e. directly measured or self-reported) was unreported in both studies. Finally, the study from Spain appears to lack affinity with the reference sample of the KR method (i.e. American), where the nationality (and region) of the sample from the other study is unknown. The lack of information, especially regarding the methodology, is an important issue that requires consideration when appraising the findings and making comparisons across the literature, though it is recognised that anonymity of the sample is sometimes required.

2.3.5.2 *The Mirwald et al. method*

As mentioned in **Section 2.3.5**, knowledge of PHV can be useful, particularly as it represents a significant biological milestone to which other parameters (e.g. strength) are related (Malina et al., 2004a; Beunen and Malina, 1988). However, the limitations of ascertaining this from traditional growth curves makes this largely unfeasible in applied settings given that players may go through repeated stages of selection and de-selection (Güllich, 2014), thereby making collection of longitudinal data impossible. Therefore, several equations were developed in order for APHV to be predicted as a derivative of maturity offset, which requires the input of CA, body mass, standing height, and sitting height (Mirwald et al., 2002). This method has been recommended for individuals -4 and +3 years from APHV, corresponding to approximately 10 – 17 years of age, where maturity offset is estimated within an error of ± 1 year 95% of the time (Mirwald et al., 2002). Accordingly, the output is the time in years away from PHV (maturity offset); an individual with a minus value (e.g. -1.5 years from PHV) is expected to be pre-PHV, an individual ± 1.0 year from PHV is expected to be circa-PHV, whereas an individual with a positive value (e.g. +1.5 years from PHV) is expected to be post-PHV. However, the authors of this equation acknowledge that the requirement to measure sitting height with this method represents a key drawback as it is prone to measurement error (Fredriks et al., 2005); this subsequently affects other variables within this equation, and thus accuracy of estimating PHV (Mirwald et al., 2002). This method has also been validated in Polish males aged 8-18 years, where the results demonstrated systematic biases in the prediction accuracy; APHV was under and over-estimated at young and older ages, respectively, and there was an inability to differentiate individuals by maturity status (i.e. identify early and late maturers) (Malina and Koziel, 2014). The reference population used for equations 1

and 2 of this method were from individuals involved in the Saskatchewan Paediatric Bone Mineral Accrual Study (Bailey, 1997), with samples from the Saskatchewan Growth and Development Study and the Leuven Longitudinal Twin Study used for equations 3 and 4 (Mirwald et al., 2002). Specifically, the Saskatchewan studies are representative of Canadian children whilst the Leuven study represents Belgian children.

This method has been widely adopted in literature concerning youth football players, which includes samples from Europe (England, Spain, France, Belgium) (Bidaurrezaga-Letona et al., 2015b; Buchheit et al., 2014; Deprez et al., 2015a; Deprez et al., 2013; Deprez et al., 2015b; Deprez et al., 2014; Deprez et al., 2015d; Deprez et al., 2015e; Hammami et al., 2016; Lloyd et al., 2014b; Lovell et al., 2015; Wrigley et al., 2014; Vandendriessche et al., 2012), Asia (Qatar) (Buchheit et al., 2014), Africa (Tunisia) (Hammami et al., 2016) and South America (Brazil) (Moreira et al., 2013). However, the sample is unreported in some studies (Buchheit et al., 2011; Buchheit and Mendez-Villanueva, 2013; Buchheit and Mendez-Villanueva, 2014; Gil et al., 2014; Mendez-Villanueva et al., 2011; Mendez-Villanueva et al., 2010). Typically, these studies have sought to relate somatic maturity to selection, anthropometry, physical and technical performances, playing position as well as between birth quartile differences. Of the aforementioned studies, almost all have used a single measurer to obtain anthropometric data, except for several studies in which information was not reported (Buchheit et al., 2014; Deprez et al., 2013; Hammami et al., 2016) and another study where multiple measurers were utilised (Lovell et al., 2015). Information regarding reliability of measurements was reported in less than half of these studies (Bidaurrezaga-Letona et al., 2015b; Deprez et al., 2015a; Deprez et al., 2015b; Deprez et al., 2014; Deprez et al., 2015d; Deprez et al., 2015e; Lovell et

al., 2015; Wrigley et al., 2014; Vandendriessche et al., 2012). In consideration of the reference samples in which the Mirwald et al. method is based, it appears that only the studies conducted in Belgian clubs are aligned with equation 3, though as previously mentioned, the Leuven study was combined with two other studies using Canadian children to derive this particular equation. Additionally, limited studies have used somatic maturity to investigate injury incidence, where differences between players with varying maturity have been observed (Van Der Sluis, 2014; Van Der Sluis, 2015).

2.3.5.3 The Sherar et al. method

The Sherar et al. method has been developed to enable the prediction of years from PHV as well as adult height (Sherar et al., 2005). This method also requires the input of CA, body mass, standing height and sitting height for the prediction equation, where it is recommended for use in children -4 to +4 years from APHV. The error for prediction of adult height is reported as ± 5.35 cm 95% of the time in males. This method offers benefits over the two previous somatic methods as it is able to estimate both APHV and adult height. However, similar to the Mirwald et al. method (Mirwald et al., 2002), there is a need to follow appropriate protocols for obtaining anthropometric measures, particularly for sitting height. The reference populations used to derive the equation have been obtained from the Saskatchewan Paediatric Bone Mineral Accrual Study (Bailey, 1997) and the Saskatchewan Growth and Development Study (Mirwald, 1978).

The Sherar et al. method has been adopted scarcely within the literature investigating youth football players, of which a sample from Europe (Belgium) (Vandendriessche et

al., 2012) was observed. This study sought to investigate the influence of maturity on performance-related variables, however, the Sherar et al. equation was only used to confirm that all participants had not reached full maturity at the start of the study; the Mirwald et al. equation was used instead for statistical analysis. Nevertheless, a single measurer was used and the measurer reported good reliability.

2.3.6 Summary of Assessing Somatic Maturity

Through the assessment of somatic maturity, useful information can be derived, including the prediction of APHV and adult height. These are particularly favourable indices to obtain in youth sport given that PHV is associated with marked changes that have implications for performance and selection (Malina et al., 2004a; Beunen and Malina, 1988; Meylan et al., 2010). However, it is important to note that each of the aforementioned methods use equations to derive indices and are consequently subject to prediction error. Whilst these are considered acceptable, this is also reliant on measurement error of predictor variables being minimised, particularly for sitting height (Mirwald et al., 2002). In light of this, the original method developed by Mirwald et al. has recently been simplified by reducing the need for sitting height, which corresponds to an error of ± 1 year 90% of the time (Moore et al., 2015). Although, similar limitations are observed with this method which includes greater error for individuals identified as early and late maturing and a lack of validation across ethnically-diverse samples (Moore et al., 2015). Furthermore, there is a lack of concordance between somatic methods (i.e. Mirwald et al. and KR) (Malina et al., 2012), which highlights that differences are expected when ascertaining maturity classifications of individuals. Still, due to the non-invasive nature of somatic methods, they appear to be more widely used across the body of literature within youth football.

This likely relates to the improved practicality of implementing these approaches, though as highlighted within the summaries of the previous sub-sections, there is a need to ensure measures are obtained reliably to maximise the accuracy of parameter estimates. Moreover, the application of somatic methods also requires consideration of the reference samples on which the prediction equations are based and the samples to which these are being applied to, especially as there is currently a lack of validation studies to support their use across different populations. Therefore, these limitations highlight the need to apply caution when assessing somatic maturity, particularly in youth sporting contexts, where there is a need to identify individuals that are late and early maturing.

2.3.7 Summary of Assessing Biological Maturity

The assessment of biological maturity has many applications for research and youth sport (Lloyd et al., 2014a), where the aforementioned research has established relationships with anthropometry, performance, injury incidence and selection. Consequently, research conducted in youth football that doesn't account for biological maturity within its methodology can be considered a limitation. However, given that various approaches can be used – that assess different biological systems – and different methods exist within these, it can be problematic for researchers and practitioners to identify the most appropriate methodology to utilise. This is illustrated by the lack of concordance between different approaches and methods (Malina et al., 2012), thus reinforcing the notion that biological processes occur independently (Flor-Cisneros et al., 2006; Marshall, 1974; Malina et al., 2012). Indeed, it has been suggested that no single measure can capture the overall biological development of an individual (Marshall, 1974), which emphasises the need to consider the strengths

and limitations of each method (Lloyd et al., 2014a; Malina et al., 2015). Thus, caution should be applied when interpreting the results of studies that include the assessment of maturity, as differences between biological systems and specific methods limit comparability between studies. Moreover, the affinity of the reference and observed samples should be appraised along with the methodological information regarding how measures were obtained. Although, it is clear that the assessment of somatic maturity is the most widely adopted approach in studies of youth football players, compared with assessments of skeletal and sexual maturity. This is likely due to the strengths of this method, which relate to being non-invasive, as well as offering superior practicality (e.g. minimal equipment, time, costs, and difficulty to employ) and perspective (e.g. predicted age at PHV and/or adult height) that can be derived from basic anthropometric measures (Lloyd et al., 2014a). Still, the validation of currently available somatic methods across diverse samples of youth football players is warranted, as well as the generation of updated and novel methods to account for ethnic variability and normative growth that reflect modern society (e.g. secular trends) (Mills et al., 2017; Malina et al., 2004a). Within the aforementioned options available for somatic methods, there is variability in the measures that are required to facilitate the predictive equations, and these can represent advantages and limitations for the practitioners and/or researchers involved. For example, whilst the KR method only requires height and body mass of the individual, the necessity to obtain height measures for biological parents can pose issues for data collection whether that involves direct or indirect (self-reported) measurements. More recently, the KR method has been advocated for use in bio-banding (Cumming et al., 2017) – a form of group composition based on biological maturity as opposed to chronological age. However, there is less known about the interaction between percentage of predicted adult height

and variance in physical performance as well as the classification of individuals by maturity status, compared to other methods (e.g. skeletal age and APHV) (Malina et al., 2004a). On the other hand, there are several commonly used methods for predicting APHV (Mirwald et al., 2002; Sherar et al., 2005), though these are inevitably limited by the lack of validation studies that support their use within the samples of youth footballers they are expected to be used on. Therefore, the decision on which somatic method to adopt is likely going to be influenced by the scope of the researcher(s) for data collection and the specific research question(s).

At this point, it must be acknowledged that revised equations for estimations of APHV have been published since the literature review was conducted and preliminary data analysis began for this thesis. As previously mentioned, the Moore et al. equation (Moore et al., 2015) served to validate and provide a modification of the original Mirwald et al. equation (Mirwald et al., 2002) with an external sample and without the need to measure sitting height, respectively. However, errors were still apparent for individuals at the extremes of the maturity spectrum (i.e. early and late maturers) and the revised equation was not validated in an external sample representative of high-level youth football players. Subsequently, another research group (Fransen et al., 2018) sought to reduce the prediction error associated with the Mirwald et al. method by utilising maturity ratio (i.e. $CA/APHV$) as opposed to maturity offset (i.e. $CA-APHV$). These authors observed that prediction error of APHV was reduced in comparison with the Mirwald et al. method, especially when the individual was far away from predicted APHV. Moreover, the new maturity ratio method was validated in a sample of high-level youth football players from Belgium, with the authors suggesting this method be used within applied practice for males aged 11-16 years due to these advantages over the previous methods.

2.4 Relative Age Effect in Youth Football

The relative age effect (RAE) refers to an overrepresentation of players born at the start of their respective selection year (Cobley et al., 2009; Sierra-Diaz et al., 2017). Typically, this is expressed according to birth quartiles (Q), where players born in the first three months (Q1) of the selection year are typically favoured (Cobley et al., 2009). A plethora of research has been conducted on this topic, with the earliest studies in ice hockey (Barnsley et al., 1985), baseball (Thompson et al., 1991) and football (Barnsley et al., 1992) demonstrating RAEs in their respective samples. The literature regarding youth football indicates that the RAE is evident in players as young as 6-8 years of age (Helsen et al., 1998), yet appears more pronounced during adolescence (Deprez et al., 2012; Lovell et al., 2015). The relative age selection bias is consistent in high-level youth teams worldwide (Deprez et al., 2012; Mujika et al., 2009; Massa et al., 2014; Hirose, 2009; Helsen et al., 2005) and more pronounced in these compared with lower playing levels (del Campo et al., 2010; Mujika et al., 2009; Romann and Fuchslocher, 2013). The prevalence of the RAE typically decreases towards the end of adolescence and is less pronounced in senior groups (Massa et al., 2014; Helsen et al., 2005; Mujika et al., 2009; Sierra-Diaz et al., 2017), though not always (Pérez-Jimenez, 2008). Still, these findings suggest that relatively younger players are able to enter high-level teams at a later stage, possibly due to a 'catch-up' in terms of physical characteristics (Lefevre et al., 1990). However, at present there is a lack literature to investigate the prevalence of RAEs across the entire developmental pathway (i.e. from early selection to senior team entry) (Delorme et al., 2010b; Mujika et al., 2009) within highly selective cohorts, including the measurement of physical attributes.

It has been suggested that the early age at which youth players are engaged in high-level competition (Helsen et al., 1998), the playing level and the popularity of the sport (Cobley et al., 2009) contribute towards the prevalence of the RAE. These findings align with the observation that the RAE is amplified within higher playing levels (Mujika et al., 2009) given that, as there are a limited number of places within these squads (Romann and Fuchslocher, 2013), greater competition for these places appear to foster the relative age selection bias (Musch and Grondin, 2001). Indeed, the RAE was not observed in senior football in Israel; the authors suggested that the lower popularity and competition for places for football teams from a young age, compared with other countries (e.g. England), likely contributes (Lidor et al., 2010). Other evidence indicates that within a country, teams with the greatest reputation and/or resources are particularly at risk of an amplified relative age selection bias (Pérez-Jimenez, 2008), which likely relates to their highly selective recruitment criteria.

Importantly, the appearance of the RAE has been attributed to the maturation-selection hypothesis (Cobley et al., 2009), whereby relatively older players are considered to demonstrate superior physical attributes over their relatively younger peers. Indeed, studies investigating between-quartile differences in highly selective cohorts have observed that players born earlier in the selection year have superior anthropometric and physical performance characteristics over their relatively younger peers (Buchheit et al., 2014; Carling et al., 2009; Sierra-Diaz et al., 2017). On the other hand, additional studies indicate that despite a RAE being evident, between-quartile differences for physical attributes were minimal when chronological age is accounted for (Deprez et al., 2013; Deprez et al., 2012; Lovell et al., 2015), thereby highlighting the need for future studies to consider a similar methodological approach. The relative homogeneity between birth quartiles has been attributed to the observation that Q4

players typically demonstrate advanced maturity relative to their CA, which likely facilitates their selection (Hirose, 2009; Lovell et al., 2015; Deprez et al., 2013; Deprez et al., 2012). Although, a limitation of these investigations is that only one measure per season was included for analyses and as age groups were typically combined into bi-annual groups, key insights may have been masked. Additionally, advantages for relatively older players disappear when biological maturity is controlled for (Fragoso et al., 2015). Therefore, whilst the RAE exists as a distinct selection bias, biological maturity operates as a related but separate selection bias and should be acknowledged by researchers and practitioners.

A limited number of studies that have followed the status of players over a sustained period of time indicate that relatively younger players selected into high level youth teams appear advantaged in terms of being retained and/or attaining professional status (Skorski et al., 2016; Carling et al., 2009; Grossmann and Lames, 2013), which may be explained, at least partly, by Galatea effects (Hancock et al., 2013). Still, it has been reported that relatively younger players are at greater risk of dropout compared to relatively older peers (Helsen et al., 1998), which would consequently appear to reduce the potential talent pool for academies to select from. However, the influence of relative age (e.g. birth quartile) on retention and/or career progression from each age group across the developmental pathway requires further investigation.

Given the robust and wide-reaching nature of the relative age selection bias, several solutions have been proposed to counter it (Cobley et al., 2009; Helsen et al., 2005; Sierra-Diaz et al., 2017). Although, many of these suggestions are limited by their impracticality and as such, have failed to be implemented within applied research.

2.5 Biological Maturation in Youth Football

Academy teams demonstrate a selection bias in favour of earlier maturing players and this has been shown to increase with age, likely reflecting advantages associated with undergoing PHV (Malina et al., 2000; Philippaerts et al., 2006; Beunen and Malina, 1988). Indeed, this biological milestone is associated with numerous changes including increases in muscle mass, hormonal activity as well as physical performances (Philippaerts et al., 2006; Malina et al., 2004a; Beunen and Malina, 1988); thus, it is important for researchers and practitioners to acknowledge this period of accelerated development. Additionally, it has been observed that not all players experience improvements around PHV as, due to individual variability, some may experience disruption to motor function as a consequence of rapid growth; this can lead to a temporary plateau in performance – referred to as ‘adolescent awkwardness’ (Philippaerts et al., 2006; Quatman-Yates et al., 2012). Given the large inter-individual variability that can be expected for growth and maturation process (**Section 2.2** and **2.3**), studies adopting cross-sectional designs or using only one measure per season (per participant) with mixed-longitudinal designs may not accurately account for the sporadic changes that occur to individuals within each year/season (Malina et al., 2004a; Meylan et al., 2010). These issues highlight that, whilst consideration of biological maturity within research is warranted (Meylan et al., 2010), there is a need for appropriate methodological approaches to account for this factor.

Due to the relationship between maturity and growth and physical performances, early maturing players are reported to demonstrate superior anthropometric and physical performance characteristics in comparison with their later maturing peers (Figueiredo et al., 2009; Malina et al., 2000; Coelho et al., 2010). This aligns with the maturation-

selection hypothesis (Cobley et al., 2009) and corresponds with some of the earliest studies investigating the relationship between maturation and physical performances (Beunen et al., 1981; Espenschade, 1940; Jones et al., 2000). More specifically, the literature typically reports that advanced maturity is related to superior sprint, lower body power and strength performances (Valente-dos-Santos et al., 2012c; Mendez-Villanueva et al., 2011; Carling et al., 2012; Malina et al., 2004b; Figueiredo et al., 2011). On the other hand, the influence of maturity on aerobic fitness, football-specific and non-specific skill performance appears non-existent (or at least reduced) (Figueiredo et al., 2011; Malina et al., 2005; Malina et al., 2004b; Vandendriessche et al., 2012), which may relate to the negative contribution of maturity-related increases in body size (Bidaurrezaga-Letona et al., 2015b; Buchheit et al., 2014; Figueiredo et al., 2011). Still, the observation that physical attributes only demonstrate moderate long-term stability (Buchheit and Mendez-Villanueva, 2013) highlights the transient nature of these factors throughout adolescence and questions their application for talent selection purposes. Other evidence supports this notion as late maturers can eventually catch up with, and even outperform, early maturers (Vandendriessche et al., 2012; Lefevre et al., 1990). However, it is important to note that the literature investigating the impact of maturity on anthropometry and performance have adopted a broad range of methodological approaches, and thus caution is required when comparing the findings.

In light of the influence of maturity on selection into high-level youth teams (Malina et al., 2000; Figueiredo et al., 2009), it is also useful for researchers and practitioners to identify if maturity also exerts an influence on retention and/or career progression within these highly selective cohorts. However, there is currently a paucity of literature that has sought to investigate this theme. Nevertheless, it has been reported that in

highly selective cohorts, maturity does not distinguish individuals that are retained or dropout from each age group, although physical performances were shown to contribute (Deprez et al., 2015e). However, players were only measured once per year (at the start of the season), as such, any individual changes to maturity status and physical attributes throughout the season may not have been accounted for. Another study tracked the playing status of a highly selective cohort in Serbia and reported that a greater proportion of late maturing players achieved professional status in comparison with early maturing players, with the authors attributing the findings to compensation effects in other pertinent skills (Ostojic et al., 2014). On the other hand, international level players were identified as being less mature than amateur level players, though the former were typically taller and had superior physical performances (le Gall et al., 2010). These studies highlight that biological maturity may influence retention in a country dependent and/or playing level dependent manner, possibly due to varying criteria used to determine which players are considered to have the greatest potential. Furthermore, it appears that in order to effectively determine the factors that contribute to player retention and/or career progression, maturity should be considered along with other pertinent factors (Reilly et al., 2000b; Williams and Reilly, 2000). In any case, the influence of maturity (and associated factors) on player retention across the entire developmental pathway requires elucidation.

Within the current literature, there have been few solutions proposed to counteract the maturation-related selection bias specifically, where these have typically addressed the relative age selection bias (Meylan et al., 2010). Still, it appears that despite not being underpinned by a scientific assessment of maturity, a 'Futures' team has been adopted in applied practice and involves creating an additional group of talented, but

later maturing players (Vandendriessche et al., 2012). More recently, 'bio-banding' has been advocated as an adjunct to normal groupings by CA, which involves grouping players according to their biological maturity (Cumming et al., 2017). However, the merits of these approaches have not yet been explored from the perspective of reducing the maturation-related selection bias.

2.6 Physical Performances in Football

As identified in **Section 2.1**, there are physical requirements for football performance that encompass several different competencies and, as highlighted in **Sections 2.4** and **2.5**, these can be influenced by relative age and biological maturity. The monitoring of physical performances has several practical applications and is therefore recommended for football clubs (Williams and Reilly, 2000; Svensson and Drust, 2005; Meylan et al., 2010). Specifically, regular monitoring of players' physical performances is an important component of applied practice for academies that operate under the EPPP; it provides data that can be used to benchmark players and evaluate the efficacy of training prescription, for example (Premier League, 2011). However, given that predictors of talent are multifactorial (Williams and Reilly, 2000), the importance of physical performances for predicting long-term career success, in light of other relevant factors, requires further investigation through longitudinal research. Still, football performance is dependent, at least in part, on numerous physical performance competencies and the assessment of these is possible with fitness testing batteries (Stølen et al., 2005). Although, determining the specific components of a fitness testing battery is not straightforward as there are several methods that can be used to monitor any given physical performance variable or component (e.g. agility) (Svensson and Drust, 2005; Turner et al., 2011).

According to the EPPP fitness testing battery, the specific components deemed essential to monitor include: lower limb power, sprinting ability, agility and aerobic endurance performance (Premier League, 2011). Each of these components can be considered appropriate for fitness testing batteries within football, where several researchers have advocated their inclusion (Turner et al., 2011; Stølen et al., 2005; Svensson and Drust, 2005). Nevertheless, the following sections will appraise some of the most commonly used tests of physical performance relevant to football, including those mandated under EPPP guidelines. This includes discussion around the validity and reliability of different tests. Specifically, correlation with a 'gold standard' criterion is typically used to determine the validity of a test, where a higher value indicates greater validity; between-measurer reliability can be determined with correlation analysis, where a higher value indicates better reliability; a coefficient of variation is typically used to ascertain within-measurer reliability, where a lower value indicates greater reliability (Svensson and Drust, 2005; Impellizzeri and Marcora, 2009).

2.6.1 Jump Performance

The need for football players to generate muscular power in the lower limbs is evident when jumping to compete in aerial duels, which can often be related to key moments during a game (Faude et al., 2012; Stølen et al., 2005). Accordingly, including a measure of jump ability within a football-specific testing battery is warranted (Turner et al., 2011). There are a number of commonly tests to measure jump performance including the: squat jump (Oliver et al., 2008), standing broad jump (Thomas and Reilly, 1979), and countermovement jump (CMJ) (Oliver et al., 2008) tests.

The squat jump involves the player initially going into a squat position (knee flexion around 90 degrees), holding that position for a short period of time (e.g. 3 s), then performing a maximal vertical jump before landing in the same place (Oliver et al., 2008). Between-subject reliability of this test is high using the intraclass correlation coefficient (0.97), with within-subject variation reported as 3.3% (using coefficient of variation) (Markovic et al., 2004). Factorial validity is also good, with the correlation coefficient reported as 0.81 (Markovic et al., 2004). Elsewhere, it was shown that mean jump height and force production was lowest in the squat jump (compared to two CMJ protocols); the authors attributed this finding to the squat jump being concentric-focussed and thus lacking use of the stretch-shortening cycle as per CMJ protocols (Zahálka et al., 2013). The squat jump test offers several advantages which include: being easy to setup, relatively quick to perform, and demonstrating good validity and reliability of measurement. On the other hand, disadvantages include: cost of equipment (e.g. mat/grid), potential inconsistencies during the pause (e.g. timing, player movement), and lack of stretch-shortening cycle activation.

The standing broad jump is also known as the standing long jump and involves the player starting from a standing position, then performing a maximal jump forwards before landing, where the distance from the starting point and heel contact is observed (Markovic et al., 2004). Between-subject reliability of this test is high according to the intraclass correlation coefficient (0.95), with the coefficient of variation reported as 2.4% (Markovic et al., 2004). However, it is important to note that the outcome variable for this test is jump distance (i.e. horizontal movement) as opposed to jump height (i.e. vertical movement) (Markovic et al., 2004), which may limit its applicability to football.

Advantages of this test include: being easy to setup and administer, low cost of equipment (e.g. measuring tape), and good reliability. Disadvantages include: possibility of the individual not landing properly and the horizontal jump focus which can be considered less relevant than vertical jumping in football (i.e. lack of validity).

The Sargent jump test involves the player initially standing with the dominant side of their body against a wall and the dominant arm stretched overhead; the standing reach from this position is subsequently marked. Next, the player performs a maximum vertical jump and uses their hand to mark their maximum jump reach on the wall (e.g. with a marker in hand or chalk applied on the fingers); the distance between the standing reach and the jump reach provides the jump height. Alternatively, there are also specialised apparatus that allow the individual to jump and strike small vanes with their hand to indicate their jump reach (Buckthorpe et al., 2012) – this can offer an advantage compared to jumping and marking against a wall as there is no risk of collision. It has been reported that this test enables a greater vertical jump height to be achieved over the squat jump and CMJ tests (Markovic et al., 2004). Between-subject reliability of this test is high using the intraclass correlation coefficient (0.96), with the coefficient of variation reported as 3.0% (Markovic et al., 2004). Factorial validity is also good, with the correlation coefficient reported as 0.80 (Markovic et al., 2004). Advantages of this test include: minimal cost of equipment (if the wall approach is being adopted), ease of administering, as well as good validity and reliability. Disadvantages include: potential error in marking the wall whilst in flight, the potential for a collision against the wall, and the skill requirement to coordinate lower and upper extremities which reduces emphasis on the lower body.

The CMJ test is similar to the squat jump test in that it involves the individual going into a squat position (knee flexion around 90 degrees). However, instead of holding the squat position for a specified time, the player immediately performs a maximal vertical jump once in the squat position, and lands in the same place (Oliver et al., 2008). Between-subject reliability of this test is high according to the intraclass correlation coefficient (0.98), with the coefficient of variation reported as 2.8% - when hands remain on the hips throughout the protocol (Markovic et al., 2004). Factorial validity is also good, with the correlation coefficient reported as 0.87, which was the highest reported when compared with other jump protocols (Markovic et al., 2004). When adopting a CMJ protocol with arm swing allowed, a significantly greater jump height is expected, although force generation does not differ between the CMJ protocol with or without arm swing (Zahálka et al., 2013). Advantages of the CMJ test include: being easy to setup and perform, translating well to football performance (due to stretch-shortening cycle contribution), and demonstrating the highest validity and reliability compared with other jump protocols. Disadvantages include: cost of equipment (e.g. mat/grid), the potential skill and coordination required to perform the countermovement jump action when required adequate familiarisation, and potential influence of arms which can place less emphasis on the lower body.

The CMJ test forms part of the EPPP testing battery to assess lower body power (Premier League, 2011). As previously mentioned, this test has demonstrated good reliability and validity (Slinde et al., 2008; Markovic et al., 2004), where instruction of participants to keep their hands on their hips can nullify the effects of the arm swing, and thus emphasise lower body power (Slinde et al., 2008); whilst this may enable greater testing control, the use of arms is typical when jumping in football and is

advocated for training purposes (Paoli et al., 2012). Due to the contribution of the stretch-shortening cycle with the CMJ, it is suggested that this movement is representative of the pre-loading and take-off phases during a jumping header in football (Paoli et al., 2012). However, the disadvantages of the CMJ should be acknowledged, which includes the need to carry out appropriate familiarisation with players and the lower ecological validity when arm swing is nullified. Also, the cost of equipment needed is likely to limit its application throughout youth sport, particularly at the grassroots level. Whilst contact mats or jump belts have typically been used to derive jump height, recent advances using photoelectric cells (e.g. the OptoJump system) demonstrates high validity and reliability for estimating jump height (Glatthorn et al., 2011).

2.6.2 Agility Performance

Football players are required to perform and change activities frequently in response to somewhat unpredictable events, corresponding to around 50 turns during a match (Di Salvo et al., 2009; Stølen et al., 2005; Little and Williams, 2003). Accordingly, agility can be defined as the ability to rapidly change direction or speed in response to sport-specific stimuli (Sheppard and Young, 2006). There are many different tests that aim to assess agility performance, where these may or may not include a perceptual and decision-making component (Gabbett, 2013). Ideally, in order for the assessment of agility in football to be specific, a test should include a perceptual decision-making component, as this may also distinguish playing level (Gabbett, 2013). However, there is no 'gold standard' method to assess agility in football, where commonly used tests do not typically include a perceptual decision-making aspect (Svensson and Drust, 2005). As there is no consensus on the most appropriate test for agility in football (i.e.

criterion measure), ascertaining test validity is problematic and seldom reported. Frequently used field-tests to assess agility performance in football include the: Illinois agility test (Getchell, 1979), agility T-test (Semenick, 1990); Balsom agility test (Balsom, 1994) and 505 agility test (Draper and Lancaster, 1985).

The Illinois agility test involves a course constructed with cones where the player performs straight, diagonal and slalom runs; timing gates can be placed at the start and finishing positions thereby allowing the time taken to complete the course to be determined (or a stopwatch can be used). Accordingly, there is no perceptual-cognitive element to the completion of this test. Across two trials, the intraclass correlation coefficient for this test was reported as 0.96, suggesting good reliability (Hachana et al., 2013). Elsewhere, the test and re-test correlation coefficient has been reported as high (0.98) in one study (Kutlu et al., 2012), with another study reporting the intraclass correlation coefficient as 0.80 and the coefficient of variation as 2.2% (Stewart et al., 2014). Advantages of this test include: being relatively simple to setup and administer, low equipment cost (if using a stopwatch), good reliability, and involving different movement patterns (i.e. straight and weaving runs). Disadvantages include: potential equipment cost (e.g. timing gates), the need for suitable familiarisation to ensure the correct path is taken, and a greater time requirement to complete a single trial in comparison with other agility tests.

The Balsom agility test is a course consisting of five pairs of cones acting as gates for the player to sprint through and around; there is a starting and finishing gate that is used to determine the time taken to complete the course (Lago-Peñas et al., 2014). This test has been suggested as appropriate for football (Svensson and Drust, 2005),

though as per a previous citation of this test, reliability does not appear to have been ascertained with the Balsom agility test (Walker and Turner, 2009). Advantages of this test include: being relatively simple to setup and administer, low equipment costs (if using a stopwatch), and involving different movement patterns (i.e. straight and curvilinear runs). Disadvantages include: the need for familiarisation to ensure the correct path is taken, being relatively long in total distance (over 40 m) compared with other agility tests, and a lack of research with this test.

The 505 agility test involves the player sprinting forward 15 m (with a timing gate at 10 m), turning 180 degrees (using a specified foot), then sprinting back through the timing gates (Stewart et al., 2014); the time taken to complete the flying 5 m, turn, and final 5 m is used to determine performance. The intraclass correlation coefficient for this test is reported as 0.77 and the coefficient of variation as 2.8% (Stewart et al., 2014). Advantages of this test include: using a relatively small space, being simple to setup and administer, low equipment costs (if using a stopwatch), being relatively short in distance (20 m), good reliability, and beginning with a flying start (ecological validity). Disadvantages include: familiarisation required in order to turn with the correct foot and limited scope of movement patterns (i.e. linear focus).

The zig-zag test involves a course of four 5 m sections that are set out at 100 degree angles, where this can be completed with or without a ball (Mirkov et al., 2008); the time taken to complete the course is used to determine performance. The intraclass correlation coefficient for the zig zag test without the ball was reported as 0.84, with the coefficient of variance as 2.5% (Mirkov et al., 2008). On the other hand, with the ball, corresponding values were 0.81 and 3.3%, respectively (Mirkov et al., 2008)

Elsewhere, the test and re-test correlation coefficient has been reported as high (0.98) (Kutlu et al., 2012). Advantages of this test include: being relatively simple to administer, low equipment costs (if using a stopwatch), being a simple course to perform, good reliability, and being relatively short in distance (20 m). Disadvantages include: greater difficulty in setting up the course (due to required angles) and the lack of a substantial change of direction (i.e. 180-degree turn) as seen in other agility tests.

The agility T-test involves the player completing a course setup using cones that form a 'T' shape. The original guidelines for this test stipulated that the individual perform a series of sprints, side shuffles (i.e. without crossing feet) and backpedalling to complete the course (Stewart et al., 2014). The intraclass correlation coefficient is 0.86 and the coefficient of variation is 1.7% (Stewart et al., 2014). Elsewhere, the test and re-test correlation coefficient has been reported as high (0.97) (Kutlu et al., 2012). Advantages of this test include: being relatively simple to setup and administer, low equipment costs (if using a stopwatch), and good reliability. Disadvantages include: requiring suitable familiarisation to ensure the correct path is taken, the requirement for shuffling and backpedal movements which poses a greater learning/technique component than other agility tests.

Due to the lack of a gold standard test for the assessment of agility, determining the validity of agility tests is somewhat problematic, thus tests with high reliability are advocated (Hachana et al., 2013). Although, it has been observed that the correlation between five different agility tests (Illinois, 505, T-test, L-run, and pro-agility test) was high, and that 89.% of the variance in each test could be explained by one significant component; this suggests that all tests measure the same factor (i.e. good validity)

and are appropriate to assess agility performance (Stewart et al., 2014). Therefore, it appears that the specific agility test chosen for fitness testing batteries is likely to be guided by the particular sport and the movement patterns that players perform during match-play.

Whilst the EPPP guidelines recommend an assessment of agility performance as part of the standardised fitness testing battery (Premier League, 2011), this is not a requirement and there is no consensus as to which agility test should be implemented (Paul et al., 2016). In other words, agility test selection is at the discretion of individual clubs. The club that was investigated in this thesis adopted a modified version of the agility T-test. The specific modifications include changes to the distances, with the dimensions being 10 m instead of 9.10 m as per the original study (Semenick, 1990). Moreover, players were not required to perform shuffle and backpedal movements or touch the cones, thereby allowing players to complete the course by running in the fastest time possible. However, it must be noted that these modifications appear specific to the club as no validation and reliability studies have been conducted – this represents a limitation. Nevertheless, implementation of this test uses wireless timing gates to determine the time taken to complete the protocol, where players are required to perform the test in both left and right directions, thus enabling asymmetry to be detected, as well as a composite score (the total of the best times for each direction). Previous research indicates that assessment of agility performance using the T-test (albeit with the original test version) is valid and reliable for football players, yet appears to be influenced by playing position (Sporis et al., 2010).

2.6.3 *Sprint Performance*

Sprint ability is an important attribute in football given the association with key defining moments during a match (Faude et al., 2012; Stølen et al., 2005). Evidence from match-play indicates that sprints are typically performed in less than 30 m, corresponding to a duration of less than 6 s (Bangsbo, 1994). There are different aspects of sprint ability that are typically associated with distance. Acceleration can be referred to as the time taken to reach maximum velocity or the time taken to reach 5 - 20 m (Lloyd and Oliver, 2013). Maximum speed can be defined as the peak velocity attained or the time to reach 20 - 30 m (Lloyd and Oliver, 2013). In light of this, whilst the use of sprint time – that is, the time taken to complete a prerequisite distance - is typically employed, recently advances with global positioning system (GPS) devices have enabled practitioners to measure peak velocity (Buchheit et al., 2010), though this may not be widely available. The importance of sprint ability during match-play (Stølen et al., 2005) highlights the need to assess this performance variable within testing batteries, where both acceleration and maximum speed are appropriate (Turner et al., 2011).

When comparing timing gates with GPS devices for the assessment of sprint ability (velocity), one study observed that there were significant differences between timing gates and GPS (5 Hz) for the speed achieved at set distances (10, 20, 30 and fly 10 m), where the GPS underestimated speeds for all distances (Waldron et al., 2011). Specifically, the coefficient of variation was greatest for 10 m (9.81%) but was lower for 30 m (6.61%); this shows a lack of concordance between the two methods with GPS systematically underestimating values. In terms of reliability, the GPS device demonstrated a coefficient of variance between 1.62 and 2.06% for all distances,

though a lower value was reported for peak speed (0.78%); the timing gates reliability was between 1.00 and 1.54% for all distances. These findings suggest that despite good reliability for the determination of peak speed over 30 m, GPS systematically underestimates speed values at set distances (up to 30 m) compared to timing gates.

However, it must be noted that recently, the sampling rate of commercially available GPS devices are able to sample at 10 and 15 Hz, where GPS devices with higher sampling rates are reported to provide greater validity and reliability for metrics such as peak speed (Scott et al., 2016). However, another study observed that determination of peak speed through a 10 Hz device was not valid, despite good reliability between units; validity for peak speed with a 15 Hz device was uncertain, where a lack of reliability between units was observed (Johnston et al., 2014). Elsewhere, when compared to a 50 Hz radar gun (used as the criterion measure), a GPS device (10 Hz) and timing gates were shown to be valid for determining peak speed, though values were underestimated with both methods corresponding to a *small* bias; correlation coefficients were between 0.95 and 0.97 (Roe et al., 2017). However, due to the *small* inter-unit variability with the GPS device, the authors advocated that the same unit should be used for the same individual, where a lack of consistency would increase measurement error.

The aforementioned literature highlights that there are several approaches to determine sprinting performance metrics. GPS devices are reported to have varying levels of validity and reliability when compared to criterion measures (and timing gates) which is likely due to differences between manufacturers and the sampling rates of the devices. The cost of GPS devices and the need to maintain consistency in unit

assignment represent further disadvantages with ascertaining maximum speed. On the other hand, timing gates show good validity and reliability and are not subject to inter-unit variability as the same timing gates are used for entire squads of players. Therefore, the use of timing gates appears advantageous for team sports as it can be used to evaluate sprint and other running-based performances (e.g. agility) and is expected to be cheaper than GPS devices.

With regards to distance, assessment of acceleration via 10 m sprint time is accepted as a valid and reliable test (Walker and Turner, 2009). Indeed, 10 m sprint time assessed (via photocells) to determine acceleration performance shows good reliability owing to an intraclass coefficient correlation of 0.81 and a coefficient of variation of 3.2% (Mirkov et al., 2008). Other evidence reports good reliability when assessing 10 m sprint time with timing gates, where the coefficient of variation was even lower (1.13%) (Waldron et al., 2011).

In terms of maximum speed, the time taken to complete 20 – 40 m has typically been used in testing batteries, where a 'rolling' or 'flying' start is said to offer greater ecological validity for football players (Walker and Turner, 2009). In Olympic-level sprinters, the percentages of maximum speed achieved after 10, 20, 30, and 40 m were 45%, 84%, 93%, and 97%, respectively; 100% of maximum speed was achieved between 50 and 60 m (Young et al., 2001). However, research from European-level football shows that mean sprint distance is 21 ± 3 m (Andrzejewski et al., 2015), suggesting that whilst a 30 m sprint testing protocol may not elicit true peak velocity, it represents an ecologically valid distance to assess sprint performance as football players are unlikely to sprint more than 30 m within a single bout. Moreover, 30 m sprint time determined via timing gates is reliable, with a coefficient of variation of

1.35% observed (Waldron et al., 2011).

As part of the EPPP fitness testing battery, time taken to complete 10 and 30 m distances are used to measure sprint performance. This involves using wireless timing gates to monitor the time taken for a player to reach these distances, where the player initially starts from a still position – without reacting to a stimulus. However, whilst the ecological validity is enhanced with ‘flying’ starts (Svensson and Drust, 2005), standing starts without a reaction component allow for greater testing control. Other research indicates that peak velocity, but not acceleration - determined via a field-test - is related to match-running performance (Buchheit et al., 2010).

2.6.4 Aerobic Endurance Performance

A high level of aerobic endurance is vital during football, as it enables players to maintain physical outputs over the duration of an entire game (Stølen et al., 2005; Ekblom, 1986). Assessment of aerobic fitness can take place in a laboratory setting by determining an individual’s maximum oxygen uptake (VO_{2max}) (Howley et al., 1995). However, sport-specific field-based tests offer a suitable, and ecologically valid alternative, in which VO_{2max} can also be estimated. There are several tests that are commonly used, including the: multi-stage fitness test (Leger and Lambert, 1982; Leger et al., 1988), Yo-Yo Intermittent Recovery Test Levels 1 (Yo-Yo IR1) and 2 (Yo-Yo IR2) (Bangsbo et al., 2008), The University of Montreal track test (Léger and Boucher, 1980), the VAM-EVAL test (Mendez-Villanueva et al., 2010), and the 30-15 Intermittent Fitness Test (Buchheit, 2008).

The multi-stage fitness test comprises a continuous 20 m shuttle between cones where the player is required to reach the cones in time with a 'beep' from an audio playback. Each level (1 or 2 min long) of the test involves a series of runs at a set speed, beginning at 7.5 km/hr, and the speed increases by 0.5 km/hr at each subsequent level (Leger and Lambert, 1982). By recording the level and shuttle that the individual completed before failure, VO_{2max} can be estimated through a regression equation. In terms of validity, the test has a correlation coefficient of 0.84; reliability of this test is high, where a correlation coefficient of 0.975 is observed (Leger and Lambert, 1982). However, it was subsequently identified that there was a systematic underestimation when applying the original regression equation (to derive VO_{2max}) to intermittent-sport athletes; a new validation study was carried out to derive a new regression equation, where the correlation coefficient was lower (0.69) for the sample of international-level, intermittent-sport athletes (Kilding et al., 2006). The lack of consistency in the correlation to VO_{2max} has also been observed elsewhere (Svensson and Drust, 2005). Whilst it is argued that the multi-stage fitness test involves turning and changes of speed (due to the shuttle format) (Kilding et al., 2006), the continuous, as opposed to intermittent nature of this test does not truly represent the activity profile of football, and it does not appear sensitive to training interventions which seemingly limit its application for football (Svensson and Drust, 2005). The advantages of this test include: being relatively easy to setup, an ability to conduct the protocol indoors, good reliability, and it also permits multiple players to be tested at the same time. Disadvantages include: not being specific to the intermittent activity profile of football and possible subjectivity in determining when the player has failed to reach a cone on time (testing control).

The University of Montreal track test involves continuous running around a track (200 or 400 m) that has markers at specified intervals throughout (e.g. 25 or 50 m) (Walker and Turner, 2009). Additionally, there is an audio playback (beep) which serves as pacing guidance for the player and this increases every 2 min. Players are required to be within a short distance (around 2 m) of the subsequent marker in accordance with the beep, as failure to reach this point results in the test terminating for that player. The original study reported that the test is valid and reliable due to correlation coefficients of 0.96 and 0.97, respectively (Léger and Boucher, 1980). Elsewhere, it was observed that performance on this test was moderately correlated with total distance (correlation coefficient of 0.58) and distance covered at high and very high speeds (correlation coefficient of between 0.64 and 0.65) during top-level football matches (Rampinini et al., 2007). Advantages of this test include: ability to assess multiple players at the same time, and good validity and reliability. Disadvantages of this test include: the track setup which may not be readily available, consideration of environmental factors (if performed outdoors), requirement for multiple assessors placed around the track to ensure the players meet the markers on time (testing control), and lack of intermittent activity profile for football specificity (ecological validity).

The VAM-EVAL test is a continuous running test used to estimate VO_{2max} as well as determine maximal aerobic speed, that is, the lowest speed at which VO_{2max} is achieved; this speed can be used to guide training prescription (Paul and Nassis, 2015). The format is very similar to the University of Montreal track test. Specifically, it is conducted on a track (typically 200 m) with markers placed at 20 m intervals where audio playback provides pacing guidance, and running speed increases every minute;

failure to reach the subsequent cone on two occasions results in test termination for that player (Paul and Nassis, 2015; Buchheit et al., 2010). As the original text for the VAM-EVAL test is in French (Cazorla and Leger, 1993), subsequent citations of this test are limited (Buchheit et al., 2010), especially with a lack of validation studies in English. Still, performance on this test was related to total distance covered as well as match-running performance, albeit for certain playing positions (i.e. strikers), in academy football players (Buchheit et al., 2010). Advantages of this test include: being able to identify maximal aerobic speed and ability to test multiple players at the same time. Disadvantages of this test include: the track setup which may not be readily available, consideration of environmental factors (if performed outdoors), requirement for multiple assessors placed around the track to ensure the players meet the markers on time (testing control), and lack of intermittent activity profile for football specificity (ecological validity).

The 30-15 intermittent fitness test involves an intermittent protocol that seeks to assess aerobic fitness, change of direction ability, inter-effort recovery abilities and anaerobic capacity (Buchheit, 2010). The protocol comprises a 40 m shuttle, where the individual performs 30 s shuttle runs interspersed with 15 s passive recovery blocks. There is an audio recording which guides the pace of the shuttle runs; there are also 3 m zones at the extremities and middle for the recovery blocks following each 30 s shuttle run. The speed increases by 0.5 km/hr after each 30 s shuttle run and failure to reach the 3 m zone on three consecutive occasions results in termination of the test for that player. VO_{2max} is subsequently estimated using the velocity of the last completed shuttle within a predictive formula (Buchheit, 2010). Reliability of this test on semi-professional football players demonstrated an intraclass correlation

coefficient of 0.80, though the authors observed that the typical error of measurement was greater than the smallest worthwhile change; it appears that small changes (i.e. two shuttle runs) on this test could be meaningful in response to training (Thomas et al., 2016). Elsewhere, an intraclass correlation coefficient of 0.91 was observed in high-level female football players; the authors also observed a relationship (correlation coefficient of 0.67) between the test and VO_{2max} determined within a laboratory setting (Čović et al., 2016). Advantages of this test include: the wide range of indices that can be deduced (though this does require additional tests), being relatively easy to setup, multiple players can be tested at the same time, it comprises an intermittent activity profile, and good validity and reliability. Disadvantages include: requiring multiple assessors to accurately monitor players (testing control), and several factors are reported to influence test performance (e.g. change of direction ability, anaerobic velocity reserve, and inter-effort recovery capacity).

The Yo-Yo intermittent recovery test involve a shuttle run (2 x 20 m) interspersed with an active recovery period of 10 s (walking/jogging to a cone and back which comprises 2 x 5 m) before returning to the starting position to begin the next shuttle. There is an audio recording to provide guidance on the pace, where individuals are required to run faster at each subsequent level; there are between 1 to 8 shuttles within each level. Returning to the starting position later than the audio cue on two occasions results in termination of the test for that player, where the distance covered of the last completed shuttle is recorded. There are variants of this test which include the Yo-Yo intermittent recovery test 1 (Yo-Yo IR1) and Yo-Yo intermittent recovery test 2 (Yo-Yo IR2). With regards to the former, there was a significant correlation with a laboratory-based treadmill test and assessment of VO_{2max} , corresponding to correlation coefficients of

0.79 and 0.71, respectively; assessment of reliability demonstrated a coefficient of variation value of 4.9% (Krustrup et al., 2003). Regarding the Yo-Yo IR2, a significant correlation with a laboratory-based treadmill test and assessment of VO_{2max} was observed, corresponding to correlation coefficients of 0.74 and 0.56, respectively; a coefficient of variation value of 9.6% (indicating reliability) was also identified (Krustrup et al., 2006). Through blood, muscle fiber, muscle metabolite and muscle enzyme analysis, the authors determined that the key difference between both tests is the enhanced stimulation of the anaerobic energy system during the Yo-Yo IR2 test (Krustrup et al., 2006). Accordingly, the Yo-Yo IR1 test is advocated for young players or individuals with a relatively low aerobic fitness, whilst the Yo-Yo IR2 test is recommended for those with moderate to high aerobic fitness (Paul and Nassis, 2015). Advantages of this test include: being relatively easy to setup, multiple players can be tested at the same time, and it comprises an intermittent activity profile. Disadvantages include: requiring multiple assessors to accurately monitor players (testing control), possible subjectivity in determining when a player has failed to reach the starting point (testing control), and differences in energy system contribution between the two iterations of the test.

Though the aforementioned continuous-based running tests typically demonstrate the highest values for reliability and (criterion) validity over the intermittent-based alternatives, the lack of specificity to football performance represents a major drawback for ecological validity. On the other hand, the 30-15 intermittent fitness test represents a practically relevant test that can have several applications, namely for optimising training prescription, due to the various indices that can be deduced from this test. However, as this is relatively new, there is currently a lack of research that

has implemented this test, especially regarding reliability and validity in football players. Alternatively, the Yo-Yo intermittent recovery tests are ecologically valid and have been implemented commonly with youth and adult football players and, as it is sensitive to training interventions and can distinguish playing levels and playing positions, this test appears favourable for regular monitoring (Svensson and Drust, 2005). Under the EPPP guidelines, the Yo-Yo IR1 and IR2 are used to assess the aerobic fitness of players. Specifically, the Yo-Yo IR2 test is recommended for higher trained players (e.g. from U16 onwards), whereas the Yo-Yo IR1 test is recommended for lower trained players (e.g. U15 and below). As highlighted previously, both Yo-Yo tests are shown to be valid and reliable indicators of match-related running capacity as well as ascertaining maximal heart rate (Bangsbo et al., 2008; Krusturup et al., 2003; Krusturup et al., 2006).

2.7 Retention and Dropout in Youth Football

Participation in youth sport is associated with a myriad of benefits that include increased physical fitness and psychological and social well-being (Crane and Temple, 2015). Therefore, maintaining participation on a national scale and reducing the number of players that dropout from sport is essential for researchers and practitioners. For high-level youth teams, this is also important, as having a large pool of players to select from enables them to identify and recruit talented players. Thereafter, it is deemed important that they are able to retain players with the greatest potential so they can progress along the developmental pathway (Premier League, 2011), and avoid the inappropriate deselection or dropout of talented players. To facilitate this, large investments into the youth development infrastructure have been implemented, which include providing players with holistic developmental

opportunities, enhanced coaching exposure, and performance benchmarking (Premier League, 2011). Thus, it can be considered that the primary focus of academy teams is to recruit talented players from a young age, nurture them in an optimal environment and progress them along the developmental pathway into senior/first team groups (Premier League, 2011; Güllich, 2014). This presumes that an early specialisation/involvement in football, continual retention through each subsequent age group is the primary route to obtaining professional status - identified as an 'individualistic' approach (Güllich and Emrich, 2012). Moreover, given that squad sizes are likely to progressively reduce with age, the expected minimum level of competence required for retention is likely to increase which suggests that immediate performances are likely to distinguish retained and dropout players (Güllich and Emrich, 2012).

As noted in **Sections 2.4** and **2.5**, the players selected from an early age are typically relatively older and/or earlier maturing, though the factors subsequently influencing retention/dropout are not clearly understood within the literature relating to high-level youth football. A limited number of studies have reported that relatively younger players are greatly at risk of dropout from the age of 12 (Helsen et al., 1998), with other evidence highlighting an increased dropout for Q4 players between U9 to U18 groups (Delorme et al., 2010a). Additionally, late maturing players appear systematically excluded as age and sport specialisation increases (Malina et al., 2000). Given that relatively younger and later maturing players can catch-up towards the end of adolescence due to the transient nature of physical attributes (Lefevre et al., 1990), this represents an issue for academy and youth national teams given that the potential talent pool could be severely reduced. Therefore, there is a need to establish if these (and other pertinent) factors influence retention throughout the developmental pathway which would then clarify if current practice is appropriate.

Evidence from Germany highlights issues of the aforementioned selection biases, as most individuals attaining professional status are not progressively retained along the developmental pathway; instead, repeated selection and de-selection across all age groups is most common – referred to as the ‘collectivistic’ approach (Güllich, 2014). This implies that current selection strategies adopted in youth development programmes are largely inappropriate, where those identified at an early age (i.e. relatively older and/or earlier maturing players) are unlikely to attain professional status. Indeed, a limited number of studies that have determined playing status after a follow up have reported that relatively younger and/or later maturing players appear advantaged for attaining professional status (Carling et al., 2009; Grossmann and Lames, 2013; Skorski et al., 2016; Ostojic et al., 2014). However, the specific mechanisms underpinning the collectivistic approach and the seemingly greater likelihood of career success for relatively younger and/or later maturing players are not clearly understood. In particular, the influence of selection biases and associated factors (e.g. anthropometry and physical performances) have rarely been addressed within the literature pertaining to retention/dropout within each age group across the developmental pathway. One study considered these variables across a broad age range (U10 to U17 groups) in high-level youth teams from Belgium (Deprez et al., 2015e). Whilst the authors observed that physical performances distinguished players that were retained within these groups, the factors influencing entry to subsequent age groups (i.e. U18 onwards) remains unknown. Additionally, given that cultural differences may influence talent selection and retention processes (le Gall et al., 2010; Sarmiento et al., 2018), it is unclear if similar findings are observed in other countries.

2.8 Implications for the EPPP

The aforementioned literature highlights a number of key considerations for the EPPP and the academies that operate within its framework. First, there is clear evidence that selection biases operate in youth football and these appear related, at least in part, to high-level competition from a young age and competition for places (Musch and Grondin, 2001; Cobley et al., 2009). The formation of a categorisation system with recruitment and reputation advantages (Pérez-Jimenez, 2008) for the highest categorised clubs (i.e. Category 1 academies) may in turn further perpetuate the selection of relatively older and/or earlier maturing players to occupy limited places within these teams. Whilst previous research has identified that relative age and biological maturity selection biases operate in youth football (Hirose, 2009; Deprez et al., 2012; Lovell et al., 2015), there have been no studies to examine the prevalence of these selection biases over a sustained period of time (i.e. since the inception of the EPPP). Additionally, given that previous studies have been limited in their approach to investigate between-quartile differences, it is unclear if birth quartile is associated within significant advantages when repeated-measures over an entire season are accounted for.

Selection biases are evident in youth football and are seemingly underpinned by the maturation-selection hypothesis that ultimately favours relatively older and/or earlier maturing players (Cobley et al., 2009). Previous research indicates that physical attributes are somewhat transient (Buchheit and Mendez-Villanueva, 2013), where relatively younger and/or later maturing players eventually catch up and may even outperform their relatively older/earlier maturing peers (Lefevre et al., 1990). Indeed, success at a young age may not necessarily translate to success as an adult (Abbott

and Collins, 2002). As such, current selection strategies may be deemed inappropriate as they discriminate against the pool of relatively younger and/or later maturing players who may have greater long-term potential. Consequently, the prevalence of selection biases would essentially contradict the primary aim of the EPPP, as many talented players with the potential to become senior first team or international-level players may dropout prematurely (Helsen et al., 1998; Malina et al., 2000). However, it is largely unknown if factors known to influence selection into high-level teams (e.g. relative age, biological maturity, anthropometry and physical performances) (Figueiredo et al., 2009; Mujika et al., 2009; Coelho et al., 2010) subsequently exert an influence on the retention process that operates within an academy, throughout the developmental pathway.

Player monitoring is a key component of the EPPP, in which information can be used for talent identification and training prescription purposes. Given that individual variability in biological maturity exists, and this factor has a relationship with anthropometry and physical performances (Malina et al., 2004a), it is paramount that maturity is considered within applied practice, especially when appraising fitness testing data (Cumming et al., 2017; Jones et al., 2000; Meylan et al., 2010). Velocity curves have previously been established for physical performance variables where peak development of physical qualities was related to the onset of PHV; despite the mixed-longitudinal design, only one measure was obtained per individual, per year (Philippaerts et al., 2006). A more recent study examined the developmental trajectories of anthropometry and physical performances, according to maturity, using a cross-sectional sample of players from English academies; a key finding was that breakpoints corresponding to the rate of development were established (Towlson et al., 2018). However, as anthropometry and physical performance are subject to growth

and maturation-related changes throughout adolescence (Malina et al., 2004a), and are likely to change within a single season (Meylan et al., 2010), it would be advantageous to utilise data that includes repeated measurements to better account for developmental changes (Low, 1970). Thus, a greater understanding of the relationship between biological maturity, anthropometry and physical performances can lead to improved practice within academies, but additional research utilising contemporary statistical analysis is required.

Finally, it has been reported that biological maturity exerts a stronger influence on selection into academies than birth date (Johnson et al., 2017), highlighting the need for academies to consider this factor in particular. Qualitative research demonstrates that physical maturity can exert an influence on the decision-making process adopted by coaches regarding player selection (Hill and Sotiriadou, 2016). This highlights that coaches have a role as talent selectors within youth football, and so any attempt to counteract the maturation-related selection bias appears dependent, at least in part, on altering their decision-making process. At present, practical approaches to nullify the maturation-related selection bias have received little attention within the literature; bio-banding has recently been proposed as a potential solution (Cumming et al., 2017), though the merits of this approach have not yet been investigated from the perspective of talent selection and retention (Cumming et al., 2018b). Therefore, there is a need to establish, through a qualitative approach, if bio-banding can offer a practical solution to reducing the maturation-related selection bias within academy football, specifically by altering the decision-making process adopted by coaches.

2.9 Summary of Literature

In summary, this chapter has provided a detailed overview of the EPPP framework that governs football academies in the UK, as well as some of the key themes that are related to applied practice within these academies. Additionally, the relevance of monitoring specific variables, and the methodology that can be used to assess them, has subsequently been evaluated. The current literature demonstrates that relative age, biological maturity, anthropometry and physical performances are important considerations for youth football academies. The potential for these factors to exert an influence on applied practice (e.g. selection and retention) highlights the necessity of further research to help inform best practice. Importantly, whilst previous literature has examined these themes in youth football, clearly the introduction of the EPPP represents a significant change to the landscape of youth football in England, thereby warranting contemporary research (Premier League, 2011). Specifically, selection biases due to relative age and biological maturity are highly prevalent within youth football and appear related, at least partly, to relatively older and/or earlier maturing players exhibiting superior anthropometric and physical performances (Sierra-Diaz et al., 2017; Meylan et al., 2010; Copley et al., 2009). However, the resultant impact of the EPPP on these selection biases throughout the developmental pathway is not yet clearly understood. Additionally, there is a need for further evidence to examine how anthropometric and physical performance characteristics develop in accordance with somatic maturity, through contemporary statistical analysis. Finally, whilst there is a clear need to counteract selection biases within youth football, there is currently a lack of research that has explored proposed solutions within an applied setting. Taken together, there is a need for contemporary research to be conducted within English youth football to investigate the influence of relative age, biological maturity,

anthropometry and physical performances on several pertinent outcomes (selection, retention, development) since the EPPP was introduced.

2.10 Specific Aims and Objectives of this Thesis

The review of current literature demonstrated that despite research being conducted on the aforementioned themes, there are a number of issues and gaps in knowledge that relate to the implementation of the EPPP, which require further investigation. Therefore, the general aim of this thesis is to investigate relative age, biological maturity, anthropometric and physical performance characteristics of male youth football players from an English Category 1 academy, as they progressed through the developmental pathway. The successful completion of the aims below will fulfil gaps in current knowledge and identify how applied practice can be optimised. The specific aims of this thesis are to:

- I. Examine the prevalence of selection biases across the developmental pathway, thereby providing contemporary evidence on whether these have persisted since the EPPP was implemented, and if they are amplified in a top categorised academy. Furthermore, multilevel modelling will enable analysis of mixed-longitudinal data with repeated measurements for individuals to determine between-quartile differences for maturity, anthropometry and physical performances.

- II. Investigate the influence of birth quartile, biological maturity, anthropometry and physical performances on player retention from each age group along the developmental pathway. The use of multilevel modelling for analysis will clarify

whether the aforementioned factors are discriminatory for retention, and if any age group related differences are evident.

- III. Examine growth curves of anthropometry and physical performances according to somatic maturity. The application of multilevel modelling will enable biologically plausible time points relating to the initiation, peak and plateau of development for each variable to be estimated.

- IV. Investigate the influence of a bio-banding intervention for potential applications within applied practice, especially regarding the reduction of the maturation-related selection bias. A qualitative approach will be advantageous in determining whether a bio-banding intervention can alter the decision-making process adopted by academy coaches with regards to the selection and retention of players.

**Chapter 3. Study 1 - Relative Age, Maturation,
Anthropometric and Physical Performance
Characteristics of Youth Football Players:
Observations from a Top Categorised
Academy**

3.1 Introduction

In the United Kingdom, youth football is a popular sport, where approximately 3.35 million children aged 5-15 years participate, including 2.49 million boys (The FA, 2015a). From this large pool of players, a subgroup of around 10,000 boys (Keble, 2015) are recruited by academies with the aim of eventually attaining professional status (Premier League, 2011).

Football academies employ talent identification strategies, where multidisciplinary characteristics appear necessary for selecting players that have the potential to achieve high-level performance at senior level (Williams and Reilly, 2000; Sarmiento et al., 2018). However, as identified within **Sections 2.4** and **2.5** of this thesis, selection biases due to relative age and biological maturity exist in youth football (Meylan et al., 2010; Sierra-Diaz et al., 2017), with recent evidence reporting that biological maturity appears more discriminant than birth date for selection into academies (Johnson et al., 2017).

In England, the RAE has been demonstrated within youth centres of excellence (now known as the Academy system) and national teams, whereby 49.1% of players (9 to 16-years-old) were born in the first quartile of the selection year (Brewer et al., 1995; Simmons and Paull, 2001). More recently, it was established that 48.6% of all Under 9 (U9) to U18 youth players from the academies of professional English clubs (League 1 and 2) were born in the first birth quartile (Lovell et al., 2015). These findings highlight the robust nature of RAEs within English youth football, which corresponds with evidence from across Europe (Sierra-Diaz et al., 2017). As highlighted in **Sections 1.1** and **2.1**, there was a significant overhaul to the English Academy system in 2011, known as the EPPP (Premier League, 2011). Under the EPPP framework, several

modifications were made to organisational practices which may have the potential to influence recruitment strategies. For example, a Category 1 academy, determined through a regular audit, has high-level coaching and training facilities and they are permitted to recruit nationally (Premier League, 2011). Pérez-Jimenez and Pain found that whilst RAEs were robust in all the Spanish youth teams they investigated, the clubs deemed to be more successful, from big cities and/or with greater reputations for their youth teams tended to exhibit stronger RAEs (Pérez-Jimenez, 2008). As such, it is plausible that since the inception of the EPPP, top categorised academies in England may demonstrate amplified selection biases compared to previous findings, though this is yet to be established.

Other pertinent research in youth football has revealed that when controlling for CA and/or biological maturity, players born in different birth quartiles demonstrate a homogenous physical profile (Carling et al., 2009; Deprez et al., 2013; Deprez et al., 2012; Lovell et al., 2015; Fragoso et al., 2015; Skorski et al., 2016). In addition, Skorski et al. (Skorski et al., 2016) observed superior physical performances in sprint and endurance performance for Q4 players in U19 and U21 groups, highlighting the potential for relatively younger players to demonstrate developmental advantages by the end of adolescence. However, these studies employed cross-sectional designs and, as such, no studies have utilised a mixed-longitudinal design to account for multiple measures over a season. To this end, multilevel modelling has recently emerged as an appropriate technique to investigate RAEs, with Wattie et al. advocating the use of this technique to account for individual, environmental and task constraints (Wattie et al., 2015). Individual variation in the timing and tempo of biological maturation processes confound anthropometrical and physical performance characteristics and this may occur sporadically throughout the season (Lloyd et al.,

2014a; Malina et al., 2004a). Furthermore, the undeniable popularity of youth football in England, along with potential competition between Category 1 academies for player recruitment, underline important constraints that need to be considered in the investigation of selection biases under the EPPP framework in English academies (Cobley et al., 2009; Premier League, 2011).

Whilst RAEs have been researched extensively (Cobley et al., 2009; Sierra-Diaz et al., 2017), there is a clear need for a contemporary investigation to clarify the impact of the EPPP on selection strategies adopted by a Category 1 academy. Furthermore, the application of multilevel modelling enables a comprehensive and more appropriate evaluation of between-quartile differences through permission of mixed-longitudinal data. Therefore, the aims of the present chapter were twofold. Firstly, to investigate the prevalence of RAEs within each age group from U9 to First Team within one English professional football club, to identify if a systematic and amplified selection bias is evident; and secondly, to determine if somatic maturity, anthropometry and physical performance characteristics differ between birth quartiles in U11 to First Team groups.

3.2 Methods

3.2.1 Participants

All participants were male football players registered to one English professional football club with Category 1 academy status (from the 2010/11 season onwards). All players were grouped into cohorts based on their CA, with the selection year in England spanning September in one year to August of the following year. Specifically,

the age groups investigated within this thesis are typical of professional football clubs in England and include: U9, U10, U11, U12, U13, U14, U15, U15, U16, U18, U21, and First Team groups. Goalkeepers and outfield players that were deemed injury-free by the medical department at the club were considered eligible for inclusion. Players were only included in this thesis if they would qualify for home-grown status according to the Premier League. That is, players were registered to this club or any other club (prior to being recruited by the current club) affiliated with The Football Association or Football Association Wales for three seasons or 36 months prior to their 21st birthday (Premier League, 2011).

It is important to note that the terminology ascribed to the sample investigated throughout this thesis will use 'academy' or 'high-level' interchangeably. Moreover 'high-level' will also be used as a broad term to encompass studies that have investigated academy (or equivalent) and/or national team samples, thereby distinguishing between individuals at a lower playing level (e.g. grassroots). This was chosen as the use of the term 'elite' can be problematic, particularly when concerning youth players, where recent discussions have challenged this use of this terminology (Kirkland and O'Sullivan, 2018). Issues regarding the use of specific nomenclature to define the samples within sport research has previously been addressed (Swann et al., 2015), yet there is currently no clear consensus on how to define samples which inevitably makes comparisons between studies challenging.

The typically weekly training and competition volume for each age group are as follows:

- Foundation Phase (U5 to U11) players typically completed between 3 and 5 hours of training per week including competitive matches/tournaments with other teams.
- Youth Development Phase (U12 to U16) players typically completed between 6 and 12 hours of training per week, including competitive matches/tournaments against other teams. U12 players received one resistance training session per week, whilst U13 to U16 players typically received two per week.
- Professional Development Phase (U17 to U21) players typically completed between 16 and 18 hours of training per week, including competitive matches/tournaments against other teams. Players typically received two resistance training sessions per week.
- First Team players typically completed 8 and 16 hours of training per week, including competitive matches against other teams. First Team players typically received two resistance training sessions per week.

All players were made aware that fitness testing was required as part of their contractual obligations with the club due to the EPPP regulations. Accordingly, the data from this thesis has been acquired as part of these routine monitoring procedures (Winter and Maughan, 2009). Still, in order to comply with regulations regarding confidentiality, players were informed that their individual data could be withdrawn at any point without providing a reason (Macauley and Bartlett, 2000). Furthermore, the club and players were made aware that data would be kept confidential which included anonymising the data to protect individuals' identity and restricting use to the research

team. Ethical approval for this chapter was received from the ethics committee from the University of Wolverhampton (**Appendix A**).

For the purposes of this particular chapter, 426 individual male players registered between 2010/11 to 2017/18 seasons were included to investigate the prevalence of RAEs. Players represented all eleven age groups within the club from U9 to First Team (i.e. U9, U10, U11, U12, U13, U14, U15, U16, U18, U21 and First Team) and were born between 1975 and 2009. Records for U9 and U10 players could only be obtained for 2016/17 and 2017/18 seasons.

To investigate between-quartile differences in somatic maturity, anthropometry and physical performance characteristics, a total of 3192 data points from 382 individual players registered from U11 to First Team age groups between 2010/11 to 2016/17 seasons were included. Players were born between 1975 and 2006. Corresponding data for U9 and U10 groups is not mandated as part of the EPPP testing battery (Premier League, 2011) and was therefore not collected by the club. Data was collected over three to four testing periods per season, separated by approximately three months, for a total of seven seasons. Accordingly, players were followed for each season they were registered to the club and typically had repeated measurements (up to a maximum of four) for each season. All available individual player data was included, corresponding to mixed-longitudinal data. The total number of measurements for individual players were as follows: 1 (n=20), 2 (n=30), 3 (n=47), 4 (n=26), 5 (n=25), 6 (n=32), 7 (n=24), 8 (n=24), 9 (n=26), 10 (n=23), 11 (n=14), 12 (n=11), 13 (n=15), 14 (n=10), 15 (n=9), 16 (n=4), 17 (n=6), 18 (n=7), 19 (n=0), 20 (n=3), 21 (n=2), 22 (n=4), 23 (n=4), 24 (n=2), 25 (n=2), 26 (n=1), 27 (n=8), 28 (n=2). First Team testing was only completed until the end of the 2014/15 season.

3.2.2 *Design*

An observational design was used to investigate the prevalence of relative age effects within the club, and to ascertain between-quartile differences in somatic maturity, anthropometry and physical performances.

3.2.3 *Procedures*

All anthropometric, physical performance and biological maturity data obtained for this thesis was the result of a standardised fitness testing battery mandated by the EPPP (Premier League, 2011). In brief, this battery involved: using the same equipment, conducting testing in the same environment (indoor gymnasium and 3G surface), at similar time points each season (approximately July, October, January, April), administering the testing battery as a one-off session to minimise disruption to the coaching programme and maintaining the same order of tests (anthropometry, jump, sprint, agility and aerobic endurance tests). All testing was administered by a team of trained exercise scientists employed by the Premier League (as fitness testing assistants) as well as members of the sport science department at the club (employed as sport scientists). All members of the testing team were experienced with administering testing procedures and followed standardised protocols set by the EPPP for quality control (Premier League, 2011).

Fitness testing data from 2010/11 to 2014/15 seasons were obtained from the club's records and thus comprised of secondary data (i.e. author not present) collected by sport scientists (employed by the club) and fitness testing assistants (employed by The Premier League). Specifically, there were seven sport scientists employed by the

club that had all completed undergraduate (and typically postgraduate) degrees in sport science and had at least one year of experience administering fitness testing within applied practice prior to their role at the current club. Of these sport scientists, four were involved with obtaining anthropometric measurements and had received ISAK accreditation; all were involved in the collection of physical performance data as part of the EPPP fitness testing battery alongside the fitness testing assistants. Fitness testing data from 2015/16 to 2016/17 seasons were obtained by sport scientists that were employed by the club and fitness testing assistants employed by The Premier League, where the author was also present during this time. Specifically, there were three sport scientists that had remained from the previous data collection period (2010/11 to 2014/15); another three sport scientists (including the author) that joined during this period (2015/16 to 2016/17 seasons) had all completed undergraduate (and typically postgraduate) degrees in sport science and had at least one year of experience administering fitness testing within applied practice (e.g. internship) prior to their role at the current club. Four of these sport scientists (including the author) were involved with obtaining anthropometric measures and had received ISAK accreditation; all six sport scientists were involved in the collection of physical performance data as part of the EPPP fitness testing battery alongside the fitness testing assistants. Fitness testing assistants employed by the Premier League had completed an undergraduate degree in sport science (minimum) and had at least one year of experience delivering sport science support, and there were at least three assistants present during each testing session.

3.2.4 Anthropometry and somatic maturity

All anthropometric measures were obtained according to ISAK protocols (Stewart et al., 2011), and conducted by ISAK accredited sport scientists that were employed by the club. Specifically, height and sitting height measurements were obtained in duplicate with a third measurement taken if the first two values differed by more than 1%; the mean value was recorded when two measures were taken and the median value was recorded when three measures were taken (Hume et al., 2018). Anthropometric testing was performed in the morning prior to training and in a t-shirt and shorts only. Anthropometry was conducted in an indoor gymnasium.

3.2.5 Standing Height

Height was measured using a portable stadiometer (Model HR001, Tanita Leicester Height Measure). Measurements were obtained using the stretch stature technique (see **Figure 3.1**). Each player was required to stand fully erect with both feet together on the floorboard of the stadiometer with the heels, buttocks and upper back touching the scale, with arms hanging to the sides with palms facing the thighs. The subject's head was then placed in the Frankfort plane, and the assessor lowered the horizontal bar to the crown of the head by gently applying pressure and compressing the hair. Subsequently, the assessor placed their hands along the jaw of the subject and applied a gentle upward lift as the subject took a deep inhale whilst instructed to maintain contact of the feet, specifically the heels, with the floorboard of the stadiometer. The assessor subsequently read the measurement from where the headboard resided, with height recorded to the nearest 0.1 cm.



Figure 3.1 Example of player position for stretch stature assessment (taken, with permission, from Stewart et al. (Stewart et al., 2011)).

3.2.6 Sitting Height

Sitting height was measured using a portable stadiometer (Model HR001, Tanita Leicester Height Measure) and an anthropometric box (height of 40 cm), as per ISAK guidelines (Stewart et al., 2011) (see **Figure 3.2**). Specifically, the anthropometric box was placed on the base of the stadiometer and the subject was instructed to sit as erect as possible on the anthropometric box with their back touching the scale, their hands resting on their thighs, and lower legs hanging freely off the edge of the box. Subsequently, their head was placed in the Frankfort plane and the assessor brought the horizontal bar down on top of the crown of the head by gently applying pressure and compressing the hair. Subjects were then instructed to take a deep inhale whilst the assessor placed their hands along the jaw of the subject and applied a gentle

upward lift. The assessor subsequently read the measurement from where the headboard resided, with sitting height recorded to the nearest 0.1 cm. Leg length was calculated as the difference between height and sitting height.



Figure 3.2 Example of player position for sitting height assessment (taken, with permission, from Stewart et al. (Stewart et al., 2011)).

3.2.7 Body Mass

Body mass was measured using a portable scale (Seca 22089, Hamburg, Germany). Prior to assessing each player, the scales were zeroed and calibrated. Subsequently, players stood on the centre of the scales with weight distributed evenly with both feet. Body mass was recorded to the nearest 0.1 kg.

3.2.8 *Maturity status*

Estimation of somatic maturity was calculated for players in U11 to U16 groups only using the non-invasive method developed by Mirwald et al. (Mirwald et al., 2002), which estimates maturity offset within an error of ± 1 year 95% of the time. Equation 3 derives estimated maturity offset from the following:

$$\begin{aligned} & -9.236 + (0.0002708 * (\textit{leg length} * \textit{sitting height})) \\ & + (-0.001663 * (\textit{age} * \textit{leg length})) \\ & + (0.007216 * (\textit{age} * \textit{sitting height})) \\ & + (0.02292 * (\textit{weight} / \textit{height} * 100)) \end{aligned}$$

Age at peak height velocity (APHV) was subsequently calculated from CA and maturity offset which was updated at each testing session, where weight in Equation 3 represents body mass reported in this study. This method was adopted due to the non-invasive nature and superior practicality within the context of the environment, given that it enabled the assessment of entire squads of players relatively quickly.

3.2.9 *Relative age*

Players birthdates were obtained from club records and categorised into birth quartiles (Q) within each age group according to the selection year spanning 1st September to 31st August; Q1=September-November, Q2=December-February, Q3=March-May, Q4=June-August.

3.2.10 Physical performances

All players were familiarised with testing protocols prior to data collection. At each testing session, all tests were carried out in the same sequence according to previously outlined recommendations by the Premier League (Premier League, 2011), and conducted by sport scientists and fitness testing assistants as outlined in **Section 2.12.3**. Specifically, this involved: standardised jump-based warm up, jump test, standardised running-based warm up, sprint and agility tests, followed by an aerobic endurance test. The jump and running-based warm-ups were standardised and consisted of dynamic movements in the gymnasium and on the 3G pitch, respectively, for 10 min each. Jump testing was conducted within an indoor gymnasium, whereas sprint, agility and aerobic endurance tests were performed on an indoor 3G surface. All players were provided a minimum of 5 min recovery between tests and had a minimum 60 s passive recovery in between attempts for sprint and agility tests, and up to 20 s between jump attempts. Players performed all tests in football boots, apart from the jump tests which were performed in running shoes. All players were provided strong verbal encouragement throughout.

For the U11 to U16 groups, the fitness testing battery was typically conducted in the morning at each time point throughout the season, with approximately one testing session per season (for each of these age groups) conducted in the evening due to scheduling constraints. For the U18 to First Team groups, the fitness testing battery was conducted in the morning at each time point throughout the season. Furthermore, club sport scientists were responsible for leading both the jump and running-based standardised warm-ups as well as the agility test; jump, sprint and aerobic endurance tests were all setup and administered by the fitness testing assistants, with club sport

scientists also present during these physical performance tests to manage the groups and, in the case of the aerobic endurance test, assist when required (e.g. reminding players to pace according to audio cues), with the final scores being recorded by the fitness testing assistants.

3.2.10.1 Jump Test

Jump performance was assessed using the countermovement jump (CMJ) test (OptoJump, Microgate, Bolzano, Italy). Prior to beginning the CMJ test, all players performed a standardised dynamic warm up in the indoor gymnasium for 10 min. The CMJ was performed with players starting in an upright position, rapidly going into a squat position with knees flexed at approximately 90 degrees, thereafter, jumping maximally and landing with minimal knee flexion in the same place. Hands remained on the hips to negate the influence of arm swing. The highest of 3 jumps was recorded to the nearest 0.1 cm.

3.2.10.2 Sprint Test

Sprint performance was assessed via three maximal sprints of 30 m using timing gates (Brower Timing System, Utah, USA). Prior to performing the sprint test, all players performed a standardised dynamic warm up on the indoor 3G surface for 10 min. Players commenced each sprint from a standing start with their front foot 0.5 m behind the first timing gate. The players began when ready, thereby nullifying the influence of reaction time, and were instructed to finish their sprint beyond the final timing gate to ensure the fastest time possible. The fastest 10 m split time and 30 m time were recorded to the nearest 0.01 s, which could have occurred in different trials.

3.2.10.3 *Agility Test*

Agility performance was assessed using a modified version of the agility T-test (Semenick, 1990). Players commenced each sprint from a standing start with their front foot 0.5 m behind the timing gate. Subsequently, players ran forward 10 m, turned right 90 degrees around a cone and ran forward 5 m, turned right 180 degrees around another cone and ran forward 10 m, turned right 180 degrees and ran forward 5 m, turned right 90 degrees and ran 10 m to the start/finishing line. Players began when ready, thereby nullifying the influence of reaction time. The fastest recorded time of three attempts to the left and right, as well as the composite score determined using the fastest time from each direction, were recorded to the nearest 0.01 s.

3.2.10.4 *Aerobic Endurance Test*

Aerobic endurance was determined via the Yo-Yo Intermittent Recovery Level 1 (Yo-Yo IR1) for U11 to U15 players and Level 2 (Yo-Yo IR2) for U16 to First Team players (Krustrup et al., 2003; Krustrup et al., 2006). Players performed 2 x 20 m shuttles with a progressively increasing speed controlled by an audio recording. Players had 10 s active rest between each 20-m shuttle run, which involved walking 2 x 5 m. There were at least four observers used during this test to ensure that all players were adhering to the testing procedures, with a verbal warning provided for players failing to reach the finishing line on one occasion or starting the level prior to the audio cue. Players ran until they failed to reach the finishing line on two occasions, with the final score recorded as the distance of the last completed shuttle.

3.2.11 Statistical analysis

Relative age analysis was conducted for each age group (U9 to First Team) using a logistic regression to derive odds ratios (OR) and 95% confidence intervals (95% CI) to calculate between-quartile comparisons, with Q4 as the referent group. Whilst previous research of RAEs has adopted chi-squared analysis (Sierra-Diaz et al., 2017), comparisons of birth data with the national population is deemed inappropriate as it does not distinguish whether a biased birth distribution is observed across all playing levels (Delorme et al., 2010b). However, as birth data for all registered youth football players within England (i.e. from grassroots above) was unavailable, the presence of a RAE within the current football club (observed birth distribution) was confirmed by examining the differences compared to national population data (expected birth distribution). Specifically, census data for males born in England between 1991 and 2014 was used as the expected birth distribution, where an approximately even birth distribution across quartiles was observed (Q1=25.4%; Q2=24.2%; Q3=24.8%; Q4=25.6%) (Office for National Statistics, 2017). Differences between the observed and expected birth distributions were examined using a chi-square goodness-of-fit test within Minitab Express (v 1.3.0), where expected proportions were specified according to the aforementioned percentages for census data. It is acknowledged that the current census dataset does not account for players born between 1975 and 1990, and thus it was assumed that births during this period were consistent with the 1991-2014 census data.

To investigate differences in somatic maturity, anthropometric and physical performance characteristics (dependent variables) between birth quartiles (independent variable), multilevel modelling was employed (MLwiN software package,

v 3.02, Bristol University, Bristol, UK). Multilevel modelling is an extension of ordinary multiple regression where the data have a hierarchical or clustered structure. A hierarchy consists of units or measurements grouped at different levels. In the current example, individual players are the level 2 variation and each of their repeated measurements are the nested observations at level 1. Here, the multilevel modelling software assumes the players to be a random sample (of academy footballers throughout the UK) that represent the level 2 units, with players' repeated measurements recorded from each testing session being nested below as level 1 units. To the author's awareness, this is the first use of multilevel modelling to address this research question. Multilevel modelling was deemed the most appropriate method for analysis of this dataset (Goldstein, 1995), particularly as the same number of measurement occasions per player is not necessary (Charlton et al., 2019). First, data was split according to standard age groups within the club (i.e. U11, U12, U13, U14, U15, U16, U18, U21, First Team). A model for each age group and each dependent variable (CA, somatic maturity, height, body mass, CMJ, agility composite, 10 m sprint time, 30 m sprint time and Yo-Yo IR1 or IR2) was then created separately, allowing for each individual to be the level 2 variation (between-subject) and repeated measurements for each individual to be the level 1 variation (within-subject). Initially, differences for CA and somatic maturity (i.e. APHV) (U11 to U16 only) across birth quartiles were examined. Subsequently, differences for all anthropometric (height and body mass) and physical performance (CMJ, agility composite, 10 m and 30 m sprint, Yo-Yo IR1 or IR2) variables were analysed, with CA and APHV included as covariates, as per previous research (Deprez et al., 2013; Lovell et al., 2015). In the U18, U21 and First Team groups, data were adjusted for CA only, as the equation to derive maturity offset had not been validated in these older groups). Statistical significance

was accepted at the 95% confidence level ($P < 0.05$). The following model was used to examine differences for each dependent variable across birth quartiles in each age group:

$$y_{ij} = \beta_{0ij}x_0 + \beta_1x_{1j} + \beta_2x_{2j} + \beta_3x_{3j} + \beta_4x_{4ij} + \beta_5x_{5ij} + u_{0j} + e_{0ij}$$

where y_{ij} is the value of the dependent variable of interest (e.g. height) on measurement occasion i for the j th player; x is the birth quartile or covariate of the j th player within the age group ($0 = Q4, 1 = Q1, 2 = Q2, 3 = Q3, 4 = CA, 5 = APHV$); the parameter β_0 is the overall mean of height (y) for birth quartile 4 players; parameters β_1 to β_3 represent the difference between the corresponding birth quartiles (1 to 3) and birth quartile 4 in the mean of the dependent variable (y); parameters β_4 and β_5 correspond to the covariates CA and APHV, respectively; the symbol u_j represents the between-subjects (level 2 units) variable (assumed Normal $(0, \sigma_u^2)$) and the symbol e_{ij} represents the within-subjects (level 1 units) variable (assumed Normal $(0, \sigma_e^2)$), where both terms are assumed to be independent.

3.3 Results

3.3.1 Relative Age Effects:

Table 3.1 shows the birth quartile distributions and odds ratio analysis for each age group. A greater proportion of players from the entire sample were born in the first quartile, with a decreasing number of players born between Q1 and Q4 (Q1: 43.4%; Q2: 29.8%; Q3: 19.5%; Q4: 7.3%). This trend was also evident within each age group, where the proportion of players born in Q1 ranged between 27.3 and 61.3%, whilst

players born in Q4 ranged between 3.2 and 14.7%. Odds ratio analysis indicated that in the U9 group, there was a 19.0 times greater chance of being selected for players born in Q1 versus Q4. Thereafter, odds ratios were reduced in the U10 and U11 groups (OR: 3.0-4.8), but increased and remained high between U12 to U16 groups (OR: 7.3-10.3), and progressively decreased with each subsequent age group from U18 (OR: 4.2; 95% CI: 2.04-8.73) to First Team (OR: 2.3; 95% CI: 0.98-5.18). Analysis of the entire sample demonstrated Q1 players were 6.0 times more likely to be represented in this club than Q4 players (95% CI: 4.08-8.73). Additionally, by using the pooled sample (i.e. U9 to First Team players), the birth date distribution of players selected into the current club differed significantly from the national population ($\chi^2=29.34$, $p < 0.05$) (**Figure 3.3**).

3.3.2 *Anthropometric Characteristics:*

Table 3.2 presents somatic maturity and anthropometric characteristics across birth quartiles for each of the age groups. In the U11 group, APHV was significantly higher for Q1 (13.4 years) compared to Q4 (13.1 years) players. No other significant between-quartiles differences were observed for any age group. CA and APHV were significant covariates for height and body mass in U11 to U16 groups, with CA significant in the U18 group and in the U21 group for body mass only.

3.3.3 *Physical Performances:*

Modelling indicated that physical performances across birth quartiles for each age group were similar, with several exceptions, which are shown in **Table 3.2**. Significant differences observed between U11 to U18 groups indicated that Q4 players outperformed other birth quartiles. In the First Team, Q4 players were inferior to all

other birth quartiles for CMJ. There was a tendency for Q4 players to achieve the best physical performances across all variables in U11 to U21 groups. CA and APHV were significant covariates for physical performances, particularly in U13 and U14 groups.

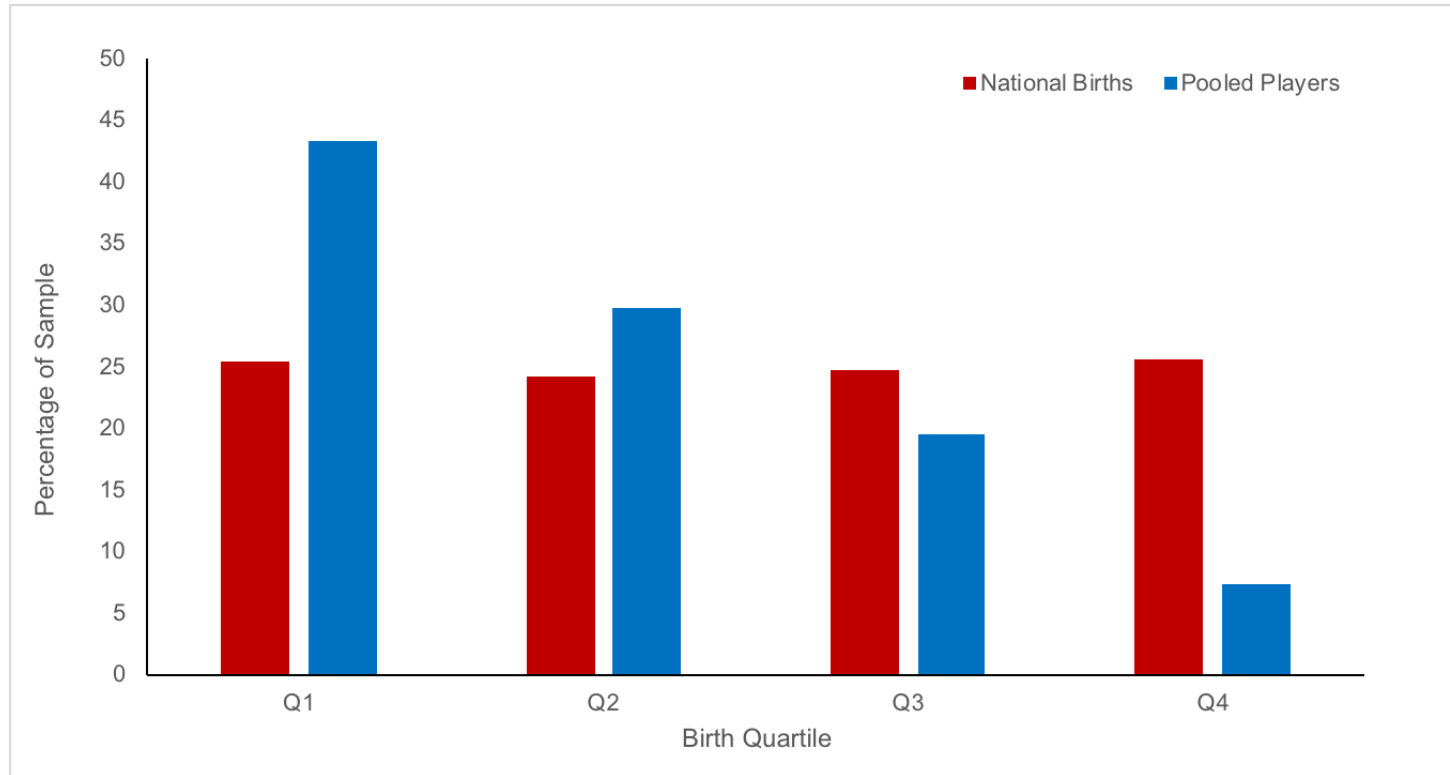


Figure 3.3 Birth quartile distributions (%) of the pooled sample of players in comparison with national population birth data.

Table 3.1 Birth date distribution per quartile (Q) and age category (n (%)) between the 2010/11 and 2017/18 seasons.

Age Group	n	Q1	Q2	Q3	Q4	Q1 vs Q4 OR (CI)	Q2 vs Q4 OR (CI)	Q3 vs Q4 OR (CI)
U9*	31	19 (61.3%)	8 (25.8%)	3 (9.7%)	1 (3.2%)	19.0 (2.67–149.15) [^]	8.0 (1.00-63.98) [^]	3.0 (0.31-28.87)
U10*	34	15 (44.1%)	7 (20.6%)	7 (20.6%)	5 (14.7%)	3.0 (1.09-8.25) [^]	1.4 (0.44-4.41)	1.4 (0.44-4.41)
U11	132	62 (47.0%)	33 (25.0%)	24 (18.2%)	13 (9.8%)	4.8 (2.62-8.67) [^]	2.5 (1.34-4.82) [^]	1.8 (0.94-3.62)
U12	134	61 (45.5%)	45 (33.6%)	20 (14.9%)	8 (6.0%)	7.6 (3.65-15.93) [^]	5.6 (2.65-11.94) [^]	2.5 (1.10-5.67) [^]
U13	140	62 (44.3%)	49 (35.0%)	23 (16.4%)	6 (4.3%)	10.3 (4.46-23.90) [^]	8.2 (3.49-19.08) [^]	3.8 (1.56-9.41) [^]
U14	153	64 (41.8%)	54 (35.3%)	27 (17.6%)	8 (5.2%)	8.0 (3.83-16.68) [^]	6.8 (3.21-14.19) [^]	3.4 (1.53-7.43) [^]
U15	129	58 (45.0%)	42 (32.6%)	21 (16.3%)	8 (6.2%)	7.3 (3.46-15.18) [^]	5.3 (2.46-11.18) [^]	2.6 (1.16-5.92) [^]
U16	121	50 (41.3%)	42 (34.7%)	23 (19.0%)	6 (5.0%)	8.3 (3.57-19.43) [^]	7.0 (2.98-16.45) [^]	3.8 (1.56-9.41) [^]
U18	101	38 (37.6%)	34 (33.7%)	20 (19.8%)	9 (8.9%)	4.2 (2.04-8.73) [^]	3.8 (1.81-7.88) [^]	2.2 (1.01-4.88) [^]
U21	81	27 (33.3%)	29 (35.8%)	18 (22.2%)	7 (8.6%)	3.9 (1.68-8.86) [^]	4.1 (1.81-9.45) [^]	2.6 (1.07-6.15) [^]
First Team	66	18 (27.3%)	22 (33.3%)	18 (27.3%)	8 (12.1%)	2.3 (0.98-5.18)	2.8 (1.22-6.18) [^]	2.3 (0.98-5.18)
All Groups*	426	185 (43.4%)	127 (29.8%)	83 (19.5%)	31 (7.3%)	6.0 (4.08-8.73) [^]	4.1 (2.77-6.06) [^]	2.7 (1.77-4.04) [^]

Table Notes: Q1 = September-November, Q2 = December-February, Q3 = March – May, Q4 = June-August; OR = Odds ratio calculation, (CI) = 95% Confidence Interval

*Note that the U9 and U10 groups were only included for 2016/17 and 2017/18 seasons.

Significant difference ($p < 0.05$) is denoted by [^]

Table 3.2 Somatic maturity, anthropometric and physical performance variables of football players (U11 to First Team) across birth quartiles (Q1 to Q4), including between-subject and within-subject variances.

Age Group	Variable	n	Q1		Q2		Q3		Q4		Covariates				Between-Subject Variance		Within-Subject Variance	
			Mean	SE	Mean	SE	Mean	SE	Mean	SE	CA	SE	APHV	SE	Mean	SE	Mean	SE
U11	CA (y)	113/113	11.2*	0.1	10.9*	0.1	10.7*	0.1	10.4	0.1	-	-	-	-	0.0	0.0	1.0	0.0
	APHV (y)	109/113	13.4*	0.1	13.2	0.1	13.2	0.1	13.1	0.1	-	-	-	-	0.1	0.0	0.0	0.0
	Height (cm)	109/113	147.8	1.5	148.4	1.6	147.3	1.7	147.1	1.4	7.8^	0.4	-8.0^	0.6	18.1	2.5	1.6	0.2
	Body Mass (kg)	109/113	38.9	1.1	38.6	1.1	37.8	1.2	38.7	1.0	6.5^	0.4	-9.7^	0.6	8.1	1.3	2.5	0.2
	CMJ (cm)	105/113	26.4	1.6	26.8	1.6	27.0	1.7	28.1	1.4	2.3^	0.8	-1.1	1.0	13.7	2.4	8.5	0.9
	Agility Comp. (s)	105/113	21.18	0.30	20.89	0.31	20.87	0.33	20.90	0.27	-0.41^	0.15	-0.41^	0.20	0.50	0.09	0.29	0.03
	10 m Sprint (s)	103/113	1.98	0.04	1.97	0.04	1.95	0.04	1.94	0.03	-0.02	0.02	-0.06^	0.02	0.01	0.00	0.00	0.00
	30 m Sprint (s)	105/113	5.07	0.10	5.05	0.10	5.01	0.11	5.06	0.09	-0.05	0.04	-0.16^	0.06	0.06	0.01	0.02	0.00
	Yo-Yo IR1 (m)	45/113	648*	194	932	195	972	188	1085	178	316^	121	344^	108	26827	14325	91426	14977
U12	CA (y)	119/119	12.2*	0.1	12.0*	0.1	11.7*	0.1	11.4	0.1	-	-	-	-	0.0	0.0	0.1	0.0
	APHV (y)	116/119	13.7	0.2	13.5	0.2	13.6	0.2	13.5	0.2	-	-	-	-	0.1	0.0	0.0	0.0
	Height (cm)	116/119	153.7	1.7	154.2	1.7	153.3	1.9	154.2	1.6	8.0^	0.4	-9.2^	0.6	14.8	2.1	2.3	0.2
	Body Mass (kg)	116/119	43.0	1.8	42.7	1.8	41.9	2.0	42.6	1.7	5.9^	0.3	-6.7^	0.5	16.9	2.3	1.3	0.1
	CMJ (cm)	115/119	27.1	2.1	27.0	2.1	27.5	2.3	29.8	2.0	1.8^	0.8	-1.4	1.0	17.3	3.0	10.0	1.1
	Agility Comp. (s)	114/119	20.96	0.37	20.74	0.37	20.75	0.40	20.42	0.35	-0.31^	0.13	-0.22	0.17	0.55	0.09	0.27	0.03
	10 m Sprint (s)	113/119	1.97	0.05	1.95	0.05	1.92	0.05	1.89	0.04	-0.06^	0.02	-0.02	0.02	0.01	0.00	0.00	0.00
	30 m Sprint (s)	114/119	5.02	0.12	5.01	0.12	4.92	0.13	4.87	0.11	-0.15^	0.04	-0.05	0.05	0.07	0.01	0.02	0.00
	Yo-Yo IR1 (m)	49/119	766*	216	970*	217	1031*	229	1583	198	297^	112	227	117	68624	21951	78024	13573
U13	CA (y)	123/123	13.2*	0.1	13.0*	0.1	12.7*	0.1	12.4	0.1	-	-	-	-	0	0	0.1	0.0
	APHV (y)	121/123	13.7	0.2	13.5	0.2	13.7	0.2	13.6	0.2	-	-	-	-	0.2	0.0	0.0	0.0
	Height (cm)	121/123	157.1	2.7	158.6	2.7	156.0	2.9	157.6	3.1	7.0^	0.2	-3.0^	0.3	37.7	4.9	0.9	0.1
	Body Mass (kg)	121/123	48.4	2.5	49.7	2.5	47.9	2.7	48.6	2.4	5.8^	0.2	-2.8^	0.4	33.3	4.4	1.2	0.1
	CMJ (cm)	118/123	30.8	2.3	30.2*	2.3	29.9*	2.4	35.0	2.1	2.2^	0.6	-1.3	0.7	22.5	3.3	6.4	0.7

	Agility Comp. (s)	117/123	20.36	0.33	20.29	0.33	20.23	0.35	19.73	0.31	-0.45^	0.10	0.26^	0.11	0.49	0.08	0.19	0.02
	10 m Sprint (s)	117/123	1.88	0.04	1.89	0.04	1.85	0.04	1.83	0.04	-0.09^	0.02	0.06^	0.01	0.01	0.00	0.01	0.00
	30 m Sprint (s)	117/123	4.80	0.11	4.84	0.11	4.77	0.11	4.66	0.10	-0.22^	0.03	0.11^	0.03	0.05	0.01	0.02	0.00
	Yo-Yo IR1 (m)	49/123	906	216	1151	212	1336	210	1331	197	426^	120	-82	76	37961	17410	88933	15804
U14	CA (y)	135/135	14.2*	0.1	14.0*	0.1	13.7*	0.1	13.4	0.1	-	-	-	-	0	0	0.1	0.0
	APHV (y)	133/135	13.6	0.2	13.5	0.2	13.6	0.3	13.8	0.2	-	-	-	-	0.3	0.0	0.0	0.0
	Height (cm)	133/135	169.1	1.7	169.4	1.7	168.6	1.8	168.8	1.6	6.2^	0.3	-6.9^	0.5	16.5	2.2	2.5	0.2
	Body Mass (kg)	133/135	55.9	2.1	57.0	2.1	56.6	2.2	55.7	2.0	6.1^	0.3	-5.5^	0.5	25.9	3.3	2.1	0.2
	CMJ (cm)	122/135	33.3	2.4	33.6	2.3	34.5	2.4	34.4	2.2	1.2	0.7	-2.2^	0.7	24.4	3.6	7.0	0.8
	Agility Comp. (s)	125/135	19.89	0.29	19.72	0.29	19.79	0.30	19.57	0.27	-0.61^	0.11	0.23^	0.10	0.39	0.06	0.21	0.02
	10 m Sprint (s)	125/135	1.83	0.04	1.82	0.04	1.82	0.04	1.76	0.04	-0.08^	0.02	0.03^	0.01	0.01	0.00	0.01	0.00
	30 m Sprint (s)	125/135	4.61	0.11	4.59	0.11	4.58	0.12	4.45	0.11	-0.15^	0.04	0.10^	0.04	0.05	0.01	0.03	0.00
	Yo-Yo IR1 (m)	49/135	1074*	157	1668	143	1570	147	1530	130	427^	126	42	68	22345	16379	93507	18236
U15	CA (y)	113/113	15.2*	0.1	14.9*	0.1	14.7*	0.1	14.4	0.1	-	-	-	-	0	0	0.9	0.0
	APHV (y)	112/113	13.5	0.2	13.4	0.2	13.6	0.2	13.6	0.2	-	-	-	-	0.2	0.0	0.0	0.0
	Height (cm)	112/113	175.8	1.8	174.8	1.8	174.1	1.9	173.8	1.7	4.2^	0.3	-5.0^	0.5	15.8	2.2	1.3	0.1
	Body Mass (kg)	112/113	65.1	2.5	65.1	2.5	65.6	2.6	66.3	2.3	6.9^	0.5	-6.1^	0.7	30.2	4.3	3.2	0.3
	CMJ (cm)	106/113	37.2	2.4	36.4	2.4	37.4	2.5	36.5	2.2	1.5	1.0	-0.6	0.9	21.7	3.9	9.7	1.4
	Agility Comp. (s)	108/113	19.22	0.26	19.14	0.26	19.21	0.27	19.15	0.24	-0.44^	0.10	0.02	0.10	0.24	0.04	0.12	0.02
	10 m Sprint (s)	108/113	1.76	0.03	1.76	0.03	1.77	0.03	1.72	0.03	-0.03^	0.02	-0.01	0.01	0.00	0.00	0.00	0.00
	30 m Sprint (s)	107/113	4.39	0.09	4.37	0.09	4.39	0.09	4.22	0.08	-0.11^	0.03	-0.01	0.03	0.03	0.01	0.01	0.00
	Yo-Yo IR1 (m)	39/113	1283	266	1584	239	1557	259	1476	235	162	185	263^	90	4023	24524	185348	37695
U16	CA (y)	106/106	16.1*	0.1	15.9*	0.1	15.7*	0.1	15.4	0.1	-	-	-	-	0	0	0.1	0.0
	APHV (y)	95/106	13.7	0.2	13.5	0.3	13.8	0.3	13.7	0.2	-	-	-	-	0.3	0.0	0.0	0.0
	Height (cm)	95/106	178.6	2.0	178.2	2.0	178.0	2.3	176.0	1.9	2.7^	0.5	-4.4^	0.6	19.9	3.0	1.3	0.2
	Body Mass (kg)	95/106	68.3	2.5	70.0	2.6	72.0	2.9	67.0	2.4	5.0^	0.5	-5.0^	0.7	31.9	4.8	1.8	0.3
	CMJ (cm)	80/106	38.5	2.2	37.7	2.2	36.3	2.5	37.9	2.0	-1.9	1.1	-0.1	0.9	18.7	3.7	5.6	1.1
	Agility Comp. (s)	82/106	19.03*	0.26	18.62	0.25	18.83	0.28	18.48	0.24	-0.3	0.17	-0.10	0.10	0.18	0.05	0.15	0.03

	10 m Sprint (s)	84/106	1.76*	0.03	1.74	0.03	1.75	0.04	1.68	0.03	-0.03	0.02	-0.02	0.01	0.00	0.00	0.00	0.00
	30 m Sprint (s)	84/106	4.34*	0.09	4.27	0.09	4.32*	0.10	4.10	0.08	-0.07	0.04	-0.09^	0.03	0.03	0.01	0.01	0.00
	Yo-Yo IR2 (m)	28/106	783	293	960	270	923	295	924	263	135	146	58	88	49333	21725	37433	12636
U18	CA (y)	89/89	17.6*	0.2	17.3	0.2	17.1	0.2	17.1	0.2	-	-	-	-	0.1	0.0	0.3	0.0
	Height (cm)	87/89	181.2	3.3	180.0	3.3	182.0	3.4	178.5	3.1	0.9^	0.1	-	-	38.1	5.8	0.4	0.0
	Body Mass (kg)	87/89	72.9	3.5	73.6	3.5	76.9	3.7	73.1	3.3	2.5^	0.2	-	-	42.6	6.5	2.3	0.2
	CMJ (cm)	88/89	39.7	1.9	39.8	1.9	39.2*	0.8	42.0	1.8	0.8^	0.3	-	-	13.0	2.2	6.6	0.5
	Agility Comp. (s)	87/89	18.69*	0.22	18.45	0.23	18.74*	0.24	18.23	0.21	-0.07	0.04	-	-	0.15	0.03	0.13	0.01
	10 m Sprint (s)	88/89	1.73*	0.03	1.72	0.03	1.75*	0.04	1.66	0.03	0.00	0.01	-	-	0.00	0.00	0.00	0.00
	30 m Sprint (s)	88/89	4.24	0.09	4.21	0.09	4.26	0.10	4.08	0.09	-0.03^	0.01	-	-	0.03	0.01	0.01	0.00
	Yo-Yo IR2 (m)	38/89	830	117	839	113	845	124	804	104	-50	38	-	-	16414	7767	42684	6875
U21	CA (y)	71/71	19.2	0.4	19.1	0.4	18.9	0.4	18.4	0.4	-	-	-	-	0.3	0.1	0.4	0.0
	Height (cm)	56/71	184.0	4.5	182.1	4.5	182.7	4.6	179.4	4.3	0.1	0.1	-	-	36.4	6.9	0.3	0.0
	Body Mass (kg)	68/71	78.1	4.9	77.3	4.8	77.6	4.9	74.0	4.7	1.4^	0.2	-	-	42.4	7.6	3.4	0.4
	CMJ (cm)	66/71	39.4	3.1	39.8	3.1	41.8	3.1	43.3	2.9	-0.3	0.4	-	-	17.7	3.9	9.5	1.3
	Agility Comp. (s)	64/71	18.43	0.32	18.46	0.31	18.14	0.32	18.43	0.30	0.02	0.04	-	-	0.19	0.04	0.09	0.01
	10 m Sprint (s)	67/71	1.70	0.05	1.72	0.05	1.67	0.05	1.65	0.04	-0.01	0.01	-	-	0.00	0.00	0.01	0.00
	30 m Sprint (s)	67/71	4.13	0.10	4.18	0.10	4.05	0.11	4.05	0.10	-0.01	0.01	-	-	0.02	0.00	0.01	0.00
	Yo-Yo IR2 (m)	34/71	869	179	882	175	927	178	956	163	12	34	-	-	23450	12264	65647	11224
First Team	CA (y)	40/40	24.3	1.9	23.5	1.9	25.8	2.0	26.1	1.6	-	-	-	-	12.5	2.9	1.0	0.1
	Height (cm)	24/40	184.8	4.8	184.2	4.7	182.3	4.9	182.7	4.0	0.0	0.1	-	-	47.5	13.7	0.2	0.0
	Body Mass (kg)	24/40	83.2	5.0	83.5	4.9	82.2	5.0	74.3	4.2	0.2	0.2	-	-	49.7	14.5	1.7	0.3
	CMJ (cm)	33/40	44.3*	2.4	46.5*	2.4	45.1*	2.5	39.5	2.0	0.1	0.2	-	-	9.9	4.0	11.2	2.3
	Agility Comp. (s)	36/40	18.22	0.24	18.13	0.23	18.29	0.25	18.19	0.22	-0.02	0.02	-	-	0.09	0.03	0.10	0.02
	10 m Sprint (s)	36/40	1.73	0.04	1.73	0.04	1.76	0.04	1.76	0.04	-0.00	0.00	-	-	0.00	0.00	0.00	0.00
	30 m Sprint (s)	35/40	4.10	0.10	4.14	0.10	4.23	0.11	4.17	0.10	-0.01	0.01	-	-	0.02	0.01	0.01	0.00
	Yo-Yo IR2 (m)	12/40	791	226	780	199	801	0	801	168	22	26	-	-	47229	25051	30267	8518

Table notes: n = number of individual players with data included for analysis/total number of individual players observed; Q1 = players born September-November, Q2 = players born December-February, Q3 = players born March-May, Q4 = players born June-August; SE = Standard Error; CA = chronological age; APHV = age at peak height velocity; CMJ = countermovement jump; Agility Comp. = agility composite; Yo-Yo IR1 or IR2 = Yo-Yo Intermittent Recovery Test Level 1 or 2

Values are provided as means and SE. Chronological age (U11 to First Team) and APHV (U11 to U16 only) were used as covariates.

*denotes significant ($P \leq 0.05$) compared to Q4, ^ denotes significant covariate

3.4 Discussion

The aims of this chapter were to investigate the prevalence of relative age effects within each age group; and secondly, to explore between-quartile differences in somatic maturity, anthropometry and physical performance characteristics within each age group. To the author's awareness, this is the first study to examine these themes using participants from a professional English football club, with Category 1 academy status, since the EPPP was introduced.

The current findings demonstrated strong RAEs upon entry to the academy (U9), as well as throughout adolescence (U12 to U16) (**Table 3.1**). Despite the magnitude of RAEs decreasing with age, the proportion of Q4 players remained low throughout the entire club (3.2 to 14.7%). The findings presented in this chapter concur with previous literature demonstrating a systematic selection bias in favour of relatively older players (Deprez et al., 2012; Helsen et al., 2012). Previous data obtained from English centres of excellence indicate that 49.1% of players (9 to 16-year-old) were born in Q1, with only 9.9% from Q4 (Simmons and Paull, 2001). Corresponding data from this chapter demonstrates that 44.0% and 6.6% of U10 to U18 players were from Q1 and Q4, respectively. Allowing for methodological differences between both studies, it is apparent that a selection bias due to relative age is firmly embedded within English youth football, with the percentage of selected Q4 players reducing over time. Moreover, the data obtained within this chapter indicate that odds ratios for each quartile in comparison with Q4 were typically greater across age groups, compared with a study of youth footballers registered to professional English clubs (competing in League 1 and 2) during the 2012/13 season (Lovell et al., 2015). This finding appears to support the suggestion that Category 1 academies demonstrate a stronger

penchant for RAEs (Pérez-Jimenez, 2008). Thus, the current findings suggest that top categorised academies under the new EPPP framework in England are particularly at risk of an amplified selection bias due to relative age, though additional evidence involving analysis of different club categorisations is required.

Between-quartile comparisons for somatic maturity revealed similarities for each age group (**Table 3.2**), yet a significant difference was observed for U11 players, with Q4 players demonstrating a lower APHV compared to Q1 peers (13.1 vs 13.4 years, respectively). It would appear that in accordance with previous research, relatively younger players demonstrating advanced growth and/or maturity have an enhanced likelihood of being selected into an academy - particularly at the earliest stages of recruitment (Deprez et al., 2013; Hirose, 2009; Lovell et al., 2015). The findings also demonstrate lower mean APHV values for each corresponding age group compared to those reported by Lovell et al. (Lovell et al., 2015) suggesting that, in this Category 1 academy, selected players demonstrate advanced maturity compared with players selected by academies from lower-league teams in England. This corresponds with the aforementioned findings for RAEs, whereby higher categorised academies under the EPPP may also be at risk of an intensified selection bias due to advanced maturity, though as stated previously, comparisons of different club categorisations are required to confirm this notion. However, it is acknowledged that limitations exist with the current method to estimate APHV (Malina et al., 2015) (see **Sections 2.3.5** and **7.2**) and thus, the findings should be interpreted with caution.

Corresponding to a similar APHV for players born in different quartiles, anthropometric characteristics did not differ significantly in each age group, when adjusted for APHV and CA (**Table 3.2**). However, a closer inspection of players' height revealed the

seemingly high importance of this characteristic for selection. It has previously been reported that academy players born in each quartile from each age group were typically between 50th and 75th centile for height (Lovell et al., 2015) when compared to reference data (Royal College of Paediatrics and Child Health, 2012). However, allowing for different methodologies between studies, the data from this chapter revealed that players from U11 to U18 groups were typically around the 75th centile for height, with Q4 and Q3 players often residing above this. Most notable was the U14 group, where players from all quartiles were above the 75th centile, with Q3 and Q4 players around the 91st centile and between 91st and 98th centile, respectively. It has previously been established within youth ice hockey that RAEs are, at least in part, related to body size (Sherar et al., 2007); the findings from this chapter corroborate that players' advanced height for their CA – particularly for relatively younger players – appears related to their selection. An association between height and the perception of domain-specific giftedness has previously been demonstrated in youth football (Furley and Memmert, 2016) and the findings from this chapter suggest this discrimination could be enhanced within a Category 1 academy and certain age groups within it (i.e. U14). Accordingly, additional research is warranted to determine if characteristics such as height are able to distinguish the players that are subsequently retained or released within a top categorised academy.

Physical performances were also typically similar between-quartiles for each age group with APHV as CA as covariates (**Table 3.2**), corresponding with previous studies in youth football (Deprez et al., 2013; Lovell et al., 2015). This indicates that academies systematically select players that demonstrate homogenous physical performances for each age group – irrespective of the birth quartile the players belong to (Carling et al., 2012). However, issues arise with this apparent selection strategy,

specifically given that there are many other predictors of talent required for football performance other than physical and physiological factors (Williams and Reilly, 2000; Reilly et al., 2000b). Thus, many talented youth players that are competent in other factors related to high-level performance (e.g. psychological and technical skills) may be overlooked by academies if they do not meet the apparent benchmark required for physical performances (Zuber et al., 2016).

Previous studies have also identified practical advantages for Q1 versus Q4 players with regards to physical performances, highlighting benefits, albeit small, for being a relatively older player within an academy (Deprez et al., 2013; Lovell et al., 2015). In contrast, a novel finding of this chapter was that Q4 players tended to outperform other birth quartiles, with significant differences observed for several variables between U11 and U18 groups (**Table 3.2**). Specifically, Q4 players performed significantly better than Q1 players for Yo-Yo IR1 in U11, U13 and U14 groups and anaerobic running performance in U16 and U18 groups. Enhanced performance for relatively younger players has previously been observed in U19 and U21 German national teams (Skorski et al., 2016), suggesting potential performance benefits gained by Q4 players towards the end of adolescence. Still, the findings of this chapter are perhaps the first to demonstrate that within a highly selective group of players, with largely homogenous anthropometric profiles, Q4 players tend to achieve superior physical performances over Q1-born peers from childhood. This finding can be attributed to the methodological approach that was implemented. To the author's awareness, the application of multilevel modelling to analyse between-quartile differences is the first in the investigation of RAEs within youth football (Sarmiento et al., 2018). Accordingly, when chronological age and maturity are accounted for within statistical analysis, Q4 players demonstrate physical performances at a higher percentile compared to Q1

players within this academy. An alternative explanation is that relatively younger players were afforded developmental advantages from childhood, thereby enabling them to achieve superior performances. Indeed, contemporary research has identified some potential benefits of being a relatively younger and/or later maturing player, often referred to as the 'underdog' hypothesis (Gibbs et al., 2012; McCarthy and Collins, 2014). In a recent study of academy footballers, Cummings et al. did not find an association between self-regulation and relative age, though the authors do not disregard that other 'underdog' advantages (e.g. motivation, decision-making, resiliency) could be cultivated in relatively younger and/or later maturing players, possibly prior to academy selection (i.e. at grassroots) (Cummings et al., 2018b). In any case, the findings from this chapter likely reflect a complex interaction with multiple factors, where further research is warranted through a comprehensive investigation of the underdog hypothesis, within academy and grassroots football.

Other findings revealed that in the First Team, Q4 players were significantly inferior compared to all other birth quartiles for CMJ performance (**Table 3.2**). This suggests that at the end of adolescence, players from other birth quartiles are able to make substantial improvements in CMJ performance and catch-up with Q4 players, likely through systematic training prescribed by the club (Wrigley et al., 2014). On the other hand, this may be explained by the observation that, whilst not significant, Q4 players were also lighter than other birth quartiles, where enhanced fat-free mass is a predictor of CMJ performance towards the end of adolescence (Deprez et al., 2015c). Still, it is possible that, at the First Team level, once a minimum benchmark of physical performance is achieved, other factors related to performance are more important for enabling these players to be selected (Williams and Reilly, 2000). Deprez et al. demonstrated that physical performances were able to distinguish players identified

as retained or dropout from high-level youth teams in Belgium (Deprez et al., 2015e), though corresponding data for all age groups within a club – particularly entry to the First Team - is yet to be elucidated and warrants further investigation.

Taken together, the findings from this chapter demonstrate the recruitment strategy adopted by this club appears to be systematically limiting the entire talent pool of youth football players. Specifically, relatively younger and/or later maturing individuals are denied access to a high-level training environment, which may consequently lead to the premature dropout of football and loss of potentially talented players (Helsen et al., 1998; Malina et al., 2000). Corresponding to previous research, it seems that organisational pressures concerned with short-term goals (e.g. selecting players for immediate performance) outweigh the notion of recruiting and nurturing talent from a long-term perspective (Hill and Sotiriadou, 2016), where the latter is central the EPPP framework (Premier League, 2011). Therefore, this chapter provides contemporary evidence highlighting the need for policy-makers within this club (and beyond – due to similar findings across the literature (Meylan et al., 2010; Sierra-Diaz et al., 2017)), to actively nullify selection biases due to relative age and biological maturity, whereby changes to current practice and/or additional research is required. This includes thorough consideration of the club categorisation system and the potential for their associated differences (e.g. recruitment opportunities) to perpetuate and even amplify selection biases. Additionally, despite evidence of the RAE within this academy in comparison with the national population (**Figure 3.3**), there is a need to ascertain the prevalence of RAEs at lower playing levels (i.e. grassroots), given that high-level players may be selected from an already biased pool of players (Delorme et al., 2010b), which may have key implications for targeting the reduction of RAEs. The availability of research documenting RAEs in youth football over the past decade

(Sarmiento et al., 2018; Sierra-Diaz et al., 2017) appears to have had little impact on reducing selection biases within this academy, suggesting that more practical approaches are necessary. To this end, talent identification and selection processes would benefit by adopting holistic approaches (Sarmiento et al., 2018), as opposed to an overreliance on transient physical characteristics that likely have limited long-term stability (Buchheit and Mendez-Villanueva, 2013). Recently, Mann et al. demonstrated the potential application of age-ordered shirts to counteract RAEs (Mann and van Ginneken, 2017), though the merit of this approach requires longitudinal investigation within an applied setting. Given that (skeletal) maturation is a stronger determinant of selection into academies than birth date (Johnson et al., 2017), this factor should also be considered when implementing approaches aimed at reducing selection biases, where bio-banding may offer a practical solution (Cumming et al., 2017). If successful, such approaches may subsequently enhance the attainment of the primary aim of the EPPP within this academy; that is, converting a greater number of talented youth into high performing First Team and international-level players (Premier League, 2011).

Limitations specific to this chapter relate to the lack of anthropometric and physical performance measures obtained for U9 and U10 groups, meaning it is unclear which factors influenced RAEs in these groups. Furthermore, this study did not measure any other factors that are associated with RAEs (e.g. experience and psychological skills) (Cobley et al., 2009), as well as performance, including technical/tactical, psychological and sociological skills (Williams and Reilly, 2000). This also includes the absence of measures to ascertain maximal effort and/or motivation during fitness testing, which may also explain the superior performances of Q4 players (McCarthy and Collins, 2014; Hancock et al., 2013). Other limitations which are general to this

thesis are addressed in **Section 7.2**. Briefly, these relate to the lack of scope in the measurements utilised, statistical analysis, the method used to derive maturity and the generalisability of findings.

3.5 Conclusion

This chapter has identified a strong relative age effect across the entire developmental pathway within this professional English football club, with a Category 1 academy. The magnitude of the RAE was particularly high at the entry-point (U9) as well as throughout adolescence (U12-U16). Multilevel modelling demonstrated that somatic maturity, anthropometry and physical performances were largely similar between-quartiles for all age groups. However, Q4 players tended to perform better than Q1 players in U11 to U21 groups, supported by several statistically significant differences. Furthermore, selected players from each quartile were typically advanced in growth for their CA and/or demonstrated advanced maturity. Taken together, the findings within this chapter highlight the robust nature of selection biases within this Category 1 academy and indicate that these may be amplified in higher categorised academies under the EPPP framework. Accordingly, this study provides contemporary evidence highlighting the need for policymakers to actively seek ways to nullify selection biases in a bid to enhance the pool of players to select from. Further research is required to identify which playing level(s) should be targeted in order to reduce selection biases in English youth football, where a number of practical solutions have recently been proposed. In addition, there is a need to investigate if these selection biases are also discriminatory with regards to distinguishing players that are retained or dropout from highly selective cohorts – this is the focus of **Chapter 4**. In any case, selection strategies adopted by this academy, and other youth football clubs demonstrating

similar selection biases, should seek to be more inclusive by adopting appropriate solutions which may result in the identification of talented players that may otherwise go unnoticed.

Chapter 4. Study 2 - The Influence of Birth Quartile, Maturation, Anthropometry and Physical Performances on Player Retention: Observations from an English Football Academy

4.1 Introduction

Youth football development programmes operated by professional clubs principally aim to progress talented young players into the respective senior team (Premier League, 2011). In England, players can be formally recruited from 9 years of age by academies in order to develop a range of competencies deemed necessary for football performance (Williams and Reilly, 2000), within a nurturing environment that includes high quality facilities and coaching (Premier League, 2011). Previous research demonstrates that individuals selected by high-level youth teams can be distinguished from lower-level peers through a multitude of factors. Specifically, the former exhibit superior sport-specific (Figueiredo et al., 2009; Huijgen et al., 2014; Vaeyens et al., 2006), perceptual-cognitive and psychological skills (Toering et al., 2012; Reilly et al., 2000b; Coelho et al., 2010), anthropometric and/or physical performance characteristics (Figueiredo et al., 2009; Huijgen et al., 2014; Reilly et al., 2000b; Vaeyens et al., 2006; Coelho et al., 2010), as well as advanced CA and/or biological maturity (Figueiredo et al., 2009; Coelho et al., 2010). Of these factors, the most extensively studied in relation to talent identification in male football are birth date, biological maturity, anthropometry and physical performances (Sarmiento et al., 2018). In order for talent identification and selection processes to be highly successful, it is important to appraise current practice so that suitable improvements can be made in light of contemporary research.

As mentioned in **Section 2.4** and **2.5**, selection biases due to relative age and biological maturity are prevalent within youth football. Additionally, the findings from **Chapter 3** revealed that selection biases are highly robust, particularly within the current Category 1 academy. In light of these selection biases, many talented young

players that are born towards the end of the selection year and/or later maturing have been shown to prematurely dropout of football (Delorme et al., 2010a; Malina et al., 2000). This loss of talent at a young age would appear to contravene one of the main outcomes of football academies, that is, to develop talented youth into professional players (Premier League, 2011). However, albeit limited in number, recent evidence from across Europe suggests that the small number of relatively younger and/or later maturing players that are selected into high-level youth teams have a greater prospect of long-term success - defined as attaining professional status (Skorski et al., 2016; Ostojic et al., 2014). These findings may relate to the 'underdog' hypothesis, whereby developmental advantages are gained through playing with older (and earlier maturing) peers (Gibbs et al., 2012).

The aforementioned findings highlight problematic aspects of player recruitment in football academies. First, it is clear that youth teams discriminate against the selection of relatively younger players, yet, it remains unclear the extent to which birth date subsequently influences the likelihood of being retained throughout the developmental pathway. Second, whilst biological maturity, anthropometry and physical performance characteristics are able to distinguish between high and low-level youth players (Figueiredo et al., 2009), the suitability of these factors to determine the most successful players within highly selective cohorts appears questionable (le Gall et al., 2010; Franks, 1999).

To date, few studies have compared the characteristics of players that either persist or dropout from football academies. Deprez et al. identified that in 8 to 16-year-old players selected by high-level youth teams in Belgium, physical performances, but not age, anthropometry or maturity were able to distinguish retained and dropout players

from each annual age group (U10 to U17) (Deprez et al., 2015e). However, it remains unclear if physical performances and anthropometry exert an influence on the retention process beyond these ages, and ultimately towards attaining professional status. Furthermore, as talent identification and selection policies may differ across nations, due to multiple factors including task and environmental constraints as well as socio-cultural influences (Sarmiento et al., 2018), the characteristics that distinguish retained and dropout players may also vary.

Therefore, the purpose of this chapter was to investigate factors associated with player retention across a broad age range within an English football academy. To the author's awareness, this is the first study to explore the retention process within an English Category 1 academy across the developmental pathway, including entry to the First Team squad (i.e. retention from the U21 group). The primary aim was to investigate the influence of birth quartile on the likelihood of being retained between U11 and U21 age groups. The secondary aim was to compare somatic maturity, anthropometric and physical performance characteristics between retained and dropout players from each age group between U11 and U21.

4.2 Methods

Aim one sought to investigate the influence of birth quartile on retention, where 355 individual male football players were included. Players were born between 1990 and 2006 and were registered to the club between 2010/11 and 2016/17 seasons. Players represented an age group for each season they were registered to the club (i.e. U11 through U16, U18, U21). Detailed player characteristics are reported in **Section 3.2**.

Aim two sought to investigate differences between players that were identified as retained or dropout, which included 3016 data points from 353 players, born between 1990 and 2006. All players performed physical testing between 2010/11 and 2016/17 seasons. Players represented an age group for each season they were registered to the club (i.e. U11 through U16, U18, U21). Data was collected as described in **Section 3.2**, corresponding to mixed-longitudinal data. The total number of measurements for individual players were as follows: 1 (n=14), 2 (n=28), 3 (n=46), 4 (n=23), 5 (n=23), 6 (n=31), 7 (n=23), 8 (n=21), 9 (n=26), 10 (n=20), 11 (n=11), 12 (n=11), 13 (n=13), 14 (n=9), 15 (n=9), 16 (n=4), 17 (n=6), 18 (n=7), 19 (n=0), 20 (n=3), 21 (n=2), 22 (n=5), 23 (n=3), 24 (n=2), 25 (n=2), 26 (n=1), 27 (n=8), 28 (n=2).

For both aims in this chapter, each player was assigned to either a “retained” or “dropout” group according to their playing status throughout the study period. Retained players were individuals that remained registered to the club in the following season they completed testing for a respective age group, and thus represented the subsequent age group in the following season. Dropout players were individuals that were no longer affiliated with the club in the following season after they were tested in a respective age group. The club and players were made aware that data would be kept confidential which included anonymising the data to protect individuals’ identity and restricting use to the research team. Ethical approval for this chapter was received from the ethics committee from the University of Wolverhampton (**Appendix A**).

4.2.1 Design

An observational design was used to investigate birth quartile, somatic maturity, anthropometry and physical performance characteristics of academy football players that were identified as retained or dropout.

4.2.2 Procedures

Players underwent a fitness testing battery up to four times per season according to the detailed procedures outlined in **Section 3.2**. In brief, this included measurements obtained for: anthropometry, somatic maturity, physical performances (jump, 10 and 30 m sprint, agility t-test and Yo-Yo IR1 or IR2) and relative age.

4.2.3 Statistical analysis

To investigate the likelihood of being retained (dependent variable) from each age group across birth quartiles (independent variable), a binary logistic regression was conducted to derive odds ratios (OR) with 95% confidence intervals (CI) for between-quartile comparisons, with Q1 as the referent group. Logistic regression (odds ratio) analysis was conducted using SPSS version 24, with statistical significance accepted at the 95% confidence level ($P < 0.05$).

To investigate differences in somatic maturity, anthropometric and physical performance characteristics (dependent variables) between retained and dropout players (independent variable) in each age group (U11 through U21), mixed-longitudinal data was analysed using multilevel modelling (MLwiN software package, v 3.02, Bristol University, Bristol, UK). The rationale for using multilevel modelling has

been described in the previous chapter (see **Section 3.2.11**). To the author's awareness, this is the first study to use multilevel modelling to address this research question. Data was initially split according to standard age groups within the club. Thereafter, a model for each age group and dependent variable (chronological age, somatic maturity [U11 to U16 only], height, body mass, CMJ, agility composite, 10 m sprint time, 30 m sprint time and Yo-Yo Intermittent Recovery Level 1 or 2) was created separately, allowing for each player to be the level 2 variation (between-subject) and repeated measurements for each player to be the level 1 variation (within-subject). Furthermore, Cohen's *d* effect sizes (ES) and thresholds (0.2, 0.5 and 0.8 corresponding to *small*, *medium* and *large*, respectively) (Cohen, 1988) were used to compare the magnitude of differences between retained and dropout players for each dependent variable. Statistical significance was accepted at the 95% confidence level ($P < 0.05$). The following model was used to determine differences between retained and dropout players for dependent variables within each age group:

$$y_{ij} = \beta_0 + \beta_1 x_j + u_j + e_{ij}$$

where y is the dependent variable of interest on measurement occasion i for the j th player, and x_j corresponds to their playing status (i.e. a [0, 1] indicator variable where 0 is for retained, and 1 is for dropout); the parameter β_0 is called the intercept and corresponds to the overall mean of the dependent variable for retained players (the baseline or reference group); the parameter β_1 represents the difference between the retained and dropout players, specifically in the mean of the dependent variable. The symbol u_j represents the between-subjects (level 2 units) variable (assumed Normal $(0, \sigma_u^2)$) and the symbol e_{ij} represents the within-subjects (level 1 units) variable (assumed Normal $(0, \sigma_e^2)$), where both terms are assumed to be independent.

4.3 Results

4.3.1 Birth Quartile Analysis:

Examination of player retention from each age group (**Table 4.1**) revealed that Q4 players had the highest proportion of dropout in the U11 group; thereafter, the highest dropout from each age group came from Q1 or Q3. Players from Q1 contributed around half of the absolute number of dropout from each age group, where this was higher in U12 and U13 groups. Odds ratios revealed only one significant difference, with Q3 players in the U21 group 4.0 times more likely to be retained in comparison with Q1 (95% CI: 1.1-15.5). Players from Q4 tended to have a greater likelihood of being retained compared with Q1, and this was particularly evident in U13, U16 and U21 groups. Moreover, the percentage of players being retained from all birth quartiles was high between U11 and U13 groups (i.e. >84%) but decreased substantially at U14 (66.2%). Thereafter, the proportion of retained players typically decreased in each subsequent age group from U15 (81.6%) to U21 (45.1%).

4.3.2 Maturity, Anthropometry and Physical Performances:

Several statistically significant differences between retained and dropout players were observed in an age group dependent manner; retained players were typically older, advanced in somatic maturity, taller, heavier, and superior in physical performances (see **Table 4.2**). Retained players in the U12 group were significantly older and faster in the agility T-test and 30 m sprint. In the U13 group, retained players demonstrated a significantly lower APHV along with superior agility T-test performance. Players retained in the U14 group were significantly older, taller, heavier, and faster in the

agility T-test as well as 10 m and 30 m sprint tests. In the U15 group, retained players were significantly faster in the agility T-test. Retained players in the U16 group were significantly older and faster in the 10 m sprint test. Retained players in the U18 group achieved a significantly faster 30 m sprint time. In the U21 group, retained players were significantly faster in the agility T-test.

Table 4.1 Number (%) of academy players from each birth quartile identified as dropout or retained from each age group within the club, as well as quartile (Q) comparisons for the likelihood of being retained.

		Birth quartile					Q2 vs Q1 OR (95% CI)	Q3 vs Q1 OR (95% CI)	Q4 vs Q1 OR (95% CI)
		Q1	Q2	Q3	Q4	Total			
U11	Dropout	8 (14.8%)	4 (12.9%)	3 (15.8%)	3 (30.0%)	18 (15.8%)	1.2 (0.32-4.3)	0.9 (0.2-3.9)	0.4 (0.1-1.9)
	Retained	46 (85.2%)	27 (87.1%)	16 (84.2%)	7 (70.0%)	96 (84.2%)			
U12	Dropout	8 (14.5%)	4 (9.8%)	1 (6.3%)	1 (14.3%)	14 (11.8%)	1.6 (0.4-5.6)	2.6 (0.3-22.1)	1.0 (0.1-9.6)
	Retained	47 (85.5%)	37 (90.2%)	15 (93.8%)	6 (85.7%)	105 (88.2%)			
U13	Dropout	9 (16.7%)	2 (4.4%)	0 (0.0%)	0 (0.0%)	11 (8.7%)	4.3 (0.9-21.0)	#	#
	Retained	45 (83.3%)	43 (95.6%)	21 (100%)	6 (100%)	115 (91.3%)			
U14	Dropout	20 (35.1%)	15 (31.3%)	9 (37.5%)	2 (28.6%)	46 (33.8%)	1.2 (0.5-2.7)	0.9 (0.3-2.4)	1.4 (0.2-7.6)
	Retained	37 (64.9%)	33 (68.8%)	15 (62.5%)	5 (71.4%)	90 (66.2%)			
U15	Dropout	11 (22.0%)	6 (15.8%)	3 (15.0%)	1 (16.7%)	21 (18.4%)	1.5 (0.5-4.5)	1.6 (0.4-6.5)	1.4 (0.1-13.4)
	Retained	39 (78.0%)	32 (84.2%)	17 (85.0%)	5 (83.3%)	93 (81.6%)			
U16	Dropout	20 (45.5%)	19 (48.7%)	10 (50.0%)	1 (16.7%)	50 (45.9%)	0.8 (0.4-2.1)	0.8 (0.3-2.4)	4.2 (0.4-38.7)
	Retained	24 (54.5%)	20 (51.3%)	10 (50.0%)	5 (83.3%)	59 (54.1%)			
U18	Dropout	12 (34.3%)	7 (21.9%)	9 (52.9%)	2 (40.0%)	30 (33.7%)	1.9 (0.6-5.5)	0.5 (0.1-1.5)	0.8 (0.1-5.3)
	Retained	23 (65.7%)	25 (78.1%)	8 (47.1%)	3 (60.0%)	59 (66.3%)			
U21	Dropout	17 (73.9%)	14 (51.9%)	7 (41.2%)	1 (25.0%)	39 (54.9%)	2.6 (0.8-8.7)	4.0 (1.1-15.5)*	8.5 (0.7-98.2)
	Retained	6 (26.1%)	13 (48.1%)	10 (58.8%)	3 (75.0%)	32 (45.1%)			

Notes: OR = odds ratio; 95% CI = 95% confidence intervals.

* denotes significant difference vs Q1 (P<0.05); # denotes calculation could not be completed due to null values.

Table 4.2 Somatic maturity, anthropometric and physical performance characteristics of academy players identified as retained or dropout from U11 to U21 groups.

Age Group	Variable	Retained			Dropout			ES	Interpretation	Between-Subject Variance		Within-Subject Variance	
		n	Mean	SE	n	Mean	SE			Mean	SE	Mean	SE
U11	CA (y)	96	11.0	0.0	17	10.9	0.1	-0.39	Small	0.1^	0.0	0.1^	0.0
	APHV (y)	94	13.3	0.0	15	13.3	0.1	0.07	Small	0.1^	0.0	0.0^	0.0
	Height (cm)	94	147.7	0.7	15	145.1	1.8	-0.32	Small	37.9^	5.4	4.5^	0.5
	Body Mass (kg)	94	38.5	0.5	15	36.1	1.3	-0.40	Small	20.5^	3.0	4.5^	0.5
	CMJ (cm)	92	27.0	0.4	14	25.0	1.2	-0.38	Small	13.9^	2.3	8.2^	0.8
	Agility Comp. (s)	94	20.89	0.09	14	21.40	0.26	0.45	Medium	0.54^	0.11	0.61^	0.06
	10 m Sprint (s)	93	1.96	0.01	14	2.01	0.03	0.46	Medium	0.01^	0.00	0.00^	0.00
	30 m Sprint (s)	94	5.04	0.03	14	5.13	0.08	0.28	Small	0.06^	0.01	0.02^	0.00
	Yo-Yo IR1 (m)	41	885	45	6	785	142	-0.27	Small	43817^	18509	11504	17055
U12	CA (y)	106	12.0*	0.0	13	11.8	0.1	-0.53	Medium	0.1^	0.0	0.1^	0.0
	APHV (y)	103	13.6	0.0	13	13.5	0.1	-0.25	Small	0.2^	0.0	0.0^	0.0
	Height (cm)	103	154.1	0.7	13	151.5	2.0	-0.30	Small	44.3^	6.1	5.0^	0.5
	Body Mass (kg)	103	42.6	0.6	13	43.5	1.9	0.11	Small	38.6^	5.2	3.0^	0.3
	CMJ (cm)	105	27.5	0.5	12	25.9	1.4	-0.28	Small	17.5^	2.8	9.7^	1.0
	Agility Comp. (s)	106	20.73*	0.09	12	21.40	0.28	0.61	Medium	0.56^	0.10	0.58^	0.06
	10 m Sprint (s)	104	1.95	0.01	12	2.01	0.03	0.47	Medium	0.01^	0.00	0.00^	0.00
	30 m Sprint (s)	105	4.98*	0.03	12	5.18	0.08	0.59	Medium	0.06^	0.01	0.03^	0.00
	Yo-Yo IR1 (m)	44	982	48	5	574	164	-1.07	Large	63382^	21867	96249^	15690

U13	CA (y)	115	13.0	0.0	8	13.1	0.1	0.42	Small	0.0^	0.0	0.1^	0.0
	APHV (y)	113	13.6*	0.0	8	14.0	0.2	0.58	Medium	0.2^	0.0	0.0^	0.0
	Height (cm)	113	161.6	0.7	8	157.0	2.9	-0.46	Medium	58.7^	7.8	5.4^	0.5
	Body Mass (kg)	113	49.1	0.7	8	44.0	2.6	-0.55	Medium	49.9^	6.6	4.2^	0.4
	CMJ (cm)	112	30.8	0.5	8	27.2	1.9	-0.60	Medium	22.9^	3.4	7.2^	0.7
	Agility Comp. (s)	112	20.23*	0.07	8	20.85	0.28	0.67	Medium	0.48^	0.07	0.21^	0.02
	10 m Sprint (s)	111	1.88	0.01	8	1.94	0.03	0.53	Medium	0.01^	0.00	0.01^	0.00
	30 m Sprint (s)	111	4.79	0.02	8	4.96	0.09	0.54	Medium	0.05^	0.01	0.02^	0.00
	Yo-Yo IR1 (m)	45	1109	46	6	874	120	-0.68	Medium	45718^	19659	98414^	17220
U14	CA (y)	93	14.0*	0.0	42	13.8	0.1	-0.36	Small	0.0^	0.0	0.1^	0.0
	APHV (y)	93	13.5	0.1	40	13.6	0.1	0.16	Small	0.3^	0.0	0.0^	0.0
	Height (cm)	93	170.0*	0.8	40	167.0	1.4	-0.28	Small	53.9^	6.9	5.5^	0.5
	Body Mass (kg)	93	57.4*	0.8	40	53.9	1.5	-0.31	Small	60.0^	7.6	5.1^	0.5
	CMJ (cm)	89	34.2	0.6	36	32.6	1.1	-0.22	Small	26.2^	3.8	7.7^	0.8
	Agility Comp. (s)	89	19.63*	0.08	38	20.02	0.15	0.37	Small	0.36^	0.08	0.59^	0.06
	10 m Sprint (s)	89	1.81*	0.01	37	1.86	0.02	0.45	Medium	0.01^	0.00	0.01^	0.00
	30 m Sprint (s)	89	4.55*	0.03	37	4.70	0.05	0.40	Small	0.06^	0.01	0.03^	0.00
	Yo-Yo IR1 (m)	33	1325	52	17	1259	92	-0.18	Small	38107	20290	99580^	19584
U15	CA (y)	92	15.0	0.0	21	14.9	0.1	-0.25	Small	0.0^	0.0	0.1^	0.0
	APHV (y)	92	13.5	0.1	20	13.4	0.1	-0.23	Small	0.2^	0.0	0.0^	0.0
	Height (cm)	92	174.8	0.6	20	175.8	1.5	0.14	Small	33.4^	4.6	2.2^	0.2
	Body Mass (kg)	92	64.6	0.8	20	68.0	1.8	0.36	Small	50.8^	7.1	5.8^	0.6
	CMJ (cm)	91	37.5	0.5	20	35.2	1.3	-0.37	Small	21.2^	3.6	10.7^	1.2
	Agility Comp. (s)	92	19.11*	0.06	20	19.43	0.15	0.44	Small	0.28^	0.05	0.14^	0.01
	10 m Sprint (s)	92	1.76	0.01	20	1.78	0.02	0.31	Small	0.00^	0.00	0.00^	0.00

	30 m Sprint (s)	92	4.38	0.02	20	4.40	0.05	0.08	Small	0.03^	0.01	0.02^	0.00
	Yo-Yo IR1 (m)	33	1563	53	10	1374	120	-0.49	Medium	30648	23197	156153^	27631
U16	CA (y)	58	16.0*	0.0	48	15.8	0.1	-0.60	Medium	0.0^	0.0	0.1^	0.0
	APHV (y)	54	13.7	0.1	41	13.6	0.1	-0.04	Small	0.3^	0.0	0.0^	0.0
	Height (cm)	54	178.1	0.8	42	177.8	1.2	-0.03	Small	33.2^	4.9	1.3^	0.2
	Body Mass (kg)	54	69.4	0.9	42	68.4	1.4	-0.11	Small	42.4^	6.4	3.3^	0.4
	CMJ (cm)	53	37.9	0.6	38	38.0	1.0	0.02	Small	18.0^	3.3	6.9^	1.0
	Agility Comp. (s)	52	18.80	0.07	41	18.86	0.11	0.08	Small	0.19^	0.04	0.15^	0.02
	10 m Sprint (s)	54	1.74*	0.01	42	1.77	0.01	0.37	Small	0.00^	0.00	0.00^	0.00
	30 m Sprint (s)	54	4.27	0.03	42	4.35	0.04	0.29	Small	0.03^	0.01	0.01^	0.00
	Yo-Yo IR2 (m)	23	917	66	8	730	128	-0.49	Medium	84788^	25174	24122^	5673
U18	CA (y)	60	17.3	0.1	29	17.4	0.1	0.10	Small	0.1^	0.0	0.3^	0.0
	Height (cm)	58	180.9	0.8	29	180.4	1.4	-0.04	Small	38.8^	5.9	0.6^	0.0
	Body Mass (kg)	58	73.5	0.9	29	74.5	1.5	0.08	Small	43.5^	6.8	4.0^	0.3
	CMJ (cm)	60	40.1	0.5	28	39.1	0.9	-0.14	Small	13.5^	2.3	6.7^	0.6
	Agility Comp. (s)	60	18.55	0.06	27	18.68	0.11	0.17	Small	0.17^	0.03	0.13^	0.01
	10 m Sprint (s)	60	1.72	0.01	28	1.75	0.02	0.21	Small	0.00^	0.00	0.00^	0.00
	30 m Sprint (s)	60	4.20*	0.02	28	4.28	0.04	0.26	Small	0.03^	0.01	0.01^	0.00
	Yo-Yo IR2 (m)	26	820	37	12	877	66	0.21	Small	18445^	8265	43109^	6916
U21	CA (y)	34	19.0	0.1	37	19.1	0.2	0.03	Small	0.3^	0.1	0.4^	0.0
	Height (cm)	31	183.3	1.1	25	181.9	1.6	-0.14	Small	37.0^	7.0	0.3^	0.0
	Body Mass (kg)	33	78.1	1.2	35	76.7	1.6	-0.11	Small	43.6^	7.7	4.1^	0.4
	CMJ (cm)	32	40.5	0.9	34	40.2	1.2	-0.03	Small	19.2^	4.2	9.7^	1.3
	Agility Comp. (s)	32	18.22*	0.09	34	18.48	0.12	0.29	Small	0.20^	0.04	0.09^	0.01
	10 m Sprint (s)	32	1.69	0.01	35	1.71	0.02	0.14	Small	0.00^	0.00	0.00^	0.00

30 m Sprint (s)	32	4.11	0.03	35	4.14	0.04	0.10	Small	0.02 [^]	0.01	0.01 [^]	0.00
Yo-Yo IR2 (m)	20	880	45	13	924	74	0.14	Small	14411	10309	70397 [^]	12143

Notes: n = total number of individual players observed; ES = effect size; SE = standard error; CA = chronological age; APHV = age at peak height velocity; CMJ = countermovement jump; Agility Comp. = agility composite; Yo-Yo IR1 or IR2 = Yo-Yo Intermittent Recovery Test Level 1 or 2.

Values are provided as means and SE.

* denotes significant difference ($P < 0.05$) compared to Dropout group; ^ denotes significant ($P < 0.05$) between or within-subject variance.

Table 4.3 Proportions (in %) of academy players that were retained into the subsequent age group between 2010/11 and 2016/17 seasons.

	Transition to age group										
	U12	U13	U14	U15	U16	U17	U18	U19	U20	U21	First Team
U11	84.3	60.9	47.8	28.7	18.3	8.7	5.2	1.7	-	-	-
U12		97.3	78.4	40.5	27.0	13.5	10.8	2.7	-	-	-
U13			97.0	48.5	33.3	33.3	12.1	9.1	6.1	-	-
U14				73.0	51.4	51.4	8.1	5.4	2.7	2.7	2.7
U15					78.9	28.9	23.7	10.5	7.9	2.6	-
U16						88.0	76.0	40.0	24.0	20.0	8.0
U17							89.7	55.2	37.9	17.2	-
U18								85.7	57.1	35.7	21.4
U19									87.0	56.5	30.4
U20										50.0	25.0

Note: Percentages should be interpreted row-wise and refer to all players having played in the previous age group (column).

4.4 Discussion

The purpose of this chapter was to investigate factors associated with player retention from each age group within an English football academy, since the inception of the EPPP. Specifically, birth quartile, somatic maturity, anthropometry, and physical performance characteristics were examined to determine if these factors distinguish individuals identified as retained or dropout between U11 to U21 groups. This is the first study to investigate player retention across the developmental pathway within an English Category 1 academy, which includes the use of multilevel modelling for statistical analysis.

The findings for the first aim of this study revealed that despite an overrepresentation of relatively older players, once selected into this academy, birth quartile did not exert a significant influence on the likelihood of being retained throughout the developmental pathway (**Table 4.1**). To the author's awareness, the relationship between birth date and retention/dropout, after selection into a youth academy, has seldom been addressed within previous research (Sierra-Diaz et al., 2017; Sarmiento et al., 2018). Still, the current results corroborate the findings within a Spanish football academy, in which birth date was not associated with being retained or promoted to a higher playing level between U14 and U18 groups (Castillo et al., 2019). However, it must be acknowledged that the low number of Q3 and Q4 players within the current study represent drawbacks in the analysis. Indeed, future studies would benefit from adopting a longer study period and/or larger sample size to improve statistical power and thus yield stronger inferences.

Recent research conducted within football and ice hockey demonstrates that dropout is enhanced for Q4 players between 10-13 and 10-15 years of age, respectively (Lemez et al., 2014; Figueiredo et al., 2018). The findings within U11 and U12 groups demonstrate that Q4 players have a lower (OR: 0.4) and similar (OR: 1.0) likelihood of being retained compared to Q1 players, respectively (**Table 4.1**). Although, it must be noted that the total number of Q4 players was low in comparison with other quartiles for each age group. Several factors have been identified to contribute to dropout in youth sport, with a systematic review conducted by Crane and Temple reporting that relative age and perceptions of physical or sport competence are important (Crane and Temple, 2015). In support of these findings, Figueiredo et al. observed that the enhanced dropout of Q4 players may be related to coaches' perceptions of talent/competence; Q1 players were rated higher, had more entries to higher-level teams and fewer dropouts in subsequent years compared to Q4 players (Figueiredo et al., 2018). Additionally, the authors observed that despite being advanced in maturity, Q4 players typically demonstrated lower actual competence (assessed via physical performances and sport-specific skills) when compared to other birth quartiles. Therefore, it appears that Q4 players not only face discrimination that denies them selection into academies at a young age (Sierra-Diaz et al., 2017) (**Chapter 3**), but also from progressing from the youngest age groups within them (**Chapter 4**), which may be related to perceptions of and/or actual competence. However, it was beyond the scope of this chapter to examine the coaches' perceptions of player competence regarding retention/dropout, yet this warrants further exploration.

Similarly, Helsen et al. observed that football players born later in the selection year tended to dropout from 12 years of age (Helsen et al., 1998). Yet, within this academy, Q4 contributed a low number of players to the overall dropout from each age group,

and typically had a slightly higher likelihood of being retained (≥ 1.4 times) in comparison with Q1, between U13 and U21 groups (**Table 4.1**). This suggests that the low number of relatively younger players selected into this academy are considered highly talented, thereby facilitating their progression along the developmental pathway. Indeed, the findings from **Chapter 3** of this thesis revealed physical performance advantages for Q4 players between U11 to U21 groups. On the other hand, there was a large number of Q1 players that dropout from this academy, suggesting that many of these are erroneously recruited at a young age due to the relative age selection bias, which is robust within English youth football (Hill et al., 2019; Lovell et al., 2015; Simmons and Paull, 2001). Moreover, given that the prevalence of the RAE throughout this particular academy is strong (**Chapter 3**), it seems that the Q1 dropouts are typically being replaced by relatively older players (i.e. high turnover of Q1 players), which supports the findings of a top-level Spanish football academy (Bidaurrezaga-Letona et al., 2019). Consequently, many talented relatively younger players may miss developmental opportunities associated with systematic training and competition (Wrigley et al., 2014; Valente-dos-Santos et al., 2012d), and thus dropout from football (at all playing levels) prematurely (Helsen et al., 1998).

In the U18 group, Q4 had a similar likelihood of retention compared to Q1 (**Table 4.1**), though a large difference was observed in the U21 group, with Q4 players demonstrating an enhanced likelihood of being retained. The only statistically significant difference was observed in the U21 group, where Q3 players had a greater likelihood of being retained compared to Q1 players, though it is plausible that this is a result of a multiple comparisons issue. Nevertheless, such findings may indicate that at the end of adolescence, the small number of relatively younger players that have persisted demonstrate superior competencies (Skorski et al., 2016). Allowing for the

lower overall number of Q4 players in the U21 group, their higher proportion of retention compared to other birth quartiles aligns with previous findings in German football (Skorski et al., 2016; Grossmann and Lames, 2013) and English rugby union (McCarthy and Collins, 2014), highlighting potential long-term advantages for relatively younger players.

Taken together, the results of this chapter demonstrate a tendency for Q4 players to have a greater likelihood of being retained throughout the developmental pathway compared to Q1 players, which may be attributed to advanced maturity of Q4 players (Deprez et al., 2013; Hirose, 2009). Indeed, the findings from **Chapter 3** demonstrated that Q4 players typically had a similar estimated APHV compared to Q1 players, with a significantly lower APHV (i.e. advanced maturity) observed in the U11 group (see **Table 3.2**). This highlights that the maturity status of Q4 players was comparable with Q1 players in absolute terms, despite having a chronological disadvantage - this was also observed in other English academies (Lovell et al., 2015). Additionally, the Q4 players had a tendency to outperform Q1 players in physical performance tests throughout the developmental pathway (U11 through U21), and this is likely to have contributed to their enhanced retention rates observed within this chapter. An alternative and related explanation for the greater retention of Q4 players can be attributed to the 'underdog' hypothesis (Gibbs et al., 2012). This notion intimates that developmental advantages are gained through competing with relatively older and/or earlier maturing peers, which may include psychological effects (e.g. enhanced motivation to improve) (McCarthy and Collins, 2014) and compensation in technical skills (Zuber et al., 2016). In contrast, more recent evidence indicates that relatively older players within Australian football have long-term career advantages, which may be attributed to developmental opportunities gained from enhanced exposure from a

young age (compared to relatively younger players) (Tribolet et al., 2019). Unfortunately, it was beyond the scope of this chapter to investigate this notion further, though future research that examines developmental opportunities for both relatively older and younger players in a longitudinal manner would be useful.

Closer inspection of the individuals that were retained from the U21 group revealed that of the three Q4 players, only one was present at U18 – the point which he was also signed. Thus, the limited number of Q4 players that were retained at U21 were recruited towards the end of adolescence from clubs competing in lower divisions. On the other hand, six of the ten Q1 players that were retained at U21 were registered to the club by U16 (or below), demonstrating that they persisted longer within this top categorised academy. This finding could imply different routes to attaining professional status for relatively older and younger players, which may relate to individualistic and collectivistic approaches (Güllich, 2014), respectively, though further research is required. Still, the greater overall number of Q1 and Q2 players being retained from the U21 group (in comparison with Q4 players) is consistent with evidence demonstrating relative age effects persist into the top professional leagues in England (Fleming and Fleming, 2012; Rada et al., 2018).

Other key findings of this study relate to aspects of the player retention process throughout the developmental pathway. **Table 4.1** indicates a high percentage (i.e. > 84%) of players retained from U11 to U13 groups in comparison with the U14 group (66.2%). Subsequently, the proportion of retained players typically decreases progressively from the U15 group (81.6%) to the U21 group (45.1%), with the second-lowest proportion of retention within this academy observed in the U16 group (54.1%). These findings lack concordance with high-level youth teams from Belgium, where the

percentage of retained players remained consistent (73-78%) between U11 and U16 groups (Deprez et al., 2015e). This could suggest that talent identification within this academy before U14 and U16 groups is somewhat ineffective given the high turnover of players from these groups. Alternatively, it may reflect the financial constraints associated with adopting a full-time training model and/or providing scholarships (Premier League, 2011), thereby limiting the number of players that can be retained from these groups. The data presented in **Table 4.3** shows the proportion of players that are retained from each age group and subsequently progress along the developmental pathway. Importantly, less than 50% of players were retained for at least three seasons (except for players recruited at U14) and less than 13% of players from each age group between U11 to U14 progress to the U18 group within this academy. The low proportion of retention along the developmental pathway corresponds with observations from German academy and youth national teams – implying a collectivistic approach for players that eventually attain professional and national team status (Güllich, 2014; Schroepf and Lames, 2018). These findings highlight that practitioners within this academy (and across youth football) should be cognisant of individualistic and collectivistic approaches, and the potential for the former – which is currently emphasised in English academies (Premier League, 2011) - to exert an unintended effect on the latter (e.g. raising performance levels), within lower categorised academies and/or grassroots clubs (Güllich, 2014).

The second aim of this chapter was to investigate the differences in somatic maturity, anthropometric and physical performance characteristics between retained and dropout players from U11 to U21 groups. Multilevel modelling revealed significant differences amongst these factors in an age group dependent manner (**Table 4.2**). This contrasts previous research demonstrating the unsuitability of these factors in

distinguishing the most talented players within highly selective cohorts that are exposed to systematic training (le Gall et al., 2010; Franks, 1999). Specifically, the results demonstrate that between U11 to U21 groups, retained players were typically superior in physical performance tests, where effect sizes were typically *small* to *medium* (**Table 4.2**). This corroborates previous findings that retained players within European football academies (Deprez et al., 2015e; Bidaurrezaga-Letona et al., 2019) and Australian (rules) football (Tribolet et al., 2018) achieved superior physical performances. Buchheit et al. reported that performances on field tests were related to match-running performance (in a position-dependent manner) (Buchheit et al., 2010), where superior match-running performance is also related to retention across age groups within an English academy (Goto et al., 2015). Of note, the current findings also revealed that (modified) agility T-test performance was superior for retained players in five out of the eight age groups investigated. This suggests that the agility T-test is particularly valuable for distinguishing players that progress along the developmental pathway within a highly selective cohort. Collectively, these findings highlight the influence of physical performances on the selection (see **Chapter 3**) and retention processes that operate within this academy.

In contrast to the findings by Deprez et al., no clear trends were observed for physical performances to distinguish retained players in relation to the timing of peak height velocity (Deprez et al., 2015e). Although, findings for the U14 group appear pertinent in that agility T-test and sprint performances were all significantly discriminant (**Table 4.2**), suggesting that retained players experienced performance enhancements concomitant with peak height velocity (Philippaerts et al., 2006). The discrepancy between both studies may reflect differences in the samples investigated and/or the

importance of specific factors that influence retention within high-level youth teams across countries; this warrants further investigation.

The second aim also revealed that retained players were typically advanced in maturity (i.e. lower APHV), taller, and heavier than dropouts (**Table 4.2**), with a greater number of significant differences for these variables evident in comparison with Deprez et al. (Deprez et al., 2015e). Specifically, as significant differences for these variables were evident in U13 and U14 groups (especially the latter), which aligns with mean values for estimated APHV, it suggests that retained players were experiencing accelerated growth. Comparisons with UK normative height values indicates that retained players between U11 and U18 groups were typically just above the 75th centile, whereas dropouts were typically just below the 75th centile (Royal College of Paediatrics and Child Health, 2012). Interestingly, retained players in U13 and U14 groups were between the 75th and 91st centile, with dropouts residing around the 50th and 75th centile, respectively. This highlights that retention in these groups favours individuals undergoing an earlier onset and/or advanced tempo in growth – corresponding with research from Australian football (Tribolet et al., 2018) - where superior height may enhance a coach's perception of player giftedness (Furley and Memmert, 2016).

Within U18 and U21 groups, there was a tendency for retained players to demonstrate superior anthropometric and physical performance characteristics compared to dropouts, with significant differences observed only for 30 m sprint and agility T-test, respectively (**Table 4.2**). This partially supports the findings by Emmonds et al. in which it was observed that players offered professional contracts at U18 achieved superior sprint (10 and 20 m) as well as Yo-Yo IR2 performances (Emmonds et al.,

2016). Given that retained players were also significantly younger in both U18 and U21 groups (current chapter), several explanations are proposed. First, this may simply reflect an artefact of the methodological approach adopted, whereby players categorised as dropout were typically in their final year within each age group (i.e. one or two years older). Alternatively, the tendency to retain younger players may be related to a greater (perceived) potential for long-term improvements by talent selectors (e.g. coaches). Finally, the lack of significant differences between retained and dropout players in these groups could suggest that, as both groups precede the First Team, other relevant predictors of performance could discriminate between the most talented players (Williams and Reilly, 2000; Bidaurrezaga-Letona et al., 2019; Castillo et al., 2019). In any case, additional research in these age groups is warranted to better understand the factors that influence progression into the First Team squad.

A synthesis of analyses from both aims of this study revealed that U14 and U16 groups had an atypically low percentage of retention (**Table 4.1**). Retained players in both age groups demonstrated superior age and sprint performance - similar to previous findings (Emmonds et al., 2016; Deprez et al., 2015e), as well as greater body size and agility performance in the U14 group (**Table 4.2**). The emphasis on running-based performances for retention in both groups is likely related to the observation that match-running performance requirements (e.g. total and sprinting distance and peak game speed) typically increase in subsequent age groups following retention from U14 and U16 groups (Buchheit et al., 2010; Saward et al., 2016). Furthermore, sprinting is an important action during decisive moments within football, such as reaching a ball before an opponent to score or prevent a goal (Faude et al., 2012).

Finally, the findings from the second aim of this chapter suggest that somatic maturity, anthropometric and physical performance characteristics exert an influence on the decision-making process regarding player retention within this academy. Data from Australia has demonstrated that youth coaches and recruitment staff consider technical, tactical and psychological attributes to be the most important factors in terms of talent identification for U13 players (Larkin and O'Connor, 2017). Similarly, a recent survey of multidisciplinary staff in England demonstrated that the perceived importance of psychological factors for player selection was significantly greater than sociological, technical/tactical and physical factors; technical/tactical factors were rated significantly higher than sociological and physical factors (Towlson et al., 2019). Though the influence of multidisciplinary factors for player retention per se were not explored in these studies, the findings suggest that individuals involved in youth talent selection consider non-physical factors to be the most important. This contrasts the findings of the current chapter where physical factors appear discriminant in a highly selective cohort (i.e. top categorised academy), though it must be acknowledged that multidisciplinary factors (i.e. technical/tactical, psychological and sociological) were not measured. On the other hand, Towlson et al. also observed that sociological and physical factors were rated significantly higher in the Youth Development Phase (U12-U16) compared to the Foundation Phase (U9-U11) (Towlson et al., 2019), which corroborates previous findings that the characteristics influencing selection are age group dependent (i.e. dynamic in nature) (Vaeyens et al., 2006), and also aligns with the findings of this chapter. Moreover, the current findings appear to parallel previous research establishing that organisational pressures and physical maturity exert an influence on the selection process adopted by the coaches of 12 to 15-year-old football players (Hill and Sotiriadou, 2016). The conflicting evidence in the aforementioned

studies could relate to a discordance between what talent selectors perceive to be the most important factors regarding player selection (and retention) and the factors that ultimately influence this within practice, where the findings in this chapter highlight that physical factors are able to distinguish players that are retained within an English academy. However, whilst there is some indication, albeit limited, that physical performances are related to future career success (Gonaus and Muller, 2012; Huijgen et al., 2014), the long-term stability of physical characteristics is questionable, thereby restricting their suitability for talent identification and selection processes within youth football (Buchheit and Mendez-Villanueva, 2013). Indeed, recent studies in youth football players demonstrate that peak development of the discriminating factors that were observed between U11 to U14 groups (i.e. anthropometry and physical performances) do not subside until around 15-17 years of age or post-peak height velocity (Fransen et al., 2017; Towlson et al., 2018). Therefore, in order to recruit and develop the most talented players, decision-making processes regarding player retention would benefit from placing less emphasis on anthropometric and physical performance characteristics until this time (Tribolet et al., 2018). Moreover, as previously stated, there appears to be a lack of affinity between what talent selectors perceive to be important and what ultimately influences selection and retention within applied practice; this issue warrants further investigation.

It must be acknowledged that there are several limitations relating to the current chapter. First, the low number of Q4 players we observed for this study is typical of football academies, where previous research has accounted for this by using bi-annual age groups for statistical analysis (Lovell et al., 2015). However, this may mask important information that operates in an age group dependent manner (Vaeyens et al., 2006). Additionally, it must be noted that retention/dropout may be influenced by

the age at which the individual first joined the academy (Huijgen et al., 2014) (among other factors), and thus future studies should seek to account for this. Thus, it is suggested that the findings for aim one of this study be interpreted with caution. Secondly, this study did not measure any other qualities that are deemed relevant for football performance (Williams and Reilly, 2000) and thus retention/dropout. Finally, it is acknowledged that the raw dataset used in this study (i.e. without ascribing retained and dropout groups), which has been obtained from an applied setting, was also available to the coaches at the club, and thus may have influenced the decision-making process on player retention. However, it was beyond the scope of this study to determine if this was the case in the current club, though other research indicates that knowledge of birth date does not nullify the relative age selection bias (Hill and Sotiriadou, 2016). Still, qualitative research is warranted to gain a clearer understanding of the decision-making process adopted by coaches and other talent selectors. Specifically, the identification of factors that influence selection and retention in highly selective cohorts would be useful. Other limitations which are general to this thesis are addressed in **Chapter 7.2**, which relate to the lack of scope in the measurements utilised, statistical analysis, the method used to derive maturity and the generalisability of findings.

In terms of future directions, the implementation of suggested approaches such as a 'Futures' team (Vandendriessche et al., 2012) and/or 'bio-banding' (Cumming et al., 2017) may enable talented youth players demonstrating inferior maturity and/or physical attributes an opportunity to continue development within a high-level environment, as opposed to premature dropout (Helsen et al., 1998; Malina et al., 2000). With regards to the latter approach, this has recently been investigated from a player development perspective, where both early and late maturing players reported

positive experiences (Cumming et al., 2018a). This observation would appear to have implications for early maturers in particular, given that the additional challenge provided by bio-banding may facilitate greater developmental opportunities for these players (Collins and MacNamara, 2012). In any case, there is currently a lack of empirical evidence justifying the use of these approaches for player selection and retention purposes. Additionally, future research identifying multidisciplinary factors that influence retention within highly selective teams would be useful, which could include longitudinal investigations of motor coordination (Deprez et al., 2015e; Vandendriessche et al., 2012) as well as technical, tactical, psychological, and sociological factors (Williams and Reilly, 2000). Indeed, several authors have reported that multidisciplinary factors can distinguish the most successful youth players (Vaeyens et al., 2006; Huijgen et al., 2014; Reilly et al., 2000b; Zuber et al., 2016; Forsman et al., 2016). Similarly, additional research that considers the most pertinent factors associated with dropout is required, particularly within the unique context of a football academy (Crane and Temple, 2015). Such investigations would help to provide greater context to the observation in this study that the standard errors for investigated variables typically overlapped between retained and dropout players. This suggests that some dropouts may have demonstrated similar (or even superior) characteristics to retained players, yet likely had weaknesses for other competencies necessary for football performance; this warrants further exploration.

4.5 Conclusion

The first aim of this chapter revealed that birth quartile does not exert a significant influence on being retained within an English Category 1 academy, between U11 and U21 groups. Still, players born in Q4, albeit low in number, typically demonstrate an

enhanced likelihood of persisting between U13 to U21 groups compared to Q1 players, and there is a seemingly high turnover of Q1 players throughout the developmental pathway. The second aim of this study revealed that retained players typically demonstrated superior age, somatic maturity, anthropometric and physical performance characteristics between U11 to U21 groups, with significant discriminatory factors identified in age group dependent manner and *small to medium* effect sizes typically observed. Taken together, the findings demonstrate that once selected into this English Category 1 academy, birth quartile does not significantly affect retention, yet somatic maturity, anthropometry and physical performance characteristics can distinguish individuals that are retained along the developmental pathway. However, given the large inter-individual variability in biological maturity, there is a need for additional research to examine the development of these characteristics in accordance with somatic maturity - this is subsequently addressed in **Chapter 5**. Nevertheless, given the transient nature of these discriminatory factors, talent selectors within this academy should seek to place less emphasis on these during the selection and retention process of players. Instead, a multidisciplinary and dynamic approach that considers these alongside technical, tactical, psychological and sociological factors would likely prevent unnecessary discrimination and loss of talented young players.

Chapter 5. Study 3 – Growth Curves of Anthropometry and Physical Performances According to Somatic Maturity

5.1 Introduction

Football talent is predicted by multidisciplinary factors (Williams and Reilly, 2000), with youth players selected by high-level youth teams demonstrating superior attributes compared to peers at lower playing levels (Figueiredo et al., 2009). However, biological maturity can vary considerably for individuals of the same CA (Malina et al., 2004a), and exert an influence on many predictors of talent as well as selection and retention (Meylan et al., 2010; Hill and Sotiriadou, 2016; Johnson et al., 2017; Malina et al., 2000). However, an overreliance on these factors for player selection and retention during adolescence can be considered a drawback given that the long-term stability of these factors can be questioned (Buchheit and Mendez-Villanueva, 2013); late maturers are also observed to catch up with earlier maturing peers after adolescence (Lefevre et al., 1990). Therefore, regular monitoring of an individual's biological maturity, anthropometric and physical performance characteristics can be deemed an important consideration for researchers and practitioners (Lloyd and Oliver, 2012).

In particular, it has been suggested that benchmarking player competencies according to maturity status (instead of only chronological age) could be advantageous for identifying individuals with the greatest potential (Lefevre et al., 1990; Jones et al., 2000; Cumming et al., 2017); the enhanced perspective for player appraisals in this way might offer a solution to counteracting the maturation-related selection bias observed within **Chapters 3 and 4** of this thesis. Given that assessments of somatic maturity are favoured in studies of youth football players (see **Section 2.3**), it is necessary to determine how this indicator can be used for maturity-based benchmarking. Moreover, as anthropometric and physical performance characteristics

are discriminant for player retention across the developmental pathway, within this academy (see **Chapter 4**), an examination of how these factors develop according to somatic maturity would appear valuable for applied practice (e.g. appraisal of players).

The development of pertinent variables (e.g. physical performances) in accordance with biological maturity can be determined through growth curves, where several methods are commonly employed (Malina et al., 2004a). First, differences for the variable of interest between individuals of contrasting maturity status can be examined relative to chronological age (Lefevre et al., 1990; Valente-dos-Santos et al., 2012d; Malina et al., 2004a); second, the relationship between the variable of interest and a maturity indicator (e.g. years from peak height velocity) can be estimated (Malina et al., 2004a; Beunen and Malina, 1988; Philippaerts et al., 2006; Towlson et al., 2018). Recently, developmental trajectories of anthropometric and physical performance characteristics, in relation to somatic maturity, were examined within 23 English youth academies, where periods of accelerated development were identified for all investigated variables (Towlson et al., 2018). However, despite presenting valuable findings, the authors acknowledged that the cross-sectional nature of the dataset was a limitation; specifically, the lack of repeated measurements for individuals per year during adolescence may not accurately reflect the rapid changes of growth and maturation that occur during this important period (Malina et al., 2004a). Instead, repeated measurements for individuals are desirable as it enables a more realistic view of biological processes (Grajeda et al., 2016). Accordingly, multilevel modelling has been identified as a suitable method to investigate developmental changes (e.g. for physical performances) that occur over time (Valente-dos-Santos et al., 2012d), given that repeated measures nested within individuals can be handled appropriately (Charlton et al., 2019).

Therefore, determination of growth curves through contemporary statistical analysis (i.e. multilevel modelling) can complement previous research and may identify novel findings that can enhance applied practice. Specifically, the ability to estimate when development for these characteristics initiate, peak and plateau (along the entire maturity spectrum) could facilitate youth players' being appraised by their maturity status to a greater extent, thereby mitigating selection biases observed within this academy (**Chapters 3 and 4**).

Thus, the aim of this chapter was to examine growth curves for anthropometry and physical performance characteristics according to somatic maturity, within a sample of youth football players from a Category 1 academy. Moreover, this includes the use of biologically plausible and contemporary statistical analysis to derive time-points relating to the initiation, peak and plateau of development for each variable.

5.2 Methods

To investigate the growth curves for anthropometry and physical performances according to somatic maturity, this chapter included a sample of 279 individual male football players. Players were aged between 9.6 and 17.2 years and were registered to the club between 2010/11 and 2016/17 seasons. Players represented an age group for each season they were registered to the club (i.e. U11 through U17). Player characteristics are reported in **Section 3.2**. Data was collected as described in **Section 3.2**, corresponding to mixed-longitudinal data. The total number of measurements for individual players were as follows: 1 (n=27), 2 (n=44), 3 (n=23), 4 (n=22), 5 (n=27), 6 (n=17), 7 (n=14), 8 (n=22), 9 (n=10), 10 (n=19), 11 (n=9), 12 (n=13), 13 (n=4), 14 (n=5), 15 (n=4), 16 (n=4), 17 (n=4), 18 (n=2), 19 (n=3), 20 (n=5).

The club and players were made aware that data would be kept confidential which included anonymising the data to protect individuals' identity and restricting use to the research team. Ethical approval for this chapter was received from the ethics committee from the University of Wolverhampton (**Appendix A**).

5.2.1 Procedures

Players underwent a fitness testing battery up to four times per season according to the detailed procedures outlined in **Section 3.2**. In brief, this included measurements obtained for: anthropometry, somatic maturity (maturity offset), and physical performances (jump, 10 and 30 m sprint, agility t-test and Yo-Yo IR1).

5.2.2 Statistical analysis

The mixed-longitudinal data was initially inspected, where changes for anthropometry and physical performance characteristics, relative to maturity offset (YPHV) indicated that developmental curves typically followed a flattened S-shaped pattern – referred to as a sigmoidal curve (LampI, 2012). Given that the dataset included repeated measurements within (Level 1 variation) and between individuals (Level 2 variation), analysis was performed using multilevel modelling (MLwiN software package, v 3.02, Bristol University, Bristol, UK), which also permits the use of data where measurement occasions vary between individuals (Charlton et al., 2019). Statistical significance was accepted at the 95% confidence level ($P < 0.05$).

Polynomial models were used to construct growth curves for all anthropometric (height and body mass) and physical performance (CMJ, agility composite, 10 and 30 m sprint time, Yo-Yo IR1) variables (dependent variable) in accordance with years from peak

height velocity (YPHV) (independent variable). A cubic function was applied to polynomial models given that cubic fits are deemed appropriate to capture the non-linear development of anthropometry and physical performances with somatic maturity. Indeed, a cubic function assumes that growth is continuous and smooth, and is well-suited to capture developmental curves when growth is substantial (e.g. around PHV), and represents a biologically sound approach for the current dataset (Grajeda et al., 2016).

The polynomial (cubic) model is given, denoted by the following equation:

$$y = a + bYPHV + cYPHV^2 + dYPHV^3$$

where y denotes all the anthropometric (height and body mass) and physical performance (CMJ, agility composite, 10 and 30 m sprint time, Yo-Yo IR1) variables.

The point of inflection, which corresponds to the point when maximum acceleration in growth/development occurs, was determined by differential calculus. The rate of increase in y is given by:

$$dy/dx = b + 2cYPHV + 3dYPHV^2$$

The rate of acceleration in y is given by:

$$d^2y/dx^2 = 2c + 6dYPHV$$

For the point of inflection, set $d^2y/dx^2 = 0$, $YPHV = -2c/6d = -c/3d$

The turning points represent the points at which growth initiates and subsequently plateaus. To find these turning points, when the y is either minimum or maximum, set $dy/dx = 0$ and solve for YPHV. These turning points (using simple algebra) are found to be given when:

$$YPHV = \pm \text{Sqrt}((c/3d)^2 - b/3d) - c/3d$$

Finally, plots of the growth curves for each anthropometric and physical performance variable, including the point of inflection and turning point(s) were generated within SPSS (version 24).

5.3 Results

An overview of the points of inflection, turning points, between and within-subject variances for each of the anthropometric and physical performance characteristics are presented in **Table 5.1**. The visual representation of growth curves for anthropometric and physical performance characteristics according to YPHV (maturity offset), including the fitted cubic curves and points of inflection are presented in **Figures 5.1 to 5.3**.

5.3.1 Anthropometry:

With regards to height, peak development (i.e. point of inflection) occurred at an estimate of -2.4 YPHV, with the first and second turning points estimated at -8.2 and +3.4 YPHV, respectively. In relation to body mass, the point of inflection was observed at an estimate of -0.1 YPHV. Corresponding turning points for body mass were

estimated at -5.1 and +5.0 YPHV. All between and within-subject variances were significant for both anthropometric variables.

5.3.2 Physical performances:

The point of inflection for Yo-Yo IR1 performance was estimated at -0.6 YPHV, where estimates of turning points were identified at -2.4 and +1.3 YPHV. Peak development for 10 and 30 m sprint performance were estimated at -0.1 and +0.0 YPHV, respectively. Turning points for 10 m sprint performance were estimated at -3.0 and +2.8 YPHV, and at -3.4 and +3.4 YPHV for 30 m sprint performance. Estimated peak development was identified at +0.5 YPHV for agility composite performance, corresponding to -3.2 and +4.2 YPHV for turning point estimates. Finally, the estimated point of inflection for CMJ performance occurred at +0.9 YPHV, with estimated turning points at -2.7 and +4.4 YPHV. Between and within-subject variances were all significant for each physical performance variable.

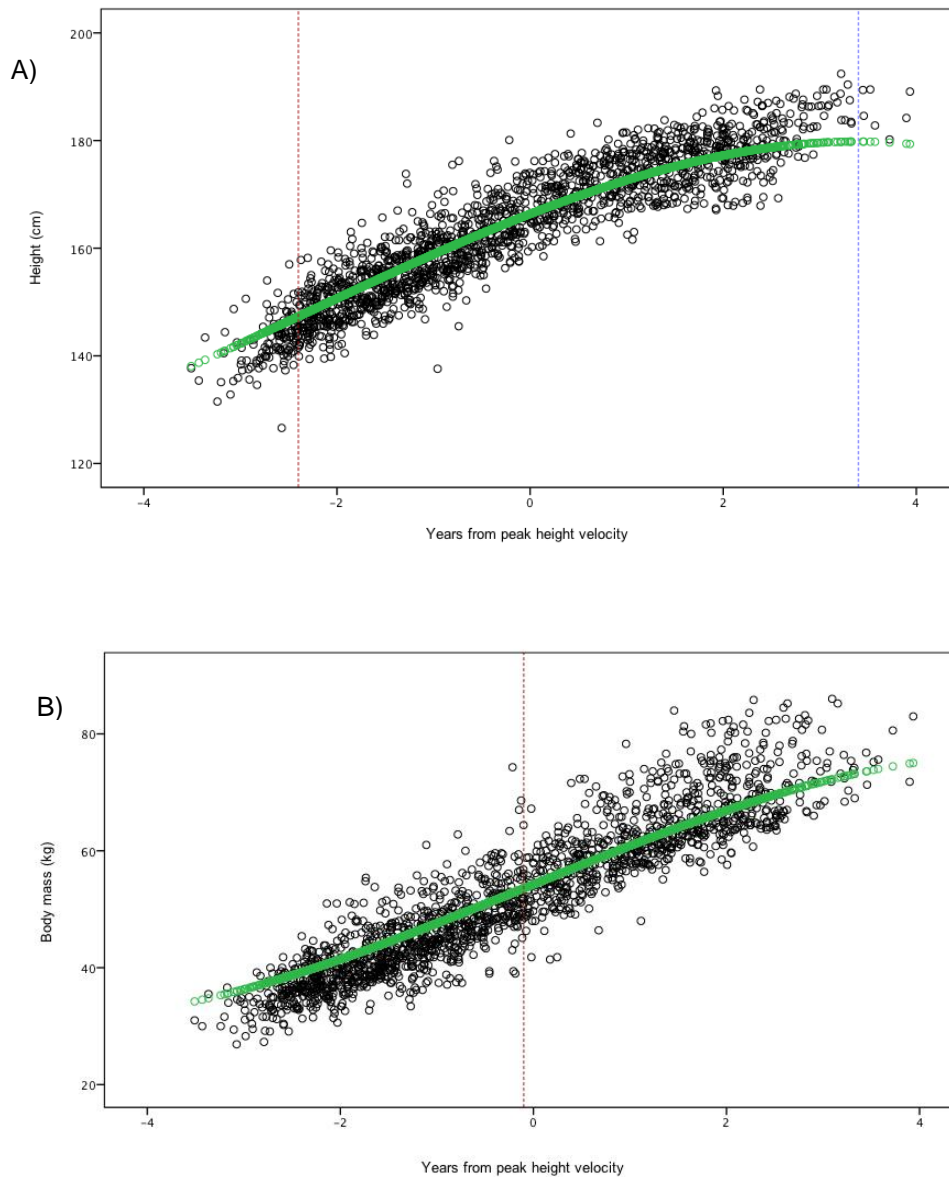


Figure 5.1 Growth curves of anthropometric characteristics according to years from peak height velocity (maturity offset), plus fitted cubic curves (green line), point of inflection (red dashed line) and turning point(s) (blue dashed line). Pane A = height (cm); Pane B = body mass (kg).

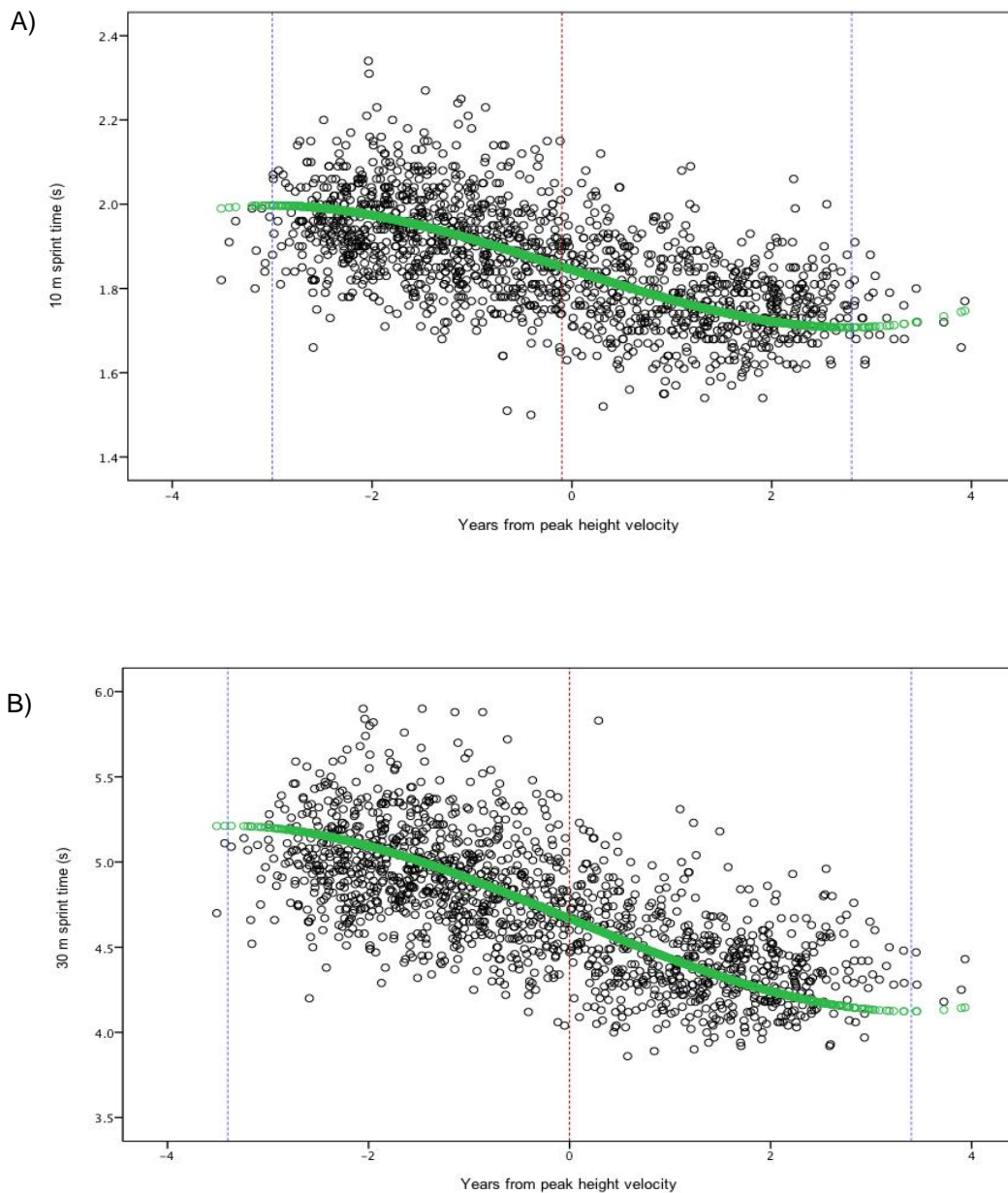


Figure 5.2 Growth curves of 10 and 30 m sprint performance according to years from peak height velocity (maturity offset), plus fitted cubic curves (green line), point of inflection (red dashed line) and turning point(s) (blue dashed line). Pane A = 10 m sprint time (s); Pane B = 30 m sprint time (s).

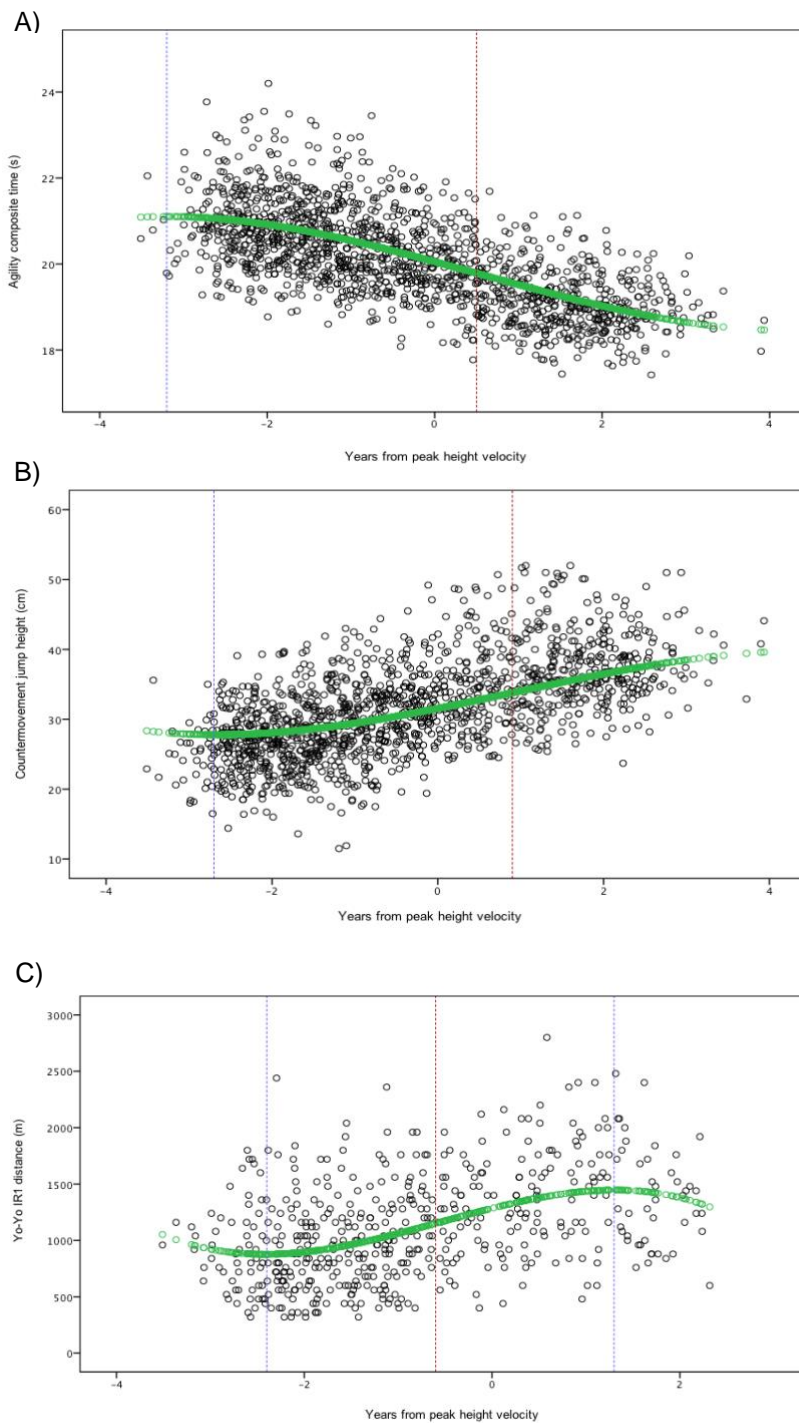


Figure 5.3 Growth curves of agility, jump and aerobic endurance performance according to years from peak height velocity (maturity offset), plus fitted cubic curves (green line), point of inflection (red dashed line) and turning point(s) (blue dashed line). Pane A = agility composite time (s); Pane B = countermovement jump height (cm); Pane C = Yo-Yo intermittent recovery level 1 (Yo-Yo IR1) distance (m).

Table 5.1 Model estimations corresponding to the point of inflection and turning points, relative to years from peak height velocity, for anthropometric and physical performance variables, including between-subject and within-subject variances.

Variable	n	Point of inflection (YPHV)	Turning point – initiate (YPHV)	Turning point – plateau (YPHV)	Between-subject variance	SE	Within-subject variance	SE
Yo-Yo IR1	519/1829	-0.6	-2.4	+1.3	57738	11487	113579	8080
10 m Sprint	1483/1829	-0.1	-3.0	+2.8	0.01	0.00	0.01	0.00
30 m Sprint	1501/1829	0.0	-3.4	+3.4	0.06	0.01	0.03	0.00
Agility Comp.	1495/1829	+0.5	-3.2	+4.2	0.38	0.04	0.29	0.01
CMJ	1455/1829	+0.9	-2.7	+4.4	20.8	2.1	10.2	0.42
Height	1829/1829	-2.4	-8.2	+3.4	18.9	1.7	3.2	0.11
Body Mass	1829/1829	-0.1	-5.1	+5.0	25.0	2.2	3.1	0.11

Table notes: n = number of measurements included for analysis/total number of measurements observed; YPHV = years from peak height velocity; SE = Standard Error; CMJ = countermovement jump; Agility Comp. = agility composite; Yo-Yo IR1 = Yo-Yo Intermittent Recovery Test Level 1.

5.4 Discussion

This chapter sought to examine the growth curves of anthropometry and physical performances according to somatic maturity, through contemporary analysis, to identify when development of each variable initiates, peaks and plateaus. The key findings highlighted that for all variables, except for height, estimated peak development (identified by the point of inflection) occurred in the period (i.e. ± 1 year) around predicted PHV. Additionally, the estimation of turning points revealed that the initiation and plateau of heightened development for investigated variables typically occurred within the maturity spectrum (-4 to +4 YPHV) of the current sample. Finally, multilevel modelling highlighted that between and within-subject variances were significant for each variable investigated.

Peak development for all indicators of physical performance (**Table 5.1**) occurred around estimated PHV (-0.6 to +0.9 YPHV) which generally corresponds with previous research in samples of youth football players (Philippaerts et al., 2006; Deprez et al., 2015a; Mendez-Villanueva et al., 2010; Towlson et al., 2018) and suggests that the observed performance enhancements are related to biological changes concomitant with PHV (Malina et al., 2004a). Although, peak development for jump and agility performance occurred slightly after, and endurance performance slightly prior to, estimated PHV, in comparison with a previous study (Philippaerts et al., 2006); variability in the tests administered or prediction error associated with the equation to derive maturity offset (in the current study) (Mirwald et al., 2002) could explain the differences. Nevertheless, the results of the current chapter corroborate previous research documenting the relationship between PHV and physical performances

(Philippaerts et al., 2006; Towlson et al., 2018; Beunen and Malina, 1988), thereby providing justification for regular monitoring of biological maturity and appraisal of player competencies according to an individuals' maturity status (Cumming et al., 2017; Jones et al., 2000; Meylan et al., 2010; Lloyd and Oliver, 2013; Till et al., 2018).

The current chapter also identified that the initiation and plateau of development for sprint and Yo-Yo IR1 performance is largely confined within the current maturity spectrum (**Figure 5.1**), suggesting a relatively high contribution of biological maturity. Given the methodological differences between studies, it was observed that accelerated development (estimated through turning points) for sprint performance occurred over a broader period in this study compared with previous findings (Towlson et al., 2018; Philippaerts et al., 2006). Whilst there are methodological differences between studies, this may reflect sprinting enhancements associated with training and match exposure within this Category 1 academy (Wrigley et al., 2014), resulting in an earlier onset of, and sustained, development (Mendez-Villanueva et al., 2010), though additional evidence is required to confirm the potential influence of club categorisation on development. The earlier plateau of Yo-Yo IR1 (+1.3 YPHV) in comparison with sprinting performance (+3.0 to +3.4 YPHV) likely relates to the low number of players performing this particular test in the post-PHV period, as the Yo-Yo IR2 test is used from U16 onwards at the current club. Alternatively, it may imply that training exposure for players in the post-PHV period (i.e. from +1.0 YPHV) at this club is insufficient at sustaining performance improvements, where training volume is a predictor of aerobic performance (Valente-dos-Santos et al., 2012a).

Similar to the aforementioned findings, the estimated initiation of development for agility and CMJ performances occurred after the lower limit of -4.0 YPHV (**Figure 5.1**).

On the other hand, the estimated turning points corresponding to the plateau in development for both variables were just beyond the upper limit of +4.0 YPHV (**Table 5.1**), suggesting that other factors (aside from those coinciding with PHV) contribute to the sustained development of these characteristics during the post-PHV period. It has previously been observed that jump performance is predicted by anthropometry (particularly fat-free mass) (Deprez et al., 2015d; Figueiredo et al., 2011; Malina et al., 2004b), and continues to develop beyond 17 years of age (approximately +3.0 YPHV) (Deprez et al., 2015d), which corresponds with the findings from the current chapter. Similarly, agility performance is predicted by anthropometry (including fat-free mass), and has been shown to continue development towards the end of adolescence (approximately 18 years of age or +4.0 YPHV) (Valente-dos-Santos et al., 2014b), which aligns with the current results. Other findings revealed that estimated development for body mass initiates (-5.1 YPHV) and plateaus (+5.0 YPHV) beyond the current maturity spectrum, thereby indicating a lower relative contribution of biological maturation compared to physical performances (as highlighted above). This could be explained by the observation that increases in body mass, particularly fat-free mass, have been attributed to exogenous factors (e.g. training, (Suarez-Arrones et al., 2018)) more so than height (Tanner et al., 1966). Taken together, these findings suggest that increases in fat-free mass lead to body mass enhancements with advancing maturity (Teixeira et al., 2015; Malina et al., 2004a), and thereby facilitate the continued development of agility and CMJ performance during the post-PHV period, though additional evidence is required to confirm this notion.

With regards to height, there was a lack of concordance between the estimated point of inflection (indicating the point of maximal growth) and predicted timing of PHV – where height gain is expected to be at its greatest (during adolescence) (Tanner et al.,

1966). Specifically, the point of inflection for height was estimated at -2.4 YPHV (**Table 5.1**) which corresponds to approximately 11.5 years of age, though mean APHV for the current sample was estimated as 13.5 years of age. In a previous study, the period of enhanced development for height persisted between -3.2 to +0.8 YPHV (or approximately 10.7 to 15 years of age) (Towlson et al., 2018), in which the authors suggested a reason for the earlier onset of height could be due to their sample comprising of relatively older players with advanced growth (Lovell et al., 2015). Similarly, findings from **Chapters 3** and **4** of this thesis identified that height was a particularly discriminatory factor for selection and retention within this club, where players also demonstrated advanced growth in comparison with national reference data. Thus, it is possible that the continual selection and retention of players demonstrating advanced growth is responsible for the early estimated inflection point for height in the current sample, which may include individuals demonstrating a midgrowth spurt (Malina et al., 2004a). Additionally, given that only 0.7% of the total measures corresponded to players between -4 to -3 YPHV in the current sample, this may have influenced the early estimated inflection point within the current statistical model, where additional data (e.g. U9 and U10 groups) would have enabled stronger inferences to be made. Finally, it is also possible that this finding highlights limitations with using the current predictive equation for maturity (see **Sections 2.3.5** and **2.3.6**) on the present sample (which is somewhat ethnically diverse), where secular changes in body size could be also be responsible. Research conducted in a biracial sample of North American children observed that boys' height increased between 1973 to 1992, with a greater tempo observed between 9 and 12 years of age, and larger increases identified for black boys compared with white boys (Freedman et al., 2000). Another study conducted between 1972 and 1994 identified that English children (white) are

becoming taller for each age between 5 and 11 years (Hughes et al., 1997). Therefore, whilst contemporary evidence is required, it can be speculated that should the aforementioned findings be applicable to the present sample, it would provide further justification for updated/creation of methods to estimate PHV, and it stresses caution when utilising the aforementioned somatic methods as they may not be representative of current samples within youth football (see **Section 2.3.5**). Nevertheless, it must also be noted that the current statistical analysis, which identifies the average growth curve from mixed-longitudinal data (i.e. players dropping in and entering sporadically), may have masked the actual development for height that occurs longitudinally at the individual-level, around the true PHV – reported to occur at approximately 13.8 ± 0.8 (Philippaerts et al., 2006) to 14.1 ± 0.1 years (Tanner et al., 1966); longitudinal data is suggested for accurately modelling human growth (Low, 1970; Malina et al., 2004a). Elsewhere, it was observed that the inflection point for body mass was -0.1 YPHV (**Table 5.1**), yet previous longitudinal research indicates that peak weight velocity (i.e. body mass in this chapter) occurs after PHV (Tanner et al., 1966). Therefore, the aforementioned issues suggested to affect the estimations for height may also be applicable to body mass, where it should be acknowledged that both variables are also used as predictors for deriving YPHV (Mirwald et al., 2002). Other findings revealed that the estimated plateau of height in the current sample (+3.4 YPHV or approximately 17 years of age) aligns with longitudinal studies which indicate that adult height is attained between 18 and 22 years of age (Malina et al., 2004a), where the slightly lower estimate in the current findings could reflect the predominance of early maturers within this club, as identified in **Chapters 3** and **4**.

An advantage of this chapter is the contemporary statistical analysis utilised, thereby enabling between (level 2) and within-subject (level 1) variances to be estimated. The

observed significance for both level 1 and 2 variances highlight that the growth curves for investigated variables differ significantly between individuals, and within-individuals at each testing moment, thereby demonstrating the advantage of using mixed-longitudinal data with repeated measures per year. Furthermore, through the use of multilevel modelling, there is scope for future studies to include suitable level 3 variables (e.g. club categorisations, playing status and ethnicity) (Malina et al., 2004a), thereby enabling the appropriate comparison of different sub-groups within samples which could provide useful findings (Philippaerts et al., 2006; Towlson et al., 2018; Wrigley et al., 2014; Meylan et al., 2010).

The aforementioned findings appear to have several theoretical implications for applied practice. First, **Chapter 4** of this thesis revealed that retained players within each chronological age group were typically distinguished by superior physical performances. However, the current chapter estimated the growth curves of these discriminatory characteristics and observed that inflection points occur around PHV (-0.1 to +0.9 YPHV) and plateaus occur during the post-PHV period (CMJ and agility: after +4 YPHV; sprint: +2.8 to +3.4 YPHV). Therefore, it is suggested that a greater consideration of players' maturity status (e.g. YPHV) may reduce the penchant for superior physical performances to distinguish player retention across the developmental pathway within this academy, especially before players have experienced peak development and/or reached their plateau in performance (Towlson et al., 2018; Tribolet et al., 2018). The identification of biologically plausible growth curves within this chapter may, tentatively, serve as a reference point to estimate where an individual is situated on the curve (e.g. 'ahead of the curve' or 'behind the curve') for physical performances based on their maturity status, and thereby reduce the maturation-related selection bias identified in **Chapters 3 and 4**. Although,

limitations associated with the method to predict somatic maturity (Mirwald et al., 2002) (see **Sections 2.3.5 to 2.3.7 and 7.2**) and the lack of 'pure' longitudinal data within this chapter should be acknowledged (Low, 1970).

Second, the relationship between somatic maturity and physical performance characteristics identified within this chapter provides justification for the use of bio-banding (Cumming et al., 2017). Specifically, the growth curves demonstrate that marked differences in anthropometry and physical performances can be expected for players that differ in somatic maturity status (which could be within the same CA group), where bio-banding may offer a solution to reducing these physical discrepancies. Actually, the reduction of physical discrepancies via bio-banding has recently been investigated from a player development perspective, where both early and late maturers have reported several benefits, although it must be noted that percentage of predicted adult height attained was used as the grouping variable (Cumming et al., 2018a), not maturity offset as per the current chapter. In any case, the potential benefits of bio-banding for reducing the maturation-related selection bias, as identified within **Chapters 3 and 4** of this thesis, is yet to be elucidated and warrants investigation.

There are several limitations that are specific to this chapter that require acknowledgement. First, whilst there was no control group to partition the effects of training exposure (within the academy) and biological maturation, this sample was drawn from a single club, meaning that exposure differences (e.g. training modality, volume and intensity) are expected to be lower than other research utilising multiple clubs and/or playing levels (Towson et al., 2018; Philippaerts et al., 2006). Still, as the players within this chapter were from a single club, the generalisability of the findings

is limited. Second, given that the estimates of turning points for many variables were beyond the current maturity spectrum of -4 to +4 YPHV, there is a need for methods of estimating PHV to be validated in additional age groups to those used within this chapter. Finally, it is recognised that despite the current statistical approach permitting analysis of the current mixed-longitudinal dataset, the use of cubic polynomials may not have been the most appropriate model to employ for all variables and interpretation of model parameters is not straightforward, where future studies should seek to improve methodology through longitudinal data, for example. Other limitations which are general to this thesis are addressed in **Section 7.2**.

5.5 Conclusion

This chapter identified growth curves for anthropometric and physical performance variables through the utilisation of mixed-longitudinal data fitted with cubic polynomials. The results demonstrate that peak development of physical performance variables (and body mass) occur around PHV, where the turning points corresponding to the initiation and plateau of development differ between variables. Furthermore, multilevel modelling identified significant between and within-subject differences for all investigated variables, highlighting the need to for practitioners to acknowledge individual variability in development. The current findings highlight that anthropometry and physical performances can differ drastically for individuals within the same CA group but with a varying somatic maturity status. Therefore, it is suggested that anthropometric and physical performance characteristics be evaluated in accordance with biological maturity (in addition to chronological age), especially with regards to important developmental timepoints (e.g. initiation, peak and plateau). Theoretical applications of these findings may include maturity-based benchmarking and

organising groups according to maturity (i.e. bio-banding) – thereby offering a potential solution to reducing the maturation-related selection bias within this academy; the latter approach is the focus of **Chapter 6**.

Chapter 6. Study 4 – Coaches’ Experiences of a Bio-Banding Intervention Within an English Football Academy: Implications for Talent Identification, Retention and Development

6.1 Introduction

In youth sports, players are typically organised by their chronological age into groups (e.g. annual or bi-annual), where specific cut-off dates determine how individuals are allocated (Cobley et al., 2009). The main purpose of this categorisation system is to promote fair competition, reduce injury risk and ultimately provide an equal opportunity of success for each participant (Musch and Grondin, 2001). However, even within these chronological age groups, a large individual variability can exist between players competing with each other, especially regarding biological maturity (Cumming et al., 2017; Musch and Grondin, 2001).

Biological maturation, which refers to progress towards an adult-like state, is largely responsible for differences observed between individuals within an age group (Malina et al., 2004a) (see **Sections 2.3 to 2.5**). Moreover, individual differences in the timing and tempo of maturation for different bodily systems is evident (Malina et al., 2004a). Accordingly, as identified in **Chapter 5**, individuals that are advanced in biological maturity typically demonstrate anthropometric, physical performance, as well as cognitive, psychological advantages compared to later maturing peers (Jones et al., 2000; Goldstein, 1987; Van den Berg et al., 2012). It is unsurprising then, that within sporting contexts, earlier maturing individuals are favoured for selection over later maturing peers (Sherar et al., 2007; Malina et al., 2000; Till et al., 2010; Zuber et al., 2016) (see **Chapters 3 and 4**). Recent evidence from academy-level football suggests that biological maturity is a stronger determinant of selection than birth date (Johnson et al., 2017), thereby highlighting the need to acknowledge this factor within youth sport.

In recognition of the variability observed between individuals, a number of approaches have been proposed and adopted across youth sports to facilitate fair competition and reduce injury risk. For example, age-weight categories are typically used in combat sports (Albuquerque et al., 2016), as well as some contact sports (Campbell et al., 2018; Kerr et al., 2015). More recently, Cummings et al. have advocated the process of grouping players according to biological maturity status - referred to as bio-banding - as an adjunct to chronological age grouping (Cumming et al., 2017). The authors propose that this approach may have a range of functions within youth sports, which include enhancing talent identification and development. Indeed, the impact of bio-banding for player development was recently investigated during a tournament for 11 to 14-year-old academy football players; qualitative evidence obtained from the participants highlighted that bio-banding provided positive experiences for both late and early maturing players (Cumming et al., 2018a). However, bio-banding was only investigated from a player development perspective, with other potential applications requiring elucidation.

Perhaps the most warranted application of bio-banding relates to talent identification and retention processes, especially as biological maturation can exert a profound influence on both (Meylan et al., 2010), as identified in **Chapters 3** and **4**. One suggested application is to supplement the benchmarking of physical performance data (e.g. field-based tests and on-field performance) according to maturity, in addition to chronological age (Cumming et al., 2017; Jones et al., 2000). Still, whilst physical performances can influence selection, retention and future playing status (Gonaus and Muller, 2012; Deprez et al., 2015e; Figueiredo et al., 2009), an overreliance on these factors can be considered one-dimensional and inappropriate given that predictors of football performance are multidisciplinary and dynamic (Williams and Reilly, 2000;

Sarmiento et al., 2018; Vaeyens et al., 2008; Zuber et al., 2016). Indeed, coaches of high-level youth players report that technical (i.e. first touch, one-versus-one ability, striking the ball, and technique under pressure), tactical (i.e. decision-making) and psychological (i.e. coachability and positive attitude) skills are deemed the most important from a talent identification perspective (Larkin and O'Connor, 2017). The successful appraisal of such competencies require context-specific conditions (i.e. real play), which offer greater ecological validity compared to field-tests performed in isolation (Unnithan et al., 2012). Indeed, relevant predictors of talent such as game intelligence, attitude and peak competencies (e.g. physical and technical skills) can only be determined through real play (Christensen, 2009). However, at present, players are habitually grouped according to chronological age and are thereby constrained by the confounding effects of biological maturation (Meylan et al., 2010), where the findings of **Chapter 5** highlight the differences expected for anthropometry and physical performances for players that vary in maturity status. Therefore, in accordance with previous research (Cumming et al., 2018a), it can be speculated that the utilisation of bio-banding during match-play and/or training would enable the holistic evaluation of player competencies that predict football performance, in an ecologically valid format.

To date, there is a dearth of empirical evidence corresponding to the application of bio-banding within applied settings. Whilst players' experiences of a bio-banding intervention have demonstrated benefits from a developmental perspective (Cumming et al., 2018a), the potential applications for player recruitment and retention remain unclear. In particular, given that coaches and scouts typically adopt the role of talent selectors in football (Williams and Reilly, 2000), there is a need to establish the impact of bio-banding on these individuals. Recent qualitative evidence has elucidated

several factors influencing the decision-making process regarding talent selection in youth football, whereby physical maturity and organisational pressures (e.g. immediate player performances and peer pressure) were reported as pertinent for coaches, subsequently resulting in selection biases (Hill and Sotiriadou, 2016; Reeves et al., 2018c). Accordingly, it would appear that the successful reduction of selection biases is dependent on, at least in part, impacting the decision-making process of talent selectors. In order to ascertain how a bio-banding intervention may provide benefits from this perspective, it is clear from the aforementioned qualitative research that a similar approach would be advantageous. Specifically, a qualitative approach would permit the impact of bio-banding (i.e. benefits and limitations) to be explored, in context, from the viewpoint of the talent selector.

Considering the above, it remains unclear if a bio-banding intervention has the potential to impact the decision-making process of talent selectors, especially as physical maturity and organisational pressures have been shown to contribute. Therefore, the purpose of this chapter was to adopt a qualitative approach to examine academy coaches' experiences of a bio-banding intervention, particularly regarding the influence on the decision-making process for player selection/retention and the observation of player competencies

6.2 *Methods*

6.2.1 Participants

This chapter adopted convenience and criterion-based sampling to identify participants that would be suitable for detailing their experience of the bio-banding

intervention through interviews (Patton, 1990). Crucially, participants were required to be involved with the talent selection process at the club in some capacity and employed by the club (i.e. full-time or part-time basis). Additionally, participants needed to have worked with any of the main corresponding age groups used for the bio-banding intervention (U12, U13 and U14) for a minimum of one year, thereby having regularly observed all players in these age groups during training and match-play. It was also deemed important that participants had worked within youth football for a minimum of five years, thereby demonstrating adequate experience within the domain. Finally, participants were required to be present throughout the entire bio-banding intervention. Subsequently, it was identified that the coaches (n=6) from each of the corresponding age groups would be the most appropriate, particularly as they had observed players during training and match-play more consistently than the scouting staff.

All coaches (n=6) were originally contacted through personal communication, and all six agreed to participate. All participants were male, with an age range from 28 to 44. All coaches held a minimum UEFA B coaching qualification and had varied experiences within professional and academy-level football. The coaches had a combined working time in football of 68 years (mean = 11 years) and had coached at this particular club for a combined time of 44 years (mean = 7 years).

All parties involved with this study (i.e. club/coaches/parent/guardian/players) were fully informed about the nature of the research prior to commencing. Passive consent was obtained from the parent/guardian(s) of the players taking part in the bio-banding intervention, with the coaches acting in loco parentis. Assent was obtained from the club and consent obtained from the coaches to use all the data obtained anonymously.

Ethical approval for this chapter was received from the ethics committee from the University of Wolverhampton (**Appendix A**).

6.2.2 Interviews

Following the bio-banding intervention, appropriate dates and times for interviews with the coaches were scheduled through personal contact or email correspondence. Face-to-face interviews conducted on a one-to-one basis were preferred as this would enable each coach to share information-rich experiences that may not be possible in focus groups (Sparkes and Smith, 2014). As the author had a 'participant-observer' or 'embedded researcher' role within the club and had previously built rapport with all coaches (Sparkes and Smith, 2014; McGinity and Salokangas, 2014), interviews were deemed a practical and viable option. However, due to time constraints and practical issues, this was not always possible. Thus, telephone interviews were conducted with two out of six coaches, where the benefits of additional data were deemed to outweigh the limitations of this approach (Opdenakker, 2006; Holt, 2010). In these cases, coaches were provided with brief instructions to mitigate any potential issues that may affect data collection (Sparkes and Smith, 2014). For example, participants were instructed to: 1) ensure their mobile phones were fully charged and/or had a charger connected; 2) find a suitable location with good network signal; 3) find a quiet location in order to minimise an interruption and maximise audio clarity.

All interviews were semi-structured, with a pre-planned interview schedule guiding discussions, but also allowing for appropriate flexibility to permit a greater depth of knowledge to be gathered (Sparkes and Smith, 2014). The interview questions were developed towards fulfilling the gaps in knowledge identified within the primary research questions. That is, ascertaining the influence of bio-banding on: how the

coaches perceived players' competencies from a holistic perspective and perceived potential applications within applied practice (including for player selection and retention). Whilst interview piloting was not possible due to the constraints of this environment (time and availability), the interview questions were deliberated thoroughly according to relevant guidelines (Sparkes and Smith, 2014). Consequently, it was deemed essential to use appropriate terminology for clarity, adopt open-ended questions, and focus on addressing the primary research questions (i.e. not too many questions).

Subsequently, the interview schedule consisted of three main areas: 1) observation of players throughout bio-banding (e.g. 'did you notice any differences when observing the players in bio-banding compared to normal age groups?'); 2) pros and cons of bio-banding (e.g. 'how do you think bio-banding could be used, if at all, within the academy programme?'); 3) overall experience (e.g. 'what was your view of the bio-banding intervention?'). Prior to the interviews, the coaches were reminded to reflect on observations from both bio-banding training and match-play. Additionally, probing encouraged the coaches to elaborate and provide greater detail on their experiences (e.g. 'could you provide some more detail?') (Leech, 2003). Also, prompts were aligned with some questions, when necessary, to gather more data in relation to the primary research questions if the coach didn't allude to it (e.g. 'any players in particular?') (Leech, 2003). The coaches were also offered the opportunity to discuss any other points that they deemed relevant to the study. Finally, following the interviews, the coaches were encouraged to ask any other questions they had in relation to the study, which led to discussions around the potential applications of this study.

All interviews were digitally recorded (Sony ICD-UX523F) and transcribed verbatim. Audio data for telephone interviews ($n=2$) were recorded from audio playback via a MacBook Pro (Apple Inc., Cupertino, CA), which enabled a greater audio volume to be achieved for recording purposes. To ensure anonymity, coaches' names were removed from interview transcripts and renamed C1 to C6. Interviews ranged in length from 12 to 23 min (total = 102 min; mean = 17 min). Interview transcripts are provided in **Appendix C**.

6.2.3 Group composition

This bio-banding intervention (i.e. training and match-play) included a total of 29 youth male football players as described in **Section 3.2**. Initially, there were 45 players considered for the intervention, registered to U11 through U14 groups during the 2018/19 season, but only 28 outfield players were able to complete the bio-banding intervention (U11: $n=2$; U12: $n=10$; U13: $n=7$; U14: $n=9$). Included players were aged between 10.9 and 13.9 years old and born between 2004 and 2007.

Maturity status of all players was determined through the assessment of anthropometry and the predictive equation outlined in **Section 3.2**, with measurements obtained by the author in the month prior to the intervention. Subsequently, estimations of maturity offset were derived, and this variable was used to order and classify players from U11, U12, U13 and U14 groups into approximately equal squads for the bio-banding intervention - guided in part by the findings of **Chapter 5**. The range in maturity offset for the players involved was between -3.0 to +0.1 years from peak height velocity. The squads were devised according to the following: Bio-Band 1 (percentile 1-33), Bio-Band 2 (percentile 33-66), Bio-Band 3 (percentile 66-100). Accordingly, the group composition for bio-banding were as

follows: Bio-Band 1, U11 (n=2), U12 (n=8), U13 (n=1); Bio-Band 2, U12 (n=2), U13 (n=5), U14 (n=2); Bio-Band 3, U13 (n=1), U14 (n=7). Characteristics for each of the bio-banding groups, as well as the corresponding squads for each chronological age group, are provided in **Table 6.1**.

Table 6.1 Anthropometric and somatic maturity characteristics of players according to each bio-banding group (intervention) and chronological age group (complete registered squad).

	Bio-Band 1 (n=11)	Under 12 (n=16)	Bio-Band 2 (n=9)	Under 13 (n=10)	Bio-Band 3 (n=8)	Under 14 (n=15)
Chronological age (y)	11.3 ± 0.5* [^]	11.2 ± 0.4	12.5 ± 0.7	12.3 ± 0.4	13.2 ± 0.7	13.3 ± 0.3
Height (cm)	145.4 ± 3.6 [^]	148.4 ± 6.4	150.9 ± 6.4 [^]	153.5 ± 7.0	166.3 ± 5.7	162.1 ± 9.3
Body mass (kg)	38.1 ± 3.2	40.4 ± 5.2	39.2 ± 4.8	42.5 ± 5.3	48.3 ± 18.4	48.3 ± 15.9
APHV (y)	13.7 ± 0.4	13.5 ± 0.3	14.2 ± 0.7	13.8 ± 0.6	13.6 ± 0.5	13.9 ± 0.7
YPHV (y)	-2.5 ± 0.3* [^]	-2.3 ± 0.4	-1.8 ± 0.2 [^]	-1.5 ± 0.4	-0.5 ± 0.4	-0.7 ± 0.7

Table notes: Values are presented as means ± SD. APHV = age at peak height velocity; YPHV = years to peak height velocity.

* denotes significant difference vs Bio-Band 2, [^] denotes significant difference vs Bio-Band 3.

6.2.4 *Bio-banding intervention*

The bio-banding intervention was conducted over one week during the off-season (August), with each player involved in one bio-banding training session, followed by one competitive match against another academy team. The intervention replaced regular training and match-play which is habitually organised by chronological age. All coaches acting as participants for the qualitative inquiry were present throughout the intervention. Specifically, coaches were assigned to the bio-banding group that replaced the regular chronological group (i.e. U12=Bio-Band 1, U13=Bio-Band 2, U14=Bio-Band 3), for both training and match-play.

For the bio-banding training sessions, the specific components or practices to be performed were initially discussed with the coaches. This was to ensure practices eliciting competencies previously reported to influence talent identification (Larkin and O'Connor, 2017) were included, as well as varying relative pitch and/or contest (e.g. 1 vs 1, 4 vs 4) sizes (Williams, 2000). Time and environmental (e.g. equipment and space) constraints were also taken into consideration. After consultation with all coaches, a total of three practices were identified that were habitually used across all respective age groups, thereby maximising ecological validity and nullifying learning effects. In brief, the training session consisted of the following practices: 1) One-versus-one; 2) Four-goal game; 3) Game. Due to varying total player numbers across all sessions, the playing area for each practice was modified to maintain a similar relative pitch size. Detailed information on these practices can be found in **Appendix B**. Players completed the training sessions within their bio-band group (i.e. Bio-Band 1, Bio-Band 2, Bio-Band 3) on an artificial turf pitch at the club's training ground. The training sessions were set-up by the author, with the respective coaches instructed to

facilitate the delivery of each practice, provide verbal encouragement, and observe the players only. The author was present for all sessions, and coaches were present during the respective bio-banding sessions (e.g. same coach for U12 and Bio-Band 1 sessions).

Bio-banding matches were played competitively against another Category 1 academy, with representatives of both clubs agreeing to replace normal age group fixtures (i.e. U12, U13, U14) with the bio-banding format (i.e. Bio-Band 1, Bio-Band 2, Bio-Band 3). Therefore, there was only one match for each bio-banding group. Goalkeepers and trialists were present during the matches and were allocated to the appropriate bio-band group to ensure each team had a sufficient squad size. Coaches were present for the same groups as training sessions. Matches took place in the same week following the bio-banding training sessions and were played on artificial turf pitches, at both club's respective training grounds. The typical rules and officiating standards remained for each respective age group fixture that was replaced with bio-banding, according to Premier League guidelines, including pitch and ball size (Premier League, 2011). The Bio-Band 1 match was contested in a 11 vs. 11 format, using a size 4 ball, with 3 x 25 min splits on a reduced pitch size. The Bio-Band 2 match was contested in a 11 vs. 11 format, using a size 4 ball, with 4 x 20 min splits on a reduced pitch size. The Bio-Band 3 match was contested in a 11 vs. 11 format, using a size 5 ball, with 4 x 20 min splits on a standard pitch size.

6.2.5 Data analysis

Differences between each bio-banding group (Bio-Band 1, Bio-Band 2 and Bio-Band 3) for anthropometric (height and body mass) and somatic maturity (APHV and YPHV)

variables were compared with multivariate analysis of variance (MANOVA). When a comparison was significant, pairwise comparisons with a Bonferroni adjustment were used. Statistical analysis was completed using SPSS (version 24), with statistical significance accepted at the 95% confidence level ($P < 0.05$).

Once all interviews with the academy coaches were transcribed into a digital format, they were imported into NVivo for Mac (version 11.4.3). In consideration of the research questions established for this study, thematic analysis was deemed the most suitable approach for data analysis. Specifically, thematic analysis enables patterns of meaning (themes) to be established from the data in relation to the research questions (The University of Auckland, 2019b), corresponding to deductive content analysis (Sparkes and Smith, 2014). Moreover, supplementary themes - not directly related to the research questions - can be identified through inductive content analysis (Sparkes and Smith, 2014). Given that research questions for this study were pre-established, a deductive approach was initially adopted (Braun and Clarke, 2006). Furthermore, in order to provide a perspective detailing the coaches' experiences of the bio-banding intervention, coding and analysis was primarily conducted semantically (Braun and Clarke, 2006).

Each transcript was analysed using the six-phase process for thematic analysis, established by Braun & Clarke (Braun and Clarke, 2006), in order to identify pertinent themes within the data. First, the author conducted 'familiarisation' with the transcripts on multiple occasions in order to become immersed and well-acquainted with the content, which included casual notetaking. Subsequently, 'coding' was performed, which included data potentially relevant to the primary research questions (deductive), as well as other data that were deemed potentially relevant, but not directly linked to

the primary research questions (inductive). Thereafter, the process of 'searching for themes' was conducted by examining the codes and associated content. Pertinent data was then aligned for each of the candidate themes which also involved creating a thematic map of all candidate themes. Additionally, transcripts were revisited to identify any data that had previously been missed that would fit into these candidate themes. Afterwards, the candidate themes were 'reviewed' for their suitability in answering the research questions and the thematic map was finalised, comprising of themes and sub-themes. Once themes were established, these were 'defined and named' according their particular focus and scope in relation to the research questions. The final phase involved constructing a detailed analysis of themes with relevant evidence (i.e. extracts), in relation to other research. It is also important to acknowledge the active role of the researcher throughout the research process, which inevitably influences the results produced (Braun and Clarke, 2006).

6.3 Results and discussion

Thematic analysis produced four core themes that were associated with bio-banding: (1) 'Detecting player competencies' reflected the coaches' observations of players' abilities throughout bio-banding (deductive); (2) 'Developmental opportunities (or not)' reflected how coaches' viewed the application of bio-banding for talent development purposes (deductive); (3) 'The landscape of youth football' reflected the implications of bio-banding in relation to current practices of player identification (deductive) and the wider culture of youth football (inductive); (4) 'Future considerations' reflected the coaches views on key issues that need to be taken into account when implementing bio-banding (deductive). These core themes and sub-themes are presented in **Figure**

6.1. The following section provides an analytic narrative which considers the aforementioned themes in the context of existing literature.

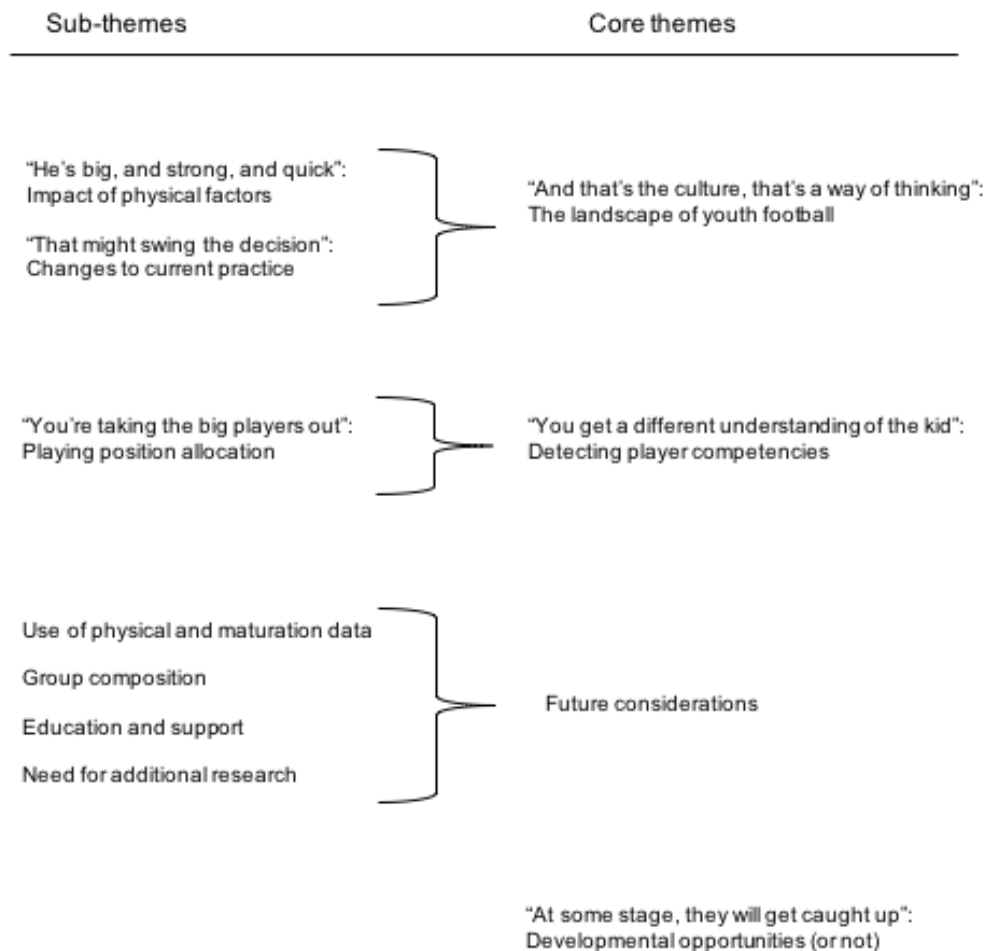


Figure 6.1 Overview of the core themes and respective sub-themes that were identified through thematic analysis.

6.3.1 "And that's the culture, that's a way of thinking": The landscape of youth football

Discussions of the bio-banding intervention were often placed within the context of the current culture and practices within youth football, and derived inductively and

deductively, respectively, from the dataset. As described within **Section 2.1**, the current landscape of academy football in England is directed by the EPPP framework and is primarily focussed on identifying and nurturing talented young players from a long-term perspective (Premier League, 2011). However, it was derived inductively from the data that the coaches considered current applied practice to be influenced by the overarching culture that has been created.

So, for me, I think there's too much of a focus on winning whether people want to admit it or not, and that goes back down to affecting the recruitment. (C6)

And that's the culture, that's a way of thinking. I'm not saying it's bad, because that's my first thought as well, and I want to win more than anyone else as well, but you've got to hold yourself back and it's got to be, "we're here for the long term." We're not here to win the game today, we're here to develop the players, and we all talk about it but don't back it up with the training we do sometimes, and the recruitment. (C6)

The ability for Category 1 academies (under the EPPP) to adopt recruitment strategies on a national scale (Premier League, 2011) provides advantages with regards to identifying young players with perceived talent. In light of this, the coaches alluded to the predominant physical bias influencing player selection and retention.

There are some boys that we make early decisions on, or rash decisions on, because of their physical maturation. (C1)

I just think sometimes we get caught up on the physical. So "he's big and strong, and quick," and maybe not so much the technical and tactical, and obviously the psychological. So, we want to produce intelligent footballers, good footballers, not athletes. (C2)

Selection biases governed by relative age and biological maturity are well-established in youth football (Johnson et al., 2017; Helsen et al., 2005; Meylan et al., 2010; Sierra-Diaz et al., 2017) and have been the focus of recent literature seeking to address these (Mann and van Ginneken, 2017; Cumming et al., 2017). In particular, findings from **Chapters 3 and 4** of this thesis revealed that the prevalence of selection biases have persisted for nearly two decades within English youth football (Lovell et al., 2015; Simmons and Paull, 2001). Previous qualitative evidence obtained from youth football coaches indicate that the pressure to select players for immediate performances, and the pressure to win, contribute towards this issue (Hill and Sotiriadou, 2016; Reeves et al., 2018b). Indeed, **Chapter 5** highlights that players advanced in biological maturity can be expected to demonstrate superior anthropometric and physical performance characteristics. Moreover, it could be said that competition from other clubs to identify and recruit players as early as possible (e.g. from 5 years of age) may also contribute (Reeves et al., 2018c). Still, whilst the apparent physical bias was acknowledged by the coaches, this strategy was deemed largely inappropriate, where consideration of other factors was advocated.

But I think the recruitment process and selection has to take all those points [i.e. four corners] into consideration probably a lot more than what they already are. And the focus on what really is going to make players in the First Team needs to take up more of the four corners [four-corner model, see Premier League (Premier League, 2011)] than the physical side, which I think at the younger age groups, definitely dominates. (C6)

The apparent discordance between the coaches' perceptions of best practice for player recruitment and actual practice has been identified by coaches' prior to the formation of the EPPP (Holt, 2002), and more recently from another English academy

(Reeves et al., 2018c). These observations suggest that the culture within English youth football exerts an influence on applied practice, seemingly perpetuating selection biases as well as disrupting compliance with a long-term development philosophy (due to a greater emphasis on winning), despite the coaches' being cognisant of these problems. However, it was reported that bio-banding may offer a solution to such issues, specifically by mitigating the overrepresentation of players with superior physical attributes and providing greater context to match results.

And what are we recruiting on? Because those key skills and mental attributes that the players have to have to make it, there needs to be more influence on that, rather than, because everyone can see the physical side, if a kid is quick, strong, and I think that's why it's easy and that's why there is more focus on that. But for me, the bio-banding can raise that awareness a lot more and then there can be more focus on the other, people say four corners, but probably for me technical/tactical, psychological, on those other areas. (C6)

It's definitely useful. And again, I think it helps to even out matches, to some degree, and I think it helps coaches, managers, clubs, look at the result a little bit more holistically, rather than literally just the result. For example, we still lost the game against [opposition team], but we didn't lose the game because the big centre forward was running in and smashing it top corner. We lost it because they had better technical players...So I think if clubs want to be able to look at the game, look at the result, and reflect on the result a little bit more honestly, and players a little more honestly, I think that's the way to maybe go about it. (C3)

I think it's a type of thing you would use if you're thinking about releasing a player, because they're physically not capable. I would always think to myself now, before we released a player and we don't think he's physically capable, we probably have to put them in a bio-banded age group and just see what they're like with players who are at the same stage of growth as them. If they're still not good enough, then that's a different argument. If they are pretty good when

they're playing with players at the same stage [of maturity] as them, then that might swing the decision or change the way it feels. (C3)

The aforementioned reflections highlight several issues prevalent within the current landscape of youth football in England which appear to contravene the primary aims of the EPPP (Premier League, 2011) (see **Section 2.1**). Consequently, it appears that in order for strategies to successfully reduce selection biases within youth football, a concerted effort to significantly shift the culture is required. In light of this, it appears that bio-banding could offer potential benefits by not only raising awareness to the impact of biological maturation, but also providing an alternative way for talent selectors to appraise players.

6.3.2 “You get a different understanding of the kid”: Detecting player competencies

All coaches made reference to bio-banding enabling an enhanced observation of players' competencies that does not normally occur when observing players in chronological age groups (deductively derived). This was described as being the result of reduced physical discrepancies between players, owing to the bio-banding group compositions (see **Table 6.1**).

And it's good for coaches as well, because you see players in one group all year and then you end up judging them. But actually, when you mix it up a little bit you get a different understanding of the kid and understand that he's a bit more confident playing with these or tries different things [in bio-banding]. (C4)

It heavily relies on how good are you now at football? How good are you at making decisions under pressure? Because that's what it's going to be. And almost the game is more free-flowing because you haven't got someone just barging through. (C5)

he [U14 player in Bio-Band 2] gets that bit and that speed with the ball, so he's able to get on the ball and accelerate and get away from players which he doesn't do at his own age group. That physical resilience, that comes out a bit more, he's able to compete in 1-v-1's and defend and regain possession in 1-v-1's. (C4)

In particular, late maturing players were typically seen to demonstrate technical and tactical competencies to a greater extent compared with chronological age groups.

So, it was really positive for me to see, from a technical and tactical point of view, receiving and turning skills, tactical ability, passing and running with the ball etc. The smaller players were getting a lot more success [in bio-banding] because they're not up against a bigger or stronger boy [as per chronological groups], for example. (C2)

This observation corresponds with Cummings et al., in which late maturing players reported similar outcomes through participation in a bio-banding tournament (Cummings et al., 2018a), and indicates an accord between players' and coaches' experiences of bio-banding. Moreover, the aforementioned competencies detected through bio-banding (i.e. technical, tactical, and psychological) have been highlighted as important from a talent identification perspective (Larkin and O'Connor, 2017; Christensen, 2009; Towlson et al., 2019), as well as for distinguishing players that reach higher playing/performance levels (Zuber et al., 2016; Forsman et al., 2016; Aquino et al., 2017; Huijgen et al., 2014).

It was also reported that under current practice, physical criteria influences playing position allocation. This parallels previous research (Deprez et al., 2015b) and may relate to the perception of giftedness (Furley and Memmert, 2016), with age and/or biological maturity acting as confounding factors (Towlson et al., 2017). However, it

was suggested that the current bio-banding intervention provided some players with opportunities to occupy different playing positions compared with chronological age groups.

So, it just gave a little more of an opportunity to play some players in different positions which we perceive need to have to fit a certain physical criteria. So you're able to, obviously you're taking the big players out and just making everyone a certain height; all of a sudden, you can look at someone potentially as say a centre back, that you usually wouldn't be able to consider as a centre back, because they are usually playing up against someone that's really tall. (C3)

Given that physical attributes are generally transient in youth players (Buchheit and Mendez-Villanueva, 2013; Malina et al., 2004a) (see **Chapter 5**), and discrepancies observed during adolescence diminish by adulthood (Lefevre et al., 1990), recent research has advocated for a 'plastic' approach to position allocation until biological maturation is complete (Towlson et al., 2017). In other words, the authors proposed that players should not be assigned into specific positions based solely on physical criteria until individual differences in physical development observed during adolescence have subsided; **Chapter 5** provides further evidence to support this point. Accordingly, bio-banding appears to have implications for this issue by enabling coaches to allocate and observe players in different positions that may not be perceived viable within chronological age groups. Indeed, the anthropometric characteristics of the groups (**Table 6.1**) indicate that whilst there was still variability in the height of players within each bio-banding group (as noted by the coaches), the standard deviations for height and body mass were typically lower in comparison with the corresponding chronological age groups.

The aforementioned observations have several theoretical implications for applied practice. Specifically, through bio-banding, the emphasis on technical, tactical and psychological competencies may enable a more holistic appraisal of players, which aligns with previous research suggesting these factors should be appraised within an ecologically valid format (Christensen, 2009; Larkin and O'Connor, 2017; Towlson et al., 2019; Unnithan et al., 2012). Similarly, the identification of talent without position-specific physical criteria distorting observations may facilitate more favourable selections from a long-term perspective, as well as providing developmental benefits associated with varying positional demands (Taylor et al., 2004). As such, it can be speculated that bio-banding may offer a practical solution to altering the decision-making process adopted by coaches (and other talent selectors), thereby reducing the maturation-related selection bias as identified in **Chapters 3** and **4**.

6.3.3 *“At some stage, they will get caught up”*: Developmental opportunities (or not)

All of the coaches reported potential implications that bio-banding could have for player development (deductive). Under the EPPP framework, the minimum number of coaching hours for each phase (i.e. Foundation [U5 to U11], Youth Development [U12 to U16], and Professional Development [U17 to U21]) has increased substantially, particularly for Category 1 academies (Premier League, 2011) (see **Section 2.1** and **Chapter 3**). These changes reflect the aim of increasing contact time with the players, thereby providing greater developmental opportunities. Accordingly, bio-banding was deemed to offer a positive developmental experience for those involved, which included presenting challenges for technical, physical, psychological and social competencies.

...needs to be more of it [bio-banding]. I think for the players' sake as an individual. I see a lot of players get frustrated because of their size, they're small players and they have to be reassured and encouraged to keep trying things and keep trying to do the right things. And we have to be patient with them as coaches and obviously we can get carried away on the other side of that with big, strong, quick, physical lad who scores five goals a game. Will he be able to do that at U18s and U23s football? I don't know, but there's a good chance maybe not because they're are relying on the physical outcomes a little bit. (C2)

Furthermore, the challenges and opportunities presented by bio-banding was viewed as beneficial for long-term player development, where it was suggested to help players become 'well-rounded' to cope with issues they will likely encounter throughout the developmental pathway (e.g. stressors, fear of failure, group transitions) (Finn and McKenna, 2010; Sagar et al., 2010; Reeves et al., 2009).

Playing in a stronger team, playing in a weaker team, all of those things, for me, is part of the development of the player. And the more you can expose them to the different potential issues that they might face, for me, if they're supported correctly, they'll end up a lot better individual player, more well-rounded, being able to cope with a lot of the issues that come up later on. (C6)

On the other hand, there were concerns that bio-banding may hinder player development, especially as variability in physical attributes is observed in senior groups (Reilly et al., 2000a).

And then again, probably the other argument is that in a real game [professional] you're going to have a mix of smaller and big players, so if you cocoon the players in bio-banding every single game or every week, then when they get to a certain age, when it opens up to all body shapes, then obviously it's going to be difficult for them. (C3)

Whilst previous research indicates that late maturing players reported bio-banding games as being less-physically challenging, they did also deem it to be beneficial overall for developing technical, tactical, physical and psycho-social competencies (Cumming et al., 2018a). Moreover, it has been proposed that bio-banding should be integrated as an adjunct to chronological age group competition, instead of replacing it (Cumming et al., 2017).

Additionally, the potential benefits that bio-banding could provide early maturers was alluded to, where it was suggested to provide a suitable challenge to facilitate their development.

And I think trying to match them up a little bit more, so the ones that are always dominating physically [in their chronological age groups], then maybe have to step up against other lads who are as physically strong or quick as them [in a bio-banding group] is a really good idea and definitely needs to be done. Because at some stage, they will get caught up, and if they are over-relying on their physical ability, they probably won't put as much time into the technical side. (C6)

Other research indicates that early maturers reported benefits of bio-banding for their development, particularly as it provided a superior physical challenge and learning stimulus compared to chronological age groups (Cumming et al., 2018a). Accordingly, a theoretical implication is that bio-banding may provide early maturers with comparable developmental benefits that have previously been attributed to relatively younger and later maturing players (Gibbs et al., 2012; McCarthy and Collins, 2014; Zuber et al., 2016; Cumming et al., 2018b), though further research is required to confirm this notion.

6.3.4 Considerations for bio-banding

Whilst all coaches perceived the bio-banding intervention positively, it was determined deductively that there were several limitations and/or suggestions for ways in which it could be improved. First, it was observed that physical discrepancies were still evident in the bio-banding groups that were adopted for this study.

I still think at times there were anomalies within the groups. There were still boys that were either much bigger than, well, mainly much bigger than others. There was probably one or two in the U14s [Bio-Band 3] game that I saw that were absolutely massive and it was still quite easy for them. (C1)

...the distance between the top player in our age bracket [Bio-Band 1] and the bottom one could still be quite sizeable even though they are grouped in the same [bio-banding] group. So, we know that they're in around the same area [in terms of maturity] but I would probably make the [bio-banding] groups a little bit more concentrated. (C3)

As highlighted in **Table 6.1**, whilst there was still a variability of greater than ± 3.5 cm for height within the bio-banding groups, this was still lower than what can be expected within chronological groups; although it must be acknowledged that the bio-banding groups did not have complete squads. Moreover, bio-banding involves organising groups with a biological maturity classification, as such, differences in current (and eventual) height of the players will inevitably vary due to factors such as genetics (Malina et al., 2004a). Therefore, education of bio-banding should reinforce that players are classified according to maturity status and not specifically body size. Nevertheless, it must be recognised that for this chapter, access was only available to a limited number of players from U12 to U14 groups (and two U11 players). The

inclusion of adjacent age groups, particularly the U15 group (typically comprised of circa and post-PHV players), would permit an additional group (i.e. Bio-Band 4) that could have reduced physical differences within each group to a greater extent. Indeed, peak developmental trajectories of body size and sprint performance have been reported to initiate <12 years of age and may not subside until >15 years of age (Towlson et al., 2018), thereby justifying additional groups being included within the bio-banding intervention. Moreover, findings from **Chapter 5** of this thesis demonstrate that initiation and plateau of physical performance characteristics can range from -3.4 to +4.4 YPHV, respectively, and thus future studies could theoretically investigate bio-banding within this maturity spectrum. However, it was observed that adopting bio-banded groups without appropriate deliberation of the competencies and developmental requirements of the individual was seen as a limitation.

My only concern would be if you're jumping up two age groups. So if you're going up from U13s to U15s [i.e. a new Bio-Band 4 group], and you've got a small U15 who's very good and drops in the 13s [Bio-Band 2], like [U15 player name] for example, I just think that's a little bit false. So, you have to weigh up the technical and tactical and the other aspects, psychologically, social aspects. So, if he's way above [technically], but just because he's smaller, we are going to stick him in with the 13s [Bio-Band 2]. I just think there needs to be a bit of thought around that and not just go because he's less mature, let's put it together and expect it to be fine. (C4)

Indeed, it is acknowledged that bio-banding is guided by an individual's biological maturity, and does not account for psycho-social and technical factors (Cumming et al., 2017). Therefore, the opportunities provided by bio-banding should be considered alongside the specific needs of the individual prior to group assignment, particularly for players identified as being close to the group cut-off and/or moving several groups.

Accordingly, practitioners may refer to the 'four-corners' (i.e. technical/tactical, physical, psychological, social) that are embedded within The Football Association player development model (Premier League, 2011) when deciding on the group composition of players.

The importance of education and support was highlighted as critical to the facilitation of bio-banding. For example, bio-banding was an unwelcome experience for one late maturing player, which was attributed to the negative connotations he perceived with playing 'down' an age group.

Yeah, so [U14 player in Bio-Band 2] was the boy that went down and couldn't handle it, just found it difficult emotionally and technically, tactically; he just really struggled and I think, just couldn't comprehend why he was there or couldn't rationalise that he should've been the best player, really. Because for his ability levels at [U]14, even though he's a smaller one, he's got good technical ability; he didn't transfer it when he went down. (C1)

Consequently, it was suggested that ample education and psychological provision be provided to all players and parents to ensure a transparent and successful integration of bio-banding within the academy programme. It was also advised that a greater awareness and insight to maturity status and fitness testing data from support staff would provide coaches with better context when appraising individuals.

Yeah, I do think developing that understanding a bit more is vitally, vitally important. They [parents] need to understand why we're doing it and obviously how that impacts their child; it's really important for them to understand. (C5)

Maybe we could be really clear. I mean again we were really clear with the boy what we were doing. But maybe be ultra-clear with anybody that we think might have a problem socially or

psychologically with going down. And also, probably afterwards feedback and support him.
(C1)

I think just make their maturation status more visible to coaching staff or for us to be more aware...I think that makes senior coaches and young coaches consider things a bit better, so I think that would be good. (C1)

Previous research demonstrates that strong links between all stakeholders (e.g. staff, player, parent) are considered fundamental from a talent development perspective (Mills et al., 2014) and should be acknowledged when implementing bio-banding interventions. Additionally, a strong integration with support staff (e.g. sports science and medical) is deemed important within an academy environment (Mills et al., 2014), and is advocated for the future delivery of bio-banding. Consequently, evaluations of physical performance results according to biological maturity, as addressed in **Chapter 5**, can provide practitioners with greater context when identifying perceived strengths and weaknesses of players' (Cumming et al., 2017; Till et al., 2018). Furthermore, in light of the psycho-social challenges that bio-banding appeared to present for some players, the availability of psychological support can be seen as a necessary provision, which may include coping strategies (Nicholls and Polman, 2007) and reflection (Toering et al., 2012).

Finally, there was a desire for more research to be conducted on bio-banding to identify what purpose(s) it can be used for within applied practice.

I think we'd need to decide what is the purpose of bio-banding before we just go ahead and start bio-banding. (C4)

At present, there are only limited studies that have addressed bio-banding within youth sport. Whilst academy staff have previously expressed their perceptions of bio-banding (Reeves et al., 2018a), this appears to be the first study to investigate coaches' experiences of a bio-banding intervention, specifically regarding player selection/retention and the observation of player competencies. However, there is a need for additional research to investigate the theoretical implications of this approach which have been highlighted within this chapter. Whilst longitudinal investigations of bio-banding within applied settings are desirable, it is acknowledged that this approach is not always feasible. Still, future studies could seek to provide empirical evidence addressing the influence of bio-banding on talent selection, retention, development and injury risk, which may involve quantitative as well as additional qualitative approaches. For example, obtaining objective (e.g. running performance) and subjective (e.g. coaches rating) measures of player performance during bio-banding and chronological-based training and matches would provide additional evidence to corroborate the findings from this chapter, as well other research on bio-banding (Cumming et al., 2018a; Reeves et al., 2018a).

As per **Table 6.1**, YPHV differed significantly between groups, suggesting that the methodological approach to classify players within this chapter was able to distinguish players by maturity status. However, it should be recognised that, as per previous classifications based on maturity offset (Buchheit et al., 2011; Hammami et al., 2016; Meylan et al., 2014), players in both Bio-Band 1 and 2 would be considered pre-PHV, with players in Bio-Band 3 deemed circa-PHV. Accordingly, mean height for players in Bio-Band 1 and 2 were similar, with a significant difference observed for Bio-Band 3 compared to the former groups. Findings from **Chapter 5** also suggest that, as peak development of physical performance variables occurs between -0.6 to +0.9 years

from PHV, differences between Bio-Band 1 and 2 for physical performances would likely be minimal (i.e. non-significant). These findings suggest that whilst maturity offset can be used to classify players into bio-banding groups, differences in body size (and physical performances) between groups may not be (statistically) significant, though may still have meaningful implications for applied practice (e.g. playing position allocation). Nevertheless, as highlighted previously, the inclusion of additional age groups would appear favourable, especially the formation of a more mature group (i.e. post-PHV), which would likely help to reduce the physical variability observed within each bio-banding group.

There are several limitations relating to this chapter that must be acknowledged. First, the findings must be interpreted with caution given that maturity offset was utilised – with a percentile approach - to group players from U11 to U14 groups, where other methods for the purposes of bio-banding have been suggested/utilised (Cumming et al., 2017; Reeves et al., 2018a). Moreover, not all registered players were available during the intervention period for this study, which may have resulted in a loss of important observations. Thus, it is suggested that future bio-banding interventions are conducted with maximum player availability (e.g. in-season), thereby enabling all players from the participating squads to be included. In addition, the interviews were conducted using a sample of coaches only, with varying experiences and potential biases in the reporting of information. Consequently, the findings may not be representative of insights from other staff involved with talent selection (e.g. scouts), as well as other clubs that adopt a different selection/retention philosophy. It is also recognised that the sample size was small due to undertaking the study at one club, where guidelines for sample sizes undertaking thematic analysis are provided elsewhere (The University of Auckland, 2019a). Finally, it is acknowledged that the

intervention period and interview times were short, meaning that potentially key insights may have been gathered with more time. Other limitations which are general to this thesis are addressed in **Section 7.2**. Briefly, these relate to the method used to derive maturity and the generalisability of findings.

6.4 Conclusion

This chapter sought to adopt a qualitative approach to investigate coaches' experiences of a bio-banding intervention, especially regarding the decision-making process for player selection/retention, and the observation of player competencies. Analysis of interviews conducted with six coaches from a Category 1 academy highlighted four key themes, which are discussed and supported with pertinent excerpts above. All coaches expressed that the bio-banding intervention was an overall positive experience and reported a willingness to continue implementing it within applied practice. The culture surrounding youth football in England was identified as an integral theme that was reported to influence current practice (e.g. player selection and retention) within the present club, yet it appeared that bio-banding may offer a solution to challenging this issue. Specifically, bio-banding seemingly enabled the coaches to detect players' competencies (including different playing positions) to a greater extent than in chronological age groups, thereby facilitating a more holistic appraisal of the players. This was achieved by reducing the physical discrepancies between players through the grouping of players according to somatic maturity, which was underpinned in part by the findings of **Chapter 5**. The potential implications for player development purposes were also highlighted, where it was mostly seen to be beneficial for all players, though the need to consider the specific requirements of the individual prior to bio-banding was alluded to. Finally, there were

several considerations that were identified by the coaches which should be acknowledged by practitioners and/or researchers when implementing bio-banding in the future. Collectively, bio-banding appears to be an ecologically valid and beneficial tool that has the potential to enhance applied practice within an academy setting, which includes providing a theoretical solution to reducing the maturation-related selection bias highlighted in **Chapters 3** and **4**. However, given the limitations of this chapter and the lack of other research investigating bio-banding, it is recommended that practitioners and researchers seek to gain a better understanding of bio-banding through further applied research, where longitudinal investigations are desirable.

Chapter 7. General Discussion, Research Limitations, Directions for Future Research, Conclusions and Practical Applications

7.1 General discussion

The purpose of the following section is to succinctly summarise the key findings of this thesis in the context of current literature; a specific and comprehensive discussion for each study is presented in **Chapters 3 to 6**.

The first aim of this thesis was to investigate the prevalence of RAEs since the inception of the EPPP. Additionally, this thesis intended to determine between-quartile differences in somatic maturity, anthropometry and physical performances. Upon achieving this, the subsequent aim of this thesis was to determine the extent to which birth quartile, somatic maturity, anthropometric and physical performance characteristics influence player retention throughout the developmental pathway. Thereafter, this thesis then sought to establish growth curves of anthropometric and physical performance characteristics according to somatic maturity, specifically to estimate timepoints relating to the initiation, peak and plateau of development. Finally, this thesis aimed to investigate coaches' experiences of a bio-banding intervention to establish any potential impact on player selection/retention and the detection of player competencies.

The introduction of the EPPP represents a significant change to the youth development system within England (Premier League, 2011), and is central to the rationale for this thesis. Since its inception, there has been limited research to examine the impact of the EPPP on applied practice in UK-based football academies. In particular, no study has documented the prevalence of selection biases over a considerable period of time within an academy under the EPPP framework. Thus, a

key finding of this thesis was the observation that RAEs have persisted within the investigated academy since the EPPP was introduced (**Chapter 3**). Additionally, as relatively younger players were less represented and/or the mean APHV was lower (indicating advanced maturity) for each age group, in comparison with previous studies in England (Lovell et al., 2015; Simmons and Paull, 2001), it suggests that this top categorised academy demonstrates a penchant for amplified selection biases. Another key finding was that despite there being a lack of between-quartile differences for APHV, anthropometry and physical performances – corresponding to previous research (Deprez et al., 2013; Deprez et al., 2012) – there was a tendency for Q4 players to demonstrate superior physical performances from U11 onwards (**Chapter 3**). This finding agrees with previous research by Skorski et al., although advantages for Q4 players were only demonstrated in U19 and U21 groups (Skorski et al., 2016). It appears that the Q4 players investigated in this thesis were particularly high performing, which could be related to developmental opportunities gained by competing with relatively older and/or earlier maturing peers from a young age (McCarthy and Collins, 2014; Collins and MacNamara, 2012). Actually, recent literature provides evidence to support this notion – coined the ‘underdog’ hypothesis (Gibbs et al., 2012). The above findings highlight key considerations for practitioners within this academy, and with additional evidence, practitioners and policymakers across English academies. Clearly, the systematic discrimination of relatively younger and/or later maturing players reduces the talent pool that this academy can select from; this appears self-limiting (given the ability to recruit nationally), as opposed to being constrained by a regional selection strategy (Mujika et al., 2009). The lack of opportunities for these players to access high-level coaching would appear to limit their ability to reach their full potential given that systematic training exposure induces

superior sport-specific skill and physical performance improvements (Wrigley et al., 2014; Valente-dos-Santos et al., 2012d). On the other hand, the formation of relatively homogenous cohorts of players, that are typically relatively older and/or earlier maturing, may inadvertently hinder development for these individuals, as they are unlikely to experience comparable developmental opportunities associated with the 'underdog' effect (Gibbs et al., 2012; Collins and MacNamara, 2012; McCarthy and Collins, 2014).

Relative age, biological maturity, anthropometry and physical performances have typically been examined for their influence on selection into high-level youth teams (Sierra-Diaz et al., 2017), including **Chapter 3**, though research regarding retention/dropout is scarce (Deprez et al., 2015e; Sierra-Diaz et al., 2017; Meylan et al., 2010). Therefore, another key finding of this thesis indicates that all of the aforementioned factors, except relative age, distinguish players that were retained between U11 to U21 groups (**Chapter 4**). Of note, the large absolute number of Q1 players that dropout from each age group in comparison with other quartiles implies that they are erroneously recruited and occupy squad places that could be better suited to others with greater potential – including relatively younger and/or later maturing players (Baker et al., 2018). Additionally, it was observed that Q4 players typically had a greater likelihood of retention throughout the developmental pathway in comparison with Q1 players, where advanced maturity and/or developmental advantages (Collins and MacNamara, 2012; McCarthy and Collins, 2014) (associated with the underdog hypothesis (Gibbs et al., 2012)) were suggested as explanations for this finding. Although, it must be noted that playing position was not considered throughout this thesis, where this factor has previously been related to the RAE (Romann and Fuchslocher, 2013; Salinero et al., 2013; Towlson et al., 2017).

Specifically, it could be hypothesised that relatively older players were typically utilised in certain positions (e.g. central defenders) – based on absolute anthropometric and maturity superiority (Towlson et al., 2017), yet did not demonstrate sufficient competencies (e.g. physical – see **Chapter 3**, and/or technical) enabling them to be retained, where early positional specialisation may have hindered their development. On the other hand, relatively younger players, allocated to other and/or a multitude of positions (e.g. lateral defender or central midfielder roles) (Towlson et al., 2017), were able to demonstrate superior physical (see **Chapter 3**) and/or technical competencies due to training exposure advantages, thereby facilitating their retention. Actually, whilst information relating to when players may have been ‘specialised’ into playing position was not provided, there is evidence to suggest that midfielders are the most skilled across time, compared to defenders and forwards (Valente-dos-Santos et al., 2012d). Therefore, whilst it was not possible to consider within this thesis, the relationship between relative age (and biological maturity) and playing position throughout the developmental pathway warrants further investigation, which should also include a differentiation of sub-positions (e.g. lateral and central defenders). Elsewhere, the observation that somatic maturity, anthropometric and physical performance characteristics were associated with retention in an age group dependent manner corresponds with previous research demonstrating that discriminating factors are dynamic (Vaeyens et al., 2006; Deprez et al., 2015e). However, given the transient nature of these characteristics (Buchheit and Mendez-Villanueva, 2013; Lovell et al., 2015; Lefevre et al., 1990), they can be deemed inappropriate from a player selection and retention perspective. As such, this academy would likely benefit from appraising the maturity status of individuals - which is associated with anthropometry and performance (Meylan et al., 2010; Malina et al., 2004a; Philippaerts et al., 2006;

Towlson et al., 2018; Güllich and Emrich, 2012; Patton, 1990; Valente-dos-Santos et al., 2012d) – and monitoring other pertinent factors of talent (Williams and Reilly, 2000) that have also been shown to contribute to retention and/or attainment of higher playing levels (Zuber et al., 2016; Huijgen et al., 2014; Toering et al., 2012).

Developmental changes of anthropometry and physical performances according to somatic maturity have been investigated in limited number of studies concerning youth football players (Philippaerts et al., 2006; Towlson et al., 2018). However, whilst useful, the findings of these studies are limited by the lack of repeated measurements per individual, per season, which is advantageous for examining developmental changes around PHV (Low, 1970; Malina et al., 2013). Therefore, a key finding of this thesis was the identification of growth curves within a highly selective sample of youth players from a Category 1 academy, through contemporary statistical analysis that includes repeated measures for individuals (**Chapter 5**). The estimation of time points for when anthropometric and physical performance characteristics show peak development typically coincides with predicted PHV (-0.6 to +0.9 YPHV). Moreover, the estimation of turning points indicate that the initiation and plateau of development of physical performance variables occurs within the maturity spectrum of -4 to +4 YPHV, except for the plateau of agility and CMJ performance (i.e. after +4 YPHV). On the other hand, turning points for anthropometry were typically beyond this maturity range. These findings correspond with previous studies in that developmental changes for anthropometry and physical performances align with the onset of PHV (Philippaerts et al., 2006; Towlson et al., 2018; Beunen and Malina, 1988), which highlights the importance of monitoring this biological milestone (Malina et al., 2004a). Additionally, given that the initiation and plateau of development of physical performances occur between Pre-PHV and Post-PHV periods, respectively, and inter and intra-individual

variability is significant, it implies that the physical performance variables should be considered according to an individual's maturity status (Cumming et al., 2017; Jones et al., 2000; Meylan et al., 2010; Till et al., 2018). Further, as identified in **Chapter 4**, factors that discriminate retention are dynamic across the developmental pathway, which includes the dropout of players demonstrating inferior body size, maturity, and physical performances. Yet, the findings from **Chapter 5** provide biologically plausible growth curves that could theoretically be used by practitioners within this academy to appraise players with greater context before decisions are made on selection/retention; this may involve maturity-based performance benchmarking (Jones et al., 2000; Till et al., 2018; Cumming et al., 2017) and grouping players according to maturity status (i.e. bio-banding) (Cumming et al., 2017).

Practical solutions to reduce selection biases in applied settings have typically addressed relative age (Sierra-Diaz et al., 2017) – see (Webdale et al., 2019) for a recent systematic review, with fewer suggestions offered to specifically counteract the influence of biological maturity (Meylan et al., 2010), despite the latter being more discriminant for selection (Johnson et al., 2017). Bio-banding has been proposed as a solution to reduce the selection bias in favour of earlier maturing players (Cumming et al., 2017), though has not been substantiated with empirical evidence. Thus, an important finding of this thesis was that through the implementation of a bio-banding intervention, the decision-making process adopted by academy coaches (talent selectors) regarding player selection and retention was seemingly altered. Additionally, it was inductively ascertained that the culture of youth football within England seemingly perpetuates selection biases, due to a greater emphasis being placed on physical competencies, as opposed to other factors that are also relevant for predicting talent (e.g. technical, tactical, psychological and social skills) (Williams

and Reilly, 2000; Christensen, 2009; Larkin and O'Connor, 2017; Towlson et al., 2019). These findings suggest that regular implementation of bio-banding may offer a practical solution to counteracting the maturation-related selection bias identified in **Chapters 3 and 4**, which may involve enhancing awareness to the impact of biological maturation and subsequently improving how players are appraised.

The novelty of this thesis relates to the unique dataset that involves mixed-longitudinal data from an English professional football club with Category 1 academy status, which includes repeated measures for individual players. As previously highlighted, there is a lack of literature documenting the impact of the EPPP on applied practice within English academies, thereby prompting the proposal for areas of research (Premier League, 2011). This may be due to difficulties for researchers in gaining access to these environments (Coutts, 2016). Thus, this thesis utilises data that provides a unique insight into a top categorised academy in England, with a relatively large sample size, since the EPPP was introduced. Additionally, previous studies have typically utilised cross-sectional data or mixed-longitudinal data with only one measurement per season, and/or have been conducted over a limited time span (Meylan et al., 2010; Sarmiento et al., 2018; Sierra-Diaz et al., 2017). Accordingly, the appropriate utilisation of repeated measures for individuals within this thesis (through multilevel modelling) enables developmental changes over time to be accounted for to a greater extent (Malina et al., 2004a; Low, 1970). Consequently, the findings from this thesis - more specifically **Chapters 3 to 5** – are supported by favourable statistical analyses over similar studies conducted previously (Sarmiento et al., 2018; Sierra-Diaz et al., 2017; Meylan et al., 2010). However, there are research limitations of this thesis that need to be acknowledged which are addressed in **Section 7.2**.

The findings from this thesis highlight that despite the premise of the EPPP being to enhance best practice within UK-based academies (Premier League, 2011) (see **Section 2.1**), a comprehensive review of this framework would be desirable given that selection biases have persisted within the current academy since its introduction. In particular, policymakers and practitioners should be cognisant of specific components of the EPPP (e.g. categorisation system, recruitment opportunities) and their potential impact on applied practice (see **Chapters 3 and 4**), which appears to contravene the primary aim of this contemporary framework. Other findings from this thesis provide guidance to researchers and practitioners on how selection biases could be counteracted within this academy (see **Chapters 5 and 6 and Section 7.5**), yet there is scope for additional research to corroborate and extend the present findings. With appropriate deliberation of the EPPP framework and current practices operating within this academy, applied practice can be enhanced which could subsequently improve attainment of the primary aim of the EPPP (Premier League, 2011). In conclusion, this thesis revealed that selection biases have persisted in the current academy since the introduction of the EPPP (**Chapters 3 and 4**), and there is a need for practical solutions to be implemented which are supported with empirical research, where other findings from this thesis could be useful (**Chapters 5 and 6**).

7.2 *Limitations of the research*

Whilst this thesis has provided original contributions to enhance the understanding of relative age effects, biological maturation, anthropometry and physical performances within academy football, it must be noted that the findings from **Chapters 3 to 6** must be viewed in the context of research limitations.

A key limitation of the thesis is the generalisability of the findings, given that the participants recruited into each of the studies were from a single professional club in England. It is possible that the specific club philosophy for player recruitment and retention is not representative of other clubs within England, and indeed across different countries. Future studies would benefit from adopting research designs that include a larger sample size (e.g. multiple clubs) and controls, which would require appropriate handling within statistical analyses; this thesis indicates that multilevel modelling could be advantageous for this issue. However, conducting larger scale studies may present a number of challenges from a practical perspective and may require national and/or local governing bodies to implement and oversee such investigations.

The experimental designs of **Chapters 3 to 6** of this thesis also represents a limitation. Mixed-longitudinal designs (used for **Chapters 3 to 5**) represent a benefit over cross-sectional designs, particularly when concerning growth and maturation, as it enables changes over time (e.g. a season) to be included within statistical analyses and thus yield stronger inferences (Malina et al., 2004a; Low, 1970). However, a drawback is that individuals can have a large variation in total measurements where, in the current dataset, some players persisted for many years during the study period and have several measures for each year, whilst others only had a single or few measures in total. Whilst the handling of this data issue was possible with multilevel modelling (**Chapters 3 to 5**), the inferences made are somewhat limited in comparison with longitudinal designs where all participants have repeated measurements over a substantial period of time (Low, 1970). In addition, it is recognised that the qualitative design to investigate the bio-banding intervention for **Chapter 6** was implemented over a short period of time and the results could be liable to biases. For example,

coaches were made aware of the rationale behind the bio-banding intervention prior to implementation and may have had expectations of performance for specific players; together these may have elicited a bias in their response during the interviews. Additionally, the inability to conduct thorough pilot testing of the interview process and interview additional talent selectors (e.g. scouts) represent drawbacks. The addition of quantitative measures of performance (e.g. GPS, heart rate and/or notational analysis) to corroborate the coaches' experience would have been useful but were unfortunately not viable due to time and equipment constraints.

Another important limitation relates to the data collection methodology that formed the datasets used within **Chapters 3 to 6** of this thesis. Whilst anthropometric data was collected by club sports scientists that had received ISAK accreditation, the inability to obtain intra and inter-measurer reliability values for all individuals over the entire data collection period represents an important drawback; especially when considering that these measures contribute to the prediction equation to derive maturity, in which prediction error is also apparent (see **Section 2.3.5.2**). The same issues are also prevalent for the physical performance data collected with the fitness testing battery. Although individuals involved in the collection of physical performance data were deemed adequately experienced (e.g. sport science degree and applied experience), the inability to ascertain inter-measurer reliability represents an important limitation. Furthermore, the test-retest reliability for each component of the fitness testing battery was not ascertained with each age group as it was unfeasible to conduct multiple fitness testing sessions and disrupt the coaching programme. Finally, due to fitness testing being conducted in the evening for approximately one session per season for U11 to U16 groups, the impact of diurnal variation on physical performance results should be acknowledged, where previous research indicates performance in the

evening is superior to the morning (Rahnama et al., 2009; Reilly et al., 2007; Chtourou et al., 2012). Given that the Premier League provides all clubs with an ability to compare their own data with national benchmarking from all clubs that operate within the EPPP framework, there is likely to be issues regarding reliability of data which require addressing to ensure sources of measurement error are reduced as much as possible at each testing session. Taken together, the aforementioned drawbacks relating to the reliability of data should be acknowledged when interpreting the findings from this thesis.

It is also recognised that the fitness testing battery that formed the dataset for **Chapters 3 to 5** of this thesis is subject to issues that affect the validity of each component. Firstly, whilst each test was included on the basis of their relevance to the requirements of football performance and sequenced according to suggested guidelines (Dodd and Newans, 2018; Svensson and Drust, 2005; Turner et al., 2011; Baechle and Earle, 2008), the application of the fitness testing battery on a single day represents a drawback in the overall validity. Specifically, the minimum rest between attempts for jump, sprint and agility tests, as described in **Section 3.2.10**, appear insufficient according to previous testing recommendations (Baechle and Earle, 2008). As well as insufficient recovery between attempts and tests, performing tests sequentially on the same day is likely to compromise the validity of each test due to cumulative fatigue experienced by the player (Walker and Turner, 2009). Therefore, drawbacks of the fitness testing battery that provided quantitative data within this thesis should be acknowledged, where adoption of a different strategy (e.g. a single testing component on each day) may have yielded different results.

The method used to derive biological maturity within this thesis represents a key a limitation and has previously been addressed in **Sections 2.3.5 to 2.3.7**. Specifically, it is acknowledged that the predictive equation used throughout **Chapters 3 to 6** has drawbacks when considering differences between the sample that the method was derived from (Mirwald et al., 2002) and the sample of players used within this thesis. Moreover, prediction error has been identified with the current method, where it is liable to a systematic bias that under/over-estimates APHV, particularly for individuals that are far away from estimated PHV (Malina and Koziel, 2014). The minimisation of this prediction error is also dependent on measurement error (i.e. anthropometry) being minimised where, as previously highlighted, was not ascertained. Due to these issues, it is likely that there is a systematic bias for the maturity data reported within this thesis, which includes inaccuracy of estimations for players that were measured at the extremes of the maturity spectrum (i.e. further away from PHV) and the inability to accurately identify later and earlier maturers. As such, key information relating to biological maturity may have been masked, where the implementation of a different non-invasive method (**Section 2.3**) may have yielded different findings. However, the strengths and weaknesses of all the aforementioned methods to assess biological maturity, evaluated within **Section 2.3**, were deliberated thoroughly within this thesis. Subsequently, the ability to utilise pre-existing data from club records, the practicality of the non-invasive method for subsequent data collection, and capacity to make comparisons with other pertinent literature, deemed the current method the most viable option to employ. Still, recent literature has provided redeveloped equations to estimate maturity from anthropometric measures (Moore et al., 2015; Fransen et al., 2018), though these are still subject to limitations which bring into question their suitability for researchers and practitioners (Nevill and Burton, 2018). Therefore, there

is a need for further non-invasive methods to accurately derive biological maturity which should be based on contemporary reference samples. Specifically, this would allow any potential secular changes and ethnic variability (Malina et al., 2004a; Mills et al., 2017) to be accounted for, where it has been reported that approximately 30% of academy players in England are from black and mixed-ethnicity backgrounds (Bradbury, 2014). In any case, it is suggested that the findings of this thesis, specifically the data relating to biological maturity, be interpreted with caution given the measurement error within data collection as well as the prediction error associated with the current non-invasive method.

It is also recognised that whilst relative age, somatic maturity, anthropometry and physical performances were measured within this thesis, other predictors of talent/performance (Williams and Reilly, 2000; Johnston et al., 2018), as well as motivation to perform testing (Svensson and Drust, 2005), were not. Indeed, other research demonstrates that along with the aforementioned factors, technical, tactical and psychological factors distinguish players that are selected by and progress within high-level teams (Huijgen et al., 2014; Forsman et al., 2016; Reilly et al., 2000b; Zuber et al., 2016). Additionally, playing position was not considered within this thesis, where this factor may impact training exposure as well as selection and retention processes (Deprez et al., 2015b; Towlson et al., 2017). Though technical, tactical and psychological factors are not currently mandated under the EPPP testing battery, they have been highlighted as proposed areas of research within EPPP documentation (Premier League, 2011). Accordingly, future studies should attempt to conduct measurement of the aforementioned factors and investigate their relationship with relative age and biological maturity using a longitudinal approach. This may include utilisation of data that is already collected (e.g. technical performance determined

through video recordings) and/or implementation of new tests (Ali, 2011). However, as per the components of the EPPP fitness testing battery (see **Section 2.6**), these should be deliberated thoroughly to ensure validity and reliability is optimised (Ali, 2011).

An additional limitation lies within the statistical analyses adopted in several chapters of this thesis. Specifically, it is plausible that the low number of Q4 players, particularly for analyses within **Chapters 3 to 4**, may have been too low to detect statistically significant differences. Whilst it is recognised that previous research has attempted to account for this issue by using bi-annual instead of annual age grouping for analyses (Lovell et al., 2015; Deprez et al., 2013; Deprez et al., 2012), this may subsequently mask important information that operates in an age group-dependent manner (Vaeyens et al., 2006; Hirose, 2009). Whilst it was deemed necessary to conduct analyses using annual age groupings within this thesis, future studies exploiting larger sample sizes would help to address this issue.

Finally, the challenges regarding the role of the author as a researcher-practitioner within the academy under investigation requires consideration. The term 'embedded researcher' is used to describe research that is conducted by an individual or team that is also granted staff status within an organisation of interest (McGinity and Salokangas, 2014). This mutually beneficial relationship between the researcher's institution and the host organisation (in the current case, represents the university and the academy, respectively) provides the researcher access to a unique dataset (Coutts, 2016); the host organisation receives a member of staff to deliver sports science provision and conduct pertinent research with the aim of improving their practice (McGinity and Salokangas, 2014). Given the dual role of the author, there are

numerous challenges that can have implications for the quality of research undertaken, and these are often related to time constraints and the pressures associated with a dual role (e.g. the need to build successful relationships with academic staff and academy staff/players; dedicating time for role as a researcher and requirements as a practitioner). Moreover, due to the immersion of the author within the academy environment, it is plausible that this may have caused a bias within the interpretation of data. The aforementioned examples represent some of the challenges that are likely to be experienced by embedded researchers and these (amongst other challenges (Champ et al., 2019)) should be acknowledged by all involved in such collaborations. Whilst there are clear benefits to obtaining data from these typically hard-to-access environments (Coutts, 2016), the aforementioned challenges highlight areas where the role of embedded researcher(s) can be evaluated so that the scientific output is as robust as possible.

7.3 Directions for future research

Despite a wealth of research having previously investigated the influence of relative age and biological maturation within youth football (Meylan et al., 2010; Sarmiento et al., 2018; Sierra-Diaz et al., 2017), including investigations within the current academy (**Chapters 3 to 6**), there remains a substantial scope for future studies to advance understanding in this area of research.

A fundamental direction for future research will be to validate the findings in this thesis on a larger scale. Specifically, the inclusion of multiple academy teams in England, with various categorisations, would determine whether the current findings are specific to the club investigated or indicative of processes operating at the national level under

the EPPP framework. However, it should be noted that this would require controlling for the variability in training exposure between clubs with different categorisations, where multilevel modelling appears appropriate for this issue due to the ability to accommodate hierarchically structured data (Charlton et al., 2019). Accordingly, the findings of larger scale research would stipulate whether changes need to be made to the EPPP framework or individual clubs.

Additionally, investigations of lower-playing levels (i.e. grassroots) in England are paramount to understanding the extent to which selection biases occur and the factors that underpin them. Furthermore, this includes an examination of potential developmental advantages gained by relatively younger and later maturing players that emerged within **Chapter 4** of this thesis and in recent studies (Cumming et al., 2018b; McCarthy and Collins, 2014). Other research indicates that the relative age selection bias in high-level teams are likely due to selections from an already biased pool of players at a lower playing level (Delorme et al., 2010b). Therefore, gaining clarity on when the relative age effect, and maturation-related selection bias, first emerge along the developmental pathway, and what factors influence them, is essential for raising awareness and conceiving appropriate solutions to this issue (Cobley et al., 2009; Musch and Grondin, 2001; Sierra-Diaz et al., 2017). However, it is acknowledged that both of the aforementioned directions are subject to issues given geographical constraints of conducting such research. It is likely that a collaboration between researchers on a national level and/or the regulation of national governing bodies is required.

A further area for future research, aligning with the points above, is the longitudinal investigation of anthropometric, physical performance, technical, tactical and

perceptual-cognitive development in accordance with CA and biological maturity. Whilst there is an emerging body of research evidencing the developmental changes of anthropometry, physical performance and motor competence (Valente-Dos-Santos et al., 2014a; Valente-dos-Santos et al., 2012b; Fransen et al., 2017; Towlson et al., 2018; Philippaerts et al., 2006), including **Chapter 5**, there is less known about technical, tactical, and perceptual-cognitive factors (Valente-dos-Santos et al., 2012d). In addition, it is desirable that such investigations include appropriate control groups, thereby enabling the partitioning of systematic training in order to detect normative changes that occur with age and maturation as previously highlighted (Philippaerts et al., 2006). Consequently, a greater understanding of factors that affect sporting performance will enable practitioners to adopt more dynamic and multidisciplinary models of benchmarking that could be used for talent identification and development purposes (Sarmiento et al., 2018).

Similarly, as highlighted within the limitations of this thesis, future research incorporating multidisciplinary factors (i.e. technical, tactical, perceptual-cognitive, psychological) that influence selection and retention throughout the entire developmental pathway is warranted. In particular, previous research demonstrates that sport-specific and non-specific motor skills are not sensitive to variability in biological maturity (Malina et al., 2005; Vandendriessche et al., 2012), which would appear to make them useful factors to consider from a talent identification perspective (Deprez et al., 2015e). However, at present little is known about how these factors influence player selection and retention across the entire developmental pathway, particularly for entry to the First Team and/or international level groups. Moreover, recent evidence demonstrates that highly skilled players across multiple competencies have a greater likelihood of progression compared to late maturing players (Zuber et

al., 2016), though it remains unclear what minimum competencies across multiple disciplines are required, and if they are confounded by factors such as playing position (Towlson et al., 2017; Valente-dos-Santos et al., 2012d) and club philosophy (Reeves et al., 2018c). It is important to note that previous studies have typically adopted varying methodology with regards to the measurement of the aforementioned factors (Sarmiento et al., 2018; Meylan et al., 2010), where no clear consensus has been established to advocate which are the most appropriate. Still, the integration of multidisciplinary measures within future studies are clearly favourable by providing more objective indicators of performance.

Within **Chapter 6** of this thesis, it was revealed that academy coaches perceived benefits of a bio-banding intervention within applied practice. Perhaps the most interesting findings obtained from qualitative evidence suggested bio-banding could potentially offer a solution to minimising the maturation-related selection bias. However, the practical applications of bio-banding have seldom been addressed within the literature at present. Accordingly, further studies are required to ascertain whether the proposed applications for talent identification, retention and development are supported with empirical evidence (Cumming et al., 2017). Specifically, longitudinal studies are required to determine if regular bio-banding interventions alter player selection and retention processes within applied practice.

As highlighted within **Sections 2.3** and **7.2**, commonly used methods of assessing biological maturity are all subject to respective weaknesses. Whilst recent evidence indicates that assessment of skeletal maturity is a more appropriate method to use to estimate PHV, particularly in the year preceding PHV (Mills et al., 2017), this method does not appear viable within applied settings due to the limitations addressed in

Section 2.3.2 (e.g. invasive nature and high costs). Consequently, there is a need for commonly used non-invasive methods to be validated in samples representative of youth sport (i.e. early and late maturers and ethnically diverse) and/or the (re)development of equations to reflect current societal norms (e.g. secular trends and ethnic diversity) (Malina et al., 2004a; Freedman et al., 2000; Hughes et al., 1997). Subsequently, additional studies establishing the accordance between different methods to assess biological maturity (e.g. skeletal and somatic) (Malina et al., 2012) would provide greater context when drawing comparisons between studies that adopt different methodological approaches.

Finally, it must be acknowledged that this thesis has conducted investigations on a highly selective sample of male youth football players. Therefore, whilst this thesis has contributed original research with the aim of informing best practice within the academy investigated, clearly there is scope to investigate relative age effects, biological maturity and the processes these affect within other academies as well as other sporting and non-sporting domains, including different playing levels and within females. Moreover, this thesis examined themes within a sample of players ranging from approximately 10-21 years, whereas knowledge individuals adjacent to this age range is limited and warrants further investigation.

7.4 Conclusions

The general aim of this thesis was to investigate relative age, biological maturity, anthropometric and physical performance characteristics within male youth football players from a Category 1 academy, as they progressed through the developmental pathway, under the EPPP framework. This aim was established in light of prior gaps

in knowledge ascertained from a review of the literature. Subsequently, the empirical research conducted within this thesis advances understanding within these contemporary areas of investigation. However, the limitations addressed within **Section 7.2** should be acknowledged, especially issues regarding the validity and reliability of data collected, as this will inevitably have affected the accuracy of results and thus careful consideration of these limitations are warranted when interpreting the findings of this thesis. Whilst the conclusions of these original studies are discussed in relation to pertinent literature throughout **Chapters 3 to 6** and in **Section 7.1**, the specific aims and objectives defined in **Section 2.10** will now be revisited in light of the findings from each respective study, thereby providing a clear overview of the contribution made by this thesis.

Aim 1: Examine the prevalence of selection biases across the developmental pathway, thereby providing contemporary evidence on whether these have persisted since the EPPP was implemented and if they are amplified in a top categorised academy. Furthermore, multilevel modelling will enable analysis of mixed-longitudinal data with repeated measurements for individuals to determine between-quartile differences for maturity, anthropometry and physical performances.

This study revealed that RAEs have remained prevalent within youth football in England for over two decades and have persisted within the investigated Category 1 academy since the inception of the EPPP. Furthermore, this was the first study to utilise multilevel modelling to explore between-quartile differences, where the results showed that whilst players in all age groups typically demonstrated homogenous somatic maturity, anthropometric and physical performance characteristics, Q4 players exhibited several statistically significant performance advantages compared

to Q1 players between U11 and U21 groups. Collectively, the findings highlighted the impact of relative age and biological maturity for selection into this academy and suggest that higher categorised academies may be particularly at risk of amplified selection biases.

Aim 2: Investigate the influence of birth quartile, biological maturity, anthropometry and physical performances on player retention from each age group along the developmental pathway. The use of multilevel modelling for analysis will clarify whether the aforementioned factors are discriminatory for retention, and if any age group related differences are evident.

This was the first study to examine differences between players identified as retained and dropout within an English Category 1 academy across the developmental pathway, including entry to the First Team. Birth quartile had no significant influence on retention, though Q4 players typically had a greater likelihood of being retained between U13 to U21 groups compared to Q1 players, and there was a seemingly high turnover of Q1 players throughout. Additionally, multilevel modelling revealed that retained players demonstrated superior age, somatic maturity, anthropometry and physical performances compared to dropout players between U11 and U16 groups, where significant factors distinguishing retention were age group dependent. Taken together, the findings highlighted that whilst birth quartile had no impact on retention after being selected into this academy, biological maturity, anthropometry and physical performances did; this should be acknowledged by practitioners within the current academy so the retention process can be improved to prevent premature dropout of talented players.

Aim 3: Examine growth curves of anthropometry and physical performances according to somatic maturity. The application of multilevel modelling will enable biologically plausible time points relating to the initiation, peak and plateau of development for each variable to be estimated.

This was the first study to examine growth curves of anthropometric and physical performance variables within a cohort of Category 1 youth players, through the utilisation of mixed-longitudinal data. Points of inflection indicating peak development for all variables (except height) corresponded with PHV, whilst turning points indicating the initiation and plateau of development were identified during pre and post-PHV periods, respectively. Furthermore, multilevel modelling demonstrated significant between and within-subject differences are observed with regards to all investigated variables. Taken together, the findings highlight that the development of anthropometry and physical performances can differ drastically for individuals within the same CA group due to biological maturity. Thus, players' anthropometry and physical performances should be considered according to maturity status, where potential applications within applied practice could lead to the reduction of the maturation-related selection bias.

Aim 4: Investigate the influence of a bio-banding intervention for potential applications within applied practice, especially regarding the reduction of the maturation-related selection bias. A qualitative approach will be advantageous in determining whether a bio-banding intervention can alter the decision-making process adopted by academy coaches with regards to the selection and retention of players.

This study was the first to adopt a qualitative approach to investigate coaches' experiences of a bio-banding intervention, specifically for its potential application of reducing the maturation-related selection bias. Analysis of interviews conducted with six coaches highlighted four key themes, which included the landscape of youth football, observation of players' competencies, implications for player development and future considerations. The main findings indicate that bio-banding enabled coaches to detect players' competencies to a greater extent than in chronological age groups alone, and it also appears to raise awareness to the influence of biological maturity in the perception of player talent. Therefore, the findings highlight that bio-banding appears to be an ecologically valid and practical tool that may have several benefits for applied practice, with perhaps the most important theoretical implication being the mitigation of the maturation-related selection bias.

7.5 *Practical applications*

In addition to the findings of this thesis providing several directions for future research, there are also a number of practical applications offered for practitioners and policymakers associated with this academy and the EPPP. It is hoped that these proposed recommendations will provide feasible solutions for addressing contemporary issues within this unique domain and subsequently enhance best practice.

1. Selection biases due to relative age and biological maturation must be discouraged, where individuals involved as talent selectors should be provided with greater education and encouraged to actively adopt approaches to counteract these. This could include in-house education to all staff, where

pertinent research is presented along with practical approaches to counteract selection biases. For example, conducting trialist events with age-ordered shirt numbering (i.e. relative ages of players are visible to talent selectors). Additionally, given the prevalence of selection biases across the existing literature (e.g. across clubs and countries), educational courses (e.g. talent identification and coaching) delivered by national governing bodies would benefit from including modules focussed on selection biases and practical approaches to reduce them.

2. Practitioners should be cognisant of the inappropriateness of maturity, anthropometry and physical performances influencing player retention in youth teams and instead consider multidisciplinary and dynamic criteria to distinguish the most talented players. This could involve technical/tactical, psychological, and sociological skills being measured alongside the normal fitness testing battery (e.g. for anthropometric, biological maturity and physical performances). Moreover, by also including these skills to benchmark players at each stage of the developmental pathway, it will likely permit a more appropriate appraisal of players to guide selection, retention and development processes. Finally, individualistic and collectivistic approaches need to be considered; whilst the former is currently emphasised, an overreliance on this could prevent the most talented players from progressing or re-entering after dropout and thus a more flexible approach to selection/retention may prove advantageous.
3. Anthropometry and physical performances should be considered according to biological maturity (as well as chronological age) to enable appraisal of players

with greater context. This could involve maturity-based performance benchmarking (e.g. through inspection of growth curves and/or interpretation of testing data) to complement chronological-based benchmarking and/or the implementation of maturity-based group compositions via bio-banding. It is envisaged that these approaches will serve to improve the decision-making process on the selection and/or retention of players which may lead to a reduction in the maturation-related selection bias.

4. Bio-banding should be investigated further and/or integrated within applied practice as a strategy to nullify the maturation-related selection bias, as well as providing benefits for other purposes such as player development. This could involve regular bio-banding micro/mesocycles that entail in-house training and matches against other teams, thereby providing talent selectors with additional opportunities to evaluate trialists and registered players before making a decision on selection/retention. Subsequently, in-house reviews (following bio-banding interventions) which involve players, parents and multidisciplinary staff would enable bio-banding to be appraised comprehensively and guide how it can be utilised effectively within applied practice.

Chapter 8. References

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Chapter 9. Appendices

Appendix A

Institute of Sport - Ethics Approval Notification



Fri 29/07/2016, 16:20

Patel, Rickesh; Wyon, Matthew (Prof) ✉



Reply all | ▾

Flag for follow up. Completed on 10 October 2016.

This message was sent with high importance.

Message sent on behalf of Professor Andy Lane

Dear Rickesh,

The review panel for ethics in sports research has now considered your recent submission. The panel have approved your project, and wish you every success in its completion.

Kind regards,

Andy



Research Administrator
Faculty of Education Health and Wellbeing
University of Wolverhampton
Walsall Campus, Gorway Road
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Appendix B

Practice 1 - One-versus-one

Work:rest ratio = 120 : 45 s

Sets = 4

Pitch size = 20 x 20 yards

Practice details: Defenders (blue) start with the ball, pass into the attacker (red), and follow the ball. The attacker controls the pass and aims to beat the defender and score into one of the mini-goals. Play continues until: the attacker scores, the defender clears the ball out of play, or 20 seconds elapses from the attacker receiving the ball and none of the previous scenarios has occurred. The next pairing of defender and attacker start immediately after the previous play finishes. After one set is complete, the teams alternate roles, and this continues for the remaining sets. To maintain a competitive element, the total number of goals scored by each team throughout was recorded.



Practice 2 - Four-goal game

Work:rest ratio = 3:1 min

Sets = 4

Pitch size = 20-26 x 30-37 yards

Practice details: In this example, the red team is attacking the top two mini-goals. One team starts with a ball from their goal line and attempts to score in either of the defending teams goals. If a team scores, they maintain possession, and restart with a new ball from their goal line. If the ball goes out of play, the team in possession starts with a new ball from their goal line. To maintain a competitive element, the winning team at the end of each mini-game (set) was recorded.



Practice 3 - Game

Work:rest ratio = 10:3 min

Sets = 3

Pitch size = 33-40 x 20-27 yards

Practice details: In this example, the red team is attacking the mini-goal on the left. This is a standard game. Following a goal, the team that conceded starts with the ball from their goal line. If the ball goes out of play, the team in possession restarts by passing the ball in (balls are placed around the pitch to maximise ball-in-play time). To maintain a competitive element, the winning team at the end of each mini-game (set) was recorded.



Appendix C

Coach 1

Researcher: First, did you notice any differences when comparing the players' performance in the bio-banding and normal age groups? Think about the four corners.

C1: In terms of technical and tactical, I think it was much. Sorry, physical to start with. It was a much more [of a] level playing field for the majority of the boys. It gave some of the older ones who were less developed an opportunity to play with players, with the same physical maturation. I still think at times there were anomalies within the groups. There were still boys that were either much bigger than, well, mainly much bigger than others. There was probably one or two in the U14s [Bio-Band 3] game that I saw that were absolutely massive and it was still quite easy for them. But then I also saw that technical and tactical ability was much more of a level playing field, for all of the boys really, and it also gave some of the smaller lads a chance to express themselves a bit more, because it was more of a level playing field. Socially it was quite interesting because you had some older boys with younger ones and they're talking about different things and experiencing different things, so that was quite interesting, socially, that they were on different levels. And you're talking about interpersonal relationships between groups, it was interesting. And then one of the boys who dropped down couldn't handle it socially, because he dropped down an age group, he's perceived himself to be playing with younger players and that was difficult for him to watch, for us to watch him. But really, he should in maturation been an older one and understand why he's doing it, because he was quite clear on why he's doing it. So, that was one I saw that was probably a negative, but more from him as character, rather than what we were doing.

Researcher: So, just on that, do you reckon there's anything that needs to be provided when doing the bio-banding to ensure that doesn't happen?

C1: Maybe we could be really clear. I mean again we were really clear with the boy what we were doing. But maybe be ultra-clear with anybody that we think might have a problem socially or psychologically with going down. And also, probably afterwards feedback and support him. I couldn't see him during the game, but I probably didn't

intervene, or we didn't intervene as a group of staff on him at the time, when we probably could have done it. But again, he's probably got to work it out emotionally, the reasons why long-term, and sometimes they probably don't get that, the reason.

Researcher: Secondly, so you briefly touched on it. Do you feel any of the players were majorly or wrongly categorised, so some of them shouldn't have been in whatever group they were playing in?

C1: Yeah I think we've got a boy in the U14s called [player name] and he was absolutely massive in that group and again he's probably at the similar band to what the other boys were, but he was just again physically so superior to them, that he realistically he should play in the 16s rather than in that 14s [Bio-Band 3] band. And there was probably only one other boy in that group that was a similar stature to him, but he was still probably about 3 or 4 inches taller than that boy. So, that was the only one I thought he was in the wrong group, but I suppose if that's his band, then that's his band he should be in.

Researcher: Next, did your perceptions or views of any of the players change when comparing their performances and competencies during the bio-banding compared to their normal age groups? For example, it might be a player that you thought was highly competent in their age group and they didn't perform or didn't excel in their bio-banding group. Or conversely, a player that you probably didn't perceive as being competent in their own age group, but they excelled within their bio-banding group?

C1: Yeah, I saw a couple of boys that had been, so one main boy, the one I was talking about that couldn't handle it emotionally, he struggled technically and tactically, maybe its cause his emotions took over him, but when I saw him playing he just couldn't do the things that he should be doing. Because he's got good ability, but again he's always found it difficult cause he's against bigger boys, so I perceived him to go down a group or down in size in maturation and be able to handle it and he couldn't. He was probably less effective in that small, younger band or the decreased band than he would be in the older one. And then I did see a boy that had been playing up across his age group and then played in a higher band, which was probably right for his

maturity and he did very well, he worked very hard and took it on board what he was there for and showed what he was about. So, both extremes there.

Researcher: Could you provide some more detail?

C1: Yeah, so [U14 player in Bio-Band 2] was the boy that went down and couldn't handle it, just found it difficult emotionally and technically, tactically; he just really struggled and I think, just couldn't comprehend why he was there or couldn't rationalise that he should've been the best player, really. Because for his ability levels at [U]14, even though he's a smaller one, he's got good technical ability; he didn't transfer it when he went down. And I think it was [U12 player in Bio-Band 2] that was the other boy that went up a band, playing with slightly bigger boys and liked the challenge, enjoyed it, and worked hard and you know showed good ability playing with older players. And I think [U14 player in Bio-Band 2], if I remember correctly, he played in a younger band because he's very sort of physically less developed and he did very well because he understands the game well and it was quite good for him.

Researcher: Ok thanks, there are just a few more questions. How do you feel that bio-banding could be used, if at all, within the academy programme?

C1: I'm quite pleased it's been integrated within the programme...or introduced. There are some boys that we make early decisions on, or rash decisions on, because of their physical maturation. And like [player name] in the U16s now, who's physically probably an U13/14, and I think the bio-banding just allows us to have a better perception of what it would be like if the physical bias was taken away. So, I think it's great that we've introduced, it's took a while to get done across the academy system anyway, but I think it's really good that we're doing it. And the only other thing is maybe, do the bands, you can probably tell me, do the bands get even smaller to help players even more? The bands are quite big I suppose, and a disparity, but I think that it's been really good.

Researcher: So, you're saying it can probably have some influence on the retention process of players already within the academy. Do you reckon it might have potential

use for talent ID either at early stages or when thinking about trialists - when they are coming in?

C1: I think, I probably needs clarity on it and some more research, but I see it as relative age effect more important at Foundation phase and then bio-banding and maturation could be introduced at 12s, 13s, 14s up to 16s really. And again, that will be a really effective way to look at recruitment, look at sort of level playing field of trialists, because we have some trialists who are very small physically, but we sort of write them off already because they are not able to compete. But we don't always have the facility to drop them in, we probably drop younger birthdays into younger groups, but we probably don't drop physically immature trialists into smaller groups yet, unless they have shown something outstanding in training, but you probably argue that they can't show something outstanding in training because they are playing with big boys anyway. But I think it would be really useful to try.

Researcher: So lastly, following on from that. Do you think there are other things that need to be looked at within the talent ID and selection aspects that are perhaps not being looked at now, where bio-banding might help?

C1: Yeah, I think with the older ones I think bio-banding can help, maybe if we done a bio-banding trialists date, which I appreciate it would be a lot of work for you guys [sport science] to get measurements to find out what band they're in. But if we had all the trialists coming in over a period and said look we're going to get measurements and put you in bands quite quickly, if there's quick method to do it, and then look at all the boys who are in their right maturation level that would probably give us a lot. And then obviously with the relative age effect, with the younger boys and the birth bias, let's try and get them into groups a bit better, I think we do it fairly well with the young Q4 birthdays, we put them in the age group down if we think so, and the recruitment guys flag it up. But again, we are just scratching the surface and I think we can do more to make sure it's a bit more of a level field for the boys.

Researcher: Last of all, how was your overall view of bio-banding?

C1: I've come away and I'm quite pleased, well I'm very pleased that we've: A) we've been able to integrate into the programme and introduce it and, B) that it's given us more awareness of what it's about because I don't think us as coaches if we're clear. And I think it's a really useful tool, but we were sort of neglecting the younger ones or the smaller ones and sort of written them off, I think now we've got an opportunity to say look even if we haven't got an opportunity to always bio-band players into specific bio-band tournaments or festivals at least we can see that his maturation level is of a younger than others and drop him into the appropriate age groups.

Researcher: Is there anything you think that needs to be looked at or adjusted, or any better ways that it [bio-banding] can fit in the programme? Basically, any way to improve it going forward?

C1: I think just make their maturation status more visible to coaching staff or for us to be more aware. So we know they are young, but you know I don't if it's on PMA (Performance Management Application) and it flashes up literally underneath with their birthday or just somewhere we can see it all the time, so you can say "no, no he's only 85% of what his maturation could be", just so we see it a bit more, and I think that makes senior coaches and young coaches consider things a bit better, so I think that would be good.

Researcher: Do you have any other views? Those are all my main questions, but is there anything you wanted to bring up?

C1: No, I suppose the frequency of how often we do it would be the next sort of debate. I think we all agree it's good for the club, how often do we do it now? Do we do it in half terms, do we do it once a month, when do we do it, because I think it can a key part to the programme. And again, do we do talent ID days based on that, how easy would that be? Again, it's not easy, but I think we could probably utilise that. I know we do Q4 birthday talent ID days, I don't know how we would do a bio-band talent ID day, without getting loads of random kids and doing their measurements, I'm not quite sure. It would be interesting to do. You know, I think the frequency of our bio-band sessions would be important to look at.

Researcher: What do you think would be ideal or practical within the programme that that is in place now?

C1: I think every six weeks or once a month, every six weeks or every mesocycle. The only difficulty would be, is getting a team to play against us that would have a similar philosophy around bio-banding. And setting that regular games programme, [academy team] have been really good, I'm not sure how many other teams would do it. Unless we do an in-house one, then you know have we got enough players to do it, I'm not sure.

Researcher: So, you're saying, potentially every mesocycle have bio-banding as a training week with a match at the end?

C1: Yes, and if we can get it against an academy opposition – great, we can do that. If not, if it's in house that's fine, but I suppose we want to get to a point where the bio-bands are as small as we can get for a more accurate group and give them a real detail around who should be in what group, so we probably need another academy that's similar thinking to do that, if that makes sense.

Researcher: Is there anything else you'd like to raise?

C2: No.

End

Coach 2

Researcher: Did you notice any differences, according to the four corners, when comparing the players' performance in the bio-banding groups compared to their normal groups?

C2: I think there's obviously certain individuals in the group, in that group [U14], who may struggle against bigger, stronger boys. So, it was really positive for me to see, from a technical and tactical point of view, receiving and turning skills, tactical ability, passing and running with the ball etc. The smaller players were getting a lot more

success [in bio-banding] because they're not up against a bigger or stronger boy [as per chronological groups], for example. But also, on the flipside on that, your boys who rely a lot on their physical outcomes such as their agility and speed and power and strength, they're then able to, they can't rely on that so much, so they have to think a bit more, probably psychologically what they want to do with the ball before they have it, finding a problem and problem solving and obviously trying to be a bit more creative. Instead of saying, for example, steamrolling someone and relying on their strength a lot more. But I thought it was a lot better, obviously you've got lads who are dropping down into that bio-banding category who will get more success on a match day, which would mean then also helps with their social stuff, so how they might behave, how it develops their confidence more because they're getting a lot more success from being against someone who's of the same ability or physical ability if you like, and the same maturation or speed, and agility and their physical outcomes.

Researcher: Were there any players in particular you noticed?

C2: Yeah, I can think of one, so [U14 player in Bio-Band 2], for example. So often with [player name] he would like to run the ball or do a trick, but he's at the age now where I think us as coaches have got to be a bit patient with him and understand and try and educate him a little bit that sometimes he's just got to pass the ball, at this age. Whereas when he's up against someone who's of his same size or someone who's maybe not as quick as him, he can then maybe do his stuff and look to creative stuff and run with the ball and travel and finish in great areas and be more creative in the final third. I just think at times that he does get bombed a little because of the physical [in the U14 group]. So, the boys up against him, obviously when you bio-band him, the kids are a little bit more of the same age and the same physical outcomes are the same, which is good, really good.

Researcher: Do you feel that within any of the groups that you observed that any of the players were categorised incorrectly?

C2: I found it interesting on the [academy team] matchday, I thought a lot of our boys [in the Bio-Band 3 group] looked a bit bigger than the [academy team] players. I watched the U13s [Bio-Band 2] game back and I think that was a bit more, a bit more

on it [balanced]. But obviously I think, so there's people in our group, we've got some big boys, like [player name], so [player name], for me he could play U15s and in our U16s. Obviously, he's got to have the technical and tactical side, so he's got a lot of work to do on his positional play and how he receives the ball and obviously psychologically, he's got to be a lot more confident. But him for example, I think he probably gets away with stuff at U14s because of his size, because he's able to use his power and his strength. People like [U14 in Bio-Band 3] is another one, very quick, very strong boy, but again his technical and tactical stuff needs to be better to get him out and obviously as he goes and grows and gets a bit older he will need to be better in those departments if he wants to be successful.

Researcher: Did your view or perception of any of the players change after the bio-banding? So, for example, a player that you previously thought was highly competent in their own age group but wasn't so much in the bio-banding? Or the reverse, where they're not typically competent in their own age group but they excelled in the bio-banding?

C2: Yeah, we've had a couple of trialists in recently that are big, strong boys, tall, strong, athletic, quick. Obviously when you match them up against someone who's got that [in bio-banding], I seem to think their tactical and technical, as you can see that, for example, receiving the ball to play out. If they get pressured by a stronger boy, they can't rely on their physical outcomes so much, so from that point of view, probably a couple of those trialists. Obviously [U14 player name] playing down in the 13s [Bio-Band 2] but I think, because he's playing down or sees it as - well he's not playing down, he's bio-banding, but he sees it as because he's smaller in that group that might knock his confidence. So he doesn't perform to this maximum, he wasn't the best player in the bio-banding 13s [Bio-Band 2] game, but he needs to be better in the aspects of developing his confidence and concentration, does he communicate, is he socially ready to be in with that group?

Researcher: Just on that, do you reckon the way that it's, how its packaged and whenever players move across age groups, that the wording possibly needs to be changed so it's not seen negatively?

C2: I think if we could do where we identify four or five or six of the lads that are definitely going to go and play with the 13s [Bio-Band 2], I think at the [academy team] game, there was [U14 player in Bio-Band 2] and I'm trying to think if there was anybody else, I can't think out of the 14s group.

Researcher: [another U14 player in Bio-Band 2] would also have been in that group.

C2: Yeah [player name] sorry, who's been with that group, yeah. [player name], so you've got two. I think if you can get five or six and five or six U13s as well, who are maybe smaller or stronger or whatever or however you look at it and get them together. I think that will develop a lot more of the social corner so communication on and off the pitch, relationships with players, teamwork obviously on a matchday, and obviously their general behaviour.

Researcher: So, you said in terms of your perceptions and your ratings of the players, that was only applicable for the trialists? In terms of that it helps you decide and identify that they might need some technical and tactical work?

C2: Yeah, so mainly just the trialists that come in here, I'm fully aware of working with the [U14] group now about the stronger boys that they can't rely on that for so long. And I think we've got a role to as coaches to show that and teach kids that here. That they can't rely on the physical outcomes because it gets to a point when they are going get to 17/18 everybody catches up [physically], so they've got to be a bit clever, outthink their opponent, be a bit smarter - intelligent if you like. And also, be ready technical and tactically.

Researcher: So next, how do you feel bio-banding could be used within the academy, if at all? That might include talent ID and talent development.

C2: So, I think it should be in every six weeks, or every five weeks, whatever you want to do where we could be entering tournaments. Like I said, I think from how we educate the players, that they are going be in bio-banding is massive. Because a lot of players think they're going to bio-banding tournament and they think they automatically think that they're playing down because they're not good enough to play in their own age

group. But if we could do that I don't know, but I think we could do that once a month and then I think the bigger, stronger boys need to be playing with bigger, stronger boys to stretch and challenge them. And then to develop the four corners, obviously they are going to be good physically, you'd expect them to be good socially because they are quite confident, but technically and tactically against a bigger, stronger boy they've got to find a solution, and obviously psychologically they've got to concentrate more. So, for example, if there's a defender and he's big and strong and there's a cross coming in against a smaller attacker, I'd expect him to win the header. But if he's up against a striker who's bigger and stronger, he's got to concentrate more not only on the cross, but what his opponent is up to. Whereas on a match, on a normal matchday [chronological groups] he might just get in good areas just to defend or his speed might get him out of trouble. Same with attackers, big, strong attackers against smaller defenders. It's a no brainer! He's going to be quicker; he's going to be stronger; he's going to get more chances to score. Whereas, if he goes up and plays up against a bigger, stronger defender who's just quick he's got to think differently and that's part of learning, for me.

Researcher: So, you said in terms of talent development, being across all the four corners. Do you see it having any use within talent ID or retention or within the selection process?

C2: It's very difficult isn't it? Because it's grassroots football, so I'd like to see it yeah. I think it would be, but again it's how we are managing that and how were educating not only the kids but the parents as well. So you mention someone like [U14 player in Bio-Band 2], who's a very good technical player I think, tactically he's very clever and, but he's very small, so he's got to, we've got to be patient with him or we've got to look at educating him to identify what is best for [player name]. Is it he's going play with his own [chronological] age group because they are a bit smaller and a bit more physical? Same with [another U14 player in Bio-Band 2], or are we actually going to say no? Because a lot of players play down don't they, or play with their own bio-banding groups in academies, but I think it would be good if we could get tournaments set up to recruit players and say you're going to play in this bio-banding tournament as a trialist. So as a defender you're 6'2" already and you're the quickest in the [region], but you're going to play against someone who's just as quick or just as quick and 6'2"

as well, an attacker, and then we can see where they are at. I just think sometimes we get caught up on the physical, so he's big and strong, and quick, and maybe not so much the technical and tactical, and obviously the psychological. So, we want to produce intelligent footballers, good footballers, not athletes; I don't know, that's another discussion. But I just think sometimes we get caught up, and I'm guilty of it as well sometimes, of the physical.

Researcher: So, overall, what was your view on bio-banding?

C2: Yeah, so I thought it was excellent. I thought the practices were really good, the kids seemed to be engaged and enjoying it. I thought there was lots of success for different players. Obviously, on the training or on a match day one player might just get success because of the physical outcomes, so it was pleasing for me to see people like [U14 player in Bio-Band 2] and [another U14 player in Bio-Band 2] especially in the [bio-banding] training session gaining success of the outcomes. So yeah, I'd like to see it more, I think it, we've seen more success from players on a matchday, so we wouldn't say judge them so much, but we probably see more success from them cause they're playing with lads of their own ability or physical outcomes if you like i.e. height, speed, strength, power. And obviously we'd have a lot more success of them getting on the ball, so the technical and tactical corner would then develop.

Researcher: So just on that, are there any ways you'd look to improve or modify things going forward to integrate bio-banding within the academy programme?

C2: Yeah, so I mean we could organise tournaments here based around bio-banding. We could look at doing that, so do the [academy team] Cup but obviously do bio-banding tournaments. How often we do that is the issue, where we'd have to get it in. I think maybe once every six weeks. I think we maybe do it once or twice a year. I think, correct me if I'm wrong, so we could that every six weeks, right it's a bio-banding tournament were going to invite [local academy team] in, and were going invite [another local academy team] in. And it could be looked at as if right who's got the smartest players, the best technical players and not so much the physical and social corner. Which would be really interesting to see and where we'd measure. We could also do one night a week where they are bio-banding training, so my U14s I work with,

[U14 player in Bio-Band 3], you're going train with the U15s [i.e. a new Bio-Band 4 group] because that's more of where you're at, at the moment. [U14 player in Bio-Band 2], [another U14 player in Bio-Band 2], you're going train with the U13s [Bio-Band 2], i.e. any 13s that are bigger and stronger, so [U13 player], for example, he could come and training with the U14s [Bio-Band 3]. I'd be happy to see that and let's see how good these players are when they are matched up in their own physical outcomes.

Researcher: Any last comments you wanted to mention?

C2: No really good what you're doing. I think it...needs to be more of it [bio-banding]. I think for the players' sake as an individual. I see a lot of players get frustrated because of their size, they're small players and they have to be reassured and encouraged to keep trying things and keep trying to do the right things. And we have to be patient with them as coaches and obviously we can get carried away on the other side of that with big, strong, quick, physical lad who scores five goals a game. Will he be able to do that at U18s and U23s football? I don't know, but there's a good chance maybe not because they're are relying on the physical outcomes a little bit.

*End

Coach 3

Researcher: Did you notice any differences, according to the four corners, when comparing players' performance during the bio-banding and normal age groups?

C3: Yeah, I'll start probably as a whole. Probably in the physical corner, my very first thought on just literally seeing the two teams walk out together is that physically they look evenly matched. Usually, when you look at a team you always get one or two players that are just, a little bit taller, or really small in comparison. But the first thing I noticed is that, if you'd have lined up both teams side by side, the differences between the smallest player and the tallest player wasn't the usual gap that it would be [in a normal U12s game], without that bio-banding really. So that was the first thing I observed. Again physically, I would've just guessed as well, sort of maturation-wise,

you didn't see anybody who looked like they were miles behind, like small and very weak, if that makes sense, or not physically strong. And even the tallest one wasn't necessarily, just because they were taller, they weren't necessarily physically bigger [muscular]. So, they were probably a little taller. In terms of speed, when the game was going on, there was nobody just powering through and getting anywhere quicker than anybody else. I think it just came a bit more down to stamina, some players just looked like they were able to go a little bit longer than other players really. One-versus-one challenges tended to be quite even, evenly matched. There was an instance where one player, I think it was [player name] was in a 50-50 [one-versus-one challenge] with one of their players who was moderately sized as well, but bit bigger than him, but he managed to hold him off, so I think that was decent. What other differences? Technically, I think the gap was probably, at times, still the same. So, I don't think it had too much relevance on letting players who weren't technically good all of a sudden being technically proficient. The best player on the pitch was the best player because he was good on the ball. So regardless of his size really, or potentially his age, he was just better on the ball, so he was able to create and do the bits he wanted to do. I think it just helped some players that weren't technically as good just get away with some things that they weren't always getting away with [in normal U12 matches]. So, they were still making the same mistakes, but it wasn't costing them as much as it usually would if they're were playing on a bigger pitch or with stronger, faster players. So that was probably that in terms of technical. Tactical, again it was difficult for pretty much both teams really because you had a mixture of players in there, but I don't think it affected anybody's understanding of being on a bigger pitch or playing with the mixed age [bio-banded] groups. I think if they understood the game, they still understood where they needed to be and what they needed to do. Socially, I mean we kind of get away with it anyway because we very much put the boys, mix the boys together anyway, socially across those age groups. There were a few boys that weren't present in there that would have been a little older [U13s players] than the youngest ones, certainly in our team [Bio-Band 2], and that would have been interesting to see. That gap, how they would have dealt with it, the players that are two years older, but the majority of players were within the same year, chronological year or within the same school year really. So, there wasn't too much difference in terms of that, so as a result they kind of knew each other and still thinking and behaving the same way.

Researcher: Would you say there was any clear differences, for any specific individuals that you'd seen, across the four corners?

C3: No, not really. I don't think the players were as receptive as to what was going on. I think they knew the obvious ones; when the biggest boy in their group [U12] all of a sudden wasn't in the team and they look around and then they get a feel for that, like "ok, we must all be in this group for a reason." But again, I don't think it was as obvious, the differences weren't as obvious just mainly because the majority of the team [U12] were in the same group [Bio-Band 2] anyway.

Researcher: Do you feel that any of the players were wrongly categorised?

C3: With the naked eye, no. On reflection after the game, if you're taking the technical ability of the players into consideration before it, it was quite obvious that [opposition team] had one player that probably was in the right [bio] band, but he was just technically too good anyway. Which meant that, I think for that [opposition team] player, he probably felt it was the easiest game, ones of the easiest games he played, because he's probably always up against it [in his normal age group]. I think it [bio-banding] evened the game out for him. I think for our players, it made it little bit more balanced; the matchups, so there were more 50-50 matchups, rather than 70-30 matchups going on [as per normal U12 matches]. I think it [bio-banding] helped our players overall to make it a game; I think the game almost, or the score, almost reflected that. Other than the fact that that one player in particular, maybe there was another little kid as well, who was quite small, but again technically very good, who, all of a sudden had the game levelled out and those two really just shined, because they looked around and everyone was the same [physically] as them.

Researcher: Did your view or perception of any of the players change after the bio-banding? For example, a player that you previously thought was highly competent in their own age group, but wasn't in the bio-banding? On the other hand, a player that you didn't think was very competent in their own age group but excelled in bio-banding?

C3: Yeah, I must admit, when I did look at both teams there were some players' I did expect to do a little better knowing that some of the older, stronger players had been taken away. I felt [player name] maybe should have done a little bit better because physically he was probably one of the tallest, probably one of the oldest and most powerful out of all that group really. So again, when I looked at what we had in terms of players and what they had, I expected him to maybe dominate a little bit more just because he was probably one of the most physical ones out there. But I think on the whole, the majority of them done what I would've expected them to do. It was interesting because the ones who were smallest in that game, are usually the smallest ones in any game anyway, so they kind of kept the same behaviours and traits they would usually have anytime I've seen them play. So, there was still that slight disadvantage in some regards, but it didn't really affect their gameplay as much because they were always at a disadvantage [in their normal U12 groupings], so they were kind of just going about it in the same manner. I think it's the ones who are the opposite, that are sometimes the more physical players, the stronger players, who sometimes get put up against players bigger than them [in their normal U12 groupings], who all of a sudden didn't cope well to the fact that they should just be now dominating the [Bio-Band 2] group, against players that a lot less physical than them, or a lot less strong than them. So, I think they found it difficult to almost be the 'big dog' on the pitch really. It was probably more along the lines of, rather than my perception changing of what they are, it's probably more position based. So, it just gave a little more of an opportunity to play some players in different positions which we perceive need to have to fit a certain physical criteria. So you're able to, obviously you're taking the big players out and just making everyone a certain height; all of a sudden, you can look at someone potentially as say a centre back, that you usually wouldn't be able to consider as a centre back, because they are usually playing up against someone that's really tall. I think for some players, I don't think it was totally beneficial psychologically, because I think they've made a trait of adapting to being the smallest one or adapting to having to battle against bigger players.

Researcher: How do you feel bio-banding could be used, if at all? Some examples could include talent ID and talent development.

C3: It's definitely useful. And again, I think it helps to even out matches, to some degree, and I think it helps coaches, managers, clubs, look at the result a little bit more holistically, rather than literally just the result. For example, we still lost the game against [opposition team], but we didn't lose the game because the big centre forward was running in and smashing it top corner. We lost it because they had better technical players, so it was easier to see that the excuse of saying "ok, well if they didn't have the big guy, you know it would've been a [more balanced] game" was almost removed. So, I think if clubs want to be able to look at the game, look at the result, and reflect on the result a little bit more honestly, and players a little more honestly, I think that's the way to maybe go about it. Because it is quite easy to cheat with another player that is too fast to be in there [match] and it distorts the result and makes it almost uneven. What I would probably say at the same time is that if that does happen [bio-banding making the game more balanced], it can be difficult for players to have an excuse, if that makes sense. So, if you're a small player, and your excuse was "I'm always playing against players that are older" and all of a sudden you are put in a bio-banding game and they are still not good enough, even when they are playing in that bio-banding age group, then it kind of removes that excuse for the player. And then again, probably the other argument is that in a real game [professional] you're going to have a mix of smaller and big players, so if you cocoon the players in bio-banding every single game or every week, then when they get to a certain age, when it opens up to all body shapes, then obviously it's going to be difficult for them. But again, it is good for the ones who haven't matured as quickly because then they are getting an accurate reflection from the coach and reflection from the staff because they're actually taking into consideration the fact that they are not as strong as other players just yet. So yeah, I think it's a type of thing you would use if you're thinking about releasing a player, because they're physically not capable. I would always think to myself now, before we released a player and we don't think he's physically capable, we probably have to put them in a bio-banded age group and just see what they're like with players who are at the same stage of growth as them. If they're still not good enough, then that's a different argument. If they are pretty good when they're playing with players at the same stage [of maturity] as them, then that might swing the decision or change the way it feels.

Researcher: Overall, what was your view of bio-banding? For example, is there anything you thought did work, didn't work, ways it could be improved or how you see it being integrated within the academy going forward?

C3: I think it did work. I don't know if you'd use it every week, but I think it's something more clubs should definitely be looking to do. I think it'll help some clubs, and it'll hinder some clubs. You know some clubs won't really buy into that [bio-banding] because I think they actually like the fact that they can go out and find players who are a little bit ahead of the curve [physically] for their teams. I think if I were to do it, maybe even stretch it over more age groups, maybe even the younger age group [U11] because I think there's still, I think it's still relevant and I think they're still close to each other. So there's a few players that were probably still around the age, the maturation, well, the distance between the top player in our age bracket [Bio-Band 1] and the bottom one could still be quite sizeable even though they are grouped in the same [bio-banding] group. So, we know that they're in around the same area [in terms of maturity] but I would probably make the [bio-banding] groups a little bit more concentrated. And if you had the players, if you include more than one club, it might even be a round robin, sort of three-way thing as a team. Or three teams maybe even mix them up, so you take away the aspect of being with a team where you just understand what you're doing and that is actually helping you through, as opposed to just your own flat out game. So yeah, I think if I was going to do it again or try something potentially different, almost make it like it a festival. So, bring four teams in, put them in their bio-banding groups, mix them all up and put them into teams, so they literally just having to play, play a game of football and just see who, who stands out. Then you might get a bit more social; so, most of these boys are social anyway because they knew each other, but you might be able to see who's really quite, who really stands out when they're playing in a team of players they don't even know. And again, it takes away the tactical aspect of "ok, I know what I'm doing anyway, so regardless of what group I'm playing with, I still know what I have to do," as opposed to "ok, just put me on a random team, the only thing that's really going help me through the game is just my football ability." That's probably one of the only things really that I'd look to build on it if I was going to do it, or if I was going to see it again.

Researcher: Is there anything else you want to comment on, or anything else you feel is relevant?

C3: I think it's just a good thing to do. Speaking to [the opposition team's] coaches as well, I think they bought into it. I think they were pleased with it as well. And again, it's probably just looking at other clubs and seeing if anybody else is interested in doing something similar at a similar stage, if that makes sense. So, if they're going to play, if they're going to release players or they're thinking about seeing at the end of the season, you know you've already played them a few times during the year, to freshen it up or to give players a new perspective. Do you just say at the end of the year were going to play a bio-banded version and just look at players there before we think about releasing or retaining players?

End

Coach 4

Researcher: Did you notice any differences, according to the four corners, when comparing the players during bio-banding sessions and their normal age groups?

C4: So, the players that probably would be most affected. Players like [U14 player in Bio-Band 2], just thinking back to the session indoors when they were combined in the collaboration day. So [player name], and one of the reasons why we're trying to play him down with the U13s, is that he gets more joy, so in a sort of technical way he gets more of the ball, so he's able to be more confident with the ball and do the things he wants, and needs to do. One of the things I noticed is that when he's with the smaller group [Bio-Band 2], and players like [player name], who when they're with the smaller group tend to try more things and be a bit more expressive. It can work in one of two ways. For confidence, one of the things I saw is that when it does work, they're confident, but when it doesn't work, even with their own [chronological] age group, it can have the negative effect, so it can knock them a little bit more. So if they're playing with kids who are maybe a year younger [in bio-banding groups], but because they're physically the same stature, and they're still not getting it right, that can kind of make them be a little bit more, what's the word, maybe less confident or they might, not

angry, but it might get them a little bit more frustrated in what they're trying to do. But again, that can identify whether the player has got ability or if he's able to progress by playing at a younger age [in bio-banding groups] or if he's at the right age group where he's allowed to express himself. So, I think the two players that come to mind were [U14 player in Bio-Band 2] and [U14 player in Bio-Band 2]. Yes, they can try things, but again if it doesn't work for them, it can go the opposite way, where they think if I can't do it against players that are a bit younger than me [in bio-banding], which is again what we're trying to do, then that can have a bit of a negative effect. But I think the positives outweigh the negatives for players like that.

Researcher: So, you've touched on some technical and psychological, are there any physical or social elements for any differences you've seen between any of the players or the group?

C4: Physically, I think that it's much better. I think when they're playing up against people that they're matched up [in bio-banding], so for example, [player name] this week was playing up against [academy team]. They were smaller players, so he tended to get more of the ball, he was able to get on it more, whereas when he's up against bigger, physical players who just push him out the way you just don't see him. So, I think he's allowed, he gets that bit and that speed with the ball, so he's able to get on the ball and accelerate and get away from players which he doesn't do at his own age group. That physical resilience, that comes out a bit more, he's able to compete in 1-v-1's and defend and regain possession in 1-v-1's. Socially, I think that it's not just on the sort of age bias or physical bias. When you talk about bio-banding, people tend to think physical, but I think the social ones are probably one of the bigger ones. So [player name] was one that played, he's an U15 now but played with U14s, but didn't really know the group or didn't really want to be involved in that group. So, he tended to, he just didn't really want an involvement. And it took a while to get his buy-in and for him to be motivated to play and train in that U13, U14s now, group. He didn't really want to be involved because he was very close with his own age group and the players around him, so he found that quite difficult. Whereas somebody like [U14 player in Bio-Band 2], who understands that for him to be better and have the better opportunity it is best for him to play a year younger [Bio-Band 2 or U12], so I think socially he's fitted in much better with that age group, and that probably with him

being involved in both age groups through the years as well. [U14 player in Bio-Band 2] is another one similar to [U15 player name, as above], when he plays in the age below [Bio-Band 2] he doesn't really know the players, he fits in socially with his own age group [U14]; so he's kind of the joker, the comedian in that group, so when he comes away from it he sees it as a negative. He thinks he's being perceived as a weak player, "I'm playing with the 12s this week, all my friends are going to think I'm not good enough etc." So, the social thing, I think that's a big thing for the player, probably the biggest thing and obviously that links with your psychological. If I see [U14 player in Bio-Band 2], for example, plays with the younger ones [Bio-Band 2 or U13], psychologically I think that's knocks his confidence, even if we have that coach-to-player conversion or club/coach-to-parent conversation. He still feels that it's a negative in terms of his confidence and how he feels, but again that's just the education. If you look at [U14 player in Bio-Band 2] who's probably more educated [around bio-banding], knows why he's doing it for certain reasons, and parents know the same, so it's easier to persuade. Whereas [U15 player name] and [U14 player name], it's probably the other way, probably knocks their confidence, but again, if they're playing in the younger age group and they start performing better, then they're more likely to be confident in their own game [normal chronological group].

Researcher: Just to elaborate, in terms of buy-in and getting players to understand it, how bio-banding is addressed and moving players into their bio-banded group, do you think there are ways to improve that, to enhance that buy-in?

C4: Yes, definitely. I think there's a reason to have parent meetings so that maybe at the start of the season we have a parent meeting to say look, if it's U13s and U14s, your son may play up or play down for different reasons. So, to educate parents, it doesn't even have to be a meeting it could just be a video or something that we're producing at the club to explain the situation and talk to players. Maybe something to show us talking to players about it and making that available for parents, whether that's through the club app or the website or something, where the parents can actually click it; we send an email and say look here's a link to explain bio-banding, why your son might play up/play down. Not necessarily workshop, it could be, but that probably explains the bio-banding a bit more. So if their son is playing down, it's not a phone call [from the parents] to say "oh, why is my son playing down this week?," and I think

that could be done if we plan for players to play down [in a bio-banded group] over six weeks and then play up in their own [chronological] age group for six weeks and just look at monitoring that. But I do think there needs to be a proper plan in place, instead of just doing it. Like what you've done with your study - which has worked, but that is something that you've planned and put in place. But if we don't do that as a club and say 'this [bio-banding] needs to be embedded into the programme' then it's not going to be picked up and it'll be lost. Yes, definitely room for that.

Researcher: In your opinion, would you say that any of the players were incorrectly categorised or grouped?

C4: I don't think so.

Researcher: So, within the bio-banding groups, do you think everyone was around the same physical maturity?

C4: Yeah, pretty much. I think probably the top end of the U14s [Bio-Band 3], people like [U14 player name] and [U14 player name], I think they were probably more physical, so if you talk about the top band, yeah, because you didn't have U15s to pull in they were probably at the top end. So you'd probably, if you're trying to do it across all the age groups, those two or three players at the top end of the 14s [Bio-Band 2], would be in the 15s group [i.e. a new Bio-Band 4 group] with [U15 player name] and [U15 player name], for example. But again, if you haven't got those players to combine and work with then it's quite difficult. But I think the rest of the boys were sort of matched up. Was [U14 player name] with us? I'm trying to think about [player name].

Researcher: He would have been in the middle group [Bio-Band 2], him and [U13 player name].

C4: Yeah, and I think [U14 player name] was identified. So, when we looked at the timetable and looked at the 'red' [players that were not available during the bio-banding intervention], we identified them as 'red' didn't we?

Researcher: Yes.

C4: We looked at the red players and thought he can't, even though he is physically an U12 or an U13, he can't go in there because he'll just get the ball and run around everybody. So [U14 player name] was an example who was identified as a 'red' to play in the 13s [Bio-Band 2] and I don't know if we ended up putting him in there.

Researcher: No, he was away on holiday so he didn't participate, but yes, he would have been in Bio-Band 2.

C4: Players like that, I just think yes, identify by their bio-banding, but I still think we need to take into consideration their ability, possibly. But does that then take away the validity of the exercise? [bio-banding intervention]...I don't know. I just think there are some players that were, who would be considered to be elite players here, who would've played in a [bio-banding] group where it just would've made the experiment or the exercise or the project just invalid. I just think you probably wouldn't have got anything out of it. So, for us to make the decision to go "well, I don't think that would quite work" was the right one.

Researcher: Just because they would be outstanding within that bio-banding group?

C4: Yeah, I think so. I think bio-banding it's all based on their physical maturation isn't it? So, is there an argument to look at combining something else with the physical, so it's not just physical? Or, do we just go right "this is a physical activity, lets bio-band it this way and hopefully the technical, tactical, social and psychological kind of works itself out?" Or, do you go right, "here's the physical" - which is what we did, and then we went, "tactically and technically he's better, he's too far ahead of these so we need to maybe move him up one group", which is what we essentially did.

Researcher: Did your view or perception of any of the players change due to the bio-banding? For example, a player that you previously thought was highly competent in their own age group, but wasn't in the bio-banding? Or the other way around, they're not typically competent in their own age group but excelled in the bio-banding?

C4: I think the boys that I mentioned, so [U14 player in Bio-Band 2], [U14 player in Bio-Band 2], a couple of players that we're still talking about now who played in the

smaller [bio-banding group], with the younger players. I felt that would be the best thing for them and they would excel, and they would be the best player in that group, but it doesn't always materialise. Do you think that cause they're not quite doing it in the U14s, physically, let's put them in the U13s [or Bio-Band 2] and give them that opportunity? They do try and express themselves, but I think because they're coming down, well, what they see as going down an age group, they think they need to do more and they've got the opportunity to go and be creative, but sometimes doing more is too much. In fact, just try and play, keep it simple and try and play and do the right things. I think [U13 player name] more likely to do that, [U14 player in Bio-Band 2] thinks that if he comes into a less physical age group [Bio-Band 2 or U13 group] he can just go and do the things he wants but he ends up losing the ball and looks a poorer player as a result of it. So, I think those two where ones. [U13 player name] stands out, so when you put [him] in that [bio-banding] group, he's probably the stand-out. I think all the coaches agree that's he's probably "the one". Physically, he's probably less matured, but he's outstanding technically, tactically and psychologically, he's just far ahead of everybody else. It just gave us a chance to look at the players that we said right, "let's try them in the smaller, with the smaller boys [bio-banding groups] and see if they do it." They got more opportunities, but I wouldn't say they were outstanding in that sort of physical group.

Researcher: How do you feel bio-banding could be used, if at all? Some of the areas might include talent ID and talent development.

C4: Yes, it can be. I think it's useful. My only concern would be if you're jumping up two age groups. So if you're going up from U13s to U15s [i.e. a new Bio-Band 4 group], and you've got a small U15 who's very good and drops in the 13s [Bio-Band 2], like [U15 player name] for example, I just think that's a little bit false. So, you have to weigh up the technical and tactical and the other aspects, psychologically, social aspects. So, if he's way above [technically], but just because he's smaller, we are going to stick him in with the 13s [Bio-Band 2]. I just think there needs to be a bit of thought around that, and not just go "because he's less mature, let's put it together and expect it to be fine." For talent ID, I think it could be used. I think probably for talent development I think that's probably where I see the value in it more. So, developing those players

that are physically less able, putting them into that [bio-banding] age group, that's where I think you'll see the benefits.

Researcher: That might include looking at trialists. Alternatively, the decisions for signed players to be retained or released, those sorts of things.

C4: It's a risky one because I'm just looking at the trialists in now; we've got big, physical lads, [player name] who comes in at U14s, does well physically, but I think if you put him in the U15s he gets found out. So, is it right to put him in the U15s because he's physically mature and then you see that he doesn't do that well, but actually in his own age group he does well? So, what's that decision made on, is it based on his U14s performance, where he does well, or his U15s performance, where he struggles, just because he's physically mature. I think there's a danger in that, but there may be a case for it. I just think, I keep going back to [U15 player name], if you've got someone who is outstanding and stick him in the U14s [Bio-Band 3] and he's a world beater, that doesn't necessarily mean that when he gets to 17s/18s/19s that he's going to be a first team player, for example. So possibly I think more for the talent development, so if we are identifying that he needs his physically challenged now like [U14 player name] – he needs to play [with the] U15s – let's give him the opportunity over the next five to six games against U15s who aren't your [highly rated academy team] or your [highly rated academy team] or your [highly rated academy team]. It might be [lower rated academy team], [lower rated academy team], [lower rated academy team], let's play him against those players, let's see how he copes. "He's done good? Right, let's keep him in there for a bit." If he struggles, size, socially, psychologically, let's bring him back into the U14s and see how he copes with that. [U13 player name], just on that point, it's something that will help you. [player name] is one of the top players in the U13s, comes up with the U14s, we said right he needs a technical and tactical challenge because he's better than the rest of them. He comes to the U14s and struggled socially, so just didn't fit in the group, didn't really enjoy it, we said "ok, for that reason we need to [review], psychologically". His confidence went, wasn't creating, didn't communicate [in the U14 group] etc. So, let's put him back in his U13s age group and he just went back up [in performance levels] again. So, it's kind of trying to weigh up the individual, and [player name], I forgot about [player name], is a prime example of that.

Researcher: So, all four corners need to be considered?

C4: Yeah, I think so. I think just to do a physical bio-band; I think that's too isolated from the bigger picture. I think there's a time for it, but I think like you say, you've got to consider all the factors as well.

Researcher: With regards to the retaining and releasing of players, do you think it could support that process, by doing bio-banding?

C4: Good question. If I think real-time, so I'm thinking now. So [U14 player], who last year was probably growing through a bit of growth, who was kind of like there, he was ok; now he hasn't grown, and he's not got quicker, and other players have had that growth over the summer, now he's struggling. So, he's [now] in the position where, technically and tactically, he's not performing. But that's as a result, I think that's as a result of his confidence. So, because, that's a good link actually you could use, because he hasn't grown physically: speed, acceleration, 1v1s, he's finding that he's getting bullied on the pitch, so his confidence is gone. Which means technically, tactically he struggles, which then means, as coaches, we then look at it and go, "not good enough." And then we end up making a decision based on that factor. But, if in fact we identified that at this stage and go "he hasn't gone through his growth in the last six months or nine months and struggling, could we put him in the U13s [or Bio-Band 2] for four or five weeks and see how he copes in that group?" But then, that obviously links to all the sports science data, so knowing in the last six months, has he progressed, has [another U14 player name] gone up [height], no? But actually, [another U14 player] has gone up by an inch or has got faster by half a second over 30 metres, whatever it is, and then comparing those and then that allows us to make a better decision on whether we keep him or not. Cause he could be, in four weeks he could be gone and that could be based on the fact that we haven't identified physically he hasn't developed which means he's stayed in a group where everyone's just overtook him. That's, I think that's where all the physical links with the psychological, technical, tactical [come in]. So, he was captain, probably won't be captain now. So socially in that group, he's going to be a bit "ok, where do I stand now?" and then the coaches go or recruitment go "we've got someone better, who's six foot [tall], wins every tackle, wins every 1v1, let's get him in," but can't play. I say can't play, he's just

technically and tactically not as good. So yeah, that's the conundrum, and I think if coaches had more of an insight from sports science, but that's where you really, really need to the data. So [the U14 player's name], what was his last fitness testing, what was his fitness testing before, what was his height last time, this time etc. Then you can kind of measure that closely. I think we're getting there, but we're not there yet.

Researcher: Overall, what was your view on bio-banding?

C4: Positive. Good. Shook it up a little bit so it gives players something to look at. And it's good for coaches as well because you see players in one group all year and then you end up judging them. But actually, when you mix it up a little bit you get a different understanding of the kid and understand that he's a bit more confident playing with these or tries different things [in bio-banding]. But it also works the opposite way, so you might see someone like you say [U14 player name] who plays with the young ones [Bio-Band 2] but still can't do it in that age group. So, you know, in my mind, I'm thinking if he can't do it in that age group, he's probably not, this probably isn't the place for him, in the nicest way, not to be too cruel. But yeah, I think it's a good way for the coaches to use the physical data and the physical output of players to measure them against each other, but still have the other bits [i.e. four corners] in mind to be able to make judgements on development.

Researcher: So just on that, how do you see bio-banding being improved going forward, in terms of its use within the academy?

C4: Within this academy, I think there needs to be similar structure to what you've done. I think there needs to be more studies so that in the summer, so we've gone through a period now where that's been done, but where does it go? So, from what you've done, what next? So, I think, we've missed a bit of a trick this summer, so you've got between the end of May to the beginning of September where you can plan that within the year. Over the next, it might be every three months, six months, nine months, however you want to do it, quarterly, you go "right, we'll have two weeks where we'll bio-band it, so have your training and your games, everything is together as a bio-banding group," and then you might have two fixtures, so you agree with two other clubs, similar to what we did with [academy team that was part of the bio-banding

intervention]. So, we do that intermittently throughout the year, so after every three months you have two fixtures together and then you go back to your normal training [i.e. chronological age groups]. Then at the end of the next three months you have another two weeks training together and then you have your two fixtures [in bio-banding]. And maybe have six to eight fixtures every year that are bio-banded. Then obviously, you need to fit that in, and the only difficulty you've got then is trying to do tours [abroad] that are [organised by] calendar year.

Researcher: So as in the European cut-off dates, January to December?

C4: Yeah, so the '04s [birth year], we're trying to do this with, getting the groups together in their calendar year to have training once or twice a week, every three months, for example, so that they're ready for the tours. It's a similar principle where you're trying to get the boys to be able, so they've got an understanding of how to play, but that's in preparation for the tours, so that's the ultimate end really. Let's get them together in the calendar year, can they train and play together, get a social understanding, right off you go. Whereas this [bio-banding] would be, this would be for a different purpose, you'd probably bio-banding it for, I mean what would be the output, what are you trying to find out? Is it talent ID? Is it talent development? Is it all about judging them? Is it all about us judging them against somebody who's the same physical output, is that why we do it? I think we'd need to decide what is the purpose of bio-banding before we just go ahead and start bio-banding. Personally, I think it should be for developing rather than just for [talent ID], especially at younger ages you're doing U11s and U12s bio-banding just to see if they're good enough or not. But yeah, I think there's good value in it, mate, real good value.

Researcher: Is there anything else you wanted to mention?

C4: No.

End

Coach 5

Researcher: Did you notice any differences, according to the four corners, when comparing the players in the bio-banding and normal age groups?

C5: Yes, I did see a difference. I saw some of the boys being able to technically compete with others when they are physically in the same group [i.e. bio-banding], rather than being, you know, sometimes having a big physical disparity [in chronological age groups]. And I also thought there was a psychological difference in some of the boys, being able to compete. In terms of success, with boys that were physically the same age as them and at the same time - same size as them even. And also, at the same time, I thought the opposite, some boys crumbled under the pressure of actually having to do it without any excuses.

Researcher: Can you elaborate on the players that done well; the ones that excelled in the bio-banding, and some of them, as you just mentioned, that didn't do so well or couldn't handle it.

C5: Yeah, I think [U13 player in Bio-Band 2] done really well with the bio-banding. I think that what he done really well was first of all understand why it was set up, why we were doing it and that allowed him then to excel, technically, within the training and also the games programme that we set up for that. And then in turn, I'd say [U14 player in Bio-Band 2] really struggled with understanding why it was setup and understanding what was asked of him and why we were doing what we were doing.

Researcher: Do you feel any of the players were categorised incorrectly? So, any of the players that shouldn't have been in the group that they were playing in?

C5: No, I think that all the boys were put in the correct group. I mean you could maybe argue that [U13 player in Bio-Band 1] potentially could have been in the bio-banded group above, but again, that's when you take into account his actual biological age. I think it was beneficial for them to look around and not see so many different shapes and sizes and just see an equivalent of where they are at physically at the moment and then, this is an assumption, but mentally giving them the satisfaction before they even get into the game that they are eliminating the physical battle because everyone is the same. It heavily relies on how good are you now at football? How good are you

at making decisions under pressure? Because that's what it's going to be. And almost the game is more free-flowing because you haven't got someone just barging through.

Researcher: What about in terms of the age range that we used? So, we used U12s to U14s, do you think that was sufficient?

C5: Yeah, I would say so. I would say it was sufficient. Because that's the time, in my experience, that boys are starting to go through a lot of their maturation...or not. So, I feel that that was the appropriate age range for us to see, for us to run the testing really.

Researcher: So, you don't think that going forward we could try and use additional age groups, either a year younger or older, so the U11s and U15s?

C5: I would maybe go U15s. I wouldn't go U11s just yet.

Researcher: Did your view or perception of any of the players change after the bio-banding? For example, it could be a player that you previously thought was highly competent in their own age group, but was not in bio-banding? Or, a player was not competent in their own age group but excelled in bio-banding?

C5: Yeah. I mentioned [U14 player in Bio-Band 2] and I'll continue on that. I feel that sometimes he can be confident in his own group. And then other times, I'm looking at him in the age group below [Bio-Band 2] and not as confident, not as able really to get success.

Researcher: Any others apart from [U14 player in Bio-Band 2] or [U13 player in Bio-Band 2]?

C5: I'd say [U14 player in Bio-Band 2]. [U14 player in Bio-Band 2] and [other U14 player in Bio-Band 2] don't get much success in their own group, so they played for the group below. But also, do they get much success in that group, especially from a bio-banding perspective? So, then your question is it a physical disparity, or is it more technical, tactical and maybe psychological?

Researcher: How do you feel bio-banding could be used, if at all? This could include talent ID and talent development.

C5: I feel that I can be used to help with the talent identification, so you're actually looking and focussing on boys that you've maybe missed, because of their birth date and their physical maturity status. How regularly would I do it? I'd do it once every six weeks. So, you are just judging again, how productive the programme actually is and how well the boys are actually doing.

Researcher: How do you see it running in the academy programme?

C5: Every six weeks I'd do a bio-banding game. And have that as part of the games programme. It just enables you to measure more consistently rather than doing it maybe once or twice a year. So yeah that would help, help gain a better understanding really of where certain players are.

Researcher: Do you think then, that it may have an influence on the selection process? So, the retaining and releasing of players?

C5: Yes, I would say so. I think that it would impact and help that decision. But then also in turn, if you're putting them in their year of birth [i.e. calendar year], rather than the way we do it in this country [i.e. September to August of the following year cut-off], so we challenge for that, but that also impacts retain and release.

Researcher: So, what about in terms of initial recruitment of players into the academy? Do you think it could potentially help with trialists?

C5: Yes, I think it will help. It could help us understand a little bit more where they are. And then matched accordingly based on their physical maturation.

Researcher: Overall, what was your view on bio-banding?

C5: I would say the frequency of how often it's done, I would increase. And then also, in turn I would have training, a bio-banding training programme setup to run alongside the games every six weeks.

Researcher: And your own personal thoughts, a positive experience, a negative one?

C5: It was a positive one. It was a positive experience for me to see what it's like and to check and challenge some of our players. And also understand them more as people, and how they mentally deal with some of the challenges or the movement between groups.

Researcher: So lastly, I know you proposed doing it every six weeks and having training and a match alongside side it. Do you think we would need to adapt anything or do anything different in terms of setting up that bio-banding week? This could include information to parents and players.

C5: Yeah, I do think developing that understanding a bit more is vitally, vitally important. They [parents] need to understand why we're doing it and obviously how that impacts their child; it's really important for them to understand.

Researcher: Is there anything else you wanted to add?

C5: No.

End

Coach 6

Researcher: Did you notice any differences, according to the four corners, when comparing the bio-banding to normal age groups?

C6: I'm a fan of the bio-banding, so I definitely think it's a good experience and exposure for the lads to play up against people that are roughly the same physical ability as the others.

Researcher: Can you provide some more detail?

C6: Yeah, I think from the physical side, I think it's the biggest of the four corners, personally. And I think trying to match them up a little bit more, so the ones that are

always dominating physically [in their chronological age groups], then maybe have to step up against other lads who are as physically strong or quick as them [in a bio-banding group] is a really good idea and definitely needs to be done. Because at some stage, they will get caught up, and if they are over-relying on their physical ability, they probably won't put as much time into the technical side. It was good that it was the technical side of the game that's coming out [in the bio-banding], especially with the 1v1s which could beat the players more so than the physical side of it, just being able to push the ball past them and run, or to bully the player off the ball. But an area that I'd thought about with the bio-banding, which is not easy to measure is probably, even if it's a young player, say [U14 player in Bio-Band 2] or something, physically he's not developed, but he's also played, probably played football longer; in his mind he's probably more developed in certain ways as well. So, then I don't know how you measure that, but it's not just a physical experiment. I haven't really seen much literature on that or even many discussions on that, but I would've thought that it's something that somehow that needs to be considered in the future. On the social side, I didn't think it seemed to be too much of a problem, although there was one player there, [other U14 player in Bio-Band 2], who I know from previous experience, didn't enjoy it, and did not really get involved. I think it was [coach] who was there that day [Bio-Band 2 training session] trying to motivate him, in terms of the training session, because he doesn't like going down. So from a social perspective, for [player name], I think that, well he doesn't take it well, I don't necessarily know if it's a negative because maybe he needs to get used to that, so I'm sort of undecided whether it's a good thing or a bad thing. But he, himself, definitely didn't like it. He was really the only one that I thought stood out in terms of it was a negative, in terms of the social, the ones going up and down [in groups]. Maybe also because there's not that many that went up and down [over the three bio-banding groups], they're mostly with their own group, you know outside of [other U14 player in Bio-Band 2] and a couple of the younger ones who were up, who were already playing up at that stage anyway [in chronological age groups], so it wasn't as big a jump for them, I guess.

Researcher: Do you feel any of the players were categorised incorrectly? So, any of the players that shouldn't have been in the group that they were playing in?

C6: I looked at the older group [Bio-Band 3] and there was a big difference there in the sizes, well, there was bigger differences. I thought the middle group was the closest one, actually, the one where everyone seemed physically closer together. I mean from a physical perspective, maybe [U13 player in Bio-Band 2] could have been lower. I mean, definitely as a player he's easily good enough to play [in Bio-Band 2], I think he uses his body really well, but I would've thought just, I mean he looks quite small, even against your [other U13 player's names]. Yeah, I'd say [U14 player name] was probably the one that I was thinking that was a bit bigger and there was another lad in there I couldn't remember at the start. But yeah [U13 player in Bio-Band 2] was the one I thought sort of looked, I mean he was easily still one of the best players, so I don't think in that regard. Maybe that's something needs to be taken into consideration, again, if you're good enough [technically] you play up [irrespective of the bio-banding categorisation]. Especially if you're borderline, and that's where I think where, all those four corners, someone like him fit perfectly because physically he's probably down, but socially he fits in everywhere, mentally he's a really strong kid and technically he's excellent. So I think physically, he's short, but he's not necessarily slow or, as he's very well-conditioned as well, and he knows how to use his body, so I think he wasn't uncategorised [i.e. categorised incorrectly], but I could see if he were put down to another group [Bio-Band 1], why that couldn't happen.

Researcher: Did your view or perception of any of the players change after the bio-banding? For example, a player that you previously thought was highly competent in their own age group but was not in bio-banding? Or a player that was not competent in their own age group but excelled in bio-banding?

C6: No, not for me personally. Because I think I always look at players in terms of that. I probably look at the player, so for example, well there's a few of the lads, especially the lads that develop early, I always personally, from previous experience from coaching and even on the recruitment side, it raises a question mark if they develop early. And then you really, from that area, you start to look at if they are making the right decisions - mentally, are they technically good enough or are they just pushing the ball past people and running? So [U14 player in Bio-Band 3] is your perfect example of that. For me, there's always big questions against those players especially in that age group because there's so many players [that] are highly considered at that

age, and coming two, three, four years down the track, they are nowhere to be seen. And so, I think about [U13 player in Bio-Band 2], I'm probably more the other way and I favour the least developed players in terms of where I rate them. In terms of, if I want to go out there and win a game, yeah, I'd pick the big guys over most of the small ones, for sure, but that's not my outlook on the coaching in academies.

Researcher: So, on that, do you feel in the academy system as it is, there is almost a bit of a pressure to put out a bigger, stronger team to get results? Or, do you think academies are still trying to focus on long-term potential and facilitating that, and including late maturers?

C6: I personally don't believe that [regarding the latter point]. I know we always talk about that and every club I've ever worked at they say the same thing, but you just have to look at the birthdates and that's the real obvious one. And then if you go into deeper into what you're doing, looking at the bio-banding side of it, a bit more of a scientific background, it's really clear what happens and if you look at the players that they are recruiting now, it's even clearer. So, for me, I think there's too much of a focus on winning whether people want to admit it or not, and that goes back down to affecting the recruitment. There is some real key indicators which clearly show are you picking the bigger guys, the more developed guys, and that's birthdate, and that's not necessarily saying that as well. You could have a later birthday who's an early developer as well, but I think it's quite obvious to what's going on. And I'm not saying it's across the board everywhere, there are the exceptions, but there's definitely a...it's not an even split, for sure.

Researcher: How do you feel bio-banding could be used, if at all? This could include talent ID and talent development.

C6: Everything, I think it should be. I don't agree with it saying "right, this is bio-banding, you're in this age group, can you do it that way rather than birth date [i.e. bio-banding replacing chronological age groups]." I definitely don't agree with that. But I believe it's much better for players to be exposed to being the smallest one, competing with your own group and then also being the bigger one, for different reasons that they can develop out of it. In terms of leadership, if you're one of the older ones, or just

physically [know] how to use your body; if you're one of the older ones or if you're one of the younger, weaker ones you change the way you play to cope. And I think it's also in an ideal world you'd do it so the players all get exposed to all of it [by playing in different groups, other than chronological-based], so they become a lot more robust and adaptable in terms of being able to cope when you're the younger one, being able to cope when you're 'run of the mill' or with everybody else, being able to cope when you've now got to lead the team. Playing in a stronger team, playing in a weaker team, all of those things, for me, is part of the development of the player. And the more you can expose them to the different potential issues that they might face, for me, if they're supported correctly, they'll end up a lot better individual player, more well-rounded, being able to cope with a lot of the issues that come up later on.

Researcher: How about in terms of recruitment, and the retention and release process?

C6: Well the recruitment, are they just picking the best players or are they looking back and saying "well, they're all born in the first half of the year." And if you want to do it that way, why don't you do it every quarter? There's a lot of different ways to do it, do it in terms of their development - physical development, do it in terms of the quarter, do a bit of a mix, I don't think there should be a hard and fast, this way, black and white way to do it, but I definitely think everything needs to be considered. And there should definitely be, if there's borderline decisions, be making sure you are fully aware of where that player sits on the scale. And I know we talk about it, I know it has been talked about, but I think you probably have to lose a few more games in the younger age groups and really look at what is going to make it as a player [in the First Team]. Is it because they are physically at a certain level that they are going to make it, when they make that jump from the U19s or U20s to the First Team? Or, is it because technically and psychologically they are stronger? And for sure those others [four corners] are just as important as the physical, whereas I think the physical dominates in those younger age groups - the physical corner.

Researcher: In terms of recruitment?

C6: Yeah, who's the better player, who's the stronger player. And the big difference, not necessarily the technical or psychological side, but the biggest difference between those players is the physical side. And that's where I think, when you get to the top level, I would say the psychological side is probably more important, and the technical is definitely going to determine which level you get to, as well as physical, but equally as important.

Researcher: So, what about the process of retention and release throughout the season and at the end of the season? Do you think bio-banding could have an impact on that process, in your opinion?

C6: Yeah, definitely. And I think that the club have got that. For example, there are a couple of the smaller players, which they've probably given second chances to [in previous years], which they wouldn't have if they weren't smaller players. Whether that's more of their experiments to see [if retaining smaller players has value], or if that's what they really think, is a different story, I guess. But I think the recruitment process and selection has to take all those points [i.e. four corners] into consideration probably a lot more than what they already are. And the focus on what really is going to make players in the First Team needs to take up more of the four corners than the physical side, which I think at the younger age groups, definitely dominates.

Researcher: Overall, what was your view of bio-banding?

C6: Yeah, it's very good. I mean, I'm sure it can be fine-tuned and I think the session that you did, the players were very tired at the end, I remember. I'm sure there's plenty of other sessions. But in terms of just the exposure to the players playing in different groups, is very good. Whether it's even done on bio-banding or even done randomly [changing group composition], I still think that would be a good idea. But the bio-banding obviously gives it a bit more purpose behind it, and probably a lot more information for the selection and recruitment, retaining later on. So no, I'd be surprised if any top academies aren't doing it to be honest, and if you're not doing it, you're definitely not up to date with what's going on.

Researcher: Is there anything you'd look to improve or, as you mentioned 'fine-tune', going forward? How do you see it being implemented within the academy and what would you do to improve it to make it as effective as possible, have you got any views on that?

C6: For me personally, the biggest, most important aspect of the bio-banding is making people more aware of how much dominance the physical side of the game has at the younger age groups and that early development. There must be much, much more awareness amongst coaches, selectors, everything, about how much further that journey of the player from 12s, 13s, 14s has to get before he's 20/22, to play [at senior level]. And what are we recruiting on? Because those key skills and mental attributes that the players have to have to make it, there needs to be more influence on that, rather than, because everyone can see the physical side, if a kid is quick, strong, and I think that's why it's easy and that's why there is more focus on that. But for me, the bio-banding can raise that awareness a lot more and then there can be more focus on the other, people say four corners, but probably for me technical/tactical, psychological, on those other areas. In terms of how we can develop the players? In terms of what we're bringing in, is it a player that you can mould? Is it a player that can put the work in to make it? So for me, there are lot more important attributes than the physical side - I'm not saying the physical side's not important - it's very, very important and it's a key piece, but there's other areas I think that are more important, especially the mental outlook of the player and the mind-set of the player.

Researcher: Are there any other points you'd like to make?

C6: It's definitely where the clubs all need to go and 100% be more aware of. And I think the fact you're doing this and raising questions and getting people to think about it is a very good thing.

Researcher: Sorry, can you clarify a point you raised earlier from your past experiences at different clubs. Would you say there's too much focus on winning within academies?

C6: That sums it up for me, in a nutshell. And that's the culture, that's a way of thinking. I'm not saying it's bad, because that's my first thought as well, and I want to win more than anyone else as well. But you've got to hold yourself back and it's got to be "we're here for the long term". We're not here to win the game today, we're here to develop the players, and we all talk about it but don't back it up with the training we do sometimes, and the recruitment.

End