THE UNIVERSITY OF HULL

Practitioners Perceived Effectiveness and Application of Maturity Status Bio-Banding for Talent Identification and Development

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ABSTRACT

Bio-banding is an approach used to group athletes based on their characteristics in relation to growth and maturity, rather than their chronological age. Although recent research has explored the effect of bio-banding on various markers (e.g., technical, tactical) of talent identification in young athletes, research has yet to explore to what extent practitioners use this approach, how they use it, or their perspectives about its perceived effectiveness. This mixed-methods study sought to address this gap by using an on-line survey with twenty-seven practitioners from Elite Player Performance Program (EPPP) affiliated clubs followed by a semi-structured individual interview with seven practitioners (age: 32.1 ± 8.44 years). Survey results revealed maturity-related differences impact practitioners' ability to accurately assess competence (e.g., physical "aggregated agree" = 68%, psycho-social "aggregated agree" = 56%), bio-banding enhances assessment when matching (*e.g., Early vs Early or pre-PHV vs pre-PHV*) (e.g., physical "aggregated agree" = 95%, technical "aggregated agree" = 85%) or pairing *(e.g., Late vs Early or pre-PHV vs post-PHV*) athletes for maturity status (e.g., physical "aggregated agree" = 55%, technical "aggregated agree" = 65%). Interview findings revealed the benefits of bio-banding include injury prevention, introducing challenge, and the design of individual development programmes. Interviews revealed barriers to the implementation of bio-banding include planning and organisation (time, resources and communication), failure to establish the buy-in, lack of understanding amongst coaches, and the prioritisation of short-term success over long-term development. Overall, the findings of this study contribute to the current knowledge and understanding of bio-banding efforts, and also emphasise the potential application of maturity status 'bio-banding' for identifying and developing professional youth soccer athletes. Increasing coaches understanding of bio-banding via the delivery of coach education courses and

workshops may be one way of increasing its uptake in the future. The study concludes by recommending sports practitioners use the findings as a basis for implementing bio-banding in their own settings.

INTRODUCTION

What is Association Football (soccer)?

Association Football (or soccer as its typically referred to within the literature) is the most popular sport in the world with approximately 130,000 professional players and 6000 in England (FIFA, 2021). In England alone, there are over 11 million people playing soccer at a recreational level (FA, 2021). The top professional football league in England underwent a governing body transformation in 1992 which witnessed the creation of the English Premier League (EPL). In total there are now 7 levels in the English professional game. The men's English soccer league pyramid which is comprised of 4 top tier levels. The Premier league (EPL) at the apex, and then sequentially the English Soccer League (EFL) Championship, EFL League One and EFL League Two. Followed by the remaining 3 levels, The National League, The National League North and The National League South (both level 6) and finally level 7 which is made from the Northern Premier, Southern Premier Central, Southern Premier South and Isthmian Premier.

The Football Association (The FA) for England and Wales is the oldest association in the world dating back to 1863 and is the national governing body for soccer in England from grassroots to the professional game. The FA created and is responsible for overseeing all aspects of the amateur and professional game sanctioning competitions, rule books, and regulating on-field matters in its territory ("The History of the FA", 2021). The FA is also responsible for the creation of the English Premier League (EPL) and English Football League (EFL). 1954 saw the formation of the Union of European Soccer Associations (UEFA). UEFA as one of the six continental confederations of FIFA which organises competitions and are responsible for the regulations of cross-border soccer in Europe for the 55 national soccer association.

In what is considered a significant moment in modern professional football, UEFA introduced the Financial Fair Play Act in 2009 (FFP) (UEFA, 2012). Financial fair play was introduced by UEFA in an attempt to regular spending by clubs, thereby seeking to prevent financial mis-management and to increase long-term survival. To comply with FFP, another concept which was recently introduced into domestic soccer in 2011/12 is the Elite Player Performance Plan (EPPP) (The English Premier League, 2011). The broad aim of this program is to expand the pool of talented home-grown players available for selection by the national team, increasing the efficiency of youth development investment in the UK. This is of importance and relevance given the obvious maturity related selection bias which is prevalent within UK and worldwide youth soccer programmes (Towlson et al., 2021). To facilitate this aim, an academy system was introduced where clubs are routinely assessed and ranked (categorised) and given a status between 1 and 4 (1 being the highest, 4 the lowest) (The English Premier League, 2011). Clubs are categorised on the basis of a range of factors including productivity rates of academy players playing for any team in the top five leagues, training facilities, coaching, educating and welfare provisions. The EPPP has three different age-group phases in the player performance plan which include under 9 to 11 (foundation phase), under 12 to 16 (Youth development phase), and under 16 to 23 (professional development phase) ("About the Premier League Games Program", 2021). The delivery of the program focuses on four key functions: games program, education, coaching, and elite performance. The games program is solely based on the EPL providing matches, festivals and tournaments, to all clubs across all ages. Education aims to provide world-class inspirational and innovative teaching, developing and rounding people through the delivery of a holistic approach. Coaching implements a range of coach development programs such as the Elite Coach Apprenticeship Scheme (ECAS). The EPPP uses a range of programs to aid player recruitment and development across a multi-disciplinary platform including physical, technical, tactical and psychological development ("Premier League Elite Player Performance Plan - EPPP", 2020).

For the EPPP, one of the primary aims is first to better understand and mitigate injury risk. This approach involves the implementation of a national injury surveillance project, where data is collected, analysed and fed back for both match and training via the Performance Management Application (PMA) on a quarterly basis ("Premier League Elite Player Performance Plan - EPPP", 2020). Doing so enables clubs to benchmark their injury profiles compared to competing clubs, alongside gaining systematic, evidence-based knowledge. An additional aim is to provide and track the physical profiles of each player against biological (bio-banded), chronological and positional standards across the academy system ("Premier League Elite Player Performance Plan - EPPP", 2020). The Sports Science and Medicine program, for example, has a National Benchmark Fitness Test with standardised equipment and strict protocols. This aspect of the program monitors players anthropometric, physical fitness and biological maturity development and this data is then again entered into the PMA in each trimester of the domestic soccer season (1st September to August 31st) (The English Premier League, 2011). Since all individuals grow and mature at different rates, using the Growth and Maturation Screening program, players can be observed providing their regular body measurements especially during Peak Height Velocity. Training programs can then be tailored to individuals with a view to reducing growth-related injuries ("Premier League Elite Player Performance Plan - EPPP", 2020).

Research Rationale

In England players can be recruited into professional academies from 8 years of age but it is difficult to determine which players have the highest chance of succeeding at the adult level, and doing so requires considering technical, tactical, physical, physiological, psychological, and cultural aspects. This can often lead to maturity selection biases within professional youth soccer. This hypothesis states that superior anthropometric dimensions (stature and weight) and performance characteristics (power, speed, strength and endurance) often characterise the likelihood of players selected for academy soccer development programs (Carling et al., 2012; Carling et al., 2009; Vaeyens et al., 2006). This selection bias is likely due to talent identification practitioners selecting relatively older players born earlier in the selection year (September to November) who often excel in stature development across the adolescent growth spurt (Malina et al., 2004; Malina et al., 2000) and therefore more often than not exhibit advanced anthropometric and physical characteristics compared to their younger peers born in the later quartiles of the selection year (June to August) (Carling et al., 2009; Hirose, 2009). Therefore, it is likely the maturation-selection hypothesis is a contributing factor to the over-selection of 'early maturing' athletes in development programs, systematically discriminating those players chronologically characterised in the later quartiles of the domestic soccer season (1st September to 31st August) (Carling et al., 2009; Deprez et al., 2013; Hirose, 2009; Lovell et al., 2015).

With this in mind, bio-banding aims to address maturity selection biases since adolescents physical, social, and psycho-social differences are likely to be widely varied, even among children of the same chronological age, because maturational events (puberty) occur at different ages. Furthermore, the age at which a person matures has significant ramifications for training, competition, and talent identification. Therefore, bio-banding is a viable option for resolving training, competition, and talent identification difficulties and has been widely introduced by national leagues and European governing bodies across academy structures (Towlson et al, 2019). As such, it is important to understand how bio-banding is being implemented by practitioners and to examine their perceptions about the efficacy of this method as a means for identifying and developing talented youth soccer players. It is equally as important to understand the perceived barriers and challenges sports practitioners face implementing this approach and what perceptions they might hold. This investigation might help generate the knowledge and information required to strengthen the talent identification and development process, serving to support the principle of the EPPP (Premier League, 2011). The findings from the current study may be used to advise practitioners on the benefits bio-banding might serve, some of the challenges they might face when seeking to implement this approach, and some of the strategies they might employ to enhance the rigor of this method. Findings might also encourage practitioners to consider player maturity during the identification and (de)selection process of players, in order to reduce the over-selection of early maturing players who benefit from transient maturity-related enhancements in performance.

To achieve this, the literature review will provide an overview on the talent identification and development process and what they entail, helping to determine the program which is adopted by professional youth soccer academies. Establishing the smallest worthwhile changes for clubs in order to monitor player identification and development throughout the development pathway. In order to do this, the literature review will highlight the physical, technical, tactical and psycho-social elements which can underpin the athlete's identification and progression through the academy. Including detail of biological maturation, which methods can be used to determine maturation and maturation-selection hypothesis. Determining the relationship between relative age, maturity status, physical, technical, tactical and psycho-social characteristics in relation to the success of athlete's journey. In addition to this, the thesis sought to examine the influence of maturity across the player development pathway, bio-banding and how multidisciplinary teams' function with athlete talent identification and development as the focal point. Doing so, will then provide insight for youth soccer practitioners regarding multidisciplinary and bio-banding approaches in order to permit a more considered approach to current talent identification and development in professional youth soccer academies.

Literature review

Talent Identification

The global interest and increased competitiveness in soccer has led to the process of scouting for the world's best players and players with the potential to become the best (Lawlor et al., 2021). However, home grown players are also crucial since top flight teams must contain a minimum of 8 athletes who fit the home-grown players criteria. Hence why national organisations, clubs, coaches, sports scientists, players and their families have all contributed a substantia amount of resources (e.g. financial, personnel, time) to the professionalisation of the identification and development processes within the game (Williams et al., 2020). That said, good players/athletes are not created overnight but instead nurtured through a development process that supports their technical, tactical, psychological and social development. Therefore, talent identification is a key area within sports development and is defined as "*the process of recognising athlete's potential to become elite players*" (Williams & Reilly, 2000). The talent identification of sports athletes aims to detect, capture, select and promote athletes who have the skills, knowledge and competencies and thus the potential to reach the upper echelons of their sport (Unnithan et al., 2012). However, it is important to note that later success in soccer is dependent on a range of external factors including, but not limited to, opportunities to practice, injuries, coaching/mentorship, and finally personal, social and cultural factors (Reilly et al., 2000).

In recent years, significant resources have been dedicated in the soccer industry to identifying young talented athletes (Carling et al., 2009). Recruiting talented athletes early into a professional soccer academy is beneficial for the clubs competitive and financial status. As such, there is a growing number of academies and "centre of excellences" throughout the UK and worldwide (Reilly et al., 2000). There are four stages involved in the process and conversion of a talented player to a professional player, these include detection, identification, development and selection but within any sporting domain talent alone does not equate to capability and success (Williams & Franks, 1998).

A more recent review by Williams et al. (2020) explains the identification and development processes (identification, detection and selection/deselection) in modern day soccer are illustrated as: identification entails identifying athletes competing in the sport who have the potential to advance into a high performance development programme that consists of a comparatively structured blend of coaching, support, training, and competitive match play to advance athletes (Williams et al., 2020). Detection involves identifying athletes from outside the game who have the potential to progress into a soccer development programme (Williams & Reilly, 2000). Identification, selection, and deselection decisions occur relatively frequently in professional youth academies. Selection refers to the ongoing process of identifying players within the development programme who exhibit qualities conducive to advancement to a future squad or team, such as the next age group team in a youth academy or nation. Whereas deselection is the process of removing players from the development programme who no longer exhibit the qualities necessary to compete for future squads or teams (Williams et al., 2020). Williams et al. (2020) also argued that it is important for scientists and those in charge of recruiting players (such as scouts, coaches, and academy directors) to collaborate in order to better understand the experiential, frequently implicit or subjective criteria that are used to choose one player over another for entry into a development programme. Sieghartsleitner et al. (2019) research supports this notion demonstrates how crucial it is to combine subjective coach/scout evaluations with objective multidisciplinary measurements. Other important variants may include social, affective, motivational and temperamental factors as shown in **figure 1**.

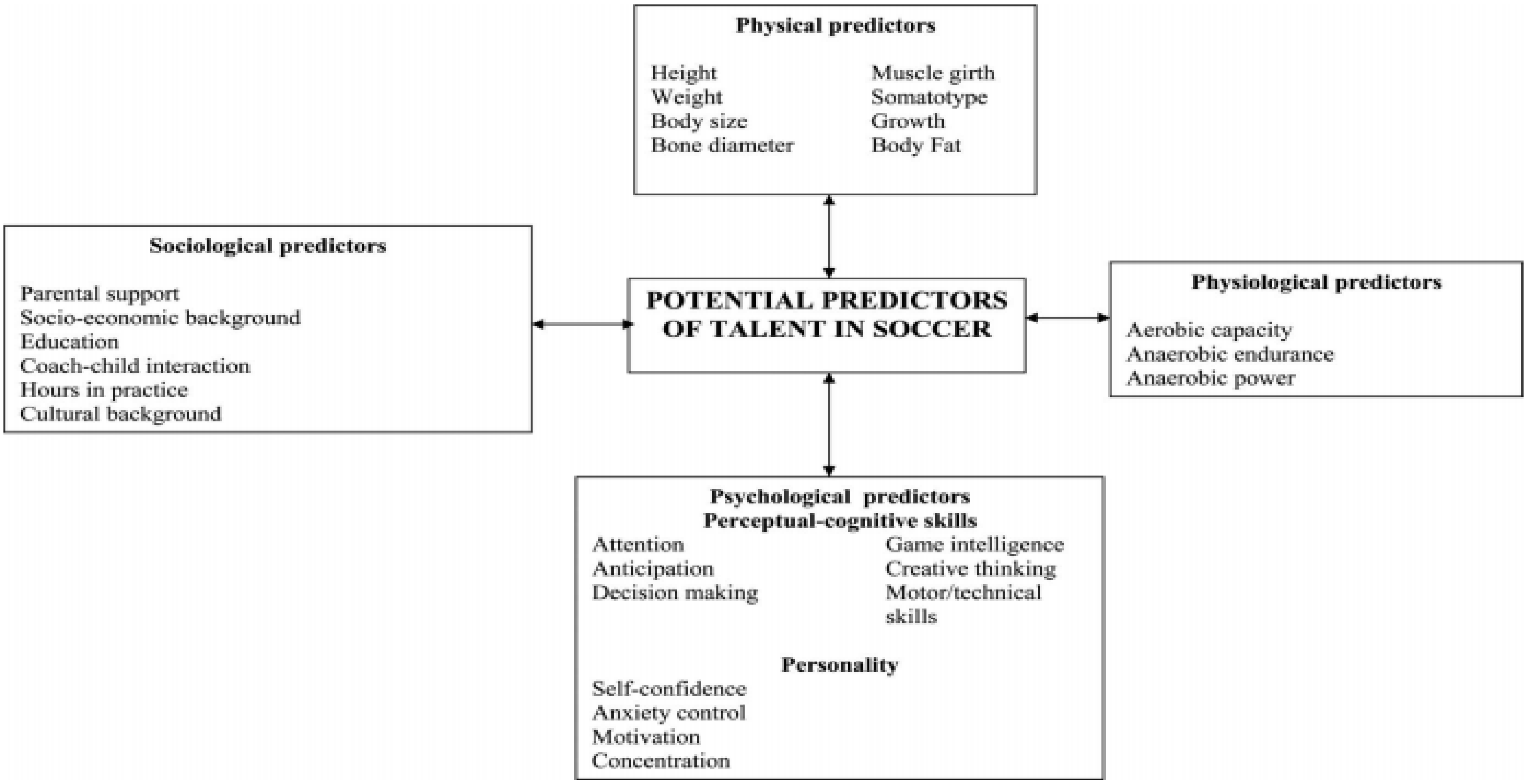

Figure 1. Potential predictors of talent in soccer (Williams & Reilly, 2000)

Monitoring Maturity Status of Professional Youth Soccer Players

Biological maturation is the process of becoming mature which is composed of several substantial changes in the biological system (Lloyd et al., 2014). It involves periods of growth and development of the human body, incorporating skeletal, sexual and somatic changes (Malina et al., 2004). However, when working in an environment where children and adolescents are the sole focus, maturity refers to the developmental stage in which the child or adolescent has attained in reference to their final adulthood status (Malina et al., 2004; Malina et al., 2000). Furthermore, children mature at a rate which is entirely individual and independent of the calendar or decimal age groupings. So, typically groups of athletes which have been categorised within the same decimal age (U9, U12, U16) may display a varied range of biological maturity attainment established using skeletal, sexual and somatic maturity methods (Towlson, 2016). Therefore, in order for programs such as the EPPP to be efficient for all athletes, the collection of player maturity data is required to benchmark player development.

Biological Maturation

Maturity is a state whereas biological maturation is a process that characterises human growth and development, with variations between the individual time and rate at which the process occurs (Malina et al., 2004; Cumming et al., 2008; Guedes, 2011). Maturation is a process in which all tissues, organs, and organ systems of the body mature, but they do so at different times and rates (Beunen et al., 2006). There are 4 stages of maturity - infant (0-4 years old), child (4-13 years old), adolescent and adult. Transitioning from childhood to puberty (adolescent) is characterised by changes in sexual maturation and changes in both body composition and physical performance in children and adolescents. Consequently, differences are often found in performance and body size of subjects of the same chronological age (Mirwald et al., 2002; Machado et al., 2009). For instance, early maturers have had as long as 12 months longer to develop physically, psychologically and emotionally compared to their late maturing counterparts. Early maturation may also be associated with enhanced performance characteristics such as aerobic power, muscular strength, power and endurance (Beunen et al., 1981; Malina et al., 2004).

Since these advantages can be deemed crucial in the individual's performance, it influences the identification and selection process. To illustrate, Gouveia et al. (2009) reported that individuals with early maturation (precocious puberty) tended to have a higher BMI values than those of their peers and this can have a long term effect into adulthood, increasing the risk of them being overweight or obese. But when working with children and adolescents within sports and athletic development environments, maturity refers to which developmental stage an athlete has reached in reference to their adulthood status (Malina et al., 2004; Malina et al., 2000). Common indicators of maturation include skeletal, sexual and somatic maturation (Malina et al., 2004; Rodrigues et al., 2010; Silva et al., 2010).

Skeletal Maturity

Skeletal maturity is a measure of development incorporating the size, shape and degree of mineralisation of the epiphyses and physeal plates of bone to define their proximity to full maturity (Mora & Gilsanz, 2010). Bone growth refers to quantifiable changes in size and mass of the bone including its length, width, and weight over time (Baroncelli & Bertelloni, 2010). Bone maturity, on the other hand, refers to the changes a bone undergoes as its structure/organization changes; including structural changes (the shape of the bone) as well as mineralization of the bone such as at its ends (the epiphyses) (Orwoll et al., 2009). It is this difference in definitions that explains how two children may have the same chronological age without the same bone age (i.e. 7 years old) as children develop at different rates. In a similar vein, bone age is not associated with a particular stage of puberty (or when puberty will begin) (Melmed et al., 2015). Despite this, bone age is often utilized in predicting the onset of puberty.

Indicators of skeletal maturity provide three types of information of bone shape and structure that are reflective of the adult form of the assessed bone; and the fusion of the epiphyses (end portion of the bone) with their diaphyses (mid-portion of the bone often referred to as the shaft) and the attainment of adult bone contours (Malina et al., 2004). Skeletal maturity or bone age is typically measured by taking an x-ray or radiography image of the wrist to assess bone development from initial ossification to adult formation (Malina et al., 2004). Several methods for measuring skeletal maturity as described below include the Greulich-Pyle method; the Tanner-

Whitehouse method; the Thumb Ossification Composite Index (TOCI) and Fels method. Each method differs. However, the overall concept remains the same of an x-ray being taken and used for evaluation of bone development from initial ossification to adult formation (Malina et al., 2004).

Greulich and Pyle Assessment of Skeletal Maturity

One of the oldest methods for assessing skeletal maturity is the Greulich-Pyle assessment of Skeletal Maturity (or the Atlas or Inspectional method) (Todd, 1937). This method matches a child's hand-wrist x-ray to a predetermined standardised plate of identified child skeletal maturity at a specified decimal age as illustrated in **figure 2**. Using this approach, each visible bone's skeletal age within the hand-wrist x-rays is assessed and the median value used to determine the child's overall skeletal age. For instance, a child can have a chronological age of 10, but their hand-wrist x-ray could closely represent the standardised plate of an 11-year-old, meaning their skeletal age is classified as 11 years old (Greulich & Pyle, 1959).

This method in particular has shown to be reliable for determining skeletal age. For example, Paxton, Lamont and Stillwell (2013) showed that when compared to decimal age in a sample of 654 children, the participants’ skeletal age was 1.5 months less for male and 3.7 months for females and not subject to significant inter and intra-observer differences (Towlson, 2016). However, despite this method being repeatable and quicker to administer compared to others, King et al.’s (1994) research suggests that it is undermined by a large amount of variability when assessing skeletal ages of children circa-adolescence. This is likely due to the method being developed for use in clinical practice, with reference values based upon solely the White American population dating back to the 1930s. Tisè et al (2011) suggests it might be possible that these methods can no longer be a representative comparison of an accurate assessment of the skeletal age of children within diverse demographics of modern society.

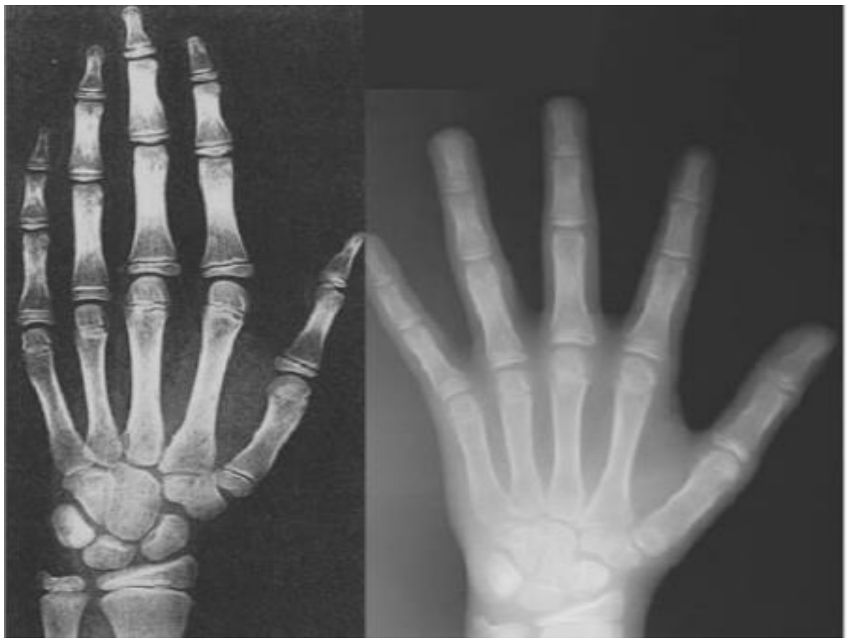

Figure 2. Comparison of a hand and wrist radiograph of a 10-year-old (right) and the corresponding standardised plate (left) in the Greulich-Pyle atlas (Greulich & Pyle, 1959).

Tanner-Whitehouse Assessment of Skeletal Maturity

In 1966 Tanner and Whitehouse published their first attempt at a bone-specific scoring system which is a way of assessing the bone age of children (Tanner & Whitehouse, 1962). There are now two updated variations of this method, TW2 from 1975 and TW3 from 2001 (Tanner et al., 1975); (Tanner et al., 2001) but all methods use a DP radiograph of the left hand and wrist to assess the relative maturity of the patient's bone. Instead of using all the bones in the left hand, as in the Greulich and Pyle method. The Tanner and Whitehouse 3 method evaluates the maturity levels of specific bones of the hand and wrist including the radius, ulna and short bones etc. as shown in

Figure 3. These then comprise the region of interest (ROI). Predefined skeletal maturity scores are assigned to individual ROIs in accordance with their maturity levels. These scores are then summed to compute the total maturity score. This score is then finally converted into a bone age (BA) using a correlation matrix for the maturity scores BAs (Son et al., 2019). Bones can be scored ranging between zero (immaturity) to 1,000 (complete maturity). This method can, however, be undermined by poor methodological execution, such as incorrect positioning of the hand or wrist when the radiograph is taken, thus enhancing the variances when determining skeletal age (Cox, 1996). One consequence of this is that it leads to an inaccurate appearance of the epiphyses, making x-rays interpretations more difficult and inconsistent between the observers. Due to this, computer-aided estimations of skeletal age are becoming increasingly common in the determination of skeletal age when using the Tanner and Whitehouse method (Tanner et al., 2001), along with the Greulich and Pyle methods (Greulich & Pyle, 1959).

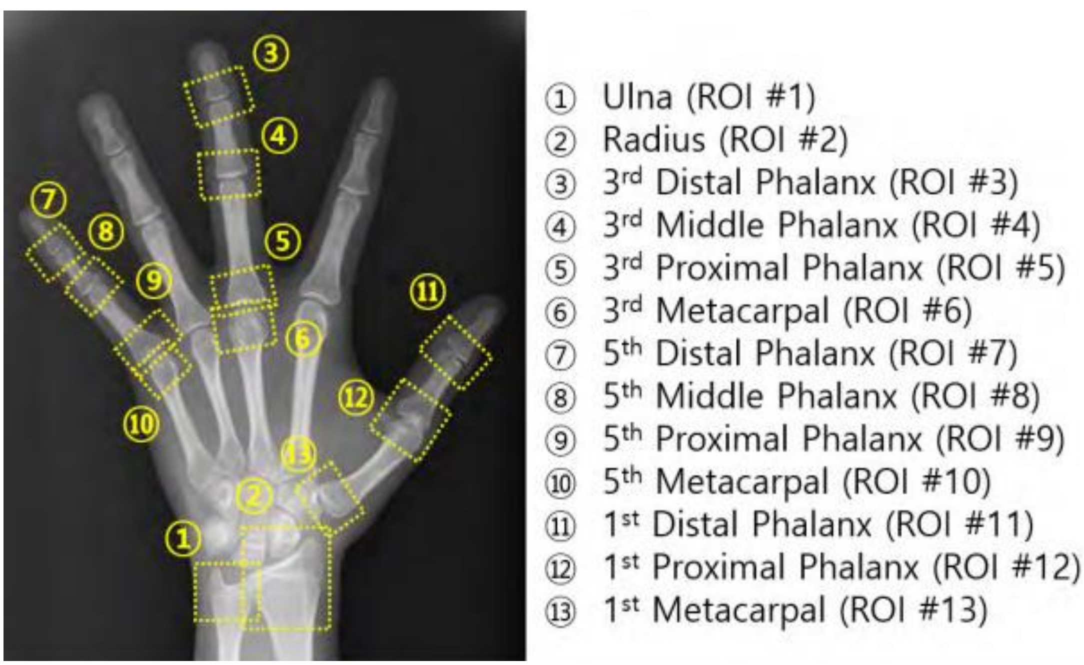

Figure 3. Region of Interest used in the TW3 method (Son et al., 2019).

FELS Assessment of skeletal Maturity

The Fels methods of assessing skeletal maturity was developed during the Fels longitudinal study using Central American children (Roche et al., 1988). The Fels method uses radiographs of the hand to wrist to grade skeletal maturity by comparing the size and shape of individual carpals and epiphyses. It also compares the corresponding diaphysis of the ulna and radius and the metacarpals and phalanges of the first, third and fifth digits against a described criterion. The ratio of the width of the epiphysis and metaphysis are then calculated and converted into a measure of skeletal age (Malina et al., 2004; Roche et al., 1988). The most accurate indicator of a child's skeletal age for their decimal age is calculated and used to calculate the skeletal age and corresponding standard error of the measures using odds-ratio based statistics (Malina et al., 2004; Roche et al., 1988). As opposed to the TW3 method, however, research reveals that the Fels method classified a professional group of youth soccer players as having a slightly younger skeletal age and being ahead of their decimal age (Malina et al., 2007).

Application of Skeletal Maturity

The assessment of skeletal age and maturity is a well-established method of assessing biological maturity in clinical, paediatric and pre-pubertal populations (Tanner et al., 1975). Skeletal maturity assessment methods have also been implemented in professional youth soccer academies in order to detect and eliminate the deliberate selection and participation of 'over-aged' players in younger age categories. Therefore, preventing unfair physical and performance advantages associated with chronologically older players which is commonly known as 'age fraud' (Malina et al., 2004; Cryer, 2014). Since age falsification has become increasingly apparent across multiple sporting environments and countries, with the largest profile of age fraud being reported in 2013 when 18 players were excluded from the African U17 Championships, 7 players from Nigeria and the FIFA U17 World club and Somalia expelled from qualifying for the participation in the African U17 Championships (Cryer, 2014). In an attempt to regulate and control such phenomenon, the world governing body for soccer The Fédération Internationale de Football Association (FIFA) introduced magnetic resonance imaging (MRI). Due to the large variation of skeletal age within chronological age groupings (Malina et al., 2010), such interventions and legislations are necessary given that MRI verifies chronological age groupings and further promotes fair play (Malina et al., 2004; Tritrakarn & Tansuphasiri, 1991).

Despite skeletal maturity being considered the ‘gold-standard’ for assessing and determining skeletal age to indicate maturational stages of development, there are still limitations to the methods used within professional youth soccer academies (Knapik, et al., 2019). A first drawback is the use of X-rays and radiographs and the requirement of financial stability, specialist equipment and specialist practitioners in order to conduct the procedure effectively. Furthermore, the collection of such data is often time-consuming and could even pose a potential health risk since there may be a requirement for several repeated procedures over time to continually update the players skeletal maturational stage of development (Romann & Fuchslocher, 2016). Another limitation to skeletal age assessments of professional youth soccer players is when those who are delayed in skeletal maturation, due to inferior anthropometrical and physical characteristics when compared to their skeletally mature counterparts (Malina et al., 2004), are often systematically discriminated against in long term athletic development pathways (Malina, et al., 2000).

To conclude, unfortunately due to the highly sophisticated, high priced and time-consuming process of assessing skeletal maturity, there is a need to explore alternative methods when assessing maturity within a professional youth sport setting.

Sexual Maturity

Sexual maturation is a process extending from the early embryonic differentiation of the sexual organs to the full maturity of these organs and fertility. Puberty is a transitional period between childhood and adulthood during which the sex organs and the reproductive system mature and the growth spurt takes place (Beunen et al., 2006). The assessment of sexual maturation is based on secondary sex characteristics: breast development and age at menarche in girls, genital (penis and testes) development in boys, and pubic hair in both sexes. Development of the breasts, genitals, and pubic hair is most often rated on five-point scales (stage 1 earliest, stage 5 latest) described by Tanner (Tanner, Blackwell, 1962) as shown in **Figure 4**. Stage 1 of each characteristic indicates the prepubertal state (absence of development) and stage 2 the initial, overt development of each characteristic that marks the transition into puberty. Stages 3- and 4-mark progress in maturation, and stage five 5 indicates the adult (mature) state. In terms of reliability and accuracy, there are two approaches to consider. The first being a clinical assessment (gold standard) which is the most reliable (r2 = 0.86 to 0.97) (Leone & Comtois, 2007). Followed by self-assessment which is derived from the clinical assessment (Schmitz et al., 2004).

Despite the testing methods being deemed reliable, there is also evidence to suggest variability between physicians, resulting in girls and boys showing to be stage 4 for instance in pubic hair development but having achieved 100% of breast or genital development (Matsudo & Matsudo, 1994). These findings could be explained by Malina et al (2004) as girls and boys are likely to achieve stage 2 of breast and genital development whilst still having only achieved stage 1 in pubic hair development since the most obvious sign of the onset of puberty is the initial enlargement of breasts and testes. This follows on in the self-assessment method too, Leone and Comtois (2007) study shows how boys over-estimated their pubic hair development whilst girls under-estimated but showed agreement between the physicians and their self-assessment in the remaining areas.

Female Sexual Maturity Rating (SMR)					
Stage	**1**	**2**	**3**	**4**	**5**
Age range (mean ± 1 SD)		10.5-12.9 yrs	11.3 – 13.5 yrs	11.8 – 14.0 yrs	13.3 – 15.5 yrs
Breasts		Breast and papilla elevated as small mound, or breast bud, areolar diameter increased.	Breast and areola enlarged, no contour separation	Areola and papilla form secondary mound projecting from the contour of the surrounding breast	Adult size and contour. Areola returns to part of general breast contour, nipple projects
Pubic Hair		Hair is sparse, lightly pigmented and straight, located on medial border of labia majora	Hair is darker, more coarse and beginning to curl, increased in amount and begins to extend laterally	Hair is coarse and curly as in the adult, hair extends across the pubis but spares the medial thighs	Adult hair – coarse and curly, spreads to medial surface of thighs
Menarche (10.8 – 14.5 yrs)		10%	30%	90%	100%
Acne			Mean age of onset – 13.2 years		

Male Sexual Maturity Rating (SMR)						
Stage		**1**	**2**	**3**	**4**	**5**
Age range (mean ± 1 SD)			12.4 - 14.5 yrs	12.9 – 14.9 yrs	13.3 – 15.4 yrs	14.1 – 16.3 yrs
Penis			Slight enlargement	Begins to lengthen	Increases in length and circumference	Adult
Testes & Scrotum	Testicular Volume	volume less than 1.5 ml	1.6 – 6 ml	6 – 12 ml	12 - 20 ml	Greater than 20ml
	Scrotal changes		Skin on scrotum- thins and reddens, scrotum enlarges	Further scrotal enlargement	Further scrotal enlargement, skin darkens	Adult
Pubic Hair			Small amount of long and slightly pigmented hair at base of the penis and scrotum	Hair is darker, starts to curl but small in amount	Hair is coarse and curly as in adult, extends across the pubis but spares the medial thighs	Adult hair – coarse and curly, distribution, spreads to medial surface of the thighs
Acne				Mean age of onset – 14.3 years		
Facial Hair					Facial hair develops	

Figure 4. Male and Female Sexual Maturity Ratings (SMR) adapted from (Tanner JM. Growth at adolescence, 2nd ed. Oxford, UK: Blackwell, 1962).

Application of Sexual Maturity

Sexual maturity has shown to be difficult to measure and there’s an insufficient evidence base to support its use as a predictor of talent/technical abilities in professional youth soccer players (Malina et al., 2004). However, it has continued to be applied within professional youth soccer academies when assessing maturity in relation to the anthropometrical, physical fitness and skill development of players (Figueiredo et al., 2011). For instance, Malina et al.'s (2004) study showed amongst professional youth soccer players, those who were in stage 5 (advanced) of pubic hair development possessed superior endurance levels to those in stage 1 (early) of pubic hair development. Whilst Vaeyans et al. (2005) reported that clinical examination of pubic hair development showed little variation when testing for shooting accuracy (8%), ball control with body (13%) or head (14%) and dribbling with a pass (21%).

Contrary to this, a more recent research published by Moreira et al (2017) found moderate to large associations between technical performance sets (inclusive of effective passes and total tackle count) and pubic hair and genitalia growth. But the discrepancy may be due to a disparity in testing conditions, as Vaeyens et al (2015) used an isolated testing environment to measure technical competence, while Moreira et al (2017) used a small sided games environment. To conclude, given the limitations, procedural, and situational difficulties (requirement of qualified clinicians, appropriate permission, invasiveness etc.) associated with monitoring sexual maturity in professional youth soccer settings, it is highly impractical for such assessments to be utilised by soccer academies. Therefore, talent identification practitioners should consider alternative methodologies to establish the sexual maturity levels of their players (Towlson, 2016). The evaluation of somatic maturity might prove fruitful in this regard.

Somatic Maturity

Somatic maturity refers to the different tempo and timing of morphological changes which occur in the body over time (Beunen et al., 1997). Thus, longitudinal collection of data is required from an individual to be able to plot a growth curve revealing the inflection point of at which age the onset of the growth spurt will occur (Malina et al., 2004). The most commonly used indicator of somatic maturity across professional soccer clubs is age at peak height velocity (APHV) (Schell, 2012) using non-invasive predictive estimations of athlete's somatic maturity, calculated using anthropometric measures (Moore, 2018). Anthropometric measures are taken using calculations of stature, body mass, leg length, sitting height and chronological age which are then applied to predict years from peak height velocity (YPHV), which is termed as a maturity offset (Fransen et al., 2018; Mirwald et al., 2002).

Peak height velocity measurement is a widespread technique in professional youth football clubs because it allows trainers and coaches to assess the athletes' physical development and choose a safe and effective training programme. It might be advised that experts evaluate the age of PHV athletes 2-3 times each year (every 4-6 months) (Walker, 2023) since before, during, and after PHV there appears to be periods or "windows of opportunity" (Balyi & Hamilton, 2004) in which athletes are more receptive to some form of training than others (strength, speed etc.) (Ford et al., 2011). Therefore, predicting APHV enables development plans to be tailored in accordance with the athletes biological age as opposed to their chronological age, resulting in a better suited and more effective training programme (Lloyd & Oliver, 2012). For instance, studies have shown that pre-adolescents benefit most from training techniques that call for high levels of neural activation (such as sprint training and plyometrics), whereas adolescents fared better from training techniques that target both neural and structural development (such as strength training and plyometrics) (Rumpf, 2012). Additionally, a study conducted by Van der Sluis et al. (2015) encourages training and match loads to be designed in a way that considers maturity, maximises athletic growth, and reduces the risk of injuries. The earliest and latest maturing athletes may have separate training schedules, be chosen based on various biological age groups, or be divided up in particular training session segments, for instance, if there are significant disparities in internal training loads. This study will now introduce Mirwald et al (2002), Moore et al (2015), Fransen et al (2018) and Khamis and Roche (1994) methods for maturity estimations.

Mirwald Somatic Maturity Method

The first somatic maturity method to be introduced in this thesis is by Mirwald et al. (2002). This method aimed to establish a non-invasive and practical application, incorporating the adolescent growth spurt inclusive of anthropometrical variables such as body mass, leg length, height and sitting height. Different timings of growth and subsequently APHV would then be subtracted from chronological age in order to estimate the current stage of maturation or determine expected peak height velocity (Mirwald et al. 2002). The Saskatchewan method has been implemented by sports practitioners within the identification of talented youth soccer players due to its time-effective, efficient use with the broad populations that reside within the multi-development centre nature of the EPPP, making it a favourable method (Unnithan et al., 2012; Vaeyans et al., 2006) However, it is important to note that although the method is inexpensive, time efficient and has been validated, it also has limitations. It is documented the Saskatchewan Paediatric Bone Mineral Accrual Study demonstrates 95% of maturity estimations could present a margin of error by one year in maturity status calculations (Mirwald et al., 2002). A validation study by Malina and Koziel (2014) identified that maturity status can be accurately predicted if the measure was conducted within two years of actual APHV. This means a predictive APHV of greater than three years may underestimate younger or overestimate older players respectively, therefore questioning the application to a youth population (Malina & Koziel, 2014).

Furthermore, given that a key element for the predictive maturity equation is leg length, the efficacy of the equation is somewhat compromised since leg length is largely complete in early maturing boys, but trunk growth may continue (Malina & Koziel, 2014) limiting its use within a youth soccer population. Accordingly, the aforementioned limitations or Mirwald et al. (2002) method should be considered when interpreting benchmark and development data of professional youth soccer players. Or further modifications of the regression equation are necessary, in order to better validate the application of the method, which leads us to the work of Moore et al. (2015) and their use of somatic maturity equations. That shouldn't detract from the comparatively non-intrusive procedure, which may be simply carried out by pertinent staff members within EPPP youth academies. It is also advantageous for this group because Lovell et al. (2015) recognised the advantages of using the straightforward equation and gathering anthropometric data on big populations all at once.

Moore et al Somatic Maturity Method

In an attempt to improve the accuracy of maturity prediction models, Moore et al. (2015) aimed to modify the widespread maturity prediction model equation of Mirwald et al (2002). In order to minimalise previously identified limitations, Moore et al. (2015) research aimed to; evaluate potential over-fitting of the originally developed prediction equations, modify such equation (employing cluster-robust variance techniques and create alternatives which do not require sitting height), and internally (k-fold cross validation) and externally (Healthy Bones Study III [HBS-III] and Harpenden Growth Study [HGS]) validate such equations. Moore et al. (2015) reported the redeveloped equations performed similarly or better than the original equation, predicting 90% of maturity offset within ± 1 year in two external samples, despite the large variance in APHV and maturity offset. As well as such modified predictive maturity equations providing an alternative for investigations in which sitting height has not been documented (Moore et al. 2015).

Despite improvements being achieved, Fransen et al (2018) and Moore et al (2015) suggest that the further away a child is from their actual APHV, the prediction error in predicted APHV is likely to increase to a greater degree. As a result, the assumption of a linear estimation of an inherently nonlinear biological process of somatic growth during the adolescent growth spurt does not yield a more accurate estimation for late maturers (those further removed from their APHV), as the assumption of a linear estimation of an inherently nonlinear biological process of somatic growth during the adolescent growth spurt does not yield a more accurate estimation for late maturers (those further removed from their APHV) (Fransen et al., 2018; Moore et al., 2015). As a result, it was proposed that the original somatic predictive maturity equation be modified to include a nonlinear relationship between anthropometrical predictors and a maturity ratio (chronological age / AHPV) (Fransen et al., 2018; Mirwald et al., 2002).

Fransen et al Somatic Maturity Method

More recently, Fransen et al (2018) attempted to validate and improve the maturity offset equation and prediction of APHV from anthropometrical assessment, using the application of a nonlinear model, maturity ratio and the reanalysis of the Mirwald et al (2002) dataset, due to the favourable and practical nature of the process. Fransen et al (2018) applied the original dataset from the Saskatchewan Paediatric Bone Mineral Accural Study (115 boys and 136 girls; 8 – 15 years of age) (mirwald et al, 2002) and noted a linear equation was previously being used in the non-linear process of the growth spurt period. Therefore, the predictive equation was altered to apply this concept, leading to the development of a new equation and data set from Belgian soccer players, producing a greater level of accuracy of prediction across youth soccer as shown in equation 1.

$$\text{Maturity Ratio} = 6.99 + (0.116 * \text{Chronological Age}) + (0.00145 * \text{Chronological age } 2) + (0.00452 \text{ x Body Mass}) - (0.0000341 \text{ x Body Mass } 2) - (0.152 \text{ x Stature} + (0.000933 \text{ x Stature } 2) - (0.00000166 \text{ x Stature } 3) - (0.0322 \text{ x Leg Length}) - (0.000269 \text{ x Leg Length } 2) - (0.000761 \text{ x } [\text{Stature x Chronological}] \text{ Age})$$

Equation 1. Fransen et al (2018) Updated Somatic Maturity Equation to Fewer Significant Figures.

The results from the new equation and study were positive, estimating APHV more accurately than the originally developed model (Original R2 = 89.72%, Fransen et al. (2018) modification = 90.82%). However, despite an improvement, the newly formed method still contains errors stemming from the earlier study of Mirwald et al, (2002). For instance, those furthest from APHV are still not predicted as accurately compared to those closest to their PHV, as well as those who are not maturing at an ‘average’ rate are still likely to have less accurate APHV predictions (Malina & Koziel, 2014). Nevill and Burton’s (2018) study also highlight the equation as misleading and fundamentally flawed since the inclusion of the subjects chronological age in both sides of the predicted equation results in higher values of R^2. Another major concern with Fransen et al.’s (2018) work is the repeated analysis of measures data (that contain both between- and within-subject errors). Hence, the requirement to identify an alternative method for assessing predicted maturity status.

Khamis and Roche Somatic Maturity Method

Assessments of maturity status can also be achieved through the calculation of the estimated percentage of adult stature, of which a child has attained at the time of measurement (Khamis & Roche, 1994). Again, using anthropometrical measures of the athletes age, weight and stature and the mid parental height (average height) of the athletes' biological parents, predicted maturity status can be interpreted through the estimated percentage of adult stature attainments (%EASA). An increase in these values demonstrates an increased level of biological development (Khamis & Roche, 1994). The Fels Longitudinal Study provided the primary source of growth, which included a population of white males (n = 223) and females (n = 210) participants (Khamis & Roche, 1994). The observed median error band between expected and actual mature height in males between the ages of 4 and 18 years is 2.2cm (Khamis & Roche, 1994). However, more recently the Khamis and Roche (1994) method has been applied within youth soccer populations (Cumming et al., 2006; Johnson et al., 2022; Salter et al., 2022) as well as being utilised in the 'bio-banding' approach for biological maturation during competitive match play (Cumming et al., 2018). The main limitation of this method is the requirement of obtaining parental height since it can bring time and methodological constraints, more predominately when players biological parents perceive their child to be at a disadvantage as a consequence of such estimations (Salter et al., 2021) or sensitive issues arise relating to the biological parents (e.g. deceased, divorced). The margin of error for this method's height prediction is 2.1 inches for boys and 1.7 inches for girls, which is another drawback. The study was also solely based on Caucasian children born to Caucasian parents, therefore estimates of children under 4 years old and participants of other races may also be erroneous (Khamis & Roche, 1994). Although the mean heights and weights of British and American boys and girls aged 9 to 15 are remarkably similar, more research is needed to confirm the validity of the formulas developed for forecasting adult stature in North American kids in British samples (Cumming et al., 2008).

However, the technique can be used on healthy Caucasian kids between the ages of 4.0 and 17.5 (Siervogel et al.,1991). It is also believed that his approach is more accessible and advantageous if the heights of the child's biological parents are known. Since the mid-parent height may be estimated and utilised to predict maturity height combined with the young football player's current height and body mass. Mid-parental height for boys can be calculated using the Khamis-Roche formula as follows: (mother's height + father's height + 13)/2; for girls, it is (mother's height + father's height - 13)/2. Their height is then expressed as a percentage of their expected adult height, which, when compared to normative norms, provides an indication of maturity status and maturity timing or the greater the value to 100%, the closer to full development.

Considering the maturity estimation approaches developed by Mirwald et al. (2002), Moore et al. (2015), Fransen et al. (2018), and Khamis and Roche (1994). This thesis will succinctly review and contrast many approaches in order to let readers decide which approach to employ in their future practice. The Mirwald et al. (2002) method first established a straightforward, non-intrusive, efficient in terms of time, and useful application to be employed with large populations. However, it has a one-year margin of error and ignores the possibility of further trunk growth, necessitating further adjustments for improved validation. The Moore et al. (2015) method offers a route for investigations in which sitting height has not been documented and performs equally to or better than the original. Late maturers, however, are more susceptible to inaccurate measures, and once more it is suggested to alter the maturity equation. A higher level of forecast accuracy for youth soccer is offered by Fransen et al. (2018). However, similar to Moore et al. (2015) method, it does not produce a more accurate prediction for athletes farther from APHV and can be misleading, making it fundamentally defective and necessitating the development of a substitute method. The most practical and advantageous approach, developed by Khamis and Roche in 1994, has a margin of error of just 2.1 inches for boys and 1.7 inches for girls. However, it is only based on Caucasian kids and necessitates acquiring data from athletes' real parents, which might be challenging.

Application of Somatic Maturity Within Professional Youth Soccer

In professional youth soccer settings, estimates of YPHV (Mirwald et al., 2002) and projected adult stature (Sherar et al., 2005) are widely used to aid in the process of developing a holistic approach to talent recognition and athlete growth (Cumming et al., 2018; Unnithan et al., 2012; Vaeyens et al., 2006), including the ability to differentiate between adolescent success and future potential (Vaeyens et al., 2008). The application of somatic maturity has also been applied to guide TID components such as performance analysis (Buchheit et al., 2010; Goto et al., 2015), physical performance (Mendez-Villanueva et al., 2011; Mendez-Villanueva et al., 2010), strength (Emmonds et al., 2017) and aerobic/anaerobic capacity (Buchheit et al., 2010; Lovell & Parkin, 2012;) enabling the comparison between players of similar somatic maturity and decimal age (Towlson, 2016). Consequently, due to related maturational advantages in performance (Buchheit & Mendez-Villanueva, 2014), it is critical to regard athletic performance and growth as a conditional construct to maturity, thus influencing the talent recognition process (Lovell et al., 2015; Meylan et al., 2010).

In addition, since advanced normative growth and maturity-related advantages are important factors in the (de)selection of players in youth soccer development programs, it is appropriate to assess players' somatic maturity across the EPPP, and the youth development process in particular (under 12 to under 16) (Premier League, 2011), as this is when players are most likely to achieve PHV (10.7 to 15.2 years of age). The recognition and selection of talent is based on "multifaceted intuitive intelligence consisting of socially constructed representations of the ideal player" (Meylan et al., 2010 p.573) which suggests that biologically advanced players who exhibit such desirable characteristics may be viewed as "talented" because of such fleeting physical and anthropometrical advantages. Further support for this claim comes from a study by Lloyd et al. (2015) who found that the older players (of the same chronological age category) outperformed their younger peers in both physical and functional measures ($p < 0.05$). Hence, the pertinence of an inclusive measure of somatic maturity to reduce the systematic over-selection of younger players born in the first quartile of the selection year with enhanced maturity related, physical fitness and anthropometrical characteristics in favour of the technically adapt players born in the latter quartiles when categorised chronologically into playing groups (Carling et al., 2009; Towlson, 2016).

The application of somatic maturity within professional youth soccer may draw criticism if clubs unnecessarily emphasise physical traits while undervaluing other equally important components including technical, tactical, and psychological skills in professional youth soccer environments. Given that research suggests that when identifying and training young athletes for football, physical, technical, tactical, and psychological traits all have equal weight. In professional youth soccer, Williams et al. (2020), for instance, identify key talent determinants as a combination of skill, physical, and psychological characteristics. There is evidence to support the predictive validity of these indicators for selection from adolescent to adult performance levels, and research also demonstrates how these variables may interact with one another. Demonstrating how mediating factors, including luck and life events, maturation, the sociocultural setting, and the outside environment, alter the predictive value of these measurements (Williams, et al., 2020).

Monitoring Anthropometric Characteristics of Academy Soccer Players

Anthropometric traits are crucial for specific player positions in soccer as they have shown a relationship between physical attributes of the body and athletic prowess (Thirumagal, 2013), whereas morphological traits vary depending on the position in the game and the level of competition (Etikan et al., 2016). Anthropometry refers to measurement, size and proportions of an individual human body and can be employed to monitor postnatal growth and development (Kent, 2006). As a result, anthropometric measures are very significant for enhancing player performance and assessing the effectiveness of implemented training plans (Sutton et al., 2009), which is a crucial part of the athletes' tailored and periodised training process (Lukaski, 2017). The growth of tissues and systems in postnatal humans can be summarised by using Scammons curves of systemic growth to divide the growth of tissues and systems into four groups (lymphoid, neural, genital, and general) (see Figure 5 (Malina, Bouchard, & Bar-Or, 2004). The ‘genital' and ‘lymphoid' traces depict the development of sex characteristics and glands, respectively, while the ‘neural' trace depicts the brain and nervous system. The ‘general' trace depicts the body's overall growth, including stature, body mass, skeletal, muscular, respiratory, and vascular system development (Malina, Bouchard, et al., 2004).

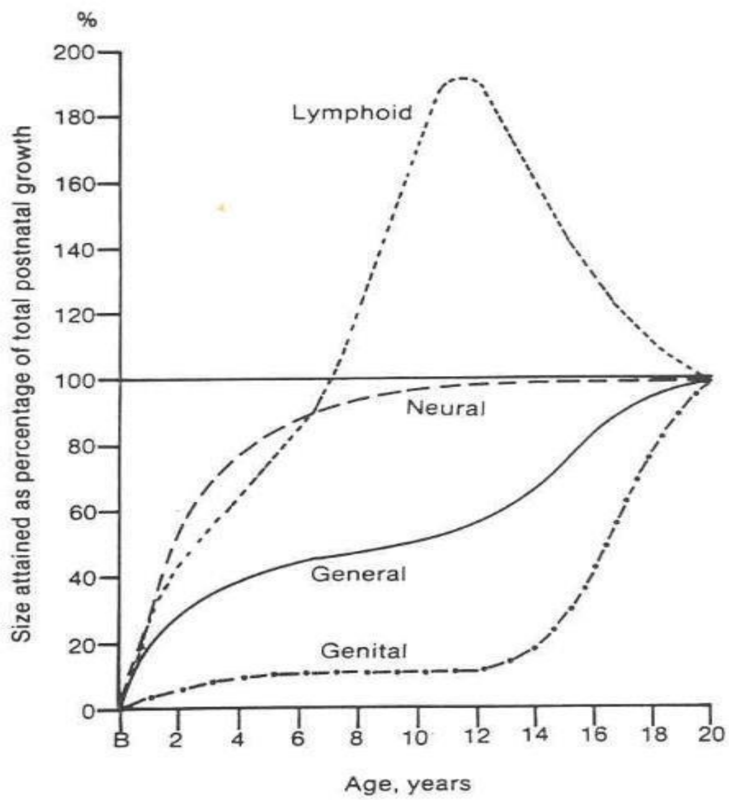

Figure 5. Scammons curves of systematic growth (Malina, Bouchard & Bar-Or, 2004).

With this in mind, as well as the over-selection of soccer players for talent development programs who have superior physical and anthropometric characteristics, Scammons' general growth development should be of interest to soccer talent recognition practitioners. The growth pattern of the 'general' trace is generally s-shaped (sigmoid), signifying four distinct phases of growth. Phase (1) represents rapid growth during infancy and early childhood followed by phase (2) which shows a steady but constant growth during middle childhood. Phase (3) is depicted by rapid growth during the adolescent spurt with phase (4) slowing thereafter during post adolescence until eventual cessation in adulthood.

Furthermore, professional youth soccer players' anthropometric characteristics have been linked to professional soccer team selection (Deprez et al., 2015) and playing position (Deprez et al., 2014). The latter finding would suggest that soccer TID practitioners should monitor the rate of players' growth, height, and body-mass development using simple anthropometric tests that can be performed in field settings on a (weekly/monthly) basis (Towlson et al., 2021). In addition, to the anthropometric characteristics of professional youth soccer players, the monitoring of maturity status is also of great importance for the talent identification and development process of players too. In consideration of this, the following sections will introduce and discuss the various growth and maturation methods (biological, skeletal, sexual and somatic) used to establish the maturity status of professional youth soccer players.

Playing Position Characteristics of Professional Youth Soccer Players

Over the last two decades there has been a growing interest in match analysis of soccer (Reilly, 1976; Rienzi et al., 2000) but more recently the physiological load and morphological characteristics of soccer players when playing/field position is accounted for (Di Salvo, et al., 2007; Rebelo, et al., 2013). Soccer players are generally categorised into four groups: goalkeepers, defenders, midfielders and strikers, with the different positions having position-specific performance and anthropometric characteristics required for success (Sylejmani, et al., 2019). As a result, knowing the physiological load and playing position characteristics (activity profile, distance covered, strength, energy systems, and muscles involved) placed on the various positions is important not only for developing position-specific training protocols, but also for TID practitioners to recognise players suitable for each role (Sylejmani, et al., 2019; Di Salvo, et al., 2007).

In general, professional youth soccer players are typically taller and heavier than non-professional peers (Figueiredo et al., 2009; Gravina, et al., 2008; Malina, et al., 2000) and perform significantly better on sprinting and jumping tests (Gissis, et al., 2006; Gravina, et al., 2008) as well as in soccer-specific tests of dribbling, shooting accuracy and juggling (Vaeyens, et al., 2006). In terms of specific playing positions, Deprez and Fransen et al.'s (2014) study of 744 professional youth (U8 to U18) Belgian soccer players' showed that goalkeepers and defenders exhibit superior stature (goalkeepers: +0.4 to +3.7 cm; central defenders: +0.5 to +2.8 cm compared to midfield and attacking players). Goalkeepers and defenders are also generally heavier (Gil, et al., 2007; Malina, et al., 2004; Wong et al., 2011) and central defenders perform better in vertical jumps (Rampininiet, al., 2007). However, there are no differences between field positions in dribbling, passing and shooting accuracy (Malina, et al., 2005), nor in shooting power, sprinting or sporadic stamina (Wong et al., 2011). Moving forward, midfield and attacking players typically possess superior anaerobic (Buchheit et al., 2010a; Malina et al., 2004) and endurance attributes (Malina, Eisenmann, et al., 2004; Stroyer et al., 2004). Furthermore, according to Buchheit et al. (2010b) study, LM and forwards (FWD) had superior acceleration (-0.01 to -0.04 s), peak speed (+0.7 to +2.0 km.h-1), and mean repeated sprint time (-0.09 to -1.08) test capacities in comparison to all other outfield p players in a sample of 77 Qatari professional youth (U13 to 18) soccer players. Whilst Rampinini et al. (2007) study showing forwards perform better in vertical jumps. Furthermore, the practical demands of wide players (e.g. right wing or left wing) have been impacted by the development of soccer match-play strategies (Bush et al., 2015). Over a 6-year span (2006-07 to 2012-13), wide EPL soccer players increased both total distances covered at high-intensity (19.8–25.1 km h1) and sprinting (>25.1 km h1) during match-play, owing to the evolution of match-play strategy and formation employed by managers (Bush et al., 2015).

Further research into professional youth playing position characteristics is likely to inform current selection criteria and allow soccer TID practitioners to make informed decisions about a player's current and future athletic and anthropometric growth based on playing position, maturity, and decimal age as a result of professional youth playing position characteristics. However, in order to improve TID theory and the accuracy of national playing position benchmark and growth trajectory data in the United Kingdom, a wide sample of UK-based professional youth soccer players must be systematically measured and tracked as they progress through the EPPP.

Match-activity profiles of academy soccer players

To date, an abundance of literature is available reporting match play characteristics, movement demands and patterns of professional soccer athletes utilising a variety of technologies (Abbott et al., 2018; Doncaster et al., 2020; Pettersen & Brenn, 2019). However, athletes' locomotive actions during a match are extremely varied. Therefore, tracking match-activity profiles is considered a critical component of today's youth development process and an essential component of the talent recognition process, aiding long-term athletic development and supplementing empirical awareness of player identification, improvement, and development over time (Goto, 2012; Vieira et al., 2019). Adult professional players usually cover 9-14 kilometers in a 90-minute game, while professional youths cover 5-12 kilometers depending on their age (Ade, 2019), implying that match-activity profiles can be influenced by age in the developmental stages (Buchheitt et al., 2012). Therefore, due to the unstandardised differences in pitch size, game duration and match conditions in professional youth soccer, normative match running performance data may not be applicable across all age groups, but it may be used to determine an age at which players demonstrate match running outputs that represent professional standards (Harley et al., 2010; Vieira et al., 2019).

Physical demands also vary between playing positions. For instance, previous research has found that central defenders and strikers cover the lowest distances whilst central midfielders produced the highest (Dellal et al., 2012; Gaudino et al., 2013). For high-speed activities and number of accelerations produced by playing positions, attacking and defending wide players produced the highest distance for sprinting and high intensity running while central players produce the lowest (Carling, 2013; Dalen et al., 2016; Ingebrigtsen et al., 2015).

Given the complexity of match-activity profiles, it is imperative for sports practitioners to carefully select and differentiate the physical fitness tests between age and playing positions of soccer players to accurately evaluate and monitor players physical fitness development and prepare for a transition into the professional game. Goto et al. (2015) analysed match-activity profiles amongst U9 and U10 EPL academy soccer players using a global positioning system and found that when players were separated into retained and released players, the retained players covered a significantly longer total distance (by ∼400 m) during a match and a significantly greater distance at low-speed running (by ∼200 m) than the released players. Such data can aid football and conditioning coaches in the implementation of training programs as well as the identification and development of talent (Goto et al., 2015).

Technical and Tactical Match-activity Profiles

Traditionally, the identification and recruitment of players based on technical and tactical aspects of their performance in soccer would be dependent upon coaches' subjective opinions (Vaeyens et al., 2008). However, with the introduction of the EPPP, there has been a greater emphasis for the investment into, and use of soccer players technical and tactical profiles for talent selectors to utilise within academies (Fenner et al., 2016; Unnithan et al., 2012). This could be due to findings regarding the technical and tactical skills and abilities of youth soccer players that have been shown to correlate with (de)selection outcomes. To illustrate, players who were selected for a professional academy or talent development program were shown to complete dribble slaloms quicker (.5 seconds faster than deselected players) and were physically faster for peak slalom and shuttle dribbles ($P < 0.05$) (Huijgen et al., 2014). In addition, technical aspects such as positioning and decision making were considerably higher for selected players (Huijgen, et al., 2012).

To account for these findings, Fenner et al. (2016) introduced a model which enabled talent selectors to evaluate prepubertal soccer players talent through the platform of small sided games (SSG) and application of a game technical scoring chart (GTSC). The model uses a systematic format to test ten different footballing features, such as assists, power, first-touch, passing, and shooting, among others. Each element is then individually scored against a criterion between poor (1) and excellent (5) (Fenner et al., 2016). The results from the study demonstrated a significant ($P < 0.001$) and very large relationship ($r = 0.76$) between total points and GTSC points. This implies that the ability to determine the most talented athlete should be based on the largest number of accumulative GTSC points, which can then be distinguished from additional functional fitness, attributes, and time-motion analysis steps (Fenner et al., 2016).

Furthermore, the tactical profiles of players can be assessed using the analysis of match-play. Folgado et al.'s (2012) study highlighted how the age of players influences the variability of player distribution, decreasing with age. Using a ratio of the length to width distribution of players on the field, older squads showed a consistent application of stretching and creating space (using the width), compressing into confined areas (concentration) and principles of play (e.g. keeping the ball, playing in movement, regaining possession, challenging opponents progression) (U9 lpwratio = 2.287 au and 2.013 au; U11 867 lpwratio = 1.130 au and 1.077 au; U13 lpwratio = 0.883 au and 0.541 au)-all of which reflect a higher level of collective tactical behaviors (Folgado, et al.,2012). To summarize, our understanding of how technical and tactical match-activity profiles can be used for talent discovery and growth is still evolving, but further work is needed to provide adequate technical and tactical talent indicators.

Psychological Profiles of Academy Soccer Players

Sports psychology is the study of how psychological factors influence sports, athlete performance, exercise and physical activity (Butler, 2020). Talent Id researchers have focused largely on physical determinants and predictors of excellence, whilst there is an increasing body of literature on psychological characteristics in high-level youth soccer, such research is still in its infancy. Psychological factors should be of the same importance as physical, technical and tactical aspects of the game, training programs and talent identification of talented athletes (Najah & Rejeb, 2015).

Sport psychologists may draw upon Butler and Hardy's (1992) performance profiling procedure to help establish an athlete's awareness of the attributes that might contribute to success in sport Phase one of Butler and Hardy's (1992) three step approach is introduced as a way of helping athletes to become aware of the attributes necessary for successful performances and their perceived strengths and weaknesses as shown in figure 6. In phase two athletes begin to elicit their strengths and weaknesses on a one-to-one basis with a sports psychologist. Phase three involves an assessment of the qualities highlighted by the athlete, ranking them on a scale of lowest possible ability (1) to ideal level of quality (10). The completed profile then offers a clear visual representation of the athlete's strengths and shortcomings, which can be used to guide growth goals and training programs (Weston, 2008).

Profiling has been suggested as a useful strategy for helping athletes to monitor progress, set appropriate performance-related goals, and evaluate performances (see Weston et al. 2012). For instance, one of the primary benefits of performance profiling has been proposed to be raising self-awareness (Weston et al., 2010), helping athletes to highlight the demands of their position and help clarify their performance strengths and weaknesses (Weston et al., 2011a). Along with the athlete's perception of what constitutes exceptional performance in their sport or position, as well as their perceived strengths and limitations, being brought to the psychologist's attention (Butler, 1997). Another fundamental benefit to performance profiling proposed by Butler and Hardy (1992) is greater intrinsic motivation to train, improve and encourage more control and responsibility for their development (Weston et al., 2011a). But it is important to note, multiple profiling sessions must be repeated across the competitive season in order to achieve the desired outcome (Weston et al., 2011b).

Soccer teams should also take note of Butler and Hardy's (1992) research, which suggested that performance profiling may have a favorable impact on team cohesion and increase efficacy, productivity, and performance success. Butler and Hardy (1992) highlighted the significance of Deci and Ryan's (1985) cognitive evaluation theory to support the use of performance profiling (CET). According to CET, the three fundamental human desires of relatedness (feeling connected to significant others within the specific context), autonomy (having internal control over one's choices), and perceived competence (having confidence in one's ability to perform in that context) will influence an individual's motivation. According to this theory, social factors that support these mediators will promote greater self-determination, which will lead to more favorable cognitive, emotional, and behavioral responses (Thøgersen-Ntoumani & Ntoumanis, 2006) (see Deci & Ryan, 2004, for a review).

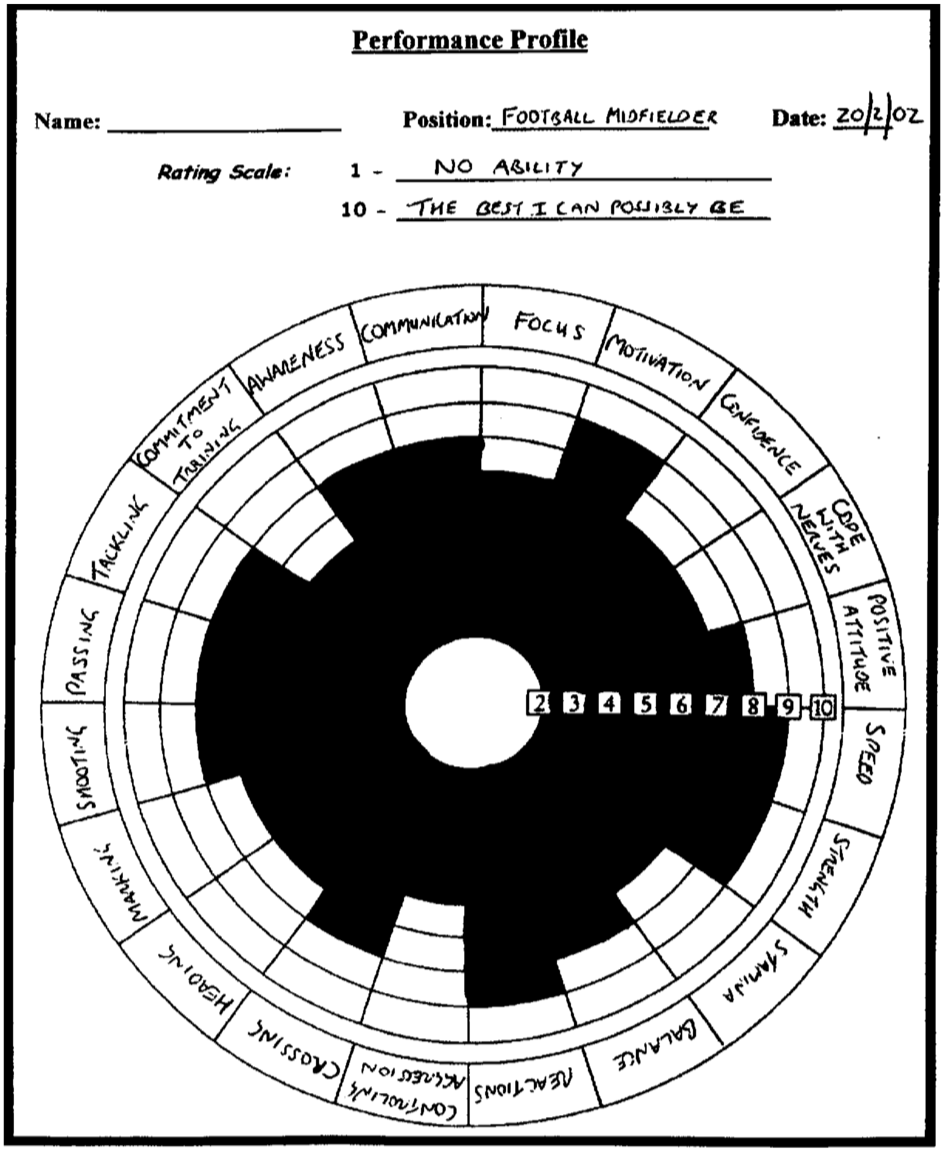

Figure 6. Performance Profile of a soccer player (Butler & Hardy, 1992).

Influence of Maturity Across the Player Development Pathway

As this thesis has detailed, a number of elements are important for soccer performance including technical, tactical and psycho-social qualities. It is also widely accepted that the systematic monitoring of physical phenotypes is also relevant since research identified the players selected for talent development programs typically display superior physical fitness and performance in comparison to those deselected players (Emmonds et al., 2016; Towlson, 2016). As a result, now that it has been established that child growth and physical development is highly individualised and dependent on individual growth curves (Malina, Bouchard, et al., 2004), TID practitioners and researchers are eager to take a comprehensive approach to TID and discover ideal anthropometric and physical characteristics of players who are eligible for soccer development programmes early in their development, based on their somatic maturity (Unnithan et al., 2012; Deprez et al.,2015). Such monitoring will help better identify and select talented players for development programs, as well as serving as a need's analysis for player physical development. Furthermore, allowing physical fitness deficits to be identified and future exercise prescriptions to be prescribed in accordance with the IOC consensus statement on youth athletic development (Bergeron et al., 2015).

There is a substantial quantity of literature on the influence of maturity across the player development pathway for professional youth soccer players' long-term athletic development (LTAD). For instance, Gouvea et al.'s (2016) results suggest that maturational development influences the body mass, height, body fat, flexibility, muscular strength of upper limbs and cardiorespiratory fitness of athletes. Biological maturity, on the other hand, does not appear to discriminate distinct technical skills in youth soccer players. As a result, coaches should regard maturational development as a major determinant in morphological and functional capacities in young soccer players.

Bio-Banding

Adolescent athletes are traditionally divided into chronological age groups with a view to minimising maturity-related variations in size, strength, and technical skill (Cumming et al., 2018; Cumming et al., 2017). Tanner, Whitehouse, Marshall and Cater's (1975) research on the rates of biological maturation indicates that there is only a maximum difference of four years in biological age between boys and girls at the time of the adolescent growth spurt, despite the fact that there are large inter-individual differences between chronological age and biological age within chronological age groups (Cumming et al., 2017; Fransen et al., 2018). The idea of "bio-banding" has been adopted in order to restrict and try to avoid disparities in physical characteristics among relevant categories caused by such biological alterations (Cumming et al., 2017).

Bio-banding is a recently adopted approach which regroups young athletes into teams/groups based on their maturity and biological age opposed to chronological age (Cumming, Brown, et al., 2017; Cumming, Lloyd, et al., 2017). Bio-banding can also be described as a talent identification tool, providing help to institutions and clubs to retain talented athletes that may otherwise ‘slip through the net’ (Cumming et al., 2017). The primary goal of this approach is to create an appropriate amount of challenge for both late and early maturing players when playing alongside people of the same maturity levels. By grouping players based on maturity, the physical advantages that early-maturing players have in comparison to less-mature players are reduced and allow for optimal development for both early- and later-developing players (Cumming et al., 2017). The bandings are frequently derived from maturity estimate equations that either model normal growth curves of adolescents, with somatic characteristics such as body-mass, leg-length, decimal age and stature (Fransen et al., 2018; Mirwald et al., 2002; Moore et al., 2015) or which encompass mid-parent height (average height of biological parents; Khamis and Roche (1994). The results are then separated into the stages of maturation: pre-puberty (85% of predicted adult height), circa-puberty (85-96% of predicted adult height), post-puberty (96+% of predicted adult height) (Pyke, 2012).

Maturity refers to progress towards the adult (mature state) and can also be defined in terms of status, timing and tempo. Status refers to the state of maturation at the time of observation, timing to the age at which specific maturational events occur and tempo the rate at which maturation progresses (Malina et al., 2015). Since children of the same age vary considerably in biological maturation bio-banding attempts to address these inter-individual differences during adolescence. Therefore, the timing of maturation has important implications for talent identification, competitions, reduced risk of injury, and training (Malina et al., 2019). Bio-banding is particularly important for talent identification and the development of athletes in soccer academies since it aims to negate the over-selection of young athletes who possess greater anthropometric dimensions (body mass and stature) or performance characteristics such as strength, speed, power and endurance in the development stages through to club and country selection (Carling et al., 2012; Carling et al., 2009; Vaeyens et al., 2006).

Despite bio-banding being widely accepted by athletes and introduced into the national leagues such as The EPL (Cumming et al., 2018), there is still limited but encouraging evidence to show its efficacy for the multi-disciplinary components in soccer such as physical, technical, tactical and psychological. More research is also required to show bio-banding efficacy as a talent identification tool. As part of the EPPP for U.K. football, all Premier League and Category 1 academies perform a standardised series of fitness tests on a tri-annual basis (Cumming & Bunce, 2015). This is an example of bio-banding for talent evaluation. The Premier League's Player Management Application receives data from each club, which is then utilised to create league-wide age- and maturity-specific reference. When assessing athletic ability and potential, the technique enables coaches and practitioners to more effectively take into account individual differences in maturation. It also assists in revealing previously unnoticed strengths and deficiencies in their athletes. The advantages of considering physical fitness and/or athletic performance in relation to standards for both age and maturity are shown in figures 7 and 8. It is not surprising that the player routinely performs above the mean on measures of speed, power, agility, and aerobic capacity when compared to his peers of the same age, given the athletic benefits associated with advanced maturation in males. However, when his ability is measured against benchmarks developed from children of the same biological maturation, the pattern of outcomes is noticeably different. In this case, fitness ratings are simply rough estimates and, in certain cases (i.e., agility and aerobic capacity), they fall below the mean, exposing previously unrecognised shortcomings. A late-maturing athlete, who might not seem particularly quick or powerful compared to peers their own age, might, nonetheless, exhibit a significantly more favourable performance contrasted against their maturational peers (Cummings et al. 2017).

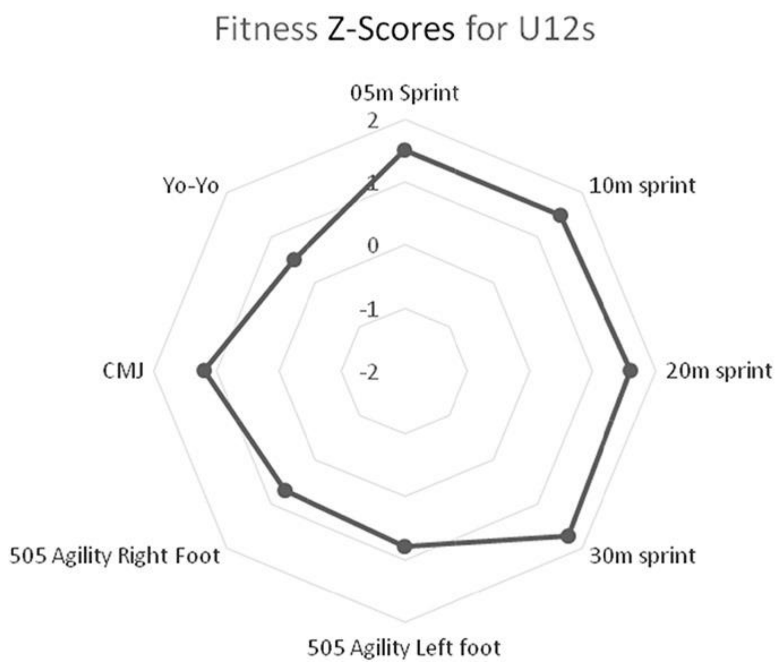

Figure 7. Fitness attributes of an early maturing 12-year-old male soccer player represented as Z-scores relative to players of the same chronological age (Cumming et al. 2017).

Figure 8. Fitness attributes of an early maturing 12-year-old male soccer player represented as Z-scores relative to players of the same maturity status (Cumming et al. 2017).

Cummings et al. (2018) also conducted a study limited to 66 soccer players (from four major clubs) who participated in a tournament aged between 11 and 14 and between 85 and 90% of adult height. All players expressed The Premier League should incorporate bio-banding into the current games programme, according to all players, who described their experiences as favourable. Early maturing players found the bio-banded games to be more physically demanding than age-group contests, and they had to adjust their playing style by putting more of an emphasis on skill and tactics. Late-maturing players valued having more opportunities to apply, develop, and demonstrate their technical, physical, and psychological competencies, despite the games' perceived lack of physical difficulty. The overall development of young football players appears to benefit from bio-banding tactics.

These results also show how bio-banding might also act as a variable in constraint-based coaching to alter the degree of difficulty for different athletes. A constraint-led approach (CLA) is non-linear and asserts that a learner will self-organize in an effort to produce effective movement solutions through the interaction of many constraints, including task, environment, and performance (Renshaw, et al., 2012). Simply put, rather than commanding athletes, coaches shape and assist them. Because CLA, in particular, changes practitioners' perceptions on how to handle individual variances and organise practice to optimise learning (Davids, et al., 2008), bio-banding athletes can therefore help to discover and manipulate biological restrictions for greater development. For instance, from a physical perspective a coach may look to play his taller most mature (early-maturing) player who is able to out size and strength his peers, against older peers of similar biological maturation (stature, weight etc.), challenging the individual to find an alternative solution to accomplish the same goal. Coaches can also manipulate technical, tactical and psychological scenarios to accomplish further development. Since, only when certain performance-limiting limitations are removed may certain types of motor behaviour arise. Here, we contend that athletes competing against one another in a chronological age group may cause the motor abilities of late development to be limited by the presence of early developers. Therefore, a different motor performance may manifest if the task constraint of an athlete's maturation changes as demonstrated in bio-banded competition Abbott, et al., 2019). This thesis will now marshal recent research the influence bio-banding can have on athletes physical, technical, tactical and psycho-social characteristics.

Physical

The large variation in physical maturity and stature between athletes undergoing puberty within youth soccer academies creates challenge within the talent identification process and success rate of athletes. Clubs potentially overlook late maturing talented athletes in training and competition when compared to early maturing team mates (Reeves et al., 2018). To compensate for this, youth soccer club's may bio-band athletes based on their biological age and maturation in order to create equal opportunities and reduce injury risk (Albuquerque et al., 2015; Delorme, 2014; Cumming et al., 2017). Therefore, one of the key aims of bio-banding is to support late-maturing athletes who are denied competitive opportunities due to their lack of physical maturation in relation to their early-maturing counterparts. This notion is supported by Bradley et al.'s (2019) qualitative findings which showed that early maturing athletes thought bio-banding presented them with new opportunities and challenges because it was more physically and technically demanding. By contrast, late maturing athletes in this study felt that they were presented with greater opportunities to showcase their technical and tactical skills, potentially aiding retention of such players.

Bio-banding may also reduce the selection bias between early and late maturing athlete's talent identification and development when physical attributes (power, speed, strength etc.) are controlled for (Cumming et al., 2017). Although with this approach late developers can experience more technical and tactical success, research suggests that they simultaneously experience less physical challenge when they are not training or playing with their early maturing peers (Abbott et al. 2019; Cummings et al. 2018). Consequently, early maturing athletes can also be ill prepared or be encouraged to play to their physical strengths at the expense of their technical and tactical skills (Malina et al., 2015). However, a failure to use or develop skills simultaneously during a developmental stage can have implications on learning and performance which is most evident in late adolescence and early adulthood when maturity-associated differences in physical attributes are either attenuated or reversed (Lefevre et al., 1990).

When evaluating the efficacy of bio-banding and how biological maturation might influence physical performance, it is crucial to analyse the effects throughout a continuum of chronological age grouping with a large variance when evaluating the effectiveness of bio-banding and how biological maturity might influence physical performance (Goto et al., 2019; Patel et al., 2019). Goto et al.'s (2019) study examined the effect of biological maturity on the match play performance of professional youth male soccer players between the ages of 8 and 16, evaluating the dynamic relationships between biological maturation and physical performance, and emphasising the significance of addressing maturity status across different chronological age groups. Early maturers in the U9/10 chronological age grouping had an increased match play duration (6 minutes, p 0.01), leading in a longer total distance covered (~13%, $p = 0.01$), giving them a greater chance to exhibit and develop physical performance characteristics. Again, when analysing the U13/14 chronological age group, early maturers covered a greater distance in relative high-speed running (~44%). Along with spending a greater percentage of time performing high-speed running when compared to the data of later maturing players (3.5% & 2.5%).

Technical and Tactical

Despite technical performance being considered a key factor for talent selectors (Towlson, et al., 2019; Moreira et al., 2017), the over-selection of earlier maturing soccer players in soccer development programs who display enhancements in anthropometric and physical fitness characteristics is still very much apparent (Deprez et al., 2015; Lovell et al., 2015). A consequence of this is the under-selection of 'later' maturing players (who are yet to show their potential of developing equal physical abilities), in favour of those players who due to their earlier onset of the adolescent growth spurt, already display maturity-related enhancements in anthropometric characteristics (height, weight, skin fold etc.) (Unnithan et al., 2012; Cumming et al., 2017).

Early research suggests bio-banding has been shown to offer players a technical and tactical benefit (Cumming et al., 2018). In one such study using a longitudinal analysis, professional swiss junior soccer players with delayed maturation were found to possess superior adaptive and technical skills compared to their early maturing counterparts (Zuber et al., 2016). Whilst Abbott et al. (2019) study showed in contrast to chronological competition, bio-banded competition changes the technical demands placed on athletes without lowering physical demand. For example, early developers during bio-banded competition showed significantly more short passes, significantly fewer dribbles, and significantly higher ratings of perceived exertion (RPE) than chronological competition (p 0.05). For on-time developers, significantly more short passes and dribbles and significantly fewer long passes were observed (p 0.05) In addition, late developers showed significantly more tackles and significantly fewer long passes (p 0.05).

A recent study by Ludin et al. (2021) represented the first to attempt to investigate whether bio-banded versus chronological age competition affects reliable technical and tactical in-game key performance indicators (KPIs). Results showed from the 65 professional U13/14 soccer players that early maturing players could no longer just rely on their physical characteristics during bio-banded games, but are more frequently forced to use their technical-tactical skills to compete. However, compared to chronological age games, bio-banded games gave late-maturing players a better chance to demonstrate their technical and tactical prowess. Another recent study produced by Towlson et al. (2021) also aimed to investigate the effect of bio-banding on technical and tactical indicators of talent identification for 11 to 14-year-old professional youth soccer players. The findings indicate that maturity-matched bio-banding had little effect on players' technical and tactical characteristics during maturity-matched bio-banded formats. This trend, however, continued during maturity mis-matched bio-banded formats, limiting the conclusions that can be drawn about the effectiveness of bio-banding in manipulating technical and tactical performance of academy soccer players during small sided games. Although it was not intended, the results presented some preliminary evidence that restricted relative pitch size may provide a playing environment that prevents maturity-related technical and tactical actions from manifesting during small sided games contested by players of varying maturity status.

However, it's important to note that more research in this area is required to improve understanding of the effectiveness of maturity-related bio-banding on talent identification processes in professional soccer academies. Overall, it can be anticipated that bio-banding results in a game that is more evenly distributed, tactically difficult, and features more duels and failed passes (Romann et al., 2020).

Psychological

Studies have attempted to demonstrate the significance of psychological characteristics and traits in the identification of talent in professional programmes (William & Reilly, 200). According to Larkin and O'Connor (2017), the most valuable psychological attributes to consider are confidence, competitiveness, X-factor, and positive attitude while Forsman et al., (2016) study presents psychological characteristics (e.g. motivation, concentration and mental preparation) to be of value when predicting long-term athletic development in professional youth soccer players. However, there is limited evidence to support the interaction between biological development and psychology and how it affects soccer performance. There is also minimal research on the development and maturation of talent, despite attempts to measure and score the significance of psychological factors on talent identification (Williams & Reilly, 2000).

One theory which has arisen from research seeking to understand how maturation might interact with psychological characteristics to influence talent development is the “underdog hypothesis” (Cumming et al., 2018; Kelly et al., 2020). The “underdog hypothesis” posits that to avoid deselection from talent programmes, later developed athletes must develop superior psychological, technical or tactical profiles compared to those of early biologically developed players (Cumming et al., 2018). This concept is supported by the results of several empirical investigations, which demonstrate that the larger difficulties faced by the less mature athletes require their selection or avoidance of deselection from talent development programmes due to stronger psychological attributes (Cumming et al., 2018). More specifically, Mills et al. (2012) study made a distinction between young soccer players who successfully proceeded into professional soccer and those who did not based on criteria like goal commitment, participation in problem-focused coping strategies, and social support seeking. Coaches continued by pointing out a significant discrepancy between the relevance of sport psychology and its systematic application: "*We don't get involved in sport psychology because the majority of us don't understand it enough*." It was also said that frequent personnel changes prevented players from developing since they frequently lacked a sense of security. Due to the continuous need for players to show themselves to a new coach, this occasionally caused the academy to be in a state of instability and hampered psychological growth (Mills et al., 2012).

Taking this into consideration, recent evidence suggests in order to be selected and retained within professional youth soccer, it would be beneficial to possess and develop an adaptive psychological response, with a specific consideration towards self-regulation (Panadero, 2017; Zimmerman, 2006). Self-regulation enables athletes to manage their thoughts, feelings, and behaviours, including self-initiated processes to translate mental skills into physical abilities. As a result, athletes will generate more effort into their work and have higher levels of self-efficacy, which has been shown to support effective learning, develop potential, and distinguish between different performance and success levels (Toering et al., 2012; Zimmerman, 2006).

Toering et al.'s (2009) study highlighted professional youth players as having high self-regulation levels in comparison to non-professional youth players. The results imply that professional players may be more conscious of their strengths and weaknesses and better able to put this awareness into practice. Professional athletes also seem to be more willing to put in extra effort during practice and competition (Toering et al., 2009). It is hypothesised that professional players may exhibit a higher capacity for performance compared to their non-professional counterparts because they have better developed self-regulatory skills, which may also transfer into a more productive learning environment.

Since psychological characteristics, such as personality traits and psychological skills, have been shown to be relevant predictors of soccer performance, Musculus and Lobinger (2018) provide recommendations on how to improve objectivity, reliability and validity for talent assessment. In terms of objectivity, for example, the instruments (e.g., scouting sheets) used to serve the coaches' assessment should include clear definitions of characteristics, allowing all raters to share common understandings of the objective. In addition, appropriate response formats from standardised sports-related questionnaire formats must be considered. A standardised evaluation sheet should include clear instructions for coaches as well as short definitions of the constructs to be evaluated on a predefined rating scale with behavioral anchors (Musculus & Lobinger, 2018).

To improve reliability, a simple solution would be for multiple practitioners to evaluate the same players multiple times (while having no influence on one another's ratings). At least two practitioners who are familiar with the athlete (e.g., the coach, assistant coach, or any other personnel) are recommended. The long-term development of athletes can also benefit from this by providing feedback and motivating players to focus on and improve their psychological characteristics (Musculus & Lobinger, 2018).

Several factors must be considered in order to improve validity. First, when determining which psychological characteristics are relevant for athlete talent identification and development, coaches' expertise and intuitive beliefs must be considered. Following that, stakeholders must provide accurate definitions of the psychological characteristics they believe are important. It is also critical to ensure that the test instrument's validity has been approved and that athletes' psychological results meet the relevant criteria established by stakeholders. The validation process should be developed and designed systematically, taking into consideration the complexity and timeframe required to test the validity of the psychological characteristics in question (Musculus & Lobinger, 2018). According to Musculus and Lobinger (2018), assessing psychological characteristics in talent development should also combine self-ratings of players and external ratings of coaches. Sports psychologists should assist clubs and coaches in improving psychological characteristic diagnostics, as well as embed psychological diagnostics and interventions in the talent and development process for professional youth soccer players.

Multidisciplinary Functioning Soccer Teams

Although talent identification practices have long been a vital part of soccer, with the introduction of the EPPP and its long-term goal of increasing the number of better ‘home-grown’ players, there has been a surge in research interest in the talent identification process and multi-disciplinary soccer teams. Such focus is likely due to the significant playing and financial benefits that can be gained by clubs implementing talent identification strategies to result in a high number of academy graduates transitioning to first-team, for their parent club (Towlson et al., 2019). The process of identifying and developing talent is complicated because future success is dependent on a variety of elements, including chances for practice, coaching, and mentorship, as well as personal, cultural, and social aspects (Reilly et al., 2000).

Soccer performance is also influenced by a variety of factors including physical, technical, tactical, and psychosocial elements. However, it has been argued that attempts to identify 'talented' players can often be reduced to 'guesswork,' as decisions are made based on coaches' and talent scouts' 'gut-feeling,' intuition, knowledge, and experiences of player movement patterns, gained from their own experiences as players and coaches (Towlson et al.,2019). Increasing attempts have been made to ensure that research-informed talent development processes are implemented so that athletes have the best chance of fulfilling talent. As Stolen et al. (2005) put it, "soccer is not a science, but it may help increase performance” (p.503).

Clubs and organisations wishing to build a healthier (both physically and mentally) individual have been encouraged to embrace a multidisciplinary strategy that focuses on the process rather than the end goal (Stratton et al., 2004; Relvas et al., 2010). As a result, coaches are encouraged to create an environment which targets all aspects of development, rather than simply for example physical characteristics. Ford et al.’s (2020) study revealed that the usage of sports science measures such as medical assessment and fitness testing, rose as youth players got older, reflective of the multidisciplinary approach to TID advocated by researchers (e.g. Williams & Reilly, 2000) is frequently adopted in these organisations. Another prime example of a multidisciplinary approach to professional youth soccer is most notably Ajax Amsterdam F.C. Ajax model challenges the old systematic view of 10,000 hours rule, rather than focusing on the quantity of these hours, a more qualitative approach is taken, which considers not only the number of hours spent performing a specific skill, but also how other factors like motivation, emotions, enjoyment, and confidence influence the successful development of these specific skills (Larsen et al., 2020).

Bartlett and Drust's (2021) framework promote a multidisciplinary approach designed to facilitate and guide sports scientists towards a more efficient and optimal knowledge translation utilising evidence-based practice, philosophy, recipients and facilitation. Evidence-based practice is the process of combining and applying data from athletes, practitioners (in this case, coaches and performance staff), and published research in order to make the best decisions feasible. In professional sport, the use of practice acquired knowledge (i.e. coaches' and practitioners' experience, intuition, and expertise) is critical, as it includes the context of previous performance difficulties and lessons learned, as well as the best available research findings.

The integration of character, leadership approach, and evaluation is referred to as philosophy, and it describes how the Sport Scientist tackles their day-to-day and how they are perceived by their peers. Its key to note that review and reflection are key elements to ensure the philosophy continues to evolve. Understanding who the stakeholders are, their diverse learning styles, and the unique personal and professional traits that come with their job will lead to deciding successful and influential information translation. In order to further impact knowledge translation, it is necessary to be aware of the traits associated with each stakeholder's role. The recipient's objectives, goals, talents, and expertise, as well as time, resource, and support, are all important factors to consider.

Finally, facilitation is a process of enabling (Harvey & Kitson, 2015), and it necessitates a wide range of personal characteristics, technical expertise, and interpersonal skills. Given the various scenarios that exist within the daily sporting environment (i.e. training monitoring, performance measurement, return to play, team selection, and coaches' performance rating, to name a few), it is critical that the facilitator role is recognised, has clarity, and is supported by peers in guiding team-based change. In turn, the development of a system that uses, records, monitors and evaluates a multitude of data types may be key to informing effective talent identification decisions (Till & Baker, 2020).

In summary, the key findings presented thus far include the growing importance of talent identification and support for the development of physical, technical, tactical, and psychosocial characteristics in professional youth soccer athletes. Taking into consideration athletes' maturation status and how biological maturation (e.g., skeletal, sexual, and somatic maturation), anthropometric (size and proportion), and position-specific characteristics can affect such identification and development. Physical, technical, tactical, and psycho-social match-activity profiles were then examined to better understand why certain characteristics are deemed essential in the talent identification process, as well as how maturity can influence the player development pathway. As a result, the bio-banding approach has been used to limit maturity influences by grouping players of similar status, thereby helping to retain athletes who would otherwise be deselected.

When determining the effect of bio-banding on talent identification and development of athletes in professional youth soccer, it considers physical, technical, tactical, and psycho-social aspects individually, resulting in multidisciplinary functioning soccer teams. However, there is an apparent gap in current literature regarding practitioners' perspectives on bio-banding and how effective they believe the process is for talent identification and athlete development. As a result, it is critical to address the effectiveness of bio-banding in professional youth soccer clubs as a means of talent identification and athlete development. Along with the question of practitioner familiarity with bio-banding, familiarity with bio-banding methods and the reasoning behind adopting such approaches. Another important question to address is the impact of bio-banding interventions on clubs, as well as the benefits and barriers this can create for clubs, practitioners, and athletes while establishing the multidisciplinary application of bio-banding for anthropometric, physical, technical, tactical, and psycho-social characteristics. To answer such question, the aims and objectives of the study are as follows:

Aims and Objectives

1. To explore practitioners perceived effectiveness and application of bio-banding within professional youth soccer academies for the talent identification and development process.
2. To assess sports practitioners from professional youth academies familiarity of bio-banding and reasoning behind using such approaches for assessing the maturity status of players.
3. To study the effect of bio-banding interventions and which barriers this can produce for sports practitioners and soccer players.
4. To establish the multidisciplinary application of bio-banding for anthropometric, physical, technical, tactical and psycho-social characteristics of youth players within a professional soccer setting.

Methodology

Overall Study Design

The study was grounded in the post-positivist paradigm (Guba & Lincoln, 2005) which has implications for both its ontological (i.e., social constructivism) and epistemological stance (i.e., modified dualist/objectivist). Additional implications include the choice of method (i.e., interviews that were informed by questionnaire findings), data collection (i.e., single interviews), and data analysis (e.g., a deductive approach using categories derived from theory). A sequential, explanatory mixed-method design was used in this study to gain an in-depth and comprehensive understanding of practitioners perceived effectiveness and application of bio-banding. Using a sequential approach to a mixed methods study means a quantitative phase is followed by a qualitative phase (Ivankova et al., 2006). One of the key goals of the quantitative phase of a mixed-methods approach is to identify the existence of a particular occurrence (Jones, 2022). The qualitative phase aims to contextualise, enhance and enrich the quantitative findings. It has been argued that combining both approaches may offer a more complete picture of a phenomenon and generate new insights than using either approach alone. For mixed methods studies to provide better understanding than quantitative or qualitative methods alone, findings must be integrated, linked and these 'strands' must be connected in some way (Sparkes, 2015). According to Sparkes (2015), integration might be in the form of "comparing, contrasting, building on, or embedding one type of conclusion with the other" (P. 22). According to a number of researchers (see Doyle, et al., 2009; Hesse-Beber, 2010; Horn, 2011), mixed methods approach offer a number of advantages including the ability to provide stronger inferences by drawing on complementary procedures. Other advantages include the use of *Triangulation* (enhancing study validity by exploring correlation between quantitative and qualitative data qualitative information), *Completeness* (combining approaches allows for more comprehensive findings and more detailed insight), and *Assisting sampling* (using quantitative survey methods can enhance purposeful sampling and case selection in qualitative studies whilst also helping to define a population of interest that was not anticipated),

This thesis used two data gathering periods to complete the mixed method approach. Phase 1 was an online survey, with phase 2 involving the use of semi-structured interviews.

Creating the Survey

The first step in the data collection process involved creating a survey that could be used to solicit practitioners' perspectives about the perceived effectiveness and application of maturity status bio-banding. The use of online surveys has numerous strengths and potential weaknesses. Strengths include being able to garner the views of a large number of people in a cost-efficient manner, data can be collected on a mobile device making it relatively easy for a range of people to complete, and surveys can allow researchers to accumulate a large amount of data in a short period of time. Potential weaknesses of surveys include the possibility that some people or populations may not be represented online, researchers might attempt to cover too much ground (i.e., too many topic areas) which can confuse respondents, and the possibility of low response rates (Evans & Mathur, 2005).

Recommended rules and procedures must be followed to properly design a survey that yields appropriate data and findings (Passmore, et al., 2002). According Passmore et al. (2002), the eight steps to creating a rigorous survey, in addition to ethical approval, are as follows:

1) Outlining the problem, drawing on prior research and conclusions, and explaining why the study is important to improve the current literature.

2) Before compiling the survey, plan the project by creating a research team, defining timetables, determining project costs, and selecting the target participants.
3) Provide a research justification that is clear, concise, important, fascinating, and answerable.
4) Review the literature to become familiar with previously published work, allowing researchers to ensure that the subject has not been addressed before, as well as to discover gaps in the literature and potential research methodologies for the study.
5) Working with experts to develop and adapt survey items, as well as define the data or structures to be collected (supervisors). Several colleagues complete and analyse the items at this time to improve the survey's face validity before it is pilot tested with people from the target group.
6) Putting together the survey, which entails compiling the individual items into a survey instrument.
7) 7) Pilot testing draft surveys allow for early detection of the repeatability of responses and the identification of inefficient questions or answers. For instance, if a question appears to be confusing a number of responders, it can be changed, omitted, or removed altogether. It is recommended to administer two pretests.
8) Administering the survey introduces mailed or emailed surveys with a brief, simple cover letter, thanking the participants and explaining (1) the purpose of the survey, (2) why that person was chosen to complete it, and (3) why that person's participation is important to the study.

The initial structure of the survey was based around six themes; general information, perceived influence on maturity practice, familiarity with bio-banding, barriers of bio-banding, multidisciplinary application of bio-banding and summary of opinions (see appendix 2). Themes were identified based on a literature review and consultations with my supervisors. To establish content validity, suitable academic (n = 3) and academy soccer practitioners (n = 3) pilot tested the topics and questions contained within the survey. Content validity refers to the extent to which the items on a test are fairly representative of the entire domain the test seeks to measure. A survey has content validity if, in the view of experts (for example academic and soccer practitioners), the survey contains questions which cover all aspects of the construct being measured (Beck & Gable, 2001). Such discussion resulted in removal of questions to assess knowledge on maturation such as "*Typically when do you think the onset of the adolescent growth spurt occurs for boys*?" due to the questions "*potentially being too challenging for the target audience*" and the inclusion of five-point Likert scale questions to assess perceived influence on maturity practice (*e.g., "To what extent do you believe that maturity-related differences in physical development characteristics impact your ability to accurately assess the physical competence of a child?" – Strongly disagree, Disagree, Neutral, Agree, Strongly Agree*).

The survey was then piloted through a group 8 of MSc Sports Health and Exercise students. The purpose of pilot testing was to identify any errors which may have been overlooked by the research team such as typographical mistakes or overlapping response sets to ambiguous instructions (Connelly, 2008). Authors are often so close to their work that they may overlook even the most obvious errors and so pilot testing helps authors to identify difficulties that may arise during subsequent data collection that might otherwise have gone unnoticed. Pilot testing surveys are also critical because they can uncover anomalies, problems, and protocol dependability, among other things (Van Teijlingen, & Hundley, 2010), such as duplicated questions, spelling, or routing mistakes. As a result, conducting pilot testing can help the researcher customise questions, improve the clarity of questions, detect the repeatability of responses, and, if necessary, shorten the survey (Connelly, 2008). Following a review of the pilot survey findings and feedback, four multiple choice type items were removed to create place for new questions that would provide further insight into practitioners' knowledge of age and maturation and its impact on talent identification and development in football. The survey questions included the following categories: 1) Inclusion criteria, 2) general information, 3) perceived influence on maturity practice, 4) bio-banding, 5) overarching summary. Simple routing tools were also added onto the inclusion criteria questions in order to prevent participants who do not fit the criteria from completing the survey. The pilot survey also enabled participants to revise and increase the clarity of questions and highlight any spelling or grammatical errors. An example of a revised question is for instance question 9, which asks practitioners to state how long they have worked in their position at the club. This question initially was a single-line free text question, however in order to ensure the accuracy of practitioner's responses it was changed to a scale/rank question.

Part A – Cross-sectional survey design

Participants

The study received ethical approval from the University of Hull's ethics committee (application number: FHS302). An invite letter (see appendix 1) was also sent to sports science practitioners aged 18 or above in category 1, 2, 3 and 4 soccer academies across the UK, inviting them to take part in a survey exploring their thoughts regarding the perceived effectiveness and application of maturity status bio-banding for talent identification and development. The EPPP academy category system is based around an independent audit process, where clubs are assessed on productivity rates, training facilities, coaching, education and welfare provisions then categorised and given a status of 1 to 4, with 1 being the highest status. In total, invites were sent to 32 clubs across the UK along with utilising social media platforms such as Twitter and LinkedIn to further generate suitable respondents for the study. The survey was open for approximately 5 months, with 31 respondents in total and 25 meeting the required inclusion criteria. The invite letter included details such as the purpose of the study, the study's aims, approximate completion times and examples of questions contained within the survey. Furthermore, professional soccer clubs were invited to distribute the survey internally to appropriate staff.

Twenty-seven professional soccer academy practitioners, working within EPPP academy development programs (category 1: n = 15 [56%]; category 2: n = 4 [15%]; category 3: n = 7 [26%]; category 4: n = 1 [3%]) completed an online survey (https://www.onlinesurveys.ac.uk/) which took approximately 10 minutes to complete. As with previous survey designs (Towlson, et al,. 2019; Abbott, et al., 2019) practitioners were required to meet specific in/exclusion criteria questions which included the following: *Have you previously completed (and submitted) responses to this survey?; Are you 18 years old or above?; Confirm that you have read the participation information sheet?; Are you currently working within an Elite Player Performance Plan (EPPP) affiliated club?* Specific responses to these questions (i.e., answering yes to the question which asked whether they had previously completed the survey) resulted in the practitioners being prevented from completing the survey and was redirected to a page thanking them for their time. Responding practitioners comprised of technical coaches (n = 6, [22%]), sport scientists (n = 13, [48%]), performance analysts (n = 1, [4%]), strength and conditioning coaches (n = 3, [11%]), injury specialists (n = 1, [4%]) and practitioners fulfilling non-specific senior management roles (n = 3, [11%]), who had positions within Foundation (U9 to U11: n = 2, [8%]), Youth (U12 to U16: n = 12, [44%]), and Professional (U17 to U21: n = 13, [48%]) development phases of the

EPPP. These practitioners had been in post for on average 22.8 months and 24 (96%) respondents were employed full-time by an academy. To capture practitioners normal working practices, the survey was electronically distributed to practitioners during the first trimester (August to October) of the 2021-2022 English domestic soccer season (August to June).

Response data was collected and stored online using online survey cloud software Jisc.

Survey content

The survey contained 38 questions across six individual sections (Section 1: "*General information"*; Section 2: "*Perceived influence of maturation on practice"*; Section 3: "*Perceptions of bio-banding"*; Section 4: *"Multidisciplinary application of bio-banding*; Section 5: "*Perceived barriers to bio-banding*; Section 6: "*Conclusion of survey"*). All the information disclosed with section 1 of the survey directly corresponded to the respondent and information stated here was coded and anonymised to ensure respondents could not be identified by the research team. Sections 2-4 examined respondents perceived influence maturity status has on their ability to assess anthropometrical, physical, technical, tactical and psycho-social player characteristics their perceptions and application of bio-banding. Responses here were given either using multi-choice or five-point Likert scales questions with qualitative anchors to best suit the narrative of question being asked.

Section 1: General information

Section 1 was comprised of 7 multiple-choice questions which were chosen and designed to provide broader context about the respondent which may offer plausible explanation for certain responses. The required information within this section included the EPPP category (i.e., category

1, 2, 3 or 4) of the academy they work within, the primary phase (i.e. Foundation Development Phase [U9 to U11], Youth Development Phase [U12-U16] or Professional Development Phase [U17 to U23]) of the EPPP they work within, nature of their employment (i.e. Full-time, part-time etc.), primary role (coach, performance analysts, sport scientist etc.), and how long they had been working in their current position.

Sections 2 to 4: Perceived influence of maturity status and application of bio-banding

Respondents were required to answer using either a multi-choice (multiple answers were permitted), five-point or six-point Likert scale. A six-point Likert scale was used for questions where it was considered appropriate to provide a "*I don't know option*" when respondent knowledge was being assessed rather than agreement per se. Agreement with statements relating to the application and perceptions of bio-banding was established using a five-point Likert scale (*e.g., "To what extent do you believe that differences in maturation status impact the development of physical characteristics" – Strongly disagree, Disagree, Neutral, Agree, Strongly Agree*). The structure of questioning was repeated throughout the survey whereby respondents were asked questions relating to their perception of bio-banding as a format to assess/control for anthropometrical, physical, technical, tactical, and psycho-social player characteristics. These broad groups were chosen on the basis that one of the key objectives of the EPPP is to develop more and better '*home grown*' players who are eligible for international representation and the widely used Football Association, Four (Technical/Tactical, Psychological, Physical and Sociological) Corner Model for long-term player development (FA, 2022) was considered an appropriate framework to structure the survey on.

Section 5: "perceived barriers to bio-banding"

The required information in this section was gathered using a five-point Likert scale (*e.g., What do you feel are the contributing factors to why you have not used bio-banding" – Very low factor, Low factor, Moderate factor, High factor, Very high factor*). Or "*do you feel bio-banding is of greater benefit for early, on-time or late maturing athletes" – No benefit, Minimal benefit, Neutral, Some benefit, Greatest benefit.* In order to ensure all avenues were explored, an additional multiple-choice question was included – "Do you feel there are any other barriers to bio-banding which are not stated above?" – Yes (please specify additional barriers below), No.

Section 6: "Conclusion of survey"

The survey's sixth section included three questions which were designed to allow participants to summarise their overall viewpoints. Two questions used a five-point Likert scale, such as "*I feel bio-banding enhances the assessment of physical characteristics in academy football players" – Strongly disagree, Disagree, Neutral, Agree, Strongly Agree* as well as *"Having completed this survey how likely are you to use bio-banding" – Highly unlikely, Unlikely, Unsure, Likely, Highly Likely.* The final question sought general consensus on when practitioners believe players should be introduced to bio-banding: "*From which stage of development do you believe players should be introduced to bio-banding*?".

Optional Participation

Having completed the 38-item survey, participants were invited to leave their name, email address, and institution/academy for a possible follow-up interview in relation to phase 2 of data collection.

Data Analysis (Survey)

All of the data that has been used was all anonymised before the analysis of the data and statistics. SPSS statistics software (IBM SPSS statistics, Version 27) was used throughout to help analyse the quantitative data. The data were analysed descriptively, with the estimated marginal mean, median, and aggregate figures calculated based on the estimated differences between the physical, technical, tactical, and psycho-social bio-banding elements for talent identification and development. Descriptive statistics are statistical summaries that quantitatively describe and summarise data that is representative of the entire population (Fisher & Marshall, 2009). By doing this, it will convert the raw data into a form that is much more understandable and easier to interpret as it is describing, showing and summarising the key data points in a beneficial way. In order to find the marginal mean, median and aggregate figures, there is a process to follow on the SPSS programme. Firstly, the variables of the data set need to be identified and the data needs to be put into the system for example, in the survey used the variables are agree, disagree, neutral and so on. Once these have been identified, highlight the section of data that requires analysis and click the analyse button. Then, click descriptive statistics, followed by frequencies, which will bring up the frequencies dialogue box. Next, select the variable for which the median is being calculated and drag it from the left into the variables box on the right. This is accomplished by selecting the desired variable from the left and then clicking the arrow in the middle, which moves the variable to the right. Following that, click the statistics button to bring up the statistics dialogue box. On the right side of this box, there is a section labelled central tendency, which contains a number of processes. These processes include median and mean, which must both be checked, as well as this standard deviation, which can be found towards the bottom section of the box. Because they are standard measures of central tendency and dispersion, the mean and standard deviation must be chosen (respectively). Finally, to proceed to the next section, click continue, followed by ok. The results should then be displayed in SPSS's output viewer in a much simpler format, with the mean, median, and aggregate figures clearly identified. For example, in the first data set (physical characteristics), all of the statistics were entered into the data set and run through this process to find the median, which was the strongly agree section with a result of 52%.

Part B – Interviews

Qualitative interviews

At the end of the survey all participants were given the opportunity to opt into a follow-up interview to further discuss in depth their views, experiences, and beliefs of the application of maturity status bio-banding for talent identification and development. Qualitative interviews were used to build upon and add further depth to the findings garnered by the survey. Qualitative approaches can be used to 'support and explicate the meaning of quantitative research' (Jayaratne, 1993, p. 117). Interviews were used with a view to collecting rich, vivid and detailed data relating to practitioners' experiences and knowledge of bio-banding. The fact that qualitative methods are designed to gain a detailed understanding of people's experiences means that they inevitably involve the use of smaller sample sizes than one typically finds in quantitative studies. The goal of qualitative research is not to generalize findings to the population from which the sample has been drawn but rather to develop rich, critical, and in-depth insights (Connelly et al., 2016). The qualitative study in this project seeks to achieve what Smith (2018) has called naturalistic (i.e., recognition of similarities and differences to results with which the reader is familiar) and theoretical (i.e., producing new theoretical understandings of a topic) generalisability.

The study is couched within a post-positivist paradigm which has a number of implications for how the interview data was collected, analysed and represented. For example, interviews were informed by survey data, existing bio-banding literature and standardised across participants. A single semi-structured interview (see appendix 3) was used and data was analysed deductively using categories derived from theory. Peer debriefing was conducted to enhance the trustworthiness of the findings and data were represented using a realist form characterized by experiential authority and the participant's point of view.

Participants

Survey respondents who indicated that they were willing to participate in an interview were contacted via email and informed of the purpose of the interview and what it would entail. 7 participants were recruited through the researchers' personal and professional networks. Purposive sampling was used to identify the latter group of participants. This form of sampling involves the non-random deliberate choice of participants due to the qualities, knowledge and experiences they hold (Tongco, 2007). Simply put, it involved identifying individuals who had experience with, or knowledge of, the bio-banding process within a professional youth soccer setting and who met the inclusion criteria of having had experience of working with a development program that employed bio-banding with academy athletes.

The interview sample consisted of 7 males (see Table 1 for demographic details). Participants were contacted prior to the interviews and informed what the interviews would seek to address. All participants signed consent forms prior to the interviews.

Table 1. Demographics of Interview Study Sample.

Participant	Pseudonym	Age	Position / Role	Category Rating	Development Phase	Gender
1	Oscar Dawson	25 Years	Strength & Conditioning Coach	3	Professional Development Phase	Male
2	Jack Gregory	51 Years	Academy Manager	3	Youth Development Phase	Male
3	Sean Bilham	30 Years	Strength & Conditioning Coach	1	Professional Development Phase	Male
4	Aiden Knight	36 Years	Performance Manager	1	Professional Development Phase	Male
5	Mason Kennedy	30 Years	Sports Scientist	N/A	Youth Development Phase	Male
6	Carter Morris	25 Years	Sports Scientist	N/A	Professional Academy Sport Scientist /PhD Researcher	Male

7	Daniel Jackson	28 Years	Physical Performance Scientist	1	Physical Performance Scientist	Male

Interview process

Existing literature on bio-banding, conversations with expert collaborators, and the outcomes from Part 1 of this project all informed the interview schedule. The schedule was created to address a variety of topics, including the reason for using bio-banding, participants' impressions of its use, and perceived impediments to implementing bio-banding. The interviews were semi-structured, which meant that participants were asked focused but open-ended questions on their knowledge and perceptions about bio-banding using a pre-planned interview guide (Newcomer et al., 2015). Probes were used to add depth and context to the survey questions, as well as to establish rationales for each participant's responses. The interviews began with a series of generic questions identical to those asked in the survey. This allowed both myself (the interviewer) and the participant to use the introduction to establish rapport and inform the participant of the interview's aim. Establishing rapport is an important means of putting interviewees at ease and encouraging them to answer questions more openly and freely (Hannabuss, 1996). To ensure that the participant had an opportunity to voice thoughts across all areas within the survey, the interview questions were developed utilising survey responses from each of the six categories. For example, participants who had expressed in the survey that they had implemented the bio-banding process were asked open-ended questions such as “could you please start by providing an example of when bio-banding has proven useful for yourself or your club?”. Whereas for participants who had expressed in the survey they had not implemented the bio-banding process where asked “what do you feel has prevented you from implementing the bio-banding process?”.

The semi-structured nature of the interviews meant that the same open-ended questions were used with all participants. The guide or schedule was used throughout the interview to provide a certain amount of structure but the order and phrasing of questions were changed according to the flow of the conversation (Smith & Sparkes, 2016). That is, participants were encouraged to direct the course of the conversation if they wished to share experiences that were personally meaningful to them. Focused questions were used to follow up on survey responses such as “why do you feel players should be introduced to bio-banding from the development phase highlighted in your survey response?”. Open-ended questions such as “Please tell me about your experiences using bio-banding?” were also used to elicit rich descriptions of experience. Follow-up probes or curiosity-drive questions (e.g., “Can you elaborate or explain in more detail why you think maturity matched bio-banding might prove beneficial to athletic learning and development?”) were used to encourage more elaborate and in-depth responses (Smith & Sparkes, 2016). Using probes also provides opportunities for the respondent to elaborate on key points they feel are integral to the topic under investigation. Some probes were detail oriented whilst others sought to encourage elaboration (e.g., “Can you give me an example of a player who benefited from maturity matched bio-banding?”) or clarification (e.g. “I’m not sure I understand what you mean by the term “YDP”. Can you help me understand what that means?”). The use of prompts was accompanied by active listening which involves being attentive and responsive to the interviewee (Smith & Sparkes, 2016). Interviewers can demonstrate active listening by restating the interviewee’s message and responding empathetically. An example of the latter approach is the use of subtle bodily cues such as nodding one’s head in an attempt to express understanding. These approaches are thought to help increase the length and depth of responses. Interviews concluded by asking participants whether they would like to add anything that hadn’t been covered during the course of the interview. Interviews were conducted and recorded via Microsoft teams' meetings. An automated transcript was produced by Microsoft teams but the researcher subsequently listened back to interviews to ensure that the transcription was accurate. Interviews lasted an average of 43 minutes.

Data Analysis (Interviews)

Having transcribed the data and ensured the transcripts accurately reflected the participant's thoughts, data were analysed using a directed approach to content analysis (Hsieh & Shannon, 2005). First, transcribed interviews were read several times to gain a clear comprehension of the participants' responses and then subjected to line-by-line analysis. This process of immersing oneself in the data ensures the researcher increases their 'familiarisation' of the data and the participant's experience. This first step in coding the data involved segmenting sentences from the interview transcripts into phrases that encompassed the participants' perception and experience of implementing bio-banding in an academy setting. These phrases or labels seek to concisely capture the meaning conveyed by the participant. Next, we used a combination of inductive and deductive approaches to identify meaning units which were subsequently grouped together to form emergent categories (lower-order themes) based on their similarity to each other and distinction from other categories (Patton, 2002). The deductive element of this process involved coding segmented text using existing theory/predetermined codes (e.g.., existing literature on bio-banding). The inductive element involved assigning a new code to any text that could not be categorised using the initial coding scheme (Hsieh & Shannon, 2005). This process was then repeated in order to generate higher-order themes. Two techniques were employed to enhance the trustworthiness of our data. First, peer-debriefing took place during the data analysis process and this involved members of the research team challenging the primary researcher's initial interpretations of the data (Cresswell & Miller, 2000). This process sought to establish a general agreement amongst the research team as to how the data was been coded. Two of the researchers identified themes independently and then acted as critical friends by questioning each other's interpretations. Trustworthiness was also enhanced by requesting a third researcher to cast a critical eye over the results and to encourage the team to consider alternative readings of the data. In addition, member-checking is done by returning whole interview transcripts to participants to ensure that an accurate impression of what they said was given, or if there is anything else they would like to add to the research. This allows participants to take a step back and reflect on the thoughts they have expressed, ensuring that they are accurate.

Judging quality

Mixed methods research is more than simply reporting two distinct 'strands' of quantitative and qualitative research; these studies must also integrate, link, or connect these 'strands' in some way. The expectation is that by the end of the manuscript, conclusions gleaned from the two strands are integrated to provide a fuller understanding of the phenomenon under investigation. Integration might be in the form of comparing, contrasting, building on, or embedding one type of conclusion with the other (Sparkes et al., 2015, P. 108). Researchers have outlined a number of criteria by which mixed-methods studies should be 'judged'. An important criteria is that the study should have high levels of *transparency.* Transparency in MMR includes the need to explicitly identify the priority of the methods, the sequence of the methods (e.g., sequential) and the stage at which both types of data were integrated (e.g., during data collection, data analysis and interpretation). Documenting these steps clarifies the alignment between mixed methods and the purpose of a study and its research question. Another criteria by which MMR studies should be judged is the *amount of mixing* (i.e., the extent to which the qualitative and quantitative strands have been integrated) that takes place. One of the main aims of the analysis and interpretation process was to integrate findings from both strands of the study. In doing so, the study hopes to have provided a fuller understanding of the promise, potential and challenges associated with the use of bio-banding. Integrating findings involved comparing, contrasting and embedding conclusions from the two phases of the study. A final criteria by which we ask the reader to judge this study is the extent to which it demonstrates *interpretative comprehensiveness*. This criterion considers whether more than one viewpoint has been incorporated during the data collection and interpretation process. The current study displays a high level of comprehensiveness as it followed up findings from the survey with a data collection phase that involved interviews with participants who'd completed the survey.

Table 2. Summary table of practitioner individual and aggregated (i.e., sum of strongly disagree and disagree; sum of strongly agree and agree) perceived agreement that differences in maturation can impact the development of and their assessment of physical, technical, tactical, and psycho-social characteristics of academy soccer players.

Survey question	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**	**Aggregated disagree**	**Aggregated agree**
To what extent do you agree that differences in maturation status impact the development of…							
Physical characteristics?	0%	4%	0%	44%	52%	4%	96%
Technical characteristics?	0%	12%	28%	40%	20%	12%	60%
Tactical characteristics?	8%	12%	32%	44%	4%	20%	48%
Psycho-social characteristics?	0%	8%	20%	40%	32%	20%	48%
To what extent do you agree that maturity-related differences impact your ability to accurately assess the…. competence of a child?							
physical	4%	16%	12%	36%	32%	20%	68%
Technical	4%	20%	32%	28%	16%	24%	44%
Tactical	8%	24%	32%	28%	8%	32%	36%

Psychological	8%	12%	24%	44%	12%	20%	56%

Quantitative Results

Response data showed that 80% of the participating practitioners had implemented bio-banding, with 80% of these practitioners using the Khamis and Roche method (i.e. PAH) (Khamis & Roche, 1994) to bio-band players. Maturity offset (Fransen, et al. 2018 [5%], Moore, et al. 2015 [5%], Mirwald, et al. 2002 [5%]) and skeletal maturation (5%) approaches were also demonstrated to have been used by practitioners. Practitioners felt that bio-banding was more beneficial for early or post-PHV (80%) and late or post-PHV (92%) players, according to the responses. On-time or circa-PHV players (48 percent) have a lower level of assurance. A near even distribution for the application of bio-banding across small-sided games (29%), full match-play (25%), technical training (23%) and strength and conditioning sessions (21%) was evident. Only 2% of responders, on the other hand, employed bio-banding for psycho-social sessions. The key goals for using bio-banding, according to practitioners' responses, were technical development (22%), physical development (21%), and talent discovery, with matched bio-banding being the preferable method (33%).

Findings indicated that participants “strongly agreed” that the differences associated in maturation status impact the development of physical characteristics (median = “strongly agree” 52% - “aggregated agree” 96%) (Table 2). In comparison, there was a reduced perception that the differences associated in maturation status impact the development of technical characteristics (median = “agree” 40%). With a further reduced perception that differences in maturation status impact the development of both tactical (median = “agree” 44%) and psycho-social (median =

“agree” 40%) characteristics. (Table 2. In line with physical characteristics, participants also agreed that maturity-related differences in physical development characteristics have most impact on practitioners’ ability to accurately assess the physical competence of a child (see Table 2, “Aggregated agree” 68%). Again, there was a reduced perception that maturity-related differences in technical (median = “agree” 28%) and tactical (median = “agree” 28%) development characteristics have most impact on your ability to accurately assess the talent of a child. However, a slightly greater percentage was shown that sports practitioners perceive that maturity-related differences in psycho-social development characteristics impact their ability to accurately assess the psycho-social competence of a child (median = “agree” 44%) (Table 2).

Table 3. Summary table of practitioner individual and aggregated perceived agreement that matched (e.g., Early vs Early or pre-PHV vs pre-PHV) and miss-matched (e.g., Late vs Early or pre-PHV vs post-PHV) bio-banding permits enhanced assessment of physical, technical, tactical, and psycho-social player characteristics in comparison to chronologically categorised (i.e., U11 etc.) player groupings.

Survey question	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	I don't know	Aggregated disagree	Aggregated agree
Please state your level of agreement for how bio-banding permits an enhanced assessment of the below characteristics when matching players for maturity status in comparison to chronologically categorised (i.e., U11 etc.) player groupings?								
Physical characteristics	0%	5%	0%	35%	60%	0%	5%	95%
Technical characteristics	0%	5%	10%	70%	15%	0%	5%	85%
Tactical characteristics	0%	10%	30%	55%	5%	0%	10%	60%
Psycho-social characteristics	0%	0%	25%	45%	30%	0%	0%	75%

Please state your level of agreement for how bio-banding permits an enhanced assessment of the below characteristics when pairing players for maturity status in comparison to chronologically categorised (i.e., U11 etc.) player groupings?

Physical characteristics	0%	10%	25%	35%	20%	10%	10%	55%
Technical characteristics	0%	0%	25%	65%	0%	10%	0%	65%
Tactical characteristics	0%	0%	50%	40%	0%	10%	0%	40%
Psycho-social characteristics	0%	0%	30%	50%	10%	10%	0%	60%

Sports practitioners indicated that bio-banding permits an enhanced assessment of physical characteristics (median = “strongly agree” 60% - 95% aggregated agree) when matching players for maturity status in comparison to chronologically categorised groupings. Whereas 70% of practitioners “agree” (85% aggregated agree) that bio-banding permits an enhanced assessment of technical characteristics when matching players for maturity status in comparison to chronologically categorised groupings. 45% of practitioners agreed that bio-banding permits an assessment of psycho-social characteristics (75% aggregated agree) whilst 55% shared this view about the assessment of tactical characteristics (60% aggregated agree) (Table 3).

Statistics revealed that most participants “agree” that bio-banding permits an enhanced assessment of technical characteristics (median = “agree” 65%) and psycho-social characteristics (median = “agree 50%) when pairing players for maturity in comparison to chronologically categorised player groupings. A continued decrease in agreement can be seen for physical characteristics (median = “agree” 35%, 55% aggregated agree) and tactical characteristics (median = “agree” 40%) (Table 3).

Table 4. Summary table of practitioner individual and aggregated (i.e., sum of strongly disagree and disagree; sum of strongly agree and agree) perceived agreement that differences in maturation can impact the development of and their assessment of physical, technical, tactical, and psycho-social attributes of academy soccer players.

Survey question	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**	**Aggregated disagree**	**Aggregated agree**
Can you please state your agreement with the statement below relating to the purpose of bio-banding?							
Bio-banding can reduce the risk of growth-related injury among young players?	5%	27%	9%	54%	5%	32%	59%
Bio-banding can reduce the risk of contact-related injury among young players?	9%	22%	42%	22%	5%	31%	27%
Bio-banding can better assist the development of physical attributes?	0%	0%	27%	55%	18%	0%	73%

Bio-banding can better assist the development of technical attributes?	0%	5%	32%	50%	13%	5%	63%
Bio-banding can better assist the development of tactical attributes?	0%	14%	41%	45%	0%	14%	45%
Bio-banding can better assist the development of psycho-social attributes?	0%	5%	23%	58%	14%	5%	72%
Bio-banding afford players with optimal learning opportunities and challenges?	0%	0%	14%	50%	36%	0%	86%

When looking at Table 4 data as a whole, it's evident that the data reflects practitioners' beliefs that bio-banding can reduce injury risk, assist in the development of physical, technical, tactical and psycho-social characteristics and provide optimal learning opportunities and challenges. The following section will now look to break the data down individually:

Injury prevention (growth related & contact-related)

The analysis of the survey data shows 59% of practitioners agree bio-banding can reduce the risk of growth-related injury among youth soccer players. With a further 27% of practitioners agreeing bio-banding can also reduce the risk of contact-related injury among youth soccer players.

Physical

Data analysis shows 73% of practitioners to believe bio-banding, is the most successful strategy for creating an environment to enhance players physical qualities (speed, strength, endurance, agility, power, acceleration, jump height, flexibility) of professional youth soccer players.

Technical

63% of practitioners feel that bio-banding is also the most effective strategy for generating an environment in which technical characteristics can be enhanced (passing, touch, use of both feet, ball handling [dribble], shooting, tackling, aerial skills, vision).

Tactical

There was a slight drop in agreement when it came to the enhancement of tactical characteristics during bio-banded groupings. 45% of practitioners agree bio-banding is the most effective environments to use when attempting to enhance tactical characteristics (marking, team tactics, distance to nearest team mate, distance to nearest opponents, counter-attacking, pitch exploration, supporting, recovering).

Psycho-social

Statistics revealed that 72% of practitioners feel that bio-banding is the most effective strategy for generating an environment in which psycho-social characteristics are enhanced (ability to perform under pressure, creativity, attitude, confidence, resilience, concentration, intuition, communication).

Learning opportunities and challenges

The highest percentage of agreement from 86% of practitioners who believe bio-banding affords players with optimal learning opportunities and challenges in order to aid professional youth soccer players development.

Table 5. Summary table of practitioner individual and aggregated (i.e., sum of strongly disagree and disagree; sum of strongly agree and agree) perception of contributing factors as to why they may not implement bio-banding.

Contributing factor	Very high factor	High factor	Moderate factor	Low factor	Very low factor	High factor	Low factor
Coaches buy-in	16%	20%	12%	40%	12%	36%	52%
Lack of bio-banding understanding	8%	24%	20%	32%	16%	32%	48%
Social stigma related to players 'playing down'	12%	20%	12%	36%	20%	32%	56%
Players buy-in	8%	20%	16%	32%	24%	28%	56%
Personnel to implement bio-banding	0%	24%	24%	40%	12%	24%	52%
Disruption to the training programme	12%	12%	28%	32%	16%	24%	48%
Knowledge of which maturation equation is most appropriate	4%	20%	24%	28%	24%	24%	52%
Parents/guardians buy-in	8%	12%	28%	28%	24%	20%	52%

Situational Factors (lack of equipment/resources, players etc.)	0%	20%	24%	32%	24%	20%	56%

In terms the 5-point Likert-scale “Very high factor” bio-banding barriers, coach buy-in (median = 16%), social stigma (related to players ‘playing down’) (median = 12%) and disruption to the training programme (median = 12%) were the three standout factors that practitioners saw as the largest impediments to bio-banding. Due to aggregated agreement (32%), the research also reveals that a substantial bio-banding barrier is a lack of bio-banding understanding (median = "high factor" 24%). Furthermore, practitioners thought having personnel with knowledge of how to implement bio-banding (median = "high factor" 24%) and player buy-in (median = "high factor" 20%) are important barriers to consider too. The “Moderate factors” considered to be barriers of bio-banding are parent/guardian buy-in (median = 28%), knowledge of which maturation equation is most appropriate (median = 24%) and situational factors (i.e. lack of equipment/resources, players etc.) (median = 24%) (Table 5). For research purposes, data gives the maximum and lowest factors of bio-banding barriers. But it's important to remember that bio-banding barriers are caused by a combination of factors and no single element. For example, when it comes to the most significant obstacle (coach buy-in), 41% of practitioners (11/27) consider it a high factor, while 48% (13/27) believe it is a low factor barrier to bio-banding (Table 5).

Qualitative Results

Table 6. Practitioners qualitative perceptions and evaluations of maturity-status bio-banding for talent identification and development in professional youth soccer academies.

Theme	Sub-Theme
Importance of Bio-Banding	
Youth Development Phase	
Perceived Benefits	*Injury Prevention*
	Introduction to Challenge and Further Opportunities for Athletes
	Matching (identifying athlete differences and designing individual development programmes)
Perceived Barriers	*Planning and Organisation (Time, Resources and Communication)*
	Failure to Establish the Buy-In of Bio-banding
	Lack of Education

Importance of Bio-banding

Six practitioners argued that bio-banding allowed them to reach an objective understanding of player development. This was important to these practitioners as they wished to make decisions about players based on valid and reliable metrics. For example, Oscar Dawson feels that bio-banding “is not just an opinion, it puts the number to the thoughts” therefore “allowing that greater insight into where the players are at that moment”. Aiden Knight highlighted that:

> what we need to just have is facts and bio banding helped us have and deliver facts to make a decision rather than the opposite way around”. This then enables coaches to make fair and objective decisions about players, taking into account as much information from the multidisciplinary team as possible.

An example Aiden gave can be seen as when he went on to describe a great experience of bio-banding for his club that may be viewed as a disadvantage for the athlete…

> We had a very small player in our U15s / U16s age group who was offered a scholarship because everybody was like “he's really small he's clearly immature, he needs to grow up, and there'll be a lot to come from him physically and technically and tactically”. However, using bio banding highlighted that he actually wasn't immature, he was 97% to 98% of his predicted adult height. He was just small and not very well physically development, although he was mature enough to be and so ultimately it helps make decisions around that although we thought technically tactically, he was probably capable, he was never going to reach the physical level that he would need to compete at this level.

Furthermore, practitioners consider bio-banding to be an excellent instrument tool for talent development. Mason Kennedy revealed that “It's a good talent development tool, because you're trying to think what someone is going to look like in 6-7 years’ time and not trying to, you know, prepare them for a Saturday and then for Tuesday game”. Similarly, Aiden stated that “bio-banding should 100% should be used, structured, planned and scheduled into a program because periods of stretching success as that’s what's going to help improve development rather than always giving success, or vice versa, always given stretch”. Sean Billham also gave an example when bio-banding was proven to be a beneficial talent development tool for an athlete:

> the kid was mostly 84% and he was playing easily with the 98/97% [of predicted adult height percentage] and the coaches knew he was a late maturer but then it gives them [the coaches] more of a positive influence because it actually means they’ll stick with him for a longer time. So, I think, yeah at 14 he got an early scholarship just because the Club knew straight away he's going to be a good under 18 player and has got high potential to be a 23s player.

The relevance of bio-banding was emphasised by the practitioners' general expressions through the interview data collection phase. According to Carter Morris, the interview enabled him to “go back and think about his reasoning for doing it [bio-banding] kind of makes you more determined to implement it because you do realize importance or the research about it” and how

> questioning the reasoning for things, or understanding of certain things makes you just kind of question your own understanding of it, and I’d say that's a quite important thing just to

reflect on your own practices, and reflect on the importance of introducing or using bio banding and then educating people as to why it's being used.

Similarly, Mason stated how the research process “makes me say things out loud that I think about in my head so it makes me question like when you're asking me why would you do that?” as well as for Oscar how “it just reminds me of how important bio-banding actually is sometimes and it is something that can help our methods at the club, motivating me to continue using it to the best of our ability”.

Youth Development Phase

When asked which stage of development they believe bio-banding is most advantageous for athletes in a professional academy context, 6/7 practitioners highlighted the youth development phase.

For instance, Carter stated “The YDP is probably one of the most important ones, as much as kind of biological developmental differences will exist within the foundational Phase I think all the measurements we've got for that kind of age group are not going to be that reliable”.

Daniel Jackson also supported this statement “the phase that I see at most important within is the YDP” along with Sean “we would only use it where was under 12 to under 16 youth development phases as that's obviously when you start to see more of the long-term changes”. Athletes at the foundational stage of development have not yet matured so there may only be minor inter-individual biological differences between them. As the foundational development phase is for athletes aged under 9 to under 11 and biological maturation typically occurs for boys between 12 and 16 (Brix, et al., 2019). Meaning, while athletes are having specific programmes developed and decisions made based on their abilities, the youth development phase is when players are starting to go through times of rapid growth and this is where practitioners might find the greatest variability in maturational status. Then follows the professional development phase, when athletes have reached or are close to attaining full maturity, making it more difficult to categorise players as early, on-time, or late using traditional somatic maturation metrics.

According to Daniel

> once you get further towards the professional development phase the classifying of players based upon early or late matures or maturity status gets more difficult as well as players reaching full maturity and you can't then necessarily classify them based upon your typical measures of semantic maturation, so the phase that I see at most important within is the youth development phase.

This statement is further support by Aiden who stated “I think YDP ultimately, because most players don't go through a period of rapid growth until they hit this phase” whilst Sean argued that:

> your 13s, 14s, 15s age group that bracket and give or take a few players that maybe sit outside of that bracket. But especially for 14s and 15s you start to get the late developers and when you get the 13s or 14s the mixture of heights and physical attributes that you get within their age groups is massively varying. I think that's something where bio-banding definitely gives a bit more influence and a bit more necessity for that to be more structured program for the individuals.

Theme 1: Perceived Benefits (injury prevention, introduction of challenge, Matching)

The perceived benefits of bio-banding included injury prevention, the introduction of challenge and the individualisation of development plans for athletes (matching).

Injury Prevention

A number of the practitioners felt that bio-banding has helped them to identify players who might be at greater risk of injury as a result of their maturational status. For example, Carter felt that bio-banding "might have allowed us to mitigate or reduce some of the injuries" that they would usually see at the academy. (Oscar Dawson) has employed bio-banding "to highlight when they [the athletes] typically are going to be going through a growth spurt and when there are greater chances of growth-related issues". Furthermore, assessing maturational status has allowed Oscar to tailor

> injury prevention programmes to their stage of maturation. So, for example, we've got one player at the moment who is in the under 16's who's 92% of his predicted height … it's enabling me to actually produce his gym programs in the evenings to suit his needs a lot more, so working on his hip strengthening and leg strength for the moment just to try and facilitate strength gains and hopefully prevent or reduce the occurrence of injuries.

Similarly, Daniel has been assessing maturation "to understand who's going through their growth spurt and who's growing at a rate and subsequently adapted their training program, and we had some real significant decreases in the likelihood of injury for those groups".

6 practitioners thought bio-banding proved especially beneficial for early maturers. To illustrate, O.G argued that this category of players "need to be playing against players who are at least

matched to them, because if they're just playing with late maturers or on time players then they could just rely on the physical side and not so much on the technical or tactical side."

For Mason, bio-banding serves an important technical and tactical function for these early maturers:

> If a big player is mixed chronologically, they get the option to just kick the ball around and push people out of the way and that touch doesn't need to be good, it doesn't need to be perfect cause they can take the bad touch and they can just shove someone out the road. But when you match them with people their own size they can no longer do that so you have to force them into a situation where they have to work technically … and tactically as well… that's something that sort of ties in because you're trying to teach them to basically problem solve and how to make sense of the chaos within the game … so yeah find an environment which forces them to work more technically.

Whilst acknowledging the benefit early maturers might derive from bio-banding, practitioners see this method as equally if not more important for late maturers. Reflecting on his experiences implementing bio-banding sessions, Mason gave the example of a player who is

> playing in an A squad and who for me wouldn't be anywhere near that if we hadn't employed those methods … you know he's just constantly playing against people who are too big for him. That's why he's not performing well and being able to strip that back and say when he's actually in a group where the people are sort of physically matched he stands out.

One practitioner noted how bio-banding has allowed his club to identify late maturers and how this has convinced coaches to retain a player who might have otherwise been released. Daniel described this as follows:

> I think the largest benefit is the identification of talented individuals. So, by bio-banding players and understanding each player individual development in terms of growth maturation you are understanding individual difference. You can also provide each player with a specific development program based upon their phase of development … we had a few notable examples of players that were purposefully retained for a number of years because we understood that they were on a different developmental path to other players and subsequently some of those players made it through to the first team.

In this case, identifying the player's maturational status allowed the club to tailor the player's training and convinced them to remain patient about his development. Sean related a similar experience when referring to a late mature "this kid was mostly 84% of his estimated final adult stature and he was playing easily against the 98% players and the coaches knew he was a late mature … it actually meant that they decided to stick with him for a long time".

Introduction to Challenge and Further Opportunities for Athletes

Practitioners felt that another important benefit of bio-banding was the level of challenge it introduced to training and further opportunities it enabled the athletes to have. According to Daniel:

> the whole point of bio-banding is to create new and challenging opportunities for the players … we had an early maturer who [having taken part in bio-banding] then had an

> increased physical challenge and they then didn’t deal with that increased challenge and that was subsequently a developmental point for them moving forward.

The introduction of challenge was seen as crucial to the development and cultivation of talent and to prepare these young players

> for the senior game … it’s not always going to be a very sterile environment where everybody is at the same level and stages. You still need to push them on and introduce different challenges … to promote that physical challenge for the more developed players is going to be good for them and it’s going to allow them to not solely rely on their physical dominance compared to less developed kids.

(Carter Morris) proceeded to explain that bio-banding might also promote “different training adaptations you would normally get within the regular season (or session), so by slightly manipulating their training will just push them to focus on areas that they might not be focusing on during normal training” as well as “setting expectations and standards for each level” (Carter Morris). Similarly, Daniel related the case of an athlete who “was moved into a different zone that then provided them with a bit of demotivation about why they were there, but then also provided them a new opportunity to play in a position that they didn't normally play in and that subsequently became that players new position moving forwards”. Moving players across bio-banded categories isn't just about physical development for OD; it's also about psycho-social development:

> bio Banding is a great way of adding in different challenges, not just physically sort psychosocially as well so if they're grouped together with people who they're not typically used to working with, can they then sort build great relationships with them? Can they

> potentially, if they're an older player chronologically, can they go with individuals who are not typically in their age group? Or can they be bit more of a leader whereas they might not be a leader in their actual age group? It's little things like that, which I think can really yeah benefit like going forwards.

Mason uses bio-banding in his academy to put athletes in situations they wouldn't normally find themselves in during chronological training or game situations. He explained this as follows:

> We try and individualise the environment that's going to help them best develop. If this big player is mixed chronologically, they get the option to just kick the ball around people and push people out the way and that touch doesn't need to be good, it doesn't need to be perfect 'cause they can take a bad touch and they can just shove someone out the road. But then when you match them with people their own size they no longer do that so you have to force them into a situation where they have to work technically.

Bio-banding also serves as a reminder for Mason that coaches need to be equally as challenged as the players:

> coaches should always be looking for new environments to challenge players or take them and put them in an environment to improve and make them better - don’t take a 13-year-old who's too strong, fast, powerful for everyone, and then put them in with other 13-year olds you know go and move them.

Challenges and new chances, according to practitioners, may not always be periods of success for an athlete. According to Aiden, this “involves putting athletes in situations in which they may not feel at ease in order to see if they can cope with the change in environment and pressure: all of the different aspects, technical, tactical, psychological, physical can be pushed to the limits, which I think is where I think you need to overload to improve them”. Aiden proceeded to explain how “understanding when there are opportunities to make sure that they [athletes] are in the best group [biological or bio-banded] can really help with success” which leads to the next benefit for bio-banding and matching athletes within a professional soccer academy.

Matching (identifying athlete differences and designing individual development programmes)

Bio-banding also allows these practitioners to individualise athlete development plans. Daniel felt that “the real benefit of bio-banding is reducing those physical differences so you can focus on the other things”. Daniel felt that the largest benefit to bio-banding:

> is within club identification of talented individuals. So, by bio-banding players and understanding each player individual development in terms of growth maturation. You are understanding those individual differences and can then provide each player with a specific development program based upon their phase of development and therefore giving all staff a better understanding of that individual player (Daniel Jackson).

Similarly, Mason argued

> If this big player is mixed chronologically, they get the option to just kick the ball around people and push people out the way and that touch doesn't need to be good it doesn't need to be perfect 'cause they can take a bad touch and they can just shove someone out the road. But then when you match them with people their own size they no longer do that so you have to force them into a situation where they have to work technically.

The individualisation of athlete's development plans was also seen as beneficial for the coach's practice. According to Oscar "it helps in terms of programming and taking things forward so you can see their progression". Athletes being matched also allows coaches to give athletes a more objective evaluation "if we've got that kind of level playing field of maturation of development, we know physically some players should be showing better than others, and then we can make more of a kind of Fair assessment" (Carter Morris). Carter proceeded to explain

> I think being able to change the groups and having the different interactions between different players is obviously positive because you know it changes the dynamic of training… things are very different for the players and also the coaching staff in terms of growth and who they are working with.

Sean gave an example of an athlete who was having physical difficulties but was able to overcome them by using bio-banding and recognising athlete variances to create an individualised programme:

> Previously we had an early maturing player who is now 21 playing for Hull City, but at U14s and U15s he was the worst physical player you could come across. He was over six feet tall, had no balance, coordination and was struggling to meet the day to day programme… But overtime, working with him and adapting the structure of the programme to improve his balance and coordination etc. to be more individual to the testing and understanding of that player paid off (Sean Billham).

Aiden offered another perspective on how bio-banding may aid in the grouping of athletes against their biological benchmarks "I think that our biggest one has been on fitness testing, data reporting and grouping players in their biological benchmarks against biological benchmarks and also providing data against chronological benchmarks". Aiden gave an example of how bio-banding allowed his club to identify a player who might have considerable potential despite scoring poorly on various physical metrics:

> A success for us are being as a club, looking at all our age groups across the board in terms of recruitment and retaining our players. They are not all early maturers [quartile 1 born], but we have a vast spread across a number of quartiles and maturation levels. In fact, we've offered one early scholar to a player who is quartile 4 and biologically a late player because we know he has potential. Although he's 15 and the smallest and slowest, he's biologically equivalent to the U14s and when he sits in that group he physically, technically, tactically and psycho-socially way above. So, we can say with confidence that he has got high potential.

Theme 2: Perceived Barriers (Planning and organisation, Buy-in, Education and Prioritisation of Short-term Success)

The perceived barriers to the effective application of bio-banding included issues surrounding planning and organisation, buy-in from coaches, education and the prioritisation of short-term success.

Planning and Organisation (Time, Resources and Communication)

Whilst the majority of the participants saw clear value in the role bio-banding might play in the identification and development of talented footballers, they also outlined a number of barriers that either hinder its implementation or reduce its potential efficacy. The logistical challenge associated with attempting to organise bio-banded sessions represents one of the biggest barriers faced by practitioners. In discussing this challenge, Mason revealed that:

> It's basically taken us from March until about 2 weeks ago to arrange like a round robin 6 bio banded games at clubs. So, it takes months and months and then data collection and then you wonder who's going to be available? Who's there, who's not there? I think the challenge to me is organizing and weighing up whether it's actually worth it … it's got to make the player better. And I think sometimes the biggest challenge is breaking down what you're doing and asking yourself is this format actually going to make the player better.

Coaches are already working under tight time constraints between trainings, recovery days, and preparation for upcoming fixtures without the added pressures of changing set, structured training routines for athletes. As a result, many of them struggle to find the to implement bio-banding within academy settings. Sean described this challenge as follows:

> players can't always make a gym session 'cause either the gym times are an hour before training ie at 5:00 o'clock and the kids are finishing at 4:00 o'clock so they're already in a rush to get back. Then if you do it after training the kids are already knackered and it's going from 7pm till 8pm and they've already been at school since 9am so then its understanding what's best off from a multidisciplinary perspective. I think more or less the way of implementing bio-banding is mainly on field and especially from an organizational structure point of view, 'cause the kids are always going to be around the field.

For Daniel, logistical challenges arise because bio-banding requires:

> moving players around between age groups when players all train in their specific age groups but who also might get lifts to sessions in those age groups. There might be particular times for those sessions and then flipping that on its head and moving players around and making them come at different times and potentially not be able to get lifts. And then there's the whole logistical factor that are associated with mixing age groups.

Furthermore, logistical challenges are exacerbated by the difficulty practitioners face in being able to predict with any certainty which players will be available for training. For example, Oscar stated that "I think the only thing [barrier] is obviously it doesn't always go to plan because the last event that we had with Exeter, we had to move a couple of players into bands who weren't technically meant to be there". According to O.G:

> So, we work on a week-to-week basis within the academy where the availability of players is literally determined that week. So, it's not really something that we can necessarily plan ahead too much. Now, obviously we can have the groupings of all the players with their

> percentage of particular under height but we can’t guarantee that the player is going to turn up the following week. And yeah, I think it’s about sort of working around that and having to adapt to it.

A lack of personnel presents sport science staff with yet another logistical challenge:

> the personnel obviously is a big one [barrier] for me and I do think personnel are limited with our category … bio banding is maybe more of a luxury tool as opposed to something that sort of needs to happen, so we’re not able to implement it as much as I would like.

Some of the practitioners found that even if coaches recognised the benefits of bio-banding they were reluctant to disrupt their team’s preparation for an upcoming competitive fixture by facilitating the use of bio-banded sessions. As Carter put it:

> sometimes coaches just want a normal training session with that group. So suddenly if you’re preparing for a game that weekend and you’re trying to manipulate squads and training groups, that can become difficult. Especially during different stages of the season because some teams are preparing for specific fixtures so you’re having to find the balance between preparation and wanting to develop the players physically and technically with all the benefits that come with bio-banding.

Failure to Establish the Buy-In of Bio-banding

A number of practitioners believe that bio-banding is frequently misunderstood or overlooked, making it difficult to gain acceptance from peers, athletes, and the players’ parents or guardians. For example, Oscar feels that “I think obviously buy-in is one of the most important things. If the coaches didn't necessarily buy into it, then it makes it more difficult.”. He went on to explain how “the lack of buy-in from coaches might also other clubs from implementing bio-banding”. Similarly, Carter stated “getting that buy-in and understanding, that’s the most crucial thing to allow bio-banding to happen as naturally as everything else does”. Mason, on the other hand, believes that acquiring coaches' agreement to use bio-banding can go one of two ways: “It's almost like 2 opposites. There's just not very many [coaches] that's in the middle. You know they are either one way or completely, the other”. He went on to explain

> A particularly famous footballer once said to me the cream will always rise to the top regardless of how you group them… But then some others [coaches] who are equally as prominent in the game [football] are keen on allowing players longer to develop because they may be better at different things in different stages.

The buy-in of senior members in the academy has also proven a potential barrier for Daniel: “some of the coaches will take it with open arms and some of the coaches will be a bit reluctant. And then depending on the seniority of those coaches, will depend on how likely it is to gain momentum being maintained within the program”.

These statements where supported by Jack Gregory (who has not implemented bio-banding) who provided an example of why, as a coach, he does not believe in implementing bio-banding and instead prefers to use other methods in his academy:

> I think however you do it, you're still going to have someone at the start of something and someone at the end of that continuum. So, whether you go from born birth dates and January 1st to December 31st or if it was on physical maturation then you still have U9s and still have U10s. So, you know whatever you do there’s an area that creates some players more advantaged and some more disadvantaged.

While sport scientists may want to focus on long-term athletic development, coaches working in a high-standard environment may have little choice but to focus on short-term competitive performance. This might mean that “sometimes coaches are resistant to the time that’s required to bio-band but not bio banding itself … because for some of them they’re preparing their team for a game then maybe they’re not thinking as much about the long-term development of the players” (Carter Morris). Sean had similar experience within his academy,

> Obviously, the biggest conversation you've got to have is with the coaching staff. They've got their own development plans for players from a tactical, technical, mental and physical perspective. But they also want to prepare for a game to make sure that they've got the right structure in place… They say, they'll want it to be about development and development of the player but when it comes to an actual game, they’ll be the person to point the finger at someone else if they've not had the best preparation for all that week… Then if that's been because of our limited access because the player has been on different scheduling program to the rest of the players, and he doesn't fit into that team structure anymore. That's when it can actually become a bit of an excuse for them rather than self-reflection upon their own skills.

Lack of Education

A perceived barrier discussed by all practitioners was the lack of education around bio-banding and a failure on behalf of stakeholders (e.g., coaches, parents) to understand why this method is being used. According to Carter “I think education would be the primary one [barrier]” and for Mason “The hardest people sometimes are their parents”. Whereas Sean feels “the battle for moving forward is always going to be making sure that coaches have that discipline to understand the bio-banding process that's in place”. A lack of understanding by some coaches as to what bio-banding entails and how it might prove beneficial to athletes is another factor that can hinder its implementation. According to O.G, this means that “If coaches don’t understand it then they potentially will be reluctant to employ it. So, because of that I think it’s important to actually educate the coaches on what it is and why we look to employ it”. Similarly, Daniel noted that “coaches’ perceptions and … their education around why they’re doing it and what the benefits are for each of the individuals, and it needs to be explained that it’s not like a holiday camp style of mixing between age groups. It should be a purposeful development tool”.

However, Daniel acknowledged that even if sports science staff possess a keen understanding of how to implement bio-banding they often “don’t have the largest say about what the training schedule and training program looks like and therefore a change in that program to incorporate bio-banding can be difficult”. Daniel noted that one way of addressing this problem might be if sport scientists are “embedded as part of the development and involved in joint decision making for the YDP age groups which makes it easier to incorporate bio banding because they have those day-to-day discussions with the coaches”.

It was clear that many of the participants felt that coach education needed to introduce coaches to bio-banding and explain how it might benefit talent development in academy settings. Oscar stated “I think it's so important to actually educate the coaches on what it is and why we look to sort of employee within the club”. The lack of education around bio-banding was also expressed as an issue which potentially needs to be reviewed nationally. Mason considers there to be:

> a lack of support, certainly or education. I think the National Association could provide more support and more education in that field and I think we could almost go and help the Clubs understand it, show them how to do it, how to organize it, why it might be beneficial.

Aiden expressed similar sentiments when claiming “there is definitely a lack of education from University courses to professional accreditations. I think education across the board from a sport science [strength and conditioning] perspective is really poor and it is on the practitioner themselves to go out and find more about it”.

All participants who work full-time in clubs felt that coaches’ failure to fully understand the rationale for the method was a significant barrier to its implementation. However, the one practitioner Jack who has no experience implementing bio-banding also believes that a lack of education can be detrimental to the process as a whole. For example, Jack stated that he feels “when you're running an Academy program it's really important, I think, to go all in on something or not at all. And not knowing enough about bio banding, to see that as something we go all in on it's just not at my level of knowledge”. This statement was supported by practitioner Aiden who revealed that “doing bio banding wrong can really exacerbate the negative side effects or the negative elements of it and therefore can increase the barrier to potentially using new kind of ideas". Mason admitted that he didn’t fully understand the method when initially employing it:

> all the smaller players or late maturing players were placed in group order, and same for the bigger and early maturing players for a range of age groups. So, we basically put the later maturing against the early maturing, which I suppose means that we've grouped the right players together so you can see them in their right environment. However, competing against you know the early maturing ones was clearly a massive negative for the later maturing players.

Finally, the results also showed that practitioners felt that a lack of parental understanding was a barrier to bio-banding. There was a suggestion that parents are concerned about their child being “played down”. As noted by MJ:

> The big problem I’ve had when I’ve worked in academies is that parents become involved and there’s external pressure that doesn’t need to be there because their 14 years old kids being told that he’s going to play with 13 years olds and they think oh my god it’s game over, he’s being released, he’s being played down.

Oscar shared similar concerns when he revealed that: “we don’t want to make it look like he is being played down or there’s any negative connotations, you want to keep it as open and honest”. Mason felt that these concerns may not arise once the rationale for bio-banding is “communicated properly”. This is an issue I return to in the conclusion.

The prioritisation of Short-Term Success

Proponents of bio-banding seek to limit disparities caused by maturity variable, and prevent injury risk amongst athletes. Coaches, according to practitioners, are frequently more concerned with future fixtures or the exploits of talented individuals than with the big picture of all the athletes' long-term development goals. As a result, bio-banding is least effective for athletes who are developing and maturing on schedule or late. “They're not trying to counteract the age groups for them [athletes] because they have always been on time anyway, so probably not as deep as neglecting their development, but probably something to consider in terms of making sure that they still considered in terms of their development” (Daniel Jackson). Or for Mason when

> there's a kid for example, playing up in fifteens and they play there every week and then a Saturday comes where the club are going to play a rival club, and it's like I'm not playing fifteens this week. He's coming back down for the 14s because they want to win the game. You know to me that's to the detriment of that player That's not about the player, that's about the club and that's about image. You know that's not what's best for that person, you're taking a challenge away from them to put them in an easier game where they're going to get very short-term success that suits you the club.

This statement can be supported by Sean:

> at category 2s and especially category 3s 'cause of limited staffing structure. It's very much more difficult to try and make sure the best intentions are there for every player, and most probably, when it comes to category 2s, category 3s the programming itself can be made just for that one individual player, that you know, that it's going to have the highest reward for the academy and getting first team appearances.

Equally for Sean "you get afforded a lot more opportunity to work individually with players if there's a capacity where they're physically limited but the coaches see him as a very high potential player technically and tactically". An example was provided of one of his athletes when "there was no guarantee that technically he was good enough or tactically good enough… and if coaches don't think a player isn't necessarily great technically then they're not really going to put too much emphasis on his individual development". In order to prevent this, Sean goes on to say how

> It's mainly understanding the coaches and finding out which ones are definitely about development 'cause that's how you can then implement that and talk about… Oh yeah, we

> can work with these players because these players need a bit more time on the ball to get better technically, tactically 'cause all they do is get bullied off the ball.

Daniel also gave an example of how the short-term success over long term athlete development could be avoided in the future when bio-banding athletes:

> I think the biggest difference would probably be down the line how it's [bio-bandings] scheduled so rather than doing bio banding week every… What I'd like to try and consider is doing a bio-banding day every week and therefore having that interaction as a regular part of the schedule… The other thing I would like to consider is more of a consideration about players individual development programs. So, to rather than it just being almost an addition to the program, it's actually embedded within the program, so that players have key elements that they need to work on throughout the season, but bio-banding could also fit into each individual development programs.

Mason then went on to argue that coaches may be using bio-banding at the incorrect moment, and that it would be more beneficial to their growth if:

> We test people that we've already committed to. Whereas to me bio banding might be better saying can we not do that first so we can see what that players like against players of their own biological age or of a different sort of chronological age? And how did they cope with being against someone who's bigger? How did they cope with being against only people who are the same size? Or all people that are bigger? So, I think maybe doing it the other way around would probably be more wise.

Discussion

This study aimed to examine practitioners perceived effectiveness and application of maturity status bio-banding in professional soccer academies. The study aims to do this by (1) investigating how bio-banding is used in professional youth soccer academies and how effective practitioners believe it to be for identifying and developing talent, (2) studying how well-versed sports professionals from elite youth academies are in bio-banding and their justifications for using such approaches when determining maturity levels, (3) investigating the impact of bio-banding interventions and any impediments that they may create for soccer players and sports professionals, (4) developing the multidisciplinary use of bio-banding for young players' anthropometric, physical, technical, tactical, and psycho-social traits in a professional soccer setting. The possible use of such data will highlight the techniques utilised to support talent identification and development of soccer players in the EPPP and highlight the differentiation of bio-banding interventions across England. Gaining knowledge of how bio-banding is implemented in the education process for sports professionals and the impact it may have on assessing maturity levels. Additionally, this enables the advantages and disadvantages of bio-banding to be discussed in order to avoid them in the future. Finally, this study supports the value of bio-banding in player development, which promotes progress across all domains rather than simply the physical (technical, tactical, and psychological).

The study’s main findings are that (1) practitioners perceive that the effect of maturation impacts players’ technical, tactical and psycho-social characteristics and that this confounds their ability to assess these characteristics, (2) 80% of those surveyed had implemented bio-banding and although there was a clear preference for the Khamis and Roche method there was no clear preference for when it should be applied (e.g., match-play), (3) practitioners who have applied bio-banding perceive the methods as an effective way of reducing injury risk and increasing the perception of challenge whilst acknowledging that implementation comes with situational and logistical challenges. Most practitioners believed that they understand the concept of bio-banding, but not all were able to implement the method as effectively as they would like. Practitioners also perceive the Youth Development Phase as being the most advantageous for bio-banding since this is when coaches believe they start to see more of the long-term physical changes of athletes. This is most likely due to the fact that the onset of puberty corresponds to a skeletal (biological) age of approximately 13 years in boys, around the same time they will be transitioning from the FDP to the YDP, and the greatest significant intraindividual variation in the timing and tempo of growth will be present (Rogol et al., 2002).

There is now a wide-range of evidence showing that early maturing adolescent soccer players who possess enhanced anthropometric and physical characteristics are selected ahead of their less mature counterparts (Radnor, et al., 2021). Findings from the current study go some way to explaining this selection phenomenon by revealing that practitioners find that PHV may interfere with their ability to identify talented soccer players when using a multi-disciplinary approach for the purposes of talent ID and development. The findings here do, however, suggest that attempts by the EPPP to mandate the systematic monitoring of maturity status of academy players has encouraged the uptake of maturity estimation methods such as the Khamis and Roche and Francis et al. methods. Despite this promising development, findings from this study suggest that some uncertainty exists amongst practitioners regarding which of the estimation methods they should use to estimate player maturity status. This could be due to the fact that bio-banding is still a relatively new phenomenon, so there are still opportunities to investigate. Because of this, practitioners struggle to convince stakeholders to support bio-banding while simultaneously supporting which maturation equation is best for the club, players, etc. Therefore, the best course of action would be for interested parties and sports professionals to simultaneously construct an athlete identification and development programme that best fits the club's ethos. This is an important finding given the need to ensure that practitioners employ a consistent approach to player maturation. Given the error inherent within each equation, and the fact that some equations possess greater criterion biological maturity, validity and reliability that others (see Towlson et al. Salter et al.), differences in application might lead to the mis-categorisation of young players.

67% of participants had implemented bio-banding within small-sided games, whilst 52% had implemented it in match-play and technical training contexts during maturity-matched formats for early and late maturing players in particular. The latter findings are in line with previous research such as Towlson et al. (2021) who showed that bio-banding and alterations of pitch size (i.e., relative pitch size) can influence the passing and tactical behaviours of academy soccer players during SSGs. This is a promising finding given that interviews with early maturing players competing in maturity status bio-banding reveals that participating in miss-matched games presents them with higher physical and technical challenges (Bradley et al., 2019). 80% of the participants had implemented bio-banding and findings revealed a clear (80%) preference for the use of the Khamis Roche method. The preference for this method is encouraging given that it has been shown to possess superior maturity estimation accuracy (Towlson et al., 2021). Indeed, findings from Parr et al. show that 96% of a sample of professional soccer academy players experienced PHV during the specified window (85-96% PAH) in comparison to only 61% using the maturity offset approach. Whilst the Khamis and Roche method has been recognised as the most suitable equation for estimating the maturity status of academy soccer players, practitioners should be aware of the prediction error inherent within it with median error being reported as 2.4-

2.8 cm to 5.5-7.3cm for those children situated on the 50th and 90th normative growth percentiles respectively (Towlson et al.).

Quantitative data from this thesis revealed that maturation status has an impact on the development of physical, technical, tactical, and psychosocial qualities of soccer, as well as the ability of coaches to appropriately judge such traits. Whilst qualitative findings reveal practitioners use bio-banding to develop physical, technical, tactical and psycho-social characteristics, to identify talent identification, and as an injury prevention strategy on a quarterly basis. In line with prior studies (see Bradley et al (2019), Romann et al., (2020)), practitioners stated that the goal of bio-banding athletes is to provide them with the best learning experiences and challenges possible in order to maximise talent development in preparation for the PDP. Findings from Bailey and Collins (2013) support this statement claiming professional performers had better skills due to extra opportunities rather than any genetic advantage, describing such experiences as playful, varied and free to experiment with different movements and tactics. Bradley et al (2019) evaluated players' impressions of bio-banded tournaments, with the majority of participants stating that bio-banding provided a greater physical and technical challenge, as well as the opportunity to play and compete with older and more experienced players. In Reeves et al.'s (2018) study, stakeholders revealed that bio-banding helped players display greater physical and technical competency, attitudes, and efficacy as a result of the shift in surroundings such as older players training with younger players. Competing against older and more experienced players, early developing athletes cannot afford to rely on their physical advantages alone and must use their technical and tactical talents to succeed (Cumming et al 2017). They must also adapt their game to a faster and more sophisticated style of play. This is in line with Reeves et al.'s (2019) study which showed that early maturing players found that bio-banding allowed them "to progress both technically and physically." By contrast, late-maturing players said they had more opportunity to express themselves and have an impact on the game. As a result, challenge has long been recognised as an important component of successful athletic growth (Gould et al., 2002; Toering et al., 2009). One implication of this finding is that bio-banding, as opposed to chronological age categories, may help allow practitioners to tailor the level of challenge to the athletes' maturational status. It should be noted, however, that less challenge does not indicate less possibility for development, and that neither chronological age groupings nor bio-banded groups should be prioritised over the other. Despite survey findings suggesting bio-banding to enhance the assessment of characteristics when matching players for maturity in comparison to chronologically, sports practitioners believe traditional and bio-banding practice should be used in tandem in a blended approach because bio-banding is merely another that might be deployed across the talent development and identification spectrum alongside more traditional methods (Cumming et al, Bradley et al).

The EPL academy system has been a pioneer in recognising and adopting bio-banding as part of their Elite Player Performance Plan (EPPP), and this thesis contributes to emerging findings in this field. For example, according to our findings, 93% of those surveyed believe bio-banding should be incorporated into the athlete's development programme. As, according to 86% of participants who were interviewed, bio-banding helps practitioners to disseminate information and add figures to thoughts. However, the qualitative findings show that a number of practitioners believe that bio-banding is commonly misunderstood, disregarded, or misapplied. For example, practitioners found it difficult to establish 'buy-in' from some coaches and the players' parents or guardians. Here we see a problem with 'knowledge translation' or the process of translating and disseminating knowledge from one area of an organisation to another (Argote & Ingram, 2000). This finding might be explained by regardless of players maturation status, when it comes to game day players are categorised according to their chronological age. Bio-banding is therefore unnecessary for coaches, players, and parents who solely focus on the immediate gains. In this case, educating stakeholders and advancing the idea that bio-banding improves talent discovery and development for long-term accomplishments would be the best course of action.

The tendency for misunderstandings between stakeholders to occur has been addressed by Coutts (2016), who provides a paradigm to describe how the practicing sport scientist's (faster-thinking) daily work can benefit from collaboration with the (slower-thinking) applied researcher. In this instance, faster-working refers to a coach who works at the cutting edge of high-performance sport in fast-paced environments, collaborating with staff and players to produce innovative, efficient, and successful performance programmes. Whereas a slower thinker, such as a research scientist, often serves as the ‘residential sceptic’, working in the background to complete tasks that a fast-working practitioner does not have time to complete, such as bio-banding. Although the slower-workers' data plays an important role in developing efficient and evidence-based practice and is used by the faster-workers to guide judgments about individual athletes. One limitation of this setting is that the data is frequently misinterpreted, while fast-workers are also expected to be innovative and successful. Bio-banding practitioners (slow-worker), for example, can advise coaches about specific players and where they believe they would be most suited, but if an important match or cup game is coming up, the complexities arise, as the coach may be inclined to prioritise short-term success. Furthermore, while most of this type of study takes time to transform into better working procedures or performance and does not directly involve athletes, it is critical in building efficient and evidence-based practices that are ethical and based on excellent data.

The conceptual model (figure 9) emphasises the importance of research in developing effective evidence-based strategies in high-performance sport, or in this instance professional youth soccer academies. This has been accomplished in a variety of ways, the most current being the embedding of personnel and the formation of collaborations between each institution to work together to bio-band athletes. Furthermore, with high stakes for success in professional soccer (Bransen et al 2019), senior members have been reported to be wary of slow-workers [bio-banding practitioners]. Strong governance, on the other hand, will necessitate sport organisations providing novel yet ethical and evidence-based ways to their players (Coutts, 2016). As a result, we should anticipate more progressive high-performance organisations developing opportunities for slow-thinking researchers to interact with their fast-moving practitioners.

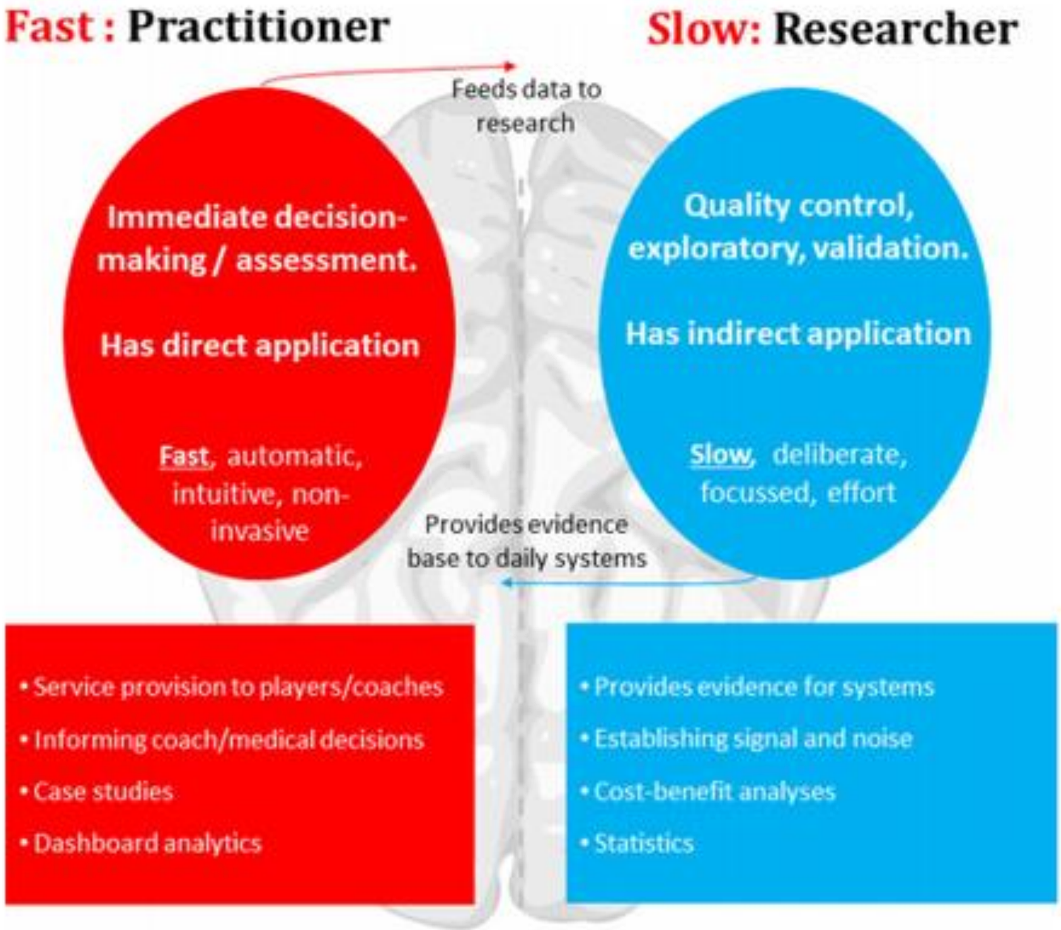

Figure 9 – A conceptual model for the complementary relationship between practitioners and researchers in high-performance sport (Coutts, 2016).

Bio-banding Benefits

Bio-banding not only helps coaches to have and deliver factual information, but matching players also allows coaches to spot athletic differences and create customised development strategies to help individuals (Cumming et al., 2017). This might provide coaches, support staff, and players a greater grasp of the team's position and the athletes in it, and determining the best path to growth for the team and club. As revealed by the interview findings, practitioners indicated that matching athletes is the most effective strategy to prevent early maturers from kicking the ball around or shoving smaller players out of the way, implying that their technical ability isn't as important. As a result of being placed in a physically matched band, they will need to concentrate and improve their technical abilities in order to become a better all-around performer. Abbot et al. (2019) results also demonstrated that maturity matched bio-banding changed the technical demands placed upon athletes compared to chronological age groupings, without reducing the physical demands. Findings from Bradley et al.'s (2019) study further supports these claims as players here were provided with new and different experiences, including new physical, technical, tactical and psycho-social challenges. Again, this concept is supported in previous research when players had more opportunities to take on leadership responsibilities in the bio-banded model than in chronological age group competition, according to previous study by Cumming et al (2018). When playing with and competing against physically matched but chronologically younger players, for example, older late maturing players may perceive increased opportunity and expectations to assume leadership positions (Cumming et al., 2018). In contrast, younger early maturing males may have greater opportunities to participate in and experience the mentoring and learning process from older peers. Leadership development is a crucial goal of the English Football Association's four-corner player development model, and it is also regarded a key factor of adult success. In addition, mixed-age game forms like bio-banding may have a positive impact on group dynamics by emphasising the usage and development of social skills like leadership, teamwork, and communication (Bradley et al., 2019).

With fewer than 1% of children in professional youth soccer academies progressing to the professional level of football, children and adolescents are exposed to increasingly demanding conditions (Kolodziej et al., 2021). The injury risk is particularly high in adolescent athletes in comparison to adult and younger athletes, owing to high training loads that coincide with significant annual growth changes (Van Der Sluis et al, 2014). Indeed, the timing of peak height velocity may coincide with changes in bone density which is thought to contribute to ‘skeletal fragility’ (Whiting et al., 2004). Maturity related anatomical adaptations have been linked to the phenomenon ‘adolescent awkwardness (Moran et al., 2018) which arises when soft tissues (e.g., muscle) fail to increase at the same rate as the trunk and limb length. This discrepancy in maturity-related adaptation is thought to disrupt movement mechanics and increase the risk of injury (Towlson et al., 2021). According to recent studies, adolescent injury rates rise with age and show seasonal variation, peaking in September and January (after periods of relative inactivity) (Read et al., 2016; Renshaw & Goodwin, 2016). Each player, on average, sustains 1.32–1.43 injuries and misses 21.9 days per season owing to injury, with the number of days missed increasing in the U14 and U15 age groups (26.2 and 25.7 days, respectively) (Read et al., 2018; Tears, Chesterton & Wijnbergen, 2018). It is reassuring to note that respondents in this study believed that bio-banding was a practical way to account for skeletal fragility and adolescent awkwardness while controlling for maturity and prescribing training loads suited to that maturity. Practitioners discussed how bio-banding has helped in identifying players who may be going through a growth spurt and therefore more prone to injury, allowing them to alter their training programme and reduce injury risk, as suggested by the interview data, for instance. These findings are supported by Malina et al.’s (2019) research which showed how bio-banding reduces, but does not eliminate injury risk. Parity in body size and athleticism should, on the surface, lessen the risk of damage, particularly harm caused by collision or physical contact (Moilanen, 2020). Nevertheless, it is unknown to what extent the bio-banded format can lower injury risk in actual competition and assessing the validity of practitioner perceptions concerning the utility of this method is difficult in this respect. Despite the promising findings from this study, more evidence is required to support the efficacy of bio-banding as a means of reducing growth-related injury burden. Studies have also shown injury prevention requires knowledge of how to assess maturity and make training adjustments based on maturity status and time, stressing the necessity of education (Caine et al., 2006; DiFiori, 2010; Launay, 2015) which moves us on to the next section which considers some of the barrier's practitioners might face in seeking to implement bio-banding in professional youth soccer academies.

Bio-banding Barriers

With bio-banding being a relatively new concept, it is perhaps unsurprising to learn that practitioners face some challenges when seeking to implement the approach. Survey findings from the current study revealed that failure to establish buy-in, social stigma (players playing down), disruption to the training programme, and a lack of bio-banding understanding are challenges encountered by the practitioners. Further barriers its implementation include difficulties surrounding planning and organisation (time, resources, communication), the failure to establish buy-in, and the prioritisation of short-term success by coaches. Consequently, practitioners are torn between adopting the new bio-banding approach or continuing to use traditional methods to ensure that the format is beneficial for the athlete's development. As such, establishing and implementing a philosophy that prioritises long-term development over short-term results could also be a key step forward for sports. Similarly, this approach may present challenges (getting stakeholder buy-in, managing resources differently, for example), but it would be an important step toward redressing the balance between what an athlete requires for long-term development and what coaches and teams require for short-term success (Till & Baker, 2020). Academies might need to delegate maturity monitoring to specially qualified personnel as this is more likely to improve transfer and so favourably influence athletic performance (i.e. reduction of injury risk) (Salter et al., 2021).

The purpose of grouping players by maturity status is to reduce, but not eliminate, maturity-related disparities in size and function. Due to genotypic characteristics, however, players of the same maturity status can nonetheless differ in size and function (power, strength, speed, etc.: MacArthur & North, 2007). Players who are genetically short in stature, like their genetically taller teammates, must learn to play within their limitations. Bio-banding, on the other hand, has the ability to lessen the impact of individual disparities in size and athleticism on player development and success (Bradley et al., 2019). However, in line with previous research (Reeves et al., 2018), a prevalent mistake is the failure to educate players, coaches, and parents about biological maturation and bio-banding. As revealed by the interview findings from this study, practitioners felt that a lack of education could be the most significant barrier to bio-banding and the effect of this is that coaches are often reluctant to accept bio-banding as a tool for development and to use it in their practice. The lack of awareness of what bio-banding includes and how it will benefit their development is the issue for players. Similarly, players' parents may have little idea as to how bio-banding might benefit their child's athletic and psycho-social development, even if it means playing against younger athletes. Previous research, such as that of Reeves et al (2018), supports the importance of educating stakeholders, staff, and parents because coaches' knowledge, understanding, and application of sports science in their practice remains a frustrating problem, with the perennial problem now extending beyond the coaches and staff to include parents.

Another common problem faced by professional youth soccer academies, as previously mentioned in this thesis, is multidisciplinary teams (e.g. Fast and slow workers) not working closely enough and acquiring the required coach buy-in in order to efficiently bio-band athletes. Practitioners could aim to alleviate such bio-banding barriers (e.g. knowledge translation and lack of buy-in) by drawing on Bartlett and Drusts (2021) framework for effective knowledge translation and performance delivery in sport as aforementioned in this thesis. For instance, the practitioner must take the athlete's viewpoint and situation into account in order to properly execute evidence-based practice. The staff members' implicit practice-based knowledge, experience, and intuition are also taken into consideration in light of the specific circumstance or situation while seeking approval from the nearby pertinent staff. Additionally, empirical data or knowledge that can affect practice is subjected to peer review. Moving a player up or down a squad is an example of this; if the research and surrounding personnel support the idea, and athlete's viewpoint considered it will be judged effective (Bartlett & Drust, 2021). In relation to philosophy, practitioners must then be self-aware and mindful of how their actions and behaviors affect those around them, adopting a collaborative approach that includes everyone in the decision-making process and emphasising relationship building. They must also promote a culture of learning that embraces change and new information while fusing "science" and "art." Additionally, practitioners need to foster self-reflection and be receptive to constructive criticism (Bartlett & Drust, 2021). The ideal way to achieve this would be for practitioners to offer pertinent evidence to support the idea of bio-banding above conventional techniques. using a bio-banding method to encourage athlete talent identification and growth with reflection considered throughout, while acknowledging how such change may affect those around them with long-term athlete development at the forefront.

Next, practitioners must be aware of those who can affect their practice (recipients), such as stakeholders or persons with influence, in order to obtain the necessary buy-in for bio-banding (e.g. administration, performance staff, medical, operations and welfare staff). They must then be aware of stakeholder preferences for receiving new knowledge information and performance delivery. This can be obtained by describing the stakeholders in terms of their motivations, objectives, skills, knowledge, availability of time and resources, and level of support (Bartlett & Drust, 2021). When attempting to gain buy-in, practitioners must focus on this crucial element. If practitioners are aware of the individuals who have the power to influence bio-banding implementation, they can create a strategy that best serves the club, players, and stakeholders while adhering to the ideology and development plans of the club. The final element that practitioners should take into account is facilitation. Through the development of skills and attributes in accordance with a development plan that is appropriate for the task at hand and makes use of a variety of technical abilities and personal qualities while being adaptable and sensitive to recipients, practitioners advance from inexperienced to experienced. Additionally, practitioners ought to focus on developing soft skills like communication and emotional intelligence (Bartlett & Drust, 2021). For instance, in order to place themselves in the best possible position to not only achieve the buy-in they need but also implement the bio-banding method they have set out to achieve, practitioners should concentrate on the development of their own talents and traits. To ensure they are best equipped while instructing professional youth athletes, practitioners must have a drive to excel from a novice to an advanced level in terms of sports and education, picking up the soft skills along the way. These suggestions imply that the study's practitioners are not limited to Bartlett and Drust's (2021) work, and as a result, they ought to consider the framework to increase bio-banding buy-in and achieve successful knowledge translation and performance delivery in professional youth soccer academies.

Practical Application

The findings of this study could help practitioners better understand the effectiveness and application of maturity status bio-banding for talent identification and development within a professional youth soccer academy structure, as well as potential barriers to using bio-banding or what has prevented them from doing so.

With the help of bio-banding, practitioners can change training circumstances to make athletes work harder overall while competing against other athletes who are similarly developed biologically. This prevents players from putting more emphasis on physical aspects of the game than technical ones. As a result, practitioners are now in a position to give athletes new challenges and further opportunities. Additionally, it allows for a truer representation of an athlete's abilities because the opponent's maturity level and potential advantages cannot obscure a player's characteristics. As a result, developed players can no longer rely solely on their physical superiority, which can lead to more opportunities for technical and tactical improvement. Since, many "early" developers have been deselected at subsequent levels because they relied on physical dominance along their development pathway rather than honing technical abilities, which has been a big worry among professional youth soccer programmes (Ostojic, et al., 2014; Figueiredo, et al., 2019). Therefore, coaches who use bio-banding and raise the technical bar are likely to see an increase in player engagement. This could improve coaches' perceptions of their technical proficiency, better inform the process of identifying and developing talent, and increase the effectiveness of a maturity-matched "bio-banded" system. Another introduction to challenge could be removing physical demand and challenging athlete’s psycho-socially for instance by competing against peers from older chronological groupings or vice versa, challenging them to compete with younger peers. Such an opportunity allows for a more representative display of true technical, tactical, and psycho-social characteristics that are required for selection into talent identification and long-term athletic development programmes, preventing the premature release of talented and technically adept players who have the potential to succeed at a professional level when physical characteristics become attenuated.

Youth athletes, unlike adults, potentially lack the understanding or autonomy to make independent, educated decisions about sport participation and health behaviours. Parents, coaches, referees, medical professionals, schools, and regulatory organisations are typically trusted to act in their best interests. Accordingly, with the well-being of athletes at the forefront all stakeholders (e.g., academy personnel, EFL club recruiters, players, and parents) must be well informed and educated in order for bio-banding to be implemented successfully. This could be achieved utilising coach education programmes focused around bio-banding and how best to implement it within professional youth soccer as research has shown "*the degree of success that professionals experience is largely dependent upon the knowledge they generate and accumulate for the tasks and obligations they undertake*" (Jones et al., 2003, p. 214). This was also supported by Stephenson and Jowett (2009) more recent study which highlights the three key factors to successful coach development being professional training (coach education programmes), social learning, and internally reflective learning situations. EFL clubs and talent academies will then be able to better enhance player identification and development by educating coaches and staff on the process of growth and maturation. As a result, bio-banding will be more widely acknowledged inside institutions, offering sports practitioners more flexibility in identifying and developing athletes within the programmes. Along with the major benefit of bio-banding, which ensures that gifted athletes do not 'slip through the net' providing greater equity to the talent identification and development process.

Educating sports practitioners can increase bio-banding 'buy-in,' as well as promoting short and long-term success for athletes, both of which have been identified as bio-banding barriers

(Reeves et al., 2018). Most talent detection appears to be based on a method of locating "diamonds in the sand" rather than developing a talent development system per se (Bergkamp et al., 2021). Most professional clubs appear to be more focused on identifying talent rather than developing it, and as a result, it is clear that a shift to a more long-term strategy in which clubs consistently produce better players is required, which is not only more cost effective, but also encourages greater enjoyment of sport and produces a more well-rounded athlete. Furthermore, when looking at things from a holistic perspective, this idea of using maturity-status bio-banding to bring out desirable features in people may not be limited to talent identification and development. It's evident that maturity status 'bio-banding' can be used to encourage the development of desirable qualities that indicate the required skills of talented adolescent soccer players. However, such an application should not be limited to professional youth soccer players; rather, it should be studied across a broader spectrum of sports, both individual and team-based (Krause et al., 2015; Moran et al., 2022). It could also be useful in an both classroom and sporting educational situations with grouped learning sessions too (The English Premier League, 2011). Less cognitively developed children may feel more at ease and engaged in a 'matched' classroom, displaying full learning skillsets that could otherwise go unnoticed when paired with more developed or advanced pupils. Whereas when better evolved learners are matched, they may be placed in a position that pushes them further by raising the level of learning environment in which they are in. However, the use of 'bio-banded' techniques, should always be seen as a supplement to current chronological age groups, with the goal of developing individuals holistically.

Limitations

As the first known data to be presented on sports practitioners perceived perceptions and application of bio-banding within a professional youth soccer academy setting. The study's merits include the use of a mixed-methods approach. Along with emphasising the necessity of matching bio-banding for assessing physical, technical, tactical, and psychosocial components, especially during the youth development phase. The study has also significantly advanced our knowledge of bio-banding. This study provides an understanding of bio-banding barriers and serves as a first step in evaluating how a relatively new approach to talent identification and development in professional youth football can better support the introduction of challenge and additional opportunities for athlete development. It does this by using athlete maturity related differences to design individual development programmes, as well as a strategy to prevent injury and promote challenge and progression.

The limitations of this study should still be noted, however. Phase one (survey) of the study included a relatively small sample (twenty-seven professional youth soccer sports practitioners) and this was in part owing to the inclusion criteria which required participants to work in an EPPP affiliated club. In addition, these practitioners work in extremely hectic and demanding environments and it's possible that they may have devoted insufficient time to the completion of the survey. A weakness that exists with all surveys that participants may not have provided accurate, honest answers or have been fully aware of their reasoning for any given answer due to lack of memory or knowledge on the subject. To further validate the results of this thesis, the time scale of data collection phase one would be extended and inclusion criteria broadened (perhaps to include practitioners from a range of other sports).

Similarly, the second phase of data collection (interview) was limited to seven sports practitioners who chose to have a follow-up interview after completing the survey. Another major drawback stemming from this is the lack of diversity among practitioners; in an ideal world, the thesis would incorporate both male and female viewpoints as well as clubs from categories 1 through to 4. Furthermore, due to Covid-19, interviews were performed online, meaning there were additional time limits. It can be challenging to build rapport with participants when completing on-line interviews although significant efforts were made to put participants at ease. Nevertheless, it's possible that participants may have struggled to maintain interest or motivation when discussing their experiences and this may have affected the depth of answers provided. Although the interviews were semi-structured in nature they could have provided interviewees with even more opportunity to share the experiences they considered most meaningful to them. The opening phase of the interviews was quite structured in nature and spent considerable time following up on questions covered by the survey. Ideally, even more time would have been given to practitioners to talk openly and raise any issues that had not been addressed by the interviewer. Employing such an approach might have enhanced the theoretical generalisability of the findings by making them more applicable to sports practitioners of different football clubs, countries, or to sports practitioners working within different divisions.

Areas for Future Research

Given the limitations identified in data collection phases one and two in this study, future research should seek to improve current research by extending the duration of data collection phases, boosting sample sizes to improve the generalizability of the findings, and expanding the inclusion criteria to include practitioners from a range of sports and increased diversity. In addition to allowing flexibility in the survey and interview format, which gives practitioners more chances to share their insights and bring up any unresolved problems, it is important that interviews be conducted in person to foster a stronger rapport and give practitioners the best chance to respond honestly and freely. The theoretical generalizability of the results could be improved by using a more open-ended approach to the study, making them more applicable to sports practitioners of various football clubs, nations, or sports practitioners operating within various divisions.

Despite research in this field still being in its infancy, the present study aimed to further develop an understanding of the efficacy of maturity status ‘bio-banding’ as a talent identification and development tool within professional youth soccer athletes. While this study’s results have shed light on the benefits of bio-banding and some of the challenges practitioners might face in seeking to implement it, it has also raised a number of questions for future research. For example, researchers may wish to explore whether bio-banding is more suited as a talent identification or a development tool for professional youth soccer academies. Other questions include the following: What prevents fast workers (coaches) and slow workers (sports practitioners) from working together in professional youth soccer settings? How effective is bio-banding within other team sports? Do category ratings of academies affect the efficiency of bio-banding?

Future research should look beyond practitioners' perceptions and opinions of bio-banding and include naturalistic observations (a research technique involving observing and detailed notes about practice as it takes place ‘in the wild’; Lang, 2010; Teques et al., 2019) of coaches using bio-banding in professional youth soccer settings in order to further inform talent identification and development. In addition, the observations would inform a follow-up interview and allow coaches to reflect on their own practices retrospectively. In terms of talent identification and development, this would allow the researcher to ascertain whether there is a difference between how the practitioner claims to apply practice and how they actually apply practice, assisting coaches in justifying their practices as well as preventing the prioritisation of short-term success over long-term development, which was identified in this study as one of the barriers to bio-banding.

Despite the current study looking at the effectiveness of bio-banding on both talent identification and athlete development, there is still a requirement of future research to consider the two separately. As a talent identification tool, practitioners expressed that bio-banding might potentially be used to identify athletes throughout recruitment periods before they are contracted to the club, rather than solely bio-banding when they are at the club. In terms of development, rather than using bio-banding to highlight singular talented athletes who may be of greatest benefit for the club as a whole, coaches would concentrate on the development of all athletes, resulting in a more equitable environment (Grove, 2022). This could once again assist in overcoming a bio-banding roadblock: a lack of buy-in. If clubs and coaches believe that bio-banding will help them improve their recruitment tactics, discover athletes who better fit their philosophy, and provide a better opportunity for more successful athletes, they will be more likely to adopt the practice (Till & Baker, 2020).

We also need to consider what hinders fast workers (coaches) and slow workers (sports practitioners) from working together in professional youth soccer environments. To do this, further research should consider the perceptions of both fast and slow practitioners and why they feel it may be difficult to utilise knowledge translation when dealing with athletes even if it *"plays an important role in developing efficient evidence-based practice*". Doing so also enables the chance to educate coaches on bio-banding, maturity estimation methods, and provide insight on how to combine fast and slow workers which would not only avoid another bio-banding barrier (lack of education). But it would also provide additional insight into the impact maturity and biological development can have on talent identification and development in youth soccer. This should eliminate any bias among practitioners, athletes or parents and give a clearer philosophy and approach to achieving common goals. A potential coach education programme would also allow practitioners to explain to parents how "playing down" or "bio-banding" works and its advantages (achieve buy-in). Due to the fact that parental engagement, including the time, effort, and money they are willing to put in their child's sporting endeavors (Knight et al., 2016), can have an impact on athletes' motivation, enjoyment, and long-term development (Fredricks & Eccles, 2004).

As previously aforementioned, bio-banding is a relatively new phenomena, with the primary source of information relating to maturity-status bio-banding in soccer academies. As a result, in order to validate bio-banding, more research on the practice should be conducted in other team sports such as rugby or ice hockey. This could act to inform team sports beyond soccer to utilise bio-banding practices and offer athletes the best possible opportunities to develop themselves whilst better informing current research. Returning to football, future research on whether the EPPP category rating of academies can alter the application and validity for talent identification and development of athletes could be of interest in order for clubs and organisations to adopt bio-banding more readily. This would not only offer clubs with realistic goals to establish for themselves and their players, but it would also help with bio-banding adoption. Furthermore, clubs might take a strategy that is tailored to their academy rather than those of clubs above or below them.

Conclusion

The data presented above provide the first known examination of sports practitioners perceived perceptions and application of bio-banding within a professional youth soccer academy setting. The only other studies that have considered perceptions of bio-banding in professional soccer academies only focused upon players perceptions and data were collected during a competitive tournament (Bradley et al., 2019) and stakeholders' perceptions of bio-banding in training (Reeves et al., 2018). This study identified seven significant themes, with practitioners emphasising the necessity of bio-banding, particularly during the youth development phase throughout. The emergent themes should be considered carefully in any junior-professional soccer academy environment prior to the use of bio-banding for talent identification and development of athletes. While the data supports the use of bio-banding in practice, the studies represent practitioners who have and have not used bio-banding practices, with the goal of overcoming the barriers that practitioners face when implementing bio-banding practices, as well as what prevents practitioners and clubs from doing so. By identifying the barriers to bio-banding, we aim to better understand the potential use of bio-banding in professional youth soccer and consider how the talent identification and development of athletes can be shaped to optimise their journey to professional football. Furthermore, with a better understanding of the sports practitioners perceptions who implement bio-banding on a daily basis, we look to offer a first step in evaluating how a relatively new approach to talent identification and development in professional youth soccer can better support the introduction of challenge and additional opportunities for athlete development by utilising athlete maturity related differences to design individual development programmes, as well as a strategy to prevent injury.

In summary, this study investigated practitioners perceived effectiveness and application of maturity status bio-banding for talent identification and development. The findings revealed that practitioners feel bio-banding should be incorporated into professional young soccer development programmes, but only during the youth development phase, when athletes' biological maturation is at its peak. In addition, the study leads practitioners to conclude that matched bio-banding is the most effective technique for assessing physical, technical, tactical, and psychosocial components. Practitioners also concur that variances in maturation state have an impact on the development of physical, technical, tactical, and psychosocial traits. Injury prevention for athletes, introduction to challenge and more opportunities, and matching (identifying athlete differences and designing individual development programmes) are some of the bio-banding benefits demonstrated in this study. While the planning and organisation (time, resources and communication / disruption to the programme) required for bio-banding to be efficient, inability to establish bio-banding buy-in, lack of education, and the prioritisation of short-term success are examples of hurdles. This study supports the contention that practitioners perceived effectiveness and application of maturity status bio-banding does contribute positively to the talent identification and development of professional youth soccer players.

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APPENDIX

Appendix 1. Interview Invite Letter

Dear Team Sport Practitioner,

The University of Hull would like to request your help by completing this short survey (approx. <15 minutes), based on your perspectives on the perceived effectiveness and application of maturity status bio-banding for talent identification and development.

The purpose of contacting you is to ask if you would be willing to contribute to a research study that we are conducting. The project aims to examine the application of maturity status bio-banding within elite youth soccer clubs for talent identification and development of athletes. The online survey will enable us to examine applied practitioners' perspectives of their opinions on the application and barriers of bio-banding.

The survey will consist of 6 sections (Section 1: General information; Section 2: knowledge on maturation, maturity etc.; Section 3: perceived influence on maturity practice; Section 4: bio-banding; Section 5: overarching summary; Section 6: concludes survey).

With your cooperation and completion of this survey you will help us to ensure that our work is of practical relevance to people like yourself, and in return we will provide you with details of our research findings upon completion.

We would like to ensure you that only the principle investigator will have access to information disclosed in section A (General information). In accordance with the General Data Protection Regulation (GDPR), all information will always remain anonymous and confidential to all coresearchers and will only be used as a point of reference when analysing the data. All documentation will be kept securely at the University of Hull.

I thank you in advance for taking the time to complete this survey.

Kind Regards

Demi Watson

Sport, Health and Exercise Science,

The University of Hull

Research Title - Practitioners Perceived Effectiveness and Application of Maturity Status Bio-Banding for Talent Identification

Example Survey Questions:

- Have you ever used or assisted in the process of bio-banding?
- How many maturity categories do you use?
- Please estimate when you think the onset of the adolescent growth spurt occurs?
- Can you please rank in order of (1 being the greatest) your perceived barriers to implementing bio-banding methods?
- Can you please state your agreement with below statements relating to the purpose of bio-banding?

Appendix 2. Survey Questions

Inclusion Criteria

- Are you 18 years old or above?
- Can you please confirm you have read the participant information sheet?
- Are you currently working within an Elite Player Performance Plan (EPPP) affiliated club?
- Have you already completed this survey?

General Information

- What is the category rating of the academy you currently work within?
- What is your primary position/role at the academy?
- What is the nature of your employment?
- What phase of development do you primarily work within?
- What is the highest relevant academic qualification you hold?
- What is the high relevant professional qualification you hold?
- How long have you worked in your position at the club?

Perceived Influence on Maturity Practice

- Can you please state your agreement with the statements below? (e.g. "To what extent do you believe that differences in maturation status impact the development of physical characteristics?")
- Can you please state your agreement with the statements below? (e.g. "To what extent do you believe that maturity-related differences in physical development characteristics impact your ability to accurately assess the physical competence of a child?")

Familiarity of bio-banding

- Have you implemented the process of bio-banding?

- Which of the below context(s) have you used bio-banding in? (select multiple where possible)
- What purpose(s) do you use bio-banding for? (select multiple where possible)
- Please select which of the below option(s) best represent how you used bio-banding?
- Please state your level of agreement for how bio-banding permits an enhanced assessment of the below components of performance when matching (e.g. Early vs Early or pre-PHV vs pre-PHV) players for maturity status in comparison to chronologically categorised (i.e. U11 etc.) player groupings?
- Please state your level of agreement for how bio-banding permits an enhanced assessment of the below components of performance when pairing (e.g. Late vs Early or pre-PHV vs post-PHV) players for maturity status in comparison to chronologically categorised (i.e. U11 etc.) player groupings?
- Which maturity estimation method did you use to bio-band players?
- How much education do you feel your coaching courses/qualifications provided you with on growth and maturation?
- Typically, how often do you assess players for maturity?
- Can you please state your agreement with the statement below relating to the purpose of bio-banding? (e.g. bio-banding can reduce the risk of contact-related injury among young players?)

Barriers of bio-banding

- What do you feel are the contributing factors for why you have not used bio-banding?
- Do you feel there are any other barriers to bio-banding which are not stated above?
- Do you feel bio-banding is of greater benefit for early, on-time or late maturing athletes?

Multidisciplinary Application of Bio-banding

- Under the assumption that primary playing position is not yet fixed, when assessing players for talent, which of the below somatic characteristics do you feel are important?
- Under the assumption that primary playing position is not yet fixed, when assessing players for talent, which of the below physical characteristics do you feel are important?
- Can you please state your level of agreement with each of the below statements?
- Under the assumption that primary playing position is not yet fixed, when assessing players for talent, which of the below technical characteristics do you feel are important?
- Can you please state your level of agreement with each of the below statements?
- Under the assumption that primary playing position is not yet fixed, when assessing players for talent, which of the below tactical characteristics do you feel are important?
- Can you please state your level of agreement with each of the below statements?
- Under the assumption that primary playing position is not yet fixed, when assessing players for talent, which of the below psycho-social characteristics do you feel are important?
- Can you please state your level of agreement with each of the below statements?

Summary

- Please state your level of agreement with the below statements? (e.g. I feel bio-banding enhances the assessment of psycho-social characteristics in academy football players)
- From which stage of development do you feel players should be introduced to bio-banding?
- Having completed this survey how likely are you to use bio-banding methods?

Optional Participation

Thank you for taking the time to complete this survey. I now invite you to leave the following details below for a potential follow up interview (Not all candidates will be invited for an interview).

- Name
- Email
- Institution/Academy

Appendix 3. Semi-Structured Interview Schedule

General Information

- Do you feel the rating of the academy you are currently working within influence your understanding and application of bio-banding?
- Would you like to apply different practice?
- Do you feel your role or you colleague's role influences your motivation to employ bio-banding practices?
- Are any of your colleagues reluctant to take implement bio-banding?
- Does the application of bio-banding vary between the 3 development phases at your academy?
- Which phase do you feel uses bio-banding most efficiently?
- Do you feel there should be more education around bio-banding for coaches?

Familiarity of bio-banding

- Could you please provide detail on a positive experience you have had when bio-banding?
- Can you please explain how you have previously bio-banded and which method you used to do so?
- How do you feel bio-banding has proven useful for your club?
- What is the club's rationale for using bio-banding practices?
- Can you provide an example of when bio-banding has provided a new challenge for yourself or for the athletes?
- Do you feel it's important to introduce new challenge?
- Do you feel bio-banding offers advantages over traditional approaches?

- Do you feel bio-banding places too much emphasis on any of the athletes? (e.g. Early, on-time, late maturing). Or runs the risk of neglecting any athletes?

Barriers of bio-banding

- Could you please provide some detail on a negative experience you have had when bio-banding and the challenges you or the athletes may have faced?
- What do you feel could be the biggest barriers of bio-banding?
- Do you feel academies face the same barriers or does it differ for each institution?
- How do you feel clubs could ease such barriers?
- Should bio-banding be a staple to the player development curriculum?

Summary

- What about bio-banding do you feel enhances the assessment within physical, technical, tactical and psycho-social characteristics?
- What age do you feel athletes should be introduced to bio-banding from?

What about the survey made you more/less likely to implement bio-banding?