UEFA Research Grant Programme Final Report

Maturity-status 'bio-banding' as a tool for ongoing talent (de)selection of academy soccer players using a multi-disciplinary approach

Principal investigator:

Dr Christopher Towlson - University of Hull, UK

Co-investigators:

Dr Grant Abt – University of Hull, UK

Dr John Toner – University of Hull, UK

Dr Jaime Sampaio - Universidade de Trás-os-Montes e Alto Douro, Portugal

Professor Niall MacFarlane – University of Glasgow

Dr Steve Barrett – Hull City Tigers AFC

Appointed postgraduate student:

Mr Calum MacMaster – University of Hull, UK

Supported by:

Mr Neil Campion - Scottish Football Association

In association with:

Hull City Tigers AFC, Middlesbrough FC and Hamilton Academicals

UEFA Research Grant Programme Final Report

Contents

UEFA Research Grant Programme Final Report

Section 1: Executive summary

There is a wealth of evidence to show that 'early'-maturing young soccer players are over-selected compared to later-maturing (and sometimes relatively younger [see Helsen, Van Winckel, and Williams (2005); Lovell et al. (2015); Towlson et al. (2017)]) players in many professional leagues throughout the world (Deconche & Maurer, 2016; Helsen, Van Winckel, & Williams, 2005). Such selection bias offers 'early'-maturing players a physical and anthropometric advantage over their later-maturing teammates when categorised according to chronological age during activities typically associated with ongoing talent (de)selection and player profiling strategies (Lovell et al., 2015; Towlson et al., 2017). One solution to this problem is to categorise young players according to their maturity status (commonly referred to as 'bio-banding') (Cumming, Lloyd, Oliver, Eisenmann, & Malina, 2017) rather than their chronological age.

Although several methods can be used to 'bio-band' players (Khamis & Roche, 1994; Mirwald, Baxter-Jones, Bailey, & Beunen, 2002; Moore et al., 2015; Sherar, Mirwald, Baxter-Jones, & Thomis, 2005), the approach used by some English Premier League (EPL) academies is to categorise players based on a percentage of estimated adult stature attainment (Cumming, Brown, et al., 2017). Cumming et al. (2017) report that 'bio-banding' was well received by both 'early' and 'late'-maturing players during a 'bio-banded' tournament. Moreover, the publication of 'Bigger shouldn't mean better' by The International Centre for Sports Studies (Deconche & Maurer, 2016) and the introduction of the EPL's 'bio-banding programme (The English Premier League, 2011), clearly demonstrates the intentions of soccer's international and national leagues to develop and apply evidence-based initiatives to reduce this over-selection of 'early' maturing (and de-selection of 'late' maturing) boys for development programs (Lovell et al., 2015; Towlson et al., 2017).

Importance and interest to UEFA

Despite 'bio-banding' being introduced by national leagues and well received by players, there is a paucity of evidence on its application and long-term effectiveness as a means of identifying the technical, physical, and psychological determinants for ongoing talent (de)selection. For example, no studies have examined the influence of maturity status on the technical or tactical performance of young players during match-play (Votteler & Höner, 2014). Certainly, qualitative evidence does exist to suggest that young players perceive there to be a technical and tactical benefit for them when playing under 'bio-banded' conditions (Cumming et al., 2017). However, no objective technical or tactical measures were reported by Cumming et al. (2017), which means there are no data to support or refute the perceptions of the players.

There is also no evidence for the effect of 'bio-banding' on other aspects of player development, such as the psychological characteristics of young players. Psychological characteristics are seen to be important by some national football associations, with these aspects contributing half of the four components that constitute the English Football Association's 'Four Corner Model' for player development (The Football Association, 2010). The importance of these aspects are also reflected in the value placed on them by scouts when evaluating players for selection (Towlson, Perry, Levett, Court, & Cope, 2019). Therefore, studies examining the effect of 'bio-banding' on these essential aspects of player development are now required if UEFA member associations and constituent clubs are to use a holistic evidence-based approach for ongoing talent (de)selection strategies.

Summary of results and practical recommendations

Preliminary findings suggest that the efficacy of maturity-status 'bio-banding' as a tool for ongoing talent (de)selection of academy soccer players using a multi-disciplinary approach is limited to identifying desired psychological traits of 'late' maturing academy soccer players only. However, maturity status 'bio-banding' has also shown between maturity banding differences in perceived effort and total player load. Therefore, practitioners should also consider maturity status bio-banding as a training method, in addition to a talent identification tool. Consequently, Practitioners should carefully consider their aims, objectives and motivations for implementing 'bio-banding' methods, to ensure that the practical benefits of its use outweigh the relative cost (i.e. time, organization, parental consent, change of philosophy etc.) of implementing it.

Section 2: Introduction and context of the research and its relevance for UEFA

The Union of European Football Associations (UEFA) Financial Fair Play regulation states that all European professional soccer clubs are to operate within their financial means or face financial or competition penalties (UEFA, 2012). In an attempt to promote 'home-grown' talent to compete at senior level soccer and reduce club financial outgoings on imported players, there is a need for domestic professional soccer clubs to install ongoing talent (de)selection strategies that are free from (sub)conscious, transient, maturity (and sometimes relative age effects; see Helsen, Starkes, and Van Winckel (1998); Lovell et al. (2015); Towlson et al. (2017)) related selection bias that will strengthen the pool of players who are inducted (and maintained) into talent development programmes and available for national selection. The over-selection of academy players who possess enhanced maturity-related physical characteristics is well documented (Lovell et al., 2015; Towlson et al., 2017). Unfortunately, few studies have examined the effect of 'bio-banding' on match-play characteristics, or indeed offered pragmatic solutions for recruitment practitioners to reduce the over-selection of 'early'-maturing players.

Despite the over-selection of 'early' maturing, taller players for soccer development programs (Lovell et al., 2015; Towlson et al., 2017) a multi-disciplinary approach to understanding the effects of 'bio-banding' during ongoing talent (de)selection is of particular relevance to soccer academies and governing bodies across the world. Our research group have previously reported that soccer academy recruitment staff place greater value on psychological characteristics than technical/tactical, and physical factors during talent selection (Towlson et al., 2019). Specifically, recruitment staff value psychological factors more than medical, sport science and fitness staff (Towlson et al., 2019). Similarly, recruitment staff also value psychological factors more than medical staff for the evaluation of player maturity (Towlson et al., 2019). Therefore, given that the timing and tempo of biological maturity impacts the physical and psychological development of children (Malina, Bouchard, & Bar-Or, 2004), it is imperative that any 'bio-banding' talent (de)selection method should be effective for identifying talented soccer players according to their technical, physical and psychological characteristics.

Although 'bio-banding' used for identifying talented young soccer players is very appealing, there is no soccer-specific objective evidence for its efficacy as a talent (de)selection tool. For 'bio-banding' to be fully endorsed by UEFA and widely used by its national associations, its efficacy must be demonstrated from a multi-disciplinary (physical, technical, psychological) perspective (The Football Association, 2010; Unnithan, White, Georgiou, Iga, & Drust, 2012). Moreover, as 'bio-banding' is designed to group players together based on anthropometric characteristics, it is unknown if staff responsible for the (de)selection of players can effectively evaluate the key tactical (e.g. spatial exploration, creativity) and psychological (e.g. confidence, attitude, competitiveness) characteristics of players as these are generally displayed in times of adversity, notably when competing against taller, stronger and faster players (i.e. more mature).

Section 3: Research aims, questions and objectives

Aims of the proposed project

The aim of the proposed project was to examine the effect of maturity-related 'bio-banding' on important aspects of a multi-disciplinary approach to talent identification. This aim was achieved by evaluating, from a multi-disciplinary perspective, the effect of different 'bio-banding' strategies on tactical, technical, psychological and physical performance variables associated with talent (de)selection of young soccer players during small-sided games (SSG) match-play.

Research questions

1) What is the effect of 'bio-banding' on the tactical, technical, psychological and physical performance of young academy soccer players?
2) What is the effect of 'bio-banding' on internal (heart rate and sRPE) and external (GPS metrics i.e. player load etc.) measures of training load?

Research objectives

Having recruited 3 professional soccer academies (England: n = 2; Scotland: n = 1), 30 adolescent (pre APHV: n = 10; 'circa'-APHV: n = 10; post APHV: n = 10) academy soccer players were identified from an initial group of ~80, with the main objective of this study to establish the effect of two different 'bio-banding' methods (Fransen et al., 2018; Khamis & Roche, 1994) as an appropriate method for talent (de)selection practitioners to evaluate players physical, technical, tactical and psychological characteristics during SSG.

Section 4: Literature review

Estimations of maturity status

Longitudinal collection of stature data for individuals during adolescence can reveal the point at which the age at onset of the growth spurt will occur (Malina et al., 2004). In turn, this can be used to determine the age of the child during the maximum rate of growth during the growth spurt, commonly referred to in the literature as age at peak height velocity (APHV) (Mirwald et al., 2002; Sherar et al., 2005). However, this method is limited to 'real-time' measures of players' growth and offers no predictive qualities to enable soccer talent identification practitioners to forecast player anthropometric development. In fact, this approach limits the practitioner's ability to make 'real-time' and informed (de)selection decisions regarding players' progression relative to their estimated final growth measures. To address this methodological shortcoming, non-invasive predictive estimations of player maturity status, calculated using anthropometric based measures, can be implemented as a cost effective alternative for estimating player maturity status (Deprez et al., 2014; Figueiredo, Coelho e Silva, & Malina, 2011; Fransen et al., 2018; Khamis & Roche, 1994; Mendez-Villanueva et al., 2011; Moore et al., 2015).

Application of maturity estimation within academy soccer

Estimating the number of years a child is away from achieving peak height velocity (YPHV: PHV – Decimal age) (Mirwald et al., 2002), predicted final adult stature (Sherar et al., 2005) and estimation of adult stature attainment (EASA) (Khamis & Roche, 1994) have frequently been used by soccer practitioners and researchers to assist talent identification processes (Cumming, Brown, et al., 2017; Cumming, Lloyd, et al., 2017; Unnithan et al., 2012; Vaeyens et al., 2006), and to conduct performance and development analyses (Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010; Mendez-Villanueva, Buchheit, Simpson, & Bourdon, 2012; Towlson et al., 2017). The advancement of such approaches has stimulated the interest of researchers and practitioners alike, who have examined the importance of age-related differences and maturity status of academy soccer players' on match-performance (Buchheit et al., 2010; Castagna, Manzi, Impellizzeri, Weston, & Alvarez, 2010), training capacity (Mendez-Villanueva et al., 2010) injury incidence (Le Gall, Carling, & Reilly, 2007; Malina, 2010) and fitness test performance (Cunha et al., 2011; Mujika, Spencer, Santisteban, Goiriena, & Bishop, 2009). The ability to accurately monitor maturity status is central to the talent development process. To illustrate, measures of player maturity have been used to discriminate players' for competition tournaments to either exclude (Doward, 2015) illegible players (i.e. age fraud), or to enhance talent identification (Cumming, Brown, et al., 2017; Cumming, Lloyd, et al., 2017) and player development processes such as the UK Elite Player Performance Plan (EPPP) (The English Premier League, 2011).

Estimating player maturity across the youth (under 12 to under 16) development phase of the EPPP (The English Premier League, 2011) is necessary, given that academy soccer players will likely achieve PHV between 10.7 to 15.2 years (Towlson, Cobley, Parkin, & Lovell, 2018) and that advanced normative growth (such as stature (Carling, Le Gall, Reilly, & Williams, 2009; Deprez et al., 2014)) and maturity-related advantages (such as superior strength and aerobic capacity) are often considered influential for the 'early' (de)selection (Deprez, Fransen, Lenoir, Philippaerts, & Vaeyens, 2015) of players' for development programs (Lovell et al., 2015). For example, Mendez-Villanueva et al. (2010) showed that the positive effects of decimal age on running speed (maximum aerobic speed, acceleration and sprint speed) development are likely to be maturity related and that superior maturity-related anthropometric and physical fitness attributes are likely to characterise specific soccer playing positions (Deprez et al., 2014; Gil, Gil, Ruiz, Irazusta, & Irazusta, 2007; Towlson et al., 2017).

In addition, Philippaerts et al. (2006) have also shown peak strength, power, speed and endurance development tempos to occur pre, and 'circa'-PHV (13.8 ± 0.8 years) and continue to improve (albeit at a reduced rate) post-PHV dependent on individual growth curves and training regime (Philippaerts et al., 2006). These findings suggest that UEFA member associations and clubs should include a measure of estimated maturity status within talent identification processes, in an effort to reduce the 'early' and often over-selection of players who exhibit enhanced, transient maturity related, anthropometric and physical fitness characteristics and who are often born in the first quartile of the selection year when categorised chronologically into playing groups (Carling et al., 2009; Deprez et al., 2013; Hirose, 2009), commonly referred to the maturation-selection hypothesis.

The Maturation-Selection Hypothesis within academy Soccer

Superior anthropometric dimensions (stature and weight) and performance characteristics (power, speed, strength and endurance) often characterise players' selected for academy soccer development programs (Carling, Le Gall, & Malina, 2012; Carling et al., 2009; Vaeyens et al., 2006). This selection bias is likely apparent due to talent identification practitioners' selection of relatively older players', born earlier in the selection year (September to November), who are beneficiaries of experiencing earlier accelerations in stature development across the adolescent growth spurt (Malina et al., 2004; Malina et al., 2000) and often exhibit advanced anthropometric and physical fitness characteristics (Carling et al., 2009; Hirose, 2009). This selection phenomena often results in the recruitment of players' for academy programmes seemingly based on transient enhancements in physical and anthropometric phenotypes, commonly referred to as the maturation-selection hypothesis (Cobley, Baker, Wattie, & McKenna, 2009; Helsen et al., 2005). It is likely that the maturation-selection hypothesis is a principle contributor to the over-selection of 'early' maturing academy soccer players for development programmes, and indeed the systematic discrimination of chronologically categorised players' born in the latter quartiles (Q) (June to August) of the domestic soccer season (1st September - 31st of August) (Carling et al., 2009; Deprez et al., 2013; Hirose, 2009; Lovell et al., 2015), ultimately contributing to the relative age effect (Cobley et al., 2009; Towlson et al., 2017; Wattie, Cobley, & Baker, 2008). Examination of the relative age effect is of relevance, as this selection phenomena is likely to be a contributing factor in the discrimination of equally talented and relatively younger players from being selected for talent development programs (Helsen et al., 1998; Hirose, 2009; Mujika, Vaeyens, et al., 2009), potentially reducing the number of players available for domestic senior and national representation.

The Relative Age Effect within Academy Soccer

The over-representation of athletes born in the first three months (quartile) in their respective selection year is commonly referred to as the relative age effect (RAE) (Cobley et al., 2009; Wattie et al., 2008). The RAE is prevalent in many elite sports including ice hockey (Wattie, Baker, Cobley, & Montelpare, 2007), rugby league (Till, Cobley, O'Hara, Cooke, & Chapman, 2014; Till et al., 2010), athletics (Vincent, 1993) and basketball (Delorme & Raspaud, 2009). As with these sports, the RAE in soccer skews the distribution of players' birth dates, favouring a 'leftward' shift towards those players' born in the first quartile of the selection year (September to November in soccer) (Carling et al., 2009; Cobley, Schorer, & Baker, 2008; Helsen et al., 2005; Hirose, 2009; Mujika, Vaeyens, et al., 2009; Romann & Fuchslocher, 2013; Schorer, Cobley, Büsch, Bräutigam, & Baker, 2009; Vaeyens, Philippaerts, & Malina, 2005; Williams, 2010). Using a large sample (n = 2175) of European academy (U15 to U18) soccer players', Helsen et al. (2005) showed a clear over-representation of players' born in the first quartile (36% to 50%) of the domestic soccer season in comparison to the last 3 months (3% to 17%).

Further evidence suggests that such between-quartile differences in birth distribution are often more pronounced during pre-adolescence, corresponding with the slowest rate of PHV since birth (Malina et al., 2004; Tanner, Whitehouse, & Takaishi, 1966). Therefore, when benchmarking player development against national records data (such as the EPPP (The English Premier League, 2011)), there might be justification for talent identification practitioners to be considerate of players' relative age, given that normative growth curves (Malina et al., 2004; Malina et al., 2000) of relatively older players, born earlier in the soccer selection year often elicit enhanced maturity and anthropometric characteristics. Although relatively younger players will likely exhibit inferior maturity-related physical phenotypes (Carling et al., 2009), evidence suggests that the minority of relatively younger players' who are recruited for academy soccer development programs are often characterised as having advanced biological maturity and subsequently possessing advanced physical and anthropometric characteristics that enables them to compete with their more mature counterparts on an absolute basis as compensation (Till et al., 2010). In addition to this selection phenomena, birthdate distribution (Romann & Fuchslocher, 2013) coupled with advanced maturity-related anthropometric and physical fitness characteristics (Deprez et al., 2014; Gil et al., 2007) have been shown to influence playing position allocation of academy soccer players (Towlson et al., 2017). For example, 'early' maturing players, who are often born earlier within the selection year and who typically possess enhanced maturity-related anthropometric characteristics, are frequently selected for key defensive (such as central defence and goalkeeper) and attacking roles, presumably due their advantage over less mature opponents during match-defining aerial and physical duals. It is likely that this creates the perception of them being more successful and gifted during initial and ongoing (de)selection process. Consequently, categorising players according to maturity status ('bio-banding') and/or birth quartile during talent (de)selection processes is of relevance and importance to the effective recruitment of players for professional soccer clubs.

Bio-banding

Given the asynchronous relationship between child growth rate and decimal age, 'bio-banding' seeks to eschew the use of traditional chronological age groupings by categorising adolescent players into teams or training groups according to discrete maturity status bandings (Cumming, Brown, et al., 2017; Cumming, Lloyd, et al., 2017). These bandings are typically derived from maturity estimate equations that either model normal growth curves of adolescents, with somatic characteristics such as stature, leg-length, body-mass and decimal age (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). Advocates of 'bio-banding' suggest that such player categorisation can likely reduce risk of player injury (Baxter-Jones, Helms, Maffulli, Baines-Preece, & Preece, 1995) and enhance talent selection processes and player perceptions (Cumming, Brown, et al., 2017). As discussed within the above sections, the over-selection of young soccer players who possess transient superior anthropometric dimensions (stature and body mass) and performance characteristics (power, speed, strength and endurance) often characterises players' (de)selected for academy soccer development programs (Carling et al., 2012; Carling et al., 2009; Vaeyens et al., 2006) and likely thwart the size of the talent pool from which club and country select from.

Although 'bio-banding' has been introduced by national leagues (i.e. The English Premier League) and well-received by players (Cumming, Brown, et al., 2017), there is limited evidence for its efficacy for uncovering the multi-disciplinary components of soccer talent (i.e. technical, physical, and psychological). As previously discussed, there are few studies that have explored the influence of maturity status on the technical or tactical performance of young players during match-play (Votteler & Höner, 2014). As Cumming, Brown, et al. (2017) have shown, players perceive there to be a technical and tactical benefit for them when playing under 'bio-banded' conditions. That said, Cumming, Brown, et al. (2017) failed to report any objective technical or tactical measures which means there are no data to support or refute such perceptions.

In addition, there is also limited objective evidence that 'bio-banding' can enhance the detection of other characteristics (i.e. psychological characteristics) of player talent. Such evidence is both of importance and relevance given that psychological characteristics are considered essential by some national soccer associations, as such attributes comprise half of the four components that constitute the English Football Association's 'Four Corner Model' for player development (The Football Association, 2010). The importance of these aspects are also reflected in the value placed on them by talent scouts when evaluating players for selection (Towlson et al., 2019). Therefore, studies examining the effect of 'bio-banding' on these essential aspects of player development are now required if UEFA member associations and constituent clubs are to use a holistic evidence-based approach for ongoing talent (de)selection strategies.

Section 5: Research design and strategy

Study design

After having completed a full and rigorous familiarisation one week prior to the commencement of testing, the study followed a three-week quantitative, repeated-measured design whereby players contested both 'bio-banded' (weeks 1 and 2) and 'mixed'-banded (week 3) SSG round robin formats. Having been 'bio-banded' using either the 'bio-banding' condition 'A'(Khamis and Roche (1994)) or condition 'B' (Fransen et al. (2018)), players were allocated into teams consisting of four players in each team, resulting in six teams in total for both condition 'A' according to estimated adult stature attainment (EASA) (2 teams of 'early'-maturing [> 92.0 % EASA], 2 teams of 'circa' maturing [87.0 – 92.0% EASA], 2 teams of 'late'-maturing [< 87.0 % EASA]), condition 'B' (2 teams of 'early'-maturing [< -1.0 YPHV], 2 teams of 'circa' maturing [-1.0 – 0 YPHV], 2 teams of 'late'-maturing [>0.0 YPHV]) and condition C (6 teams of 'mixed' maturity). Teams were identified as either 'A' or 'B' where there are two teams representing the same maturity band. Each team then participated in a 'round-robin' SSG mini-league format (see Table 1).

In **Week 1**, after completing a standardised 15 minute warm up, each player was categorised according to the aforementioned Khamis and Roche (1994) method and contested five, four versus four SSGs (18.3 x 23 m pitch), lasting 5 min each (25 min total playing time) on an outdoor 3G surface during which players' physical, technical/tactical, psychological determinants were measured (Figure 1 [right]). As per previous validated and reliable methods (Fenner, Iga, & Unnithan, 2016), two (2 m × 1 m) goals with no identified goalkeepers were used. To provide greater opportunity for players to demonstrate tactical and creative match-play behaviours, goals were only permitted to be scored from a position in the attacking half of the pitch. To ensure match-fluency, a multi-ball system was used (i.e., balls were placed around the perimeter of the pitch) so that the game maintained a continuous nature. To prevent (sub)conscious coaching and selection bias from club staff, no verbal encouragement or feedback was allowed from coaches throughout the session. Only referee decisions and the score were provided to players during each SSG. Players scored *four* points for a win, *two* points for a draw and *zero* points for a loss respectively for each SSG, accompanied by an additional *one* point if their team scored (Fenner, Iga, & Unnithan, 2016). Each team received a minimum of five and maximum of 15 minutes of low intensity, active recovery between SSGs. During this time, players performed one of three standardised technical drills to maintain match-readiness and to reduce tedium. The sequence of SSGs was repeated one-week later (**Week 2**) using the Fransen et al. (2018) predictive equation to 'bio-band' players, and again in **Week 3** with all players having been randomly allocated to a team irrespective of maturity status to serve as the control measure.

Table 1. Schedule of fixtures for the small-sided game 'round-robin' mini league format.

Team category		Team category
'early' maturing (B)	*Versus*	'early' maturing (A)
'late' maturing (B)	*Versus*	'late' maturing (A)
On-time (A)	*Versus*	On-time (B)
'early' maturing (B)	*Versus*	'late' maturing (B)
'early' maturing (A)	*Versus*	On-time (B)
'late' maturing (A)	*Versus*	On-time (A)
On-time (B)	*Versus*	'early' maturing (B)
'early' maturing (A)	*Versus*	'late' maturing (A)
'late' maturing (B)	*Versus*	On-time (A)
'late' maturing (A)	*Versus*	On-time (B)
'early' maturing (A)	*Versus*	'late'-maturing (B)
'early' maturing (B)	*Versus*	On-time (A)
'late' maturing (B)	*Versus*	On-time (B)
'late' maturing (A)	*Versus*	'early' maturing (B)
On-time (b)	*Versus*	'early' maturing (A)

Note: The same order of fixtures was repeated for condition A, B and C.

General methods

Participants

Eighty highly trained 11 to 14-year-old male soccer players residing within two English and one Scottish professional soccer academies participated in the study. Using two separate anthropometric-based methods for predicting biological maturity status (Fransen et al., 2018; Khamis & Roche, 1994), 24 players identified as being either 'early'-maturing [< -1.0 YPHV; n = 8)], on-time maturing, 'circa' PHV [-1.0 – 0.0 YPHV; n = 8], 'late'-maturing [>0.0 YPHV; n = 8] or as 'early'-maturing [> 92.0% EASA; n = 8], 'circa' maturing [87.0 – 92.0% EASA; n = 8], 'late'-maturing [< 87.0 % EASA; n = 8] using percentages of estimated adult stature attainment (EASA), were selected for each trial, from the initial sample. Available players possessing the most extreme values for 'late' and 'early' maturing players were selected to participate, where as those closest to the median value of the cohort were selected for the 'on-time', transitioning 'bio-band'. In total, 72 UK academy soccer players participated in the 3-week study.

Maturity status

WEEK 1 – 'Bio-banding' condition 'A' (Khamis and Roche (1994)): The Khamis and Roche (1994) method was used to estimate maturity status from current decimal age, stature and body mass of the participant and mid-parent stature (average stature of biological parents), reporting a measurement error of 2.2 cm between actual and estimated adult stature in male athletes aged between 4 and 18 years. As with previous work (Cumming, Brown, et al., 2017), the present study collected self-reported stature of both biological parents and adjusted for over-estimation using equations based on measured and self-reported stature of US adults (Epstein, Valoski, Kalarchian, & McCurley, 1995). This method has been validated against criterion skeletal maturity methods (Malina, Chamorro, Serratosa, & Morate, 2007; Malina, Silva, Figueiredo, Carling, & Beunen, 2012) with an adjusted threshold of 87.0 to 92.0% of final estimated adult stature attainment (EASA) used to 'bio-band' players into their respective 'bio-banded' groupings, defined as: 'early'-maturing [> 90.1% EASA], 'circa' maturing [85.0 – 90.0% EASA], 'late'-maturing [< 84.9 % EASA]. This choice of banding were based on a previously published study (Cumming, Brown, et al., 2017) that stated these bandings represent a developmental phase which includes 'late' childhood and the initiation of the pubertal growth spurt. However, bandings in the present study were adjusted to permit adequate statistical sample power, resulting in the 'early' maturing band defined as > 92.0 % EASA, the 'circa' maturing band defined as 87.0 – 92.0% EASA and the 'late'-maturing band defined as < 87.0 % EASA.

WEEK 2 – 'Bio-banding' condition 'B' (Fransen et al. (2018)): Estimated YPHV (Mirwald et al., 2002) can be calculated using a cross-validated algorithm that uses somatic components (stature, seated height, and leg length) and decimal age, to an accuracy of ± 0.24 years (Mirwald et al., 2002). However, given the limitations associated with the Mirwald et al. (2002) maturity predictive equation (Deprez et al., 2014; Malina & Kozieł, 2014) the Fransen et al. (2018) predictive equation was elected for use within the present study. This equation was developed using an 'enhanced' predictive model based on the original work by Mirwald et al. (2002). The Fransen et al. (2018) method uses a predictive algorithm based on longitudinal (six years; cumulative number of observations = 4829; relative number of observation: n = 1-19 per player) 'normative' Belgian pre-post adolescent (aged 8-17 years) child soccer player data from various ethnic backgrounds, growth rates (and exclusion of estimated leg length) and uses the interactions between somatic components (stature and body-mass) and calendar age to determine the player's predicted APHV. Each player's maturity offset was determined by subtracting their decimal age in years from their predictive APHV to give the estimated YPHV. Similar to previous literature (Till & Jones, 2015), and for the purpose of the current study, the following thresholds were used to define YPHV categories: 'early'-maturing [< -1.0 YPHV], on-time maturing, 'circa' PHV [-1.0 – 0.0 YPHV], 'late'-maturing [>0.0 YPHV] to permit adequate statistical sample power.

WEEK 3 – Random allocation: Players who had competed in weeks 1 and 2 were randomly and independently assigned to 6 'mixed' maturity teams by a practitioner with no prior knowledge regarding each player's somatic characteristics. For the purpose of analysis, teams were aggregated in to three 'mixed' maturity bandings (i.e. team 1A and 1B were aggregated to form group A, team 2A and 2B were aggregated to form group B and team 3A and

3B were aggregated to form group C) to permit pairwise comparisons of anthropometric, age and maturity characteristics.

Anthropometric measurements

Following the International Society for the Advancement of Kinanthropometry (ISAK) recommendations (Stewart, Marfell-Jones, Olds, & Ridder, 2011), a semi-fixed, portable stadiometer (seca© 217,Chino, U.S.A) was used to measure player stature. Players' were required to place their shoeless feet together and heels touching the scale, while their head were positioned in the Frankfort plane to perform the stretch stature method. Duplicate measures of stature were recorded to an accuracy of 0.1 cm (Stewart et al., 2011). Following similar procedures, players' seated height was measured (seca© 217,Chino, U.S.A) while they were in a seated position on a standardised plinth with their hands resting on their thighs (Stewart et al., 2011). As with the measurement of stature, seated height was measured using the stretch stature method with estimated leg length recorded as stature minus seated height (Malina et al., 2004). In addition, player body mass (seca© robusta 813, Chino, U.S.A) was measured using previously outlined procedures with players wearing their normal training attire and without shoes (Stewart, 2002). If the measurements varied ≥ 0.4 cm or 0.4 kg, a third measure was taken, and the median value recorded. The interaction between stature, seated height (i.e. leg length), body mass and age were used to estimate player maturity status.

Physical Measures:

As displayer in figure 1 (centre), players were fitted with a Micro-Electro-Mechanical Sensors (MEMS) device (MEMS; MinimaxX S4, Catapult Innovations, Melbourne, Australia) containing a 10 Hz global positioning satellite (GPS) chip that was used to record player location and derivative time-motion data (i.e. total distance covered [m], metres per minute [$m.min^{-1}$], maximum running velocity [$km{\cdot}h^{-1}$], high speed running [HSR: >13 $km{\cdot}h^{-1}$] distance [m], number of accelerations [> 2 $m{\cdot}s^{-2}$] and decelerations [< 2 $m{\cdot}s^{-2}$] and total player load [AU], using arbitrary speed thresholds (Buchheit et al., 2010). In addition to GPS and MEMS metrics, mean and maximum heart rate ($beats{\cdot}min^{-1}$) was recorded (every 5 s; T31, Polar Electro Oy, Finland) using the same MEMS device. Manufacturer-derived heart rate exertion index (HREI) was used to calculate the internal training load. This method follows the same principles as Edwards (1994) utilising arbitrary exponential weighting factors. Players were also asked to provide a session rating of perceived exertion (s[RPE]) (Coutts, Reaburn, Murphy, Pine, & Impellizzeri, 2003) determined as the arbitrary rating of perceived exertion given by each player immediately after each SSG, multiplied by the duration (i.e. 5 minutes). To control for bias and coercion, each player gave their RPE independently using the Category Ratio 10 scale (Foster et al., 2001).

Technical/Tactical measures

<u>Recruitment staff measures</u> - The valid and reliable (Fenner, Iga, & Unnithan, 2016; Unnithan et al., 2012) Game Technical Scoring Chart (GTSC) is a tool that measures the perception of a coach or scout when they are identifying talented players or making a decision on whether to retain or release a player. Wearing coloured and numbered bibs, all players were evaluated using the GTSC comprised of 10 soccer elements that subsequently gave a score between 0 and 5. Each point described the players' performance using the following criteria: 1 – *poor*, 2 – *below average*, 3

– *average*, 4 – *very good* and 5 – *excellent*. The criteria in the GTSC were 'cover/support', 'communication', 'decision-making', 'passing', 'first touch', 'control', 'one versus one', 'shooting', 'assists' and 'marking' as defined by Fenner, Iga & Unnithan, (2016). Therefore, points accrued over five SSGs were aggregated and scored out of fifty. Thus, during a game, if a player was perceived by the coach to be a *poor* 'passer' of the ball during that SSG, then they were given a score of *1* in the 'passing' element. To determine the reliability of the GTSC for use within 'bio-banded' match-play, four to six different player selectors retrospectively scored the players using video footage of the SSG recorded using a 4K video-camera (SONY Handycam FDR-AX33 4K Ultra HD Camcorder) mounted on a telescopic video tower (Figure 1[left]: EndZone EVS25 telescopic video tower). Qualified (minimum FA Level II coaching) academy soccer practitioners independently watched the SSG footage and scored each player again using the GTSC.

Creative behaviours - The following creative components were assessed based on the individual technical actions recorded: a) fluency, considered as the ability to execute as many successful actions as possible; b) attempts, or any effort to perform different actions, but non-successful; and c) versatility, recognized as an ability to produce a diversity of actions, different from the standard movements, with success (Santos, Jiménez, Sampaio, & Leite, 2017). Accordingly, the successful actions were considered as fluency, while the unsuccessful different actions will be considered as attempts, and the versatility comprised of the successful different movement patterns (Santos et al., 2017). Tactical behaviours - The players' latitude and longitude coordinates will be processed using appropriate routines in Matlab® (MathWorks, Inc., Massachusetts, USA) to compute the spatial exploration index (SEI) (Gonçalves et al., 2017). The SEI is obtained for each player by calculating his mean pitch position, computing the distance from each positioning time-series to the mean position and, finally, computing the mean value from all the obtained distances. The SEI is a candidate variable to provide information about the players' spatial exploration where higher values might be associated with players who are covering more space during the games.

Objective technical measures:

Construct validity of each 'bio-banding' method was examined by F.A. qualified (F.A. Level II coaching) coaches (n = 6) who assessed players using the GTSC via video feedback (Figure 1), in comparison to a coach assessing the same players live in the field during five SSGs.

Figure 1. EndZone EVS25 telescopic video tower funded by the UEFA Research Programme (left), GPS device and heart rate monitors (centre) and ongoing SSG round robin (right).

Psychological measures:

Using a modified version of a F.A. template for player evaluation, coaching staff (n = ≥ 6) were asked to evaluate players on the four psychological attributes (‘confidence’, ‘competitiveness’, ‘X-Factor’, ‘positive attitude’) that youth coaches and recruiters perceive as most important when identifying players for talent development programmes (see Larkin & O’Connor, 2017). Coaches were provided with an operational definition for each of these attributes (Table 2). As with the GTSC, these attributes were given a score between 0 and 5. Each point describes the players’ performance during live match-play using the following criteria: 1 – *poor*, 2 – *below average*, 3 – *average*, 4 – *very good* and 5 – *excellent* and the points accrued over 5 SSGs for psychological measures were aggregated to represent their overall score. Coaches then retrospectively reviewed 4K video-camera (SONY Handycam FDR-AX33 4K Ultra HD Camcorder) footage of the SSGs and once again scored participants on the psychological attributes (an estimate of intra-observer reliability).

Table 2. Psychological characteristics and associated operational definitions used by coaches to score players during small sided game match-play

Attribute	Operational definition
Positive Attitude	Positive reaction after a mistake; how they handle disappointments; resilience; ability to overcome adversities; not wanting to give up
Confidence	Brave; wants to be involved; wants the ball; wants the ball under pressure; wants to get into positions to receive the ball all of the time; have the guts to try and fail and do something different;
Competitive	Resolve; desire; hunger; strong willed; determination; intense; fighting approach towards wanting the ball; winning mentality.
X-Factor	Unpredictable, creative, thinks outside of the box.

Hypotheses

1) Matched/’mixed’ ‘bio-banding’ will reduce the magnitude of difference in technical behaviours between players during SSG match-play. However, these measures for ‘early’ maturing players will be greater when matched against their later maturing counterparts.
2) Matched/’mixed’ ‘bio-banding’ will reduce the magnitude of difference for tactical behaviours between players during SSG match-play. However, these measures for ‘early’ maturing players will be greater when matched against their later maturing counterparts.
3) Matched/’mixed’ ‘bio-banding’ will reduce the magnitude of difference for physical measures between players during SSG match-play. However, these measures for later maturing players will be greater when matched against their earlier maturing counterparts.
4) Matched/’mixed’ ‘bio-banding’ will reduce the magnitude of difference for psychological behaviours between players during SSG match-play. However, these measures for later maturing players will be greater when matched against their earlier maturing counterparts.

5) Matched/'mixed' 'bio-banding' will reduce the magnitude of difference of internal (heart rate and sRPE) and external (GPS metrics i.e. player load etc.) measures during SSG match-play. However, these measures for 'later' maturing players will be greater when matched against their earlier maturing counterparts.

Preliminary statistical analysis

Linear marginal models and pairwise comparisons, with Sidak-adjusted P values, were conducted to determine differences in physical, technical/tactical, and psychological player characteristics according to either Khamis and Roche (1994), Fransen et al. (2018) and 'mixed' maturity status bandings methods according to 'early', 'circa' and 'late' maturity band categories. Statistical significance for all null hypothesis tests was set at $P \leq 0.05$. Values are reported as the estimated marginal means and associated 95% confidence intervals, accompanied by Cohen's d effect size, with d evaluated according to the following scale of magnitudes: <0.2 *trivial*, 0.2-0.59 *small*, 0.6-1.19 *moderate*, 1.2-1.99 *large* and ≥2.0 *very large*) (Hopkins, Marshall, Batterham, & Hanin, 2009). All statistical assumptions were examined using standard graphical methods (Grafen, 2002) and analyses were completed using IBM SPSS Statistics for windows (release 22; SPSS Inc., Chicago, IL, USA).

Ethical considerations and control measures

There was no added risk to players than that was present within each soccer academy's typical in-season training cycles. Participating players did not complete any additional activities or interventions beyond what they would normally have done during their daily training activity. All activities completed by the players were dictated by the club within the pre-existing agreements between club, player and parent/guardian. That said, parental/guardian informed consent was obtained prior to each player's participation. Each player and parent/guardian was informed that they would be free to withdraw from the study at any time and if they chose to do so the principle investigator would facilitate their withdrawal. All players and parents/guardians were informed that they would not be required to give a reason for their withdrawal. In addition to this, any personal information that players and parents/guardians provided would be destroyed or deleted as soon as possible after their withdrawal. After completion of the study, each player parent/guardian was given the opportunity to withdraw any personal information and data by contacting the principle investigator. Only the primary researcher, the player's principle coach and immediate research collaborators had knowledge of participant information in its raw form. Data were coded to maintain anonymity and confidentiality thereon in. All player data were temporarily uploaded to a secure, username and password encrypted storage server (Box), where it was removed to a secure and password encrypted external storage digital hard drive. As part of the study, players were asked to participate in filmed SSG match-play scenarios. Such practice is typical for soccer academies to engage in. However, risks associated with this were assessed and suitable control measures were approved by the local ethics application approval system. All premises used within the study were approved by each individual soccer academy and all equipment was checked prior to use by academic and soccer academy staff. All participating staff were Disclosure and Barring Service (DBS) checked and approved.

Section 6: Preliminary main research findings

Anthropometric measures

In both the Khamis & Roche (1994) and Fransen et al. (2018) 'bio-banded' methods, the 'early' banded group had a mean age of 14.2 (14.1 to 14.4) and 14.4 (14.3 to 14.5 y) years respectively and were shown to be significantly (P = ≤ 0.001) older (mean difference [MD] = 1.0 and 1.7 y), while displaying a *moderate* to *very large* effect size (ES) (ES = 0.86 to 2.93) in comparison to the 'circa' and later maturing banded groups. This trend continued for estimated maturity status for both the Khamis and Roche (1994) ($P \leq 0.001$; MD = 4.2 to 8.1 EASA%; ES = 2.1 to 4.0, *very large*) and Fransen et al. (2018) ($P \leq 0.001$; MD = 1.1 to 2.2 YPHV; ES = 2.0 to 4.2, *very large*). Intuitively supported by similar findings for stature ($P \leq 0.001$; MD = 10.1 to 23.5 cm; ES = 1.67 to 4.04, *large* to *very large*) and body-mass ($P \leq 0.001$); MD = 8.4 to 17.4 kg; ES = 1.53 to 3.33, *large* to *very large*) for players, across all SSGs. Such differences dissipated during the 'mixed' maturity banded sessions for EASA (P = 0.724 to 0.992; MD = 0.1 to 0.5; ES = 0.1 to 0.2, *trivial*), YPHV (P = 0.907 to 0.996; MD = -0.06 to 0.09 YPHV; ES = 0.0 to 0.1, *trivial*), stature (P = 0.255 to 0.946); MD = 0.5 to 2.0 cm; ES = 0.07 to 0.17, *trivial* to *small*) and body-mass (P = 0.51 to 0.955; MD = 0.5 to 3.1 kg; ES = 0.07 to 0.40, *trivial* to *small*) respectively.

Physical

As displayed in Table 3, according to the Fransen et al. (2018) method, 'circa' banded players covered significantly ($P \leq 0.001$; ES = 0.52 to 0.56, *small*) less total distance (MD = -47.2 to -50.9 m) and performed significantly ($P \leq$ 0.001 to 0.019; ES = 0.29 to 0.61, *small* to *moderate*) lower (MD = -0.6 to -0.3 km·h^{-1}) maximum velocities during SSGs in comparison to 'early' and 'late' banded players. Differences between 'circa' versus 'early' and 'late' banded players dissipated for total distance covered (P = 0.213; MD = 21.5 m; ES = 0.23, *small*) during the 'mixed' maturity banded condition. However, these differences remained for maximum velocity (P = 0.002; MD = 0.4 km·h^{-1}; ES = 0.45, *small*). During both methods of maturity status 'bio-banding', total player load increased for both 'circa' and 'late' maturity bandings, culminating in mainly *small* (ES = 0.22 to 0.53) and significant ($P \leq$ 0.001 to 0.035) increases for the 'late' banded players in comparison to 'circa' and 'early' banded players. Differences in total player load remained for both maturity estimations methods during 'mixed' banded SSGs (P = 0.001 to 0.046; MD = 3.0 to 4.3 AU; ES = 0.31 to 0.47, *small*). As with total player load, sRPE demonstrated a similar trend whereby the 'early' banded players displayed a significantly ($P \leq$ 0.001 to 0.004) lower mean sRPE (MD = -4.2 to -8.9) for each SSG in comparison to the 'circa' (ES = 0.43 to 0.67, *moderate*) and 'late' (ES = 0.70 to 1.41, *moderate* to *large*) maturing bandings for both the Khamis and Roche (1994) and Fransen et al. (2018) methods. Such differences in sRPE remained between the 'late' and 'early'-banded players ($P \leq 0.001$; MD = 2.3 to 2.5 AU; ES = 0.54 to 0.57, *small*) during the 'mixed' maturity banded SSGs.

Technical/Tactical

As shown in Table 4, few between-maturity 'bio-band' differences existed for many of the technical/tactical attributes. Only coach's scores for 'circa' banded players' ability to 'cover' during the Fransen et al. (2018) method was shown to have had a *small* (ES = 0.21) decrease (MD = -0.1) in comparison to players within the 'late' banded group, reaching a level of significance (*P* = 0.032; MD = -0.2; ES = 0.33) for the 'early' banding. Such differences were absent (*P* = 0.054 to 0.921, MD = -0.2 to 0.1; ES = 0.07 to 0.32, *trivial* to *small*) during 'mixed' maturity banded SSGs. Coaches also demonstrated a *small* (ES = 0.34 to 0.44) enhancement for 'first touch' scores of 'late' banded players in comparison to 'early' and 'circa' players. These became *trivial* (ES = 0.10) during 'mixed' maturity banded SSGs.

Psychological

During the Khamis and Roche (1994) method of maturity status 'bio-banding', coaches scored the 'late' banded group significantly higher for evidence of 'confidence' (*P* = 0.08; MD = 0.3; ES = 0.39, *small*), 'competitiveness' (*P* = 0.03, MD = 0.4; ES = 1.1, *moderate*) and 'positive attitude' (P ≤ 0.001; MD = 0.5, ES = 0.65, moderate). With both methods of banding showing a *small* (ES = 0.30 to 0.35) enhancement for 'X-factor' within the 'late' maturing banded grouping (reaching significance [*P* = 0.038] within the Fransen et al. (2018) method) in comparison to their 'early' and 'circa' counterparts (See Table 5). However, during the 'mixed' maturity banded SSGs such differences disappeared for 'confidence' (*P* = 0.223 to 0.769; MD = 0.1 to 0.2; ES = 0.12 to 0.29 , *trivial* to *small*), 'competitiveness' (*P* = 0.954 to 0.474; MD = 0.1 to 0.5; ES = 0.06 to 0.17, *trivial*), 'positive attitude' (*P* = 0.072 to 0.249; MD = 0.1 to 0.2; ES = 0.22 to 0.29, *small*) and 'X-Factor' (P = 0.960 to 1.000, MD = 0.0 to 0.1; ES = 0.01 to 0.02, *trivial*) according to both methods of estimating maturity status.

Table 3. Estimated marginal mean (95% confidence intervals) somatic characteristics and associated magnitude of effect sizes of academy soccer players during maturity sta bio-banded (early, circa and late) small-sided games using the Khamis Roche and Fransen et al maturity estimation methods.

		Khamis Roche			Fransen et al		
Variable	***N***	**Early**	**Circa**	**Late**	**Early**	**Circa**	**Late**
Age (years)		14.2 (14.1 to 14.4) **Circa*^{M}, Late*^{VL}**	13.5 (13.4 to 13.6) **Early*^{M}, Late*^{M}**	12.8 (12.7 to 12.9) **Early*^{VL}, Circa*^{M}**	14.4 (14.3 to 14.5) **Circa*^{L}, Late*^{VL}**	13.4 (13.3 to 13.5) **Early*^{L}, Late*^{M}**	12.7 (12.6 to 12.8 **Early*^{VL}, Circa***
Maturity status		94.0 (93.6 to 94.4) **Circa*^{VL}, Late*^{VL}**	89.6 (89.3 to 90.0) **Early*^{VL}, Late***	85.9 (85.5 to 86.2) **Early*, Circa*^{L}**	0.83 (0.73 to 0.93) **Circa*^{VL}, Late*^{VL}**	-0.34 (-0.44 to -0.23) **Early*^{VL}, Late*^{VL}**	-1.39 (-1.50 to -1.2 **Early*^{VL}, Circa***
Stature (cm)		173.0 (169.6 to 176.5) **Circa*^{M}, Late*^{L}**	161.1 (157.7 to 164.5) **Early*^{M}, Late*^{M}**	149.5 (146.1 to 152.9) **Early*^{L}, Circa*^{M}**	171.7 (170.6 to 172.8) **Circa*^{L}, Late*^{VL}**	161.5 (160.4 to 162.6) **Early*^{L}, Late*^{M}**	154.9 (153.8 to 156 **Early*^{VL}, Circa***
Body mass (Kg)		58.2 (57.0 to 59.4) **Circa*^{L}, Late*^{VL}**	48.1 (46.9 to 49.3) **Early*^{L}, Late*^{M}**	43.7 (42.5 to 44.9) **Early*^{VL}, Circa*^{M}**	57.8 (56.4 to 59.2) **Circa*^{L}, Late*^{VL}**	49.4 (48.0 to50.8) **Early*^{L}, Late*^{L}**	40.3 (38.9 to 41.7 **Early*^{VL}, Circa***

Bold font* Denotes statistically significant difference for subscripted variables ($P \leq 0.05$); Observed effect magnitudes are denoted as trivial (^{T}), small (^{S}), moderate (^{M}), large (^{L}), very large (^{VL}). – No of small-sided game match files. Maturity status: Khamis Roche method - Estimated adult stature attainment (EASA) to categorise early-maturing (> 96.1% EASA), on-time maturing (85.0 96.0% EASA) and late-maturing (< 84.9 % EASA) players. Fransen et al 2018 method - Estimated number of years to peak height velocity (PHV) to categories early-maturing (< -0.49 YPHV), time maturing (-0.50 – 0.50 YPHV) and late-maturing (>0.51 YPHV) players.

Table 4. Estimated marginal mean (95% confidence intervals) micro-electromechanical systems (MEMS) device, subjective key performance metrics and associated magnitude effect sizes of academy soccer players during maturity status bio-banded (early, circa and late) small-sided games using the Khamis Roche and Fransen et al maturity estimat methods.

Variable	*N*	Khamis Roche method			Fransen et al method		
		Early	**Circa**	**Late**	**Early**	**Circa**	**Late**
Total distance covered (m)		451.9 (439.4 to 464.3) Circa^{T}, Late^{S}	455.6 (443.2 to 467.9) Early^{T}, Late^{T}	467.9 (455.3 to 480.1) Early^{S}, Circa^{T}	450.0 (431.6 to 468.4) **Circa*** ^{S}, Late^{T}	402.7 (385.7 to 419.8) **Early*** ^{S}, **Late*** ^{S}	453.7 (437.3 to 470 Early^{T}, **Circa*** ^{S}
Metres per minute ($m \cdot min^{-1}$)		89.3 (86.8 to 91.7) Circa^{T}, Late^{S}	90.6 (88.2 to 93.0) Early^{T}, Late^{T}	92.8 (90.4 to 95.7) Early^{S}, Circa^{T}	89.3 (85.6 to 92.9) Circa^{S}, Late^{S}	79.9 (76.5 to 83.3) Early^{S}, Late^{T}	90.1 (86.9 to 93.4 Early^{S}, Circa^{T}
Max velocity ($km \cdot h^{-1}$)		5.0 (4.9 to 51) Circa^{T}, Late^{T}	4.9 (4.8 to 5.0) Early^{T}, Late^{T}	4.9 (4.8 to 5.0) Early^{T}, Circa^{T}	5.1 (4.9 to 5.3) **Circa*** ^{M}, Late^{S}	4.5 (4.3 to 4.7) **Early*** ^{M}, **Late*** ^{S}	4.8 (4.7 to 5.0) Early^{S} **Circa*** ^{S}
HSR (>13$km \cdot h^{-1}$) distance (m)		33.1 (29.0 to 37.1) Circa^{T}, Late^{T}	34.2 (30.2 to 38.2) Early^{T}, Late^{T}	34.0 (30.7 to 38.1) Early^{T}, Circa^{T}	30.7 (26.7 to 34.8) Circa^{T}, Late^{T}	27.0 (23.8 to 32.0) Early^{T}, Late^{T}	32.0 (27.9 to 36.0 **Early*** ^{T}, Circa^{T}
Accels frequency (> 2 $m \cdot s^{-2}$)		0.8 (0.6 to 1.0) Circa^{S}, Late^{S}	0.7 (0.5 to 0.9) Early^{S}, Late^{T}	0.6 (0.4 to 0.7) Early^{S}, Circa^{T}	0.8 (0.6 to 1.0 Circa^{T}, **Late*** ^{T}	0.5 (0.4 to 0.7) Early^{T}, Late^{T}	0.5 (0.3 to 0.7) Early^{T}, Circa^{T}
Decels frequency (< 2 $m \cdot s^{-2}$)		0.3 (0.2 to 0.4) Circa^{T}, Late^{T}	0.3 (0.2 to 0.4) Early^{T}, Late^{S}	0.2 (0.1 to 0.3) Early^{T}, Circa^{S}	0.2 (0.1 to 0.3) Circa^{T}, Late^{T}	0.2 (0.1 to 0.3) Early^{T}, Late^{T}	0.2 (0.1 to 0.3) Early^{T}, Circa^{T}
Total Player Load (AU)		55.6 (53.8 to 57.4) Circa^{S}, **Late*** ^{S}	57.8 (56.0 to 59.6) Early^{S}, Late^{S}	60.8 (59.0 to 62.6) **Early*** ^{S}, Circa^{S}	54.9 (52.9 to 57.0) **Circa*** ^{S}, **Late*** ^{S}	58.5 (56.6 to 60.4) **Early*** ^{S}, Late^{T}	59.8 (58.0 to 61.6 **Early*** ^{S}, Circa^{T}
Mean heart rate ($b \cdot min^{-1}$)		151 (128 to 147) Circa^{S}, Late^{S}	139 (130 to 149) Early^{S}, Late^{T}	137 (128 to 147) Early^{S}, Circa^{T}	157 (147 to 167) Circa^{S}, Late^{S}	142 (133 to 151) Early^{S}, Late^{T}	143 (134 to 152) Early^{S}, Circa^{T}
Session RPE (AU)		18.0 (16.9 to 19.2) **Circa*** ^{M}, **Late*** ^{L}	22.3 (21.1 to 23.4) **Early*** ^{M}, **Late*** ^{M}	18.0 (16.9 to 19.2) **Early*** ^{M}, **Circa*** ^{M}	21.0 (20.0 to 22.1) **Circa*** ^{S}, **Late*** ^{M}	23.5 (22.4 to 24.5) **Early*** ^{S}, Late^{S}	15.1 (24.0 to 26.1 **Early*** ^{M}, Circa^{S}

Bold font* Denotes statistically significant difference for subscripted variables ($P \leq 0.05$); Observed effect magnitudes are denoted as trivial (T), small (^{S}), moderate (^{M}), large (^{L}), very large (^{VL}) HSR – High speed running; Accels – Accelerations; Decels – Decelerations; RPE – Rating of perceived exertion; AU – Arbitrary units. n – No of small sided game match files. Maturity status: Khamis Roche method - Estimated adult stature attainment (EASA) to categorise early-maturing (> 96.1% EASA), on-time maturing (85.0 – 96.0% EASA) and late-maturing (< 84.9 % EASA) players. Fransen et al 2018 method - Estimated number of years to peak height velocity (PHV) to categories early-maturing (< -0.49 YPHV), on-time maturing (-0.50 – 0.50 YPHV) and late-maturing (>0.51 YPHV) players.

Table 5. Estimated marginal mean (95% confidence intervals) perceived importance placed by academy talent practitioners (n = 12) on Game Technical Scoring Cha performance metrics and associated magnitude of effect sizes during maturity status bio-banded (early, circa and late) small-sided games using the Khamis Roche and Franse et al maturity estimation methods.

		Khamis Roche			Fransen et al		
Variable	***N***	**Early**	**Circa**	**Late**	**Early**	**Circa**	**Late**
Assist **(AU)**		2.8 (2.4 to 3.2) Circa^{T}, Late^{T}	2.9 (2.5 to 3.3) Early^{T}, Late^{S}	2.7 (2.3 to 3.0) Early^{T}, Circa^{S}	3.2 (2.8 to 3.6) Circa^{S}, Late^{T}	3.0 (2.6 to 3.3) Early^{S}, Late^{S}	3.0 (2.6 to 3.3) Early^{T}, Circa^{S}
Control **(AU)**		2.8 (2.6 to 2.9) Circa^{T}, Late^{T}	2.8 (2.6 to 2.9) Early^{T}, Late^{T}	2.8 (2.6 to 2.9) Early^{T}, Circa^{T}	2.8 (2.7 to 3.0) Circa^{S}, Late^{T}	2.5 (2.4 to 2.7) Early^{S}, Late^{S}	2.8 (2.7 to 3.0) Early^{T}, Circa^{S}
Communication **(AU)**		2.6 (2.5 to 2.7) Circa^{T}, Late^{S}	2.6 (2.4 to 2.7) Early^{T}, Late^{T}	2.4 (2.3 to 2.6) Early^{S}, Circa^{T}	2.5 (2.4 to 2.6) Circa^{T}, Late^{S}	2.4 (2.2 to 2.5) Early^{T}, Late^{T}	2.3 (2.2 to 2.5) Early^{S}, Circa^{T}
Cover **(AU)**		2.8 (2.7 to 2.9) Circa^{T}, Late^{T}	2.8 (2.7 to 2.9) Early^{T}, Late^{T}	2.7 (2.6 to 2.8) Early^{T}, Circa^{T}	2.8 (2.6 to 2.9) **Circa***^{S}, Late^{T}	2.5 (2.4 to 2.6) **Early***^{S}, Late^{S}	2.7 (2.5 to 2.8) Early^{T}, Circa^{S}
Decision making **(AU)**		2.7 (2.6 to 2.8) Circa^{T}, Late^{T}	2.8 (2.6 to 2.9) Early^{T}, Late^{T}	2.7 (2.5 to 2.8) Early^{T}, Circa^{T}	2.6 (2.5 to 2.8) Circa^{T}, Late^{T}	2.5 (2.4 to 2.7) Early^{T}, Late^{T}	2.7 (2.5 to 2.8) Early^{T}, Circa^{T}
Marking **(AU)**		2.8 (2.6 to 2.9) Circa^{T}, Late^{S}	2.6 (2.5 to 2.8) Early^{T}, Late^{T}	2.6 (2.4 to 2.7) Early^{S}, Circa^{T}	2.5 (2.4 to 2.6) Circa^{T}, Late^{T}	2.4 (2.3 to 2.6) Early^{T}, Late^{T}	2.5 (2.4 to 2.6) Early^{T}, Circa^{T}
Passing **(AU)**		2.9 (2.7 to 3.0) Circa^{T}, Late^{T}	2.9 (2.7 to 3.0) Early^{T}, Late^{T}	2.8 (2.7 to 2.9) Early^{T}, Circa^{T}	2.8 (2.6 to 2.9) Circa^{T}, Late^{T}	2.8 (2.7 to 2.9) Early^{T}, Late^{T}	2.9 (2.8 to 3.0) Early^{T}, Circa^{T}
Shooting **(AU)**		2.9 (2.5 to 3.0) Circa^{T}, Late^{T}	2.8 (2.6 to 3.0) Early^{T}, Late^{T}	2.8 (2.5 to 3.0) Early^{T}, Circa^{T}	2.7 (2.5 to 3.0) Circa^{S}, Late^{T}	2.9 (2.7 to 3.1) Early^{S}, Late^{S}	2.7 (2.4 to 2.9) Early^{T}, Circa^{S}
First touch **(AU)**		2.9 (2.8 to 3.1) Circa^{T}, Late^{T}	2.9 (2.8 to 3.1) Early^{T}, Late^{T}	2.9 (2.8 to 3.0) Early^{T}, Circa^{T}	2.8 (2.7 to 3.0) Circa, **Late***	2.8 (2.6 to 2.9) Early, **Late***	3.1 (2.9 to 3.2) **Early*, Circa***
1 Vs 1 situations **(AU)**		2.7 (2.6 to 2.9) Circa^{T}, Late^{T}	2.8 (2.6 to 2.9) Early^{T}, Late^{T}	2.7 (2.5 to 2.8) Early^{T}, Circa^{T}	2.7 (2.6 to 2.9) Circa^{T}, Late^{S}	2.5 (2.4 to 2.7) Early^{T}, Late^{S}	2.6 (2.5 to 2.8) Early^{S}, Circa^{S}

Bold font* Denotes statistically significant difference for subscripted variables ($P \leq 0.05$); Observed effect magnitudes are denoted as trivial (^{T}) small (^{S}), moderate (^{M}), large (^{L}), very large (^{VL} AU – Arbitrary units. n – No of small sided game match files. Maturity status: Khamis Roche method - Estimated adult stature attainment (EASA) to categorise early-maturing (> 96.1% EASA), on-time maturing (85.0 – 96.0% EASA) and late-maturing (< 84.9 % EASA) players. Fransen et al 2018 method - Estimated number of years to peak height velocity (PHV) to categories early-maturing (< -0.49 YPHV), on-time maturing (-0.50 – 0.50 YPHV) and late-maturing (>0.51 YPHV) players.

Section 7: Preliminary discussion

The aim of the present study was to examine the effect of maturity-status ‘bio-banding’ on important aspects of a multi-disciplinary approach to talent identification. This was achieved by assessing, from a multi-disciplinary perspective, the effect of two ‘bio-banding’ strategies (Fransen et al., 2018; Khamis & Roche, 1994) on tactical, technical, psychological and physical performance variables associated with talent (de)selection of young soccer players during small-sided games (SSG) match-play. We specifically focused our analysis on 11 to 14-year-old male academy soccer players, and attempted to identify differences between either players who were banded as of ‘early’, ‘circa’ or ‘late’ maturity status.

The key findings were as follows. First, during the Fransen et al (2018) condition, ‘circa’ players covered less total distance resulting in a *small* difference compared to ‘early’ and ‘late’-banded players ($P \leq 0.001$; ES = 0.52 to 0.56). The maximum velocity for ‘circa’ players was also lower resulting in a *small* to *moderate* difference compared to ‘early’ and ‘late’-banded players ($P \leq 0.001$ to 0.019; ES = 0.29 to 0.61). Second, during both methods of maturity status ‘bio-banding’, total player load increased for both ‘circa’ and ‘late’ maturity bandings, resulting in *small* ($P \leq 0.001$ to 0.035; ES = 0.22 to 0.53) increases in total player load for the ‘late’ banded players in comparison to ‘circa’ and ‘early’ banded players, which remained for both maturity estimations methods during ‘mixed’ banded SSGs ($P = 0.001$ to 0.046; ES = 0.31 to 0.47, *small*). Third, the ‘early’ banded group of players reported a *moderately* lower mean sRPE for SSG match-play in comparison to the ‘circa’ ($P \leq 0.001$ to 0.004; ES = 0.43 to 0.67) and a *moderately* to *largely* lower mean compared to ‘late’ (ES = 0.70 to 1.41) maturing bandings for both the Khamis and Roche (1994) and Fransen et al (2018) methods. These differences remained between the ‘late’ and ‘early’ banded players ($P \leq 0.001$; ES = 0.54 to 0.57, *small*) during the ‘mixed’ maturity banded SSGs. Fourth, few between-maturity ‘bio-band’ differences existed for practitioner scoring for many of the technical/tactical attributes. Any *small* differences that were revealed during maturity ‘bio-banded’ sessions were either substantially reduced or dissipated during the ‘mixed’ banded condition. Fifth, observing coaches scored the ‘late’ banded group higher for evidence of ‘confidence’ ($P = 0.08$; ES = 0.39, *small*), ‘competitiveness’ ($P = 0.03$; ES = 1.1, *moderate*) and ‘positive attitude’ ($P \leq 0.001$; ES = 0.65, *moderate*), with both methods of ‘bio-banding’ showing a *small* (ES = 0.30 to 0.35) enhancement for ‘X-factor’ within the ‘late’ banded group in comparison to their ‘early’ and ‘circa’ counterparts.

Findings here have for the first time demonstrated evidence to suggest differences in match-play performance characteristics likely exist when assessing players from a multi-disciplinary perspective according to their maturity status. When banded using the Fransen et al. (2018) method, players who were deemed as ‘circa’ PHV (-0.50 – 0.50 YPHV) completed less total distance (MD = -47.2 to -50.9 m), while performing slower (MD = -0.6 to -0.3 $km.h^{-1}$) maximum running velocities in comparison to their ‘early’ and ‘late’ banded counterparts. Although not originally hypothesized, this finding might be indicative that match-play between ‘early’ and ‘late’ banded players is equally (as opposed to favoring early maturing players) more expansive and frantic in comparison to SSGs involving the ‘circa’ banded players. Although our match-fluency and relative player positioning analysis is ongoing, such an assertion is intuitive given that ‘early’ maturing players, who are often beneficiaries of transient, maturity-related enhancements in stature tend to characterize key defensive roles (such as central defense), while later maturing, smaller players likely occupy key attacking roles (such as lateral midfielders and attackers) (Towlson et al., 2017). Therefore, it is possible that the enhanced mean difference in maturity status and stature between the 'late' and 'early' bandings within the present study likely polarized these bandings. As a result, the 'early' banded teams largely comprised of defensively minded players, while the 'late' banded teams consisted of attacking players. This ultimately led to more extensive match-play and resulted in greater total distances and higher maximum velocities performed by 'early' and 'late' banded players in comparison to SSGs that featured 'circa' banded players. This finding is of relevance given that match-running capacity is likely a function of age and playing position (with playing position having a greater impact than age), with older more mature players generally covering greater distances at high-intensities (Buchheit et al., 2010). Although such findings were not revealed when employing the Khamis and Roche (1994) method for 'bio banding', findings here do suggest that playing position should be considered when banding players according to the Fransen et al. (2018) maturity status method for the purpose of talent identification. However, until our analysis is complete, findings here should be considered with some caution.

Micromechanical electrical system (MEMS) devices that contain GPS and high-resolution triaxial accelerometers capable of performing vector-magnitude algorithms to determine the amount of accumulated external load endured by an athlete across all three planes (X [horizontal], Y [vertical], Z [forward/back]) of motion (commonly referred to as player load), permits practitioners to quantify the mechanical stressors placed on athletes during training and match-play (Barrett, Midgley, & Lovell, 2014). Arbitrary player load is derived from three-dimensional measures of the instantaneous rate of acceleration and has been validated against criterion measures of internal (RPE and heart rate) and external (total distances covered) measures of load (Aughey, 2011; Drust, Atkinson, & Reilly, 2007; Mooney, Cormack, O'brien, Morgan, & McGuigan, 2013). However, despite only *trivial* to *small* differences in external (total distance covered, meters per minute, maximum velocity, high speed running distance, number of accelerations and decelerations) and internal (max and mean heart rate) loads between 'early' and 'late' banded players for both the Khamis and Roche (1994) and Fransen et al. (2018) methods within the present study, total player load increased for the 'late' maturing banded players. This resulted in *small* ($P \leq 0.001$ to 0.035; ES = 0.22 to 0.53) increases in total player load for the 'late' banded players in comparison to 'circa' and 'early' banded players, which remained for both maturity estimations methods during 'mixed' banded SSG's ($P = 0.001$to 0.046; ES = 0.31 to 0.47, *small*). Although this finding might seem somewhat counterintuitive, it has been suggested that tri-axial accelerometry has the sensitivity to detect changes within an individual's movement mechanics, typically owing to fatigue (Mooney et al., 2013). Although only *small* differences in mean heart rate were apparent between 'late' and 'early' banded players within the present study, 'early' banded players did reveal a lower mean sRPE for SSG match-play in comparison to the 'circa' ($P \leq 0.001$ to 0.004; ES = 0.43 to 0.67, *moderate*) and 'late' (ES = 0.70 to 1.41, *moderate* to *large*) banded players for both the Khamis and Roche (1994) and Fransen et al (2018) methods. This result might confirm our hypothesis that 'matched'/'mixed' 'bio-banding' will reduce the magnitude of difference of internal load measures during SSG match-play. That said, 'late'-banded players showed little differences in internal load in the form of mean heart rate in comparison to the earlier banded groups. This raises the question of whether 'late'-banded players did in fact perceive SSG match-play as more physically intense and fatiguing or were simply unable to separate the perception of physical effort from technical and psychological demands of each SSG. While the influence of fatigue theory is appealing to explain the between-band differences in player load, it has been suggested that when an athlete is in a state of neuromuscular fatigue vertical loading is likely reduced due to vertical 'stiffness' or a reduction in rapid changes in running acceleration/deceleration. This is turn likely elicits a possible reduction (rather than increase) in movement mechanics and consequently reduces player load. Therefore, this theory perhaps offers little explanation for the increase in player load for 'late' banded players in comparison to their 'early' banded counterparts.

With this in mind, it is reasonable to suggest that the increase in player load for 'late' banded players is a result of adolescent awkwardness (Malina et al., 2004; Philippaerts et al., 2006; Quatman-Yates, Quatman, Meszaros, Paterno, & Hewett, 2012). This refers to the tendency for the extremities (i.e. legs and arms) of the skeletal system to undergo periods of accelerated growth (typically between 10.7 to 15.2 y [-3.2 to 0.8 YPHV]; See Towlson et al. (2018)) while the associated musculature develops at a slower rate (Malina et al., 2004). Consequently, this can lead to a transient decline in a young players movement mechanics and indeed performance due to the temporary disturbance in sensorimotor capacity (Ryan et al. 2018). Ryan et al. (2018) demonstrated that although 'pre' and 'circa' maturity banded UK adolescent academy soccer players achieved lower functional movement scores than 'post' PHV banded players, 'early' and 'circa' banded players showed little difference in movement quality between each other. This suggests that the development of movement quality is perhaps nonlinear (Ryan et al., 2018), and related to adolescent awkwardness. Given that Ryan et al. (2018) demonstrated that the functional movement scores of 130 UK academy soccer players (age 13.8 ± 2.9 y) were related to 10 m running acceleration (r = -0.32 [-0.47 to -0.16]*, possibly moderate*) and lower limb power (r = 0.40 [0.25 to 0.54], *likely moderate*), it seems plausible that a decline in functional movement quality would likely impinge on running mechanics and efficiency, which in turn could elicit greater loading patterns across lateral planes of motion (in addition to vertical and forward planes) of movement and subsequently increase total player load accrued by 'late' banded players. Although we cannot support or refute this theory at present, it is anticipated that our ongoing analysis will further explore the distribution of player load across all three planes of motion in an attempt to offer further explanation for an increase in PL within 'late' banded academy players. Therefore, the present study has demonstrated plausible evidence to accept our hypothesis that 'mixed' 'bio-banding' will reduce the magnitude of difference for many physical measures between players during SSG match-play. However, between maturity differences findings in player load seemingly manifest independent of maturity status 'bio-banding' and therefore individual player load management strategies should be considered. That said, the present study has also demonstrated strong evidence to accept our hypothesis that 'bio-banding' will reduce the magnitude of difference of internal (sRPE) measures during SSG match-play and that these measures for 'later' maturing players will be greater when matched against their earlier maturing counterparts.

Although maturity status 'bio-banding' demonstrated some between-banding differences to be evident for physical qualities, players technical/tactical attributes mean score determined by coaches using the Game Technical Scoring Chart (Fenner et al., 2016) remained unchanged across each of the three banding conditions. With any *small* differences for players' perceived ability to 'cover' and 'first touch' revealed during maturity-banded sessions being substantially reduced or dissipated during the 'mixed' banded condition. Such findings are somewhat expected at this stage of our analysis, given that the authors of the GTSC aggregated the points accrued by players over the 5 SSGs which provided a total score out of fifty for each player that was correlated with key physical performance indicators for match-performance. For instance, Fenner et al. (2016) demonstrated that high speed running distance had a *large* correlation with GTSC scoring (r = 0.547, $P < 0.05$) which was *accompanied* by total distance covered also displaying a *moderate* correlation with the GTSC scoring (r = 0.545, $P < 0.05$) and total points (r = 0.438, $P < 0.05$) during chronologically grouped SSGs. This suggests that there was a strong agreement between the highest rated players and SSG outcome. The authors conclude that the higher rated players had an enhanced capacity to cover larger distances at greater speeds and that a using the GTSC during a SSG 'round robin' format should be considered for talent identification purposes (Fenner et al., 2016). With this in mind, our ongoing analysis will attempt to explore if manipulating this format via the implementation of maturity status 'bio-banding' will influence the opportunity for maturity 'bio-banded' players to showcase technical/tactical prowess and ultimately enhance or restrict coach scoring opportunity. Therefore, we believe that until full data analysis of the technical/tactical attributes is complete, our hypothesis that 'mixed' maturity status 'bio-banding' will reduce the magnitude of difference in technical behaviours between players during SSG match-play and that 'early' maturing players will score greater when matched against their 'late' maturing counterparts remains unknown.

Traditional approaches to talent identification prioritized technical and tactical competencies as the key metrics in the evaluation of soccer player performance and ability. Recent evidence, however, suggests that practitioners perceive psychological factors to be of higher importance during soccer talent identification than sociological, technical/tactical, and physical factors (Towlson et al 2019). It has been postulated that increased opportunities to engage in formalized educational provision that relates to talent identification, have led to a greater awareness among practitioners of psychological principles and their importance when identifying players for specialized soccer academies. This trend is reflected within the present study for scores of perceived evidence of key psychological characteristics during maturity status 'bio-banding' SSGs. When categorized using the Khamis and Roche (1994) method, results revealed that coaches scored the 'late' banded players more favourably for evidence of 'confidence' (P = 0.08; ES = 0.39, *small*), 'competitiveness' (P = 0.03; ES = 1.1, *moderate*) and 'positive attitude' ($P \leq 0.001$; ES = 0.65, *moderate*) than their 'early' and 'circa' counterparts. One explanation for these findings is that being closely matched physically with their peers increased opportunities to develop technical attributes, exert a greater influence on the game, and demonstrate leadership skills (Cumming et al. 2017). Both methods of 'bio-banding' showed a *small* (ES = 0.30 to 0.35) enhancement for 'X-factor' within the 'late' maturing banded players. Although our analysis pertaining to the reliability of our psychological scoring is ongoing, it is encouraging to view evidence suggesting that the implementation of maturity status 'bio-banding' can provide opportunity for later maturing players to display key psychological characteristics for talent identification that might otherwise be hidden during chronologically banded match-play. Maturity related differences in coaches perceptions of desired psychological characteristics displayed by players is of relevance given that talent identification practitioners have demonstrated a preference for soccer players who possess specific psychological related characteristics such as being hard-working, dedicated and possessing a willingness to learn (Christensen, 2009). In light of this, researchers and practitioners alike have called for multi-disciplinary approaches to talent identification which offers equal recognition to players' psychological and social characteristics, as well as the technical/tactical and physical components of performance (Reilly, Williams, Nevill, & Franks, 2000; Towlson et al., 2019; Unnithan et al., 2012). Given the findings thus far for psychological behaviours, we can confirm the hypothesis that 'mixed' 'bio-banding' does reduce the magnitude of difference for psychological behaviours between players during SSG match-play and that these measures for later maturing players will be greater when matched against their earlier maturing counterparts.

Section 8: Limitations

Maturity estimation equations

Players' estimated YPHV (maturity offset [YPHV]) (Mirwald et al., 2002) has typically been calculated using cross-validated algorithms (Bailey, 1997; Bailey, McKay, Mirwald, Crocker, & Faulkner, 1999; Fransen et al., 2018; Moore et al., 2015) that use somatic components (stature, seated height, and leg length) and decimal age, to an accuracy of ± 0.24 years (Mirwald et al., 2002). However, although somatic maturity, skeletal age, stage of pubic hair development, and decimal age are interrelated, cross-sectional analyses of academy soccer players' has revealed differences between skeletal age and decimal age versus predicted PHV maturity measures (Malina et al., 2012). Such contrasts are likely to be the result of anthropometric measurement and method error. However, although skeletal and somatic methods are both measures of maturity, it is important to note that these processes are not necessarily always synchronised (Houston, 1980). For example, for boys aged 13 to 17 years, the radial-ulna bone age is more closely associated (r^2 = 0.65 to 0.75) to APHV than carpal age (r^2 = 0.47 to 0.51) (Houston, 1980). Therefore, although skeletal age and somatic maturity are interlinked (to an extent), it is likely misleading for soccer practitioners to assume that the adolescent growth spurt will be 'earlier' or 'later' to the same degree as bone ossification or age, suggestive that skeletal age and PHV are asynchronous. Although cost effective and time efficient, some caution is warranted when using estimated measures of somatic maturity to identify 'early', on-time and 'late' developing soccer players' for 'bio-banding' purposes.

It is also important to note that, although predictive equations (Fransen et al., 2018; Khamis & Roche, 1994; Mirwald et al., 2002; Moore et al., 2015) are inexpensive, time efficient and have been validated, it is recognised that the longitudinal accuracy of some somatic maturity estimation procedures have been questioned (Deprez et al., 2014; Malina & Kozieł, 2014). In particular, a validation study (Malina & Kozieł, 2014) of the maturity offset equation (Mirwald et al., 2002) used in a longitudinal sample of Polish boys (n = 193) identified that the predicted APHV was influenced by decimal age and maturity status, showing the predictive equation to be a valid measure of determining maturity status in boys of 'on-time' maturation trajectory. However, the predictive equation (Mirwald et al., 2002) purportedly underestimates (-0.32 years) APHV for boys 3 years prior to PHV and overestimates (0.56 years) predicted APHV for boys 3 post PHV (Malina & Kozieł, 2014). Malina and Kozieł (2014) state that mean predicted APHV was the same as the criterion measure (Preece–Baines Model (Preece & Baines, 1978)) of APHV for boys of 12 years and that APHV for boys who are younger or older was either under (for younger) and over-estimated (for older) respectively. Therefore, in consideration of these findings, the authors suggest that such disagreement is possibly explained by the systematic error (0.59 years) and 95% confidence interval (1.18 years) encompassed within the predicted equation (Malina & Kozieł, 2014). In addition to this, such variation might also be explained by variance in measurement error, especially for stature (0.29 cm) and estimating leg length from seated height (0.35 cm) (Malina & Kozieł, 2014).

Lastly, the validity of some predictive equations, specifically the Mirwald et al. (2002) equation for use within athletic populations has also been questioned (Deprez et al., 2014; Malina & Kozieł, 2014). Given that the estimation of leg length is a key component of many predictive maturity equations (Fransen et al., 2018; Mirwald et al., 2002), coupled with the over-representation of skeletally mature athletes within elite team sports (Malina et al., 2000), the efficacy of such equations (particularly Mirwald et al., 2002) may be somewhat compromised as growth in leg length is largely complete in 'early' maturing boys, but trunk growth may continue (Malina & Kozieł, 2014). This potentially limits its use within this population. That being said, recent and modified predictive equations (Fransen et al., 2018; Khamis & Roche, 1994; Moore et al., 2015) offer improved levels of reliability and validity and given their effectiveness and time efficiency for use within a broad population of academy soccer players that reside within the multi-development centres, the implementation of such techniques to estimate player maturity are seemingly vindicated on the principle that its limitations are considered during player monitoring and development assessment.

In attempting to compensate for such limitations, this study used the modified predictive equation by Fransen et al. (2018). Unlike previous maturity estimates (Mirwald et al., 2002; Moore et al., 2015), the Fransen et al. (2018) modified equation has been validated using longitudinal growth data collected using a representative sample of high level youth soccer players. Data was collected on the same month each year across a period of six years for 1330 high level male youth (aged 8.0-17.0 years) soccer players who were recruited from 145 Belgian soccer academies (a total of 4829 observations). In addition, these athletes were from several ethnic backgrounds, with many players being Caucasian in descent. The Fransen et al., (2018) equation models the non-linear relationship between anthropometric measures. Unlike the Mirwald et al. (2002) predictive equation which utilised only linear predictors, the modified equation by Fransen uses a polynomial equation which permits a more accurate representation of the non-linear relationship between the anthropometric variables and maturity offset. However, caution is still necessary when using a maturity offset (decimal age – APHV) due to an increased variance within the prediction (Malina & Kozieł, 2014). Therefore, the Fransen et al. (2018) modified equation has the same explained variance as the Mirwald et al. (2002) equation, but there seems to be no systematic change in the prediction error as the predicted maturity ratio (decimal age : APHV) changes. This is of relevance as the Fransen et al. (2018) demonstrated enhanced reliability for estimations of APHV.

An important element of this project was the need to ensure that the scoring of psychological characteristics was completed in a consistent manner so that the data can be shown to be reliable. To do so, an acceptable level of *inter*-observer and *intra*-observer agreement was set at 85 percent (the minimum standard as recommended by Siedentop, 1976). *Intra*-observer agreement was enhanced by ensuring a minimum fourteen-day period had elapsed between the coding of the initial SSG and the re-scoring of the same session (so as to avoid memory influencing the scored data). We also sought to enhance *Inter*-observer agreement by providing coaches with behavioural definitions and video footage of each of the psychological attributes so that they could clearly ascertain the attribute they were being asked to identify.

Preliminary confirmation/rejection of hypotheses

The following outcomes are preliminary and will require verification once all data has been collected and final analysis is complete. Until we have completed full data collection and subsequent analyses, the below outcomes should be considered as preliminary.

1) Matched/'mixed' 'bio-banding' will reduce the magnitude of difference in technical behaviours between players during SSG match-play. However, these measures for 'early' maturing players will be greater when matched against their later maturing counterparts. **REJECT**
2) Matched/'mixed' 'bio-banding' will reduce the magnitude of difference for tactical behaviours between players during SSG match-play. However, these measures for 'early' maturing players will be greater when matched against their later maturing counterparts. **REJECT**
3) Matched/'mixed' 'bio-banding' will reduce the magnitude of difference for physical measures between players during SSG match-play. However, these measures for later maturing players will be greater when matched against their earlier maturing counterparts. **ACCEPT – However special individualised consideration should be given to player load management.**
4) Matched/'mixed' 'bio-banding' will reduce the magnitude of difference for psychological behaviours between players during SSG match-play. However, these measures for later maturing players will be greater when matched against their earlier maturing counterparts. **ACCEPT**
5) Matched/'mixed' 'bio-banding' will reduce the magnitude of difference of internal (heart rate and sRPE) and external (GPS metrics i.e. player load etc.) measures during SSG match-play. However, these measures for later maturing players will be greater when matched against their earlier maturing counterparts. **ACCEPT**

Section 8: Preliminary practical recommendations

Although our data analysis is still ongoing, our findings thus far have for the first time demonstrated evidence to suggest differences in match-play performance characteristics likely exist when assessing players from a multi-disciplinary perspective according to their maturity status. It is positive to see those involved in soccer talent identification looking beyond technical/tactical and physical characteristics of performance and giving greater consideration to psychological characteristics. However, findings here perhaps highlight a need to be cautious that physical and technical/tactical characteristics are not overlooked altogether. Practitioners should consider the manipulation of SSG format (i.e. 'bio-banding') during the talent selection process in order to tease out certain desirable player characteristics which might otherwise be masked during chronologically aged match-play (Cumming et al., 2018). With this in mind, our practical recommendations are four-fold:

1) Practitioners should afford later maturing players the opportunity to have their psychological characteristics assessed during maturity 'matched' 'bio-banding' SSG match-play (i.e. 'late' versus 'late');

2) To assess players' ability to perform during extensive and high intensity periods of match-play, practitioners should consider employing SSG contested by opposing maturity bands (i.e. 'Late versus Early') to foster a game environment that encourages greater total distances and maximum velocities to be performed;

3) Practitioners should also be aware of increased accrued player load and perceived exertion (sRPE) for later maturing players (i.e. 'circa' and 'late') during SSG formats. Therefore, between maturity banding differences in player load and perceived exertion should be factored in when considering each young players training micro-cycles in attempt to reduce the risk of possible non-contact injury and subsequent muscle soreness;

4) Practitioners should use the Khamis and Roche (1994) and Fransen et al. (2018) maturity estimate equations independently and be considerate of limitations with each maturity estimate equation, while also being aware of the between maturity banding differences in key performance indicators.

Does maturity status 'bio-banding' work?

Preliminary findings suggest that the efficacy of maturity-status 'bio-banding' as a tool for ongoing talent (de)selection of academy soccer players using a multi-disciplinary approach is limited to identifying desired psychological traits of 'late' maturing academy soccer players only. That said, given the maturity related differences in perceived effort and total player load shown in the present study, practitioners should consider maturity status bio-banding as a training method as well as a talent identification tool. Future research should focus on the longitudinal (i.e. season long) efficacy of maturity status 'bio-banded' SSGs for on-going (de)selection processes and physical training methods of academy soccer players via the manipulation of relative pitch size and rule changes. It is anticipated that findings from this study will enhance national and international governing body knowledge of the impact of maturity-status 'bio-banding' on talent identification processes, with specific reference to physical, technical, tactical and psychological player attributes. It is hoped that this study has identified both the strengths and weaknesses of its use and has provided a pragmatic solution for talent identification practitioners to better assess a range (physical, technical/tactical and psychological) of player characteristics during maturity 'bio-banded' match-play, which might otherwise will have been masked.

The 'Take-Home' message

Although the present study has identified practical benefits of maturity status 'bio-banding' for talent identification purposes, practitioners should carefully consider their aims and objectives for using 'bio-banding', to ensure that the practical benefits of its use outweigh the relative cost (i.e. time, organization, parental consent, change of philosophy etc.) of implementing it.

Section 9: Acknowledgments

This study was supported by Neil Campion Scottish (Funding Manager, Scottish Football Association). We would like to thank all of the practitioners and players who either supported and/or participated within the data collection process of the study. Specifically, we would like to thank all of our collaborators, giving specific thanks to Calum Macmaster (Appointed MSc student and Lead Sport Scientist, Hull City Tigers AFC), Alistair Hamilton (Head of Academy Sports Science and Medicine, Hull City Tigers AFC), Frances Hunter (Head of Science, Strength and Conditioning, Middleborough FC), Rory Jack (First Team Physiotherapist, Hamilton Academicals FC) and Chris Hill (Catapult Sports) for their continued support and engagement throughout the process.

Section 10: References

Aughey, R. J. (2011). Increased high-intensity activity in elite Australian football finals matches. *International Journal of Sports Physiology and Performance, 6*(3), 367-379.

Bailey, D. (1997). The Saskatchewan Pediatric Bone Mineral Accrual Study: bone mineral acquisition during the growing years. *International Journal of Sports Medicine, 18*(S 3), S191-S194.

Bailey, D., McKay, H., Mirwald, R., Crocker, P., & Faulkner, R. (1999). A six-year longitudinal study of the relationship of physical activity to bone mineral accrual in growing children: the university of Saskatchewan bone mineral accrual study. *Journal of Bone and Mineral Research, 14*(10), 1672-1679.

Barrett, S., Midgley, A., & Lovell, R. (2014). PlayerLoad™: reliability, convergent validity, and influence of unit position during treadmill running. *International Journal of Sports Physiology & Performance, 9*(6).

Baxter-Jones, A., Helms, P., Maffulli, N., Baines-Preece, J., & Preece, M. (1995). Growth and development of male gymnasts, swimmers, soccer and tennis players: a longitudinal study. *Annals of Human Biology, 22*(5), 381-394.

Buchheit, M., Mendez-Villanueva, A., Simpson, B., & Bourdon, P. (2010). Match running performance and fitness in youth soccer. *International Journal of Sports Medicine, 31*(11), 818-825.

Carling, C., Le Gall, F., & Malina, R. M. (2012). Body size, skeletal maturity, and functional characteristics of elite academy soccer players on entry between 1992 and 2003. *Journal of Sports Sciences, 7*(30(15)), 1683-1693.

Carling, C., Le Gall, F., Reilly, T., & Williams, A. (2009). Do anthropometric and fitness characteristics vary according to birth date distribution in elite youth academy soccer players? *Scandinavian Journal of Medicine & Science in Sports, 19*(1), 3-9.

Castagna, C., Manzi, V., Impellizzeri, F., Weston, M., & Alvarez, J. C. B. (2010). Relationship between endurance field tests and match performance in young soccer players. *Journal of Strength & Conditioning Research, 24*(12), 3227-3233.

Christensen, M. K. (2009). "An eye for talent": Talent identification and the "practical sense" of top-level soccer coaches. *Sociology of Sport Journal, 26*(3), 365-382.

Cobley, S. P., Baker, J., Wattie, N., & McKenna, J. (2009). Annual age-grouping and athlete development. *Sports Medicine, 39*(3), 235-256.

Cobley, S. P., Schorer, J., & Baker, J. (2008). Relative age effects in professional German soccer: A historical analysis. *Journal of Sports Sciences, 26*(14), 1531-1538.

Coutts, A., Reaburn, P., Murphy, A., Pine, M., & Impellizzeri, F. (2003). Validity of the session-RPE method for determining training load in team sport athletes. *Journal of Science and Medicine in Sport, 6*, 525.

Cumming, S. P., Brown, D. J., Mitchell, S., Bunce, J., Hunt, D., Hedges, C., . . . Franklin, E. (2017). Premier League academy soccer players' experiences of competing in a tournament bio-banded for biological maturation. *Journal of Sports Sciences*, 1-9.

Cumming, S. P., Lloyd, R. S., Oliver, J. L., Eisenmann, J. C., & Malina, R. M. (2017). Bio-banding in sport: applications to competition, talent identification, and strength and conditioning of youth athletes. *Strength & Conditioning Journal, 39*(2), 34-47.

Cumming, S. P., Searle, C., Hemsley, J. K., Haswell, F., Edwards, H., Scott, S., . . . White, P. (2018). Biological maturation, relative age and self-regulation in male professional academy soccer players: A test of the underdog hypothesis. *Psychology of Sport and Exercise, 39*, 147-153.

Cunha, G., Lorenzi, T., Sapata, K., Lopes, A. L., Gaya, A. C., & Oliveira, Á. (2011). Effect of biological maturation on maximal oxygen uptake and ventilatory thresholds in soccer players: An allometric approach. *Journal of Sports Sciences, 29*(10), 1029-1039.

Deconche, E., & Maurer, D. (2016). Bigger shouldnt mean better. *UEFA Direct, 162*.

Delorme, N., & Raspaud, M. (2009). The relative age effect in young French basketball players: a study on the whole population. *Scandinavian Journal of Medicine & Science in Sports, 19*(2), 235-242.

Deprez, Coutts, A., Fransen, J., Deconinck, F., Lenoir, M., Vaeyens, R., & Philippaerts, R. (2013). Relative age, biological maturation and anaerobic characteristics in elite youth soccer players. *International Journal of Sports Medicine, 34*(10), 897-903.

Deprez, Fransen, J., Boone, J., Lenoir, M., Philippaerts, R., & Vaeyens, R. (2014). Characteristics of high-level youth soccer players: variation by playing position. *Journal of Sports Sciences*, 1-12.

Deprez, Fransen, J., Lenoir, M., Philippaerts, R. M., & Vaeyens, R. (2015). A Retrospective Study on Anthropometrical, Physical Fitness, and Motor Coordination Characteristics That Influence Dropout, Contract Status, and First-Team Playing Time in High-Level Soccer Players Aged Eight to Eighteen Years. *The Journal of Strength & Conditioning Research, 29*(6), 1692-1704.

Doward, J. (2015). Bio-banding: How scientists can help late developers become sporting superstars. . *The Guardian*.

Drust, B., Atkinson, G., & Reilly, T. (2007). Future perspectives in the evaluation of the physiological demands of soccer. *Sports Medicine, 37*(9), 783-805.

Edwards, S. (1994). The heart rate monitor book. *Medicine and Science in Sports and Exercise, 26*(5), 647.

Fenner, J. S., Iga, J., & Unnithan, V. (2016). The evaluation of small-sided games as a talent identification tool in highly trained prepubertal soccer players. *Journal of Sports Sciences, 34*(20), 1983-1990.

Figueiredo, A., Coelho e Silva, M., & Malina, R. (2011). Predictors of functional capacity and skill in youth soccer players. *Scandinavian Journal of Medicine & Science in Sports, 21*(3), 446-454.

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., . . . Dodge, C. (2001). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research, 15*(1), 109-115.

Fransen, J., Bush, S., Woodcock, S., Novak, A., Deprez, D., Baxter-Jones, A. D., . . . Lenoir, M. (2018). Improving the prediction of maturity from anthropometric variables using a maturity ratio. *Pediatric Exercise Science, 30*(2), 296-307.

Gil, S. M., Gil, J., Ruiz, F., Irazusta, A., & Irazusta, J. (2007). Physiological and anthropometric characteristics of young soccer players according to their playing position: relevance for the selection process. *Journal of Strength and Conditioning Research, 21*(2), 438-445.

Gonçalves, B., Esteves, P., Folgado, H., Ric, A., Torrents, C., & Sampaio, J. (2017). Effects of pitch area-restrictions on tactical behavior, physical, and physiological performances in soccer large-sided games. *The Journal of Strength & Conditioning Research, 31*(9), 2398-2408.

Grafen, A., and Hails, R. (2002). *Modern statistics for the life sciences: learn to analyse your own data.* : Oxford University Press Inc.

Helsen, W. F., Starkes, J. L., & Van Winckel, J. (1998). The influence of relative age on success and dropout in male soccer players. *American Journal of Human Biology, 10*(6), 791-798.

Helsen, W. F., Van Winckel, J., & Williams, A. M. (2005). The relative age effect in youth soccer across Europe. *Journal of Sports Sciences, 23*(6), 629-636.

Hirose, N. (2009). Relationships among birth-month distribution, skeletal age and anthropometric characteristics in adolescent elite soccer players. *Journal of Sports Sciences, 27*(11), 1159-1166.

Hopkins, W., Marshall, S., Batterham, A., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise, 41*(1), 3.

Houston, W. (1980). Relationships between skeletal maturity estimated from hand-wrist radiographs and the timing of the adolescent growth spurt. *The European Journal of Orthodontics, 2*(2), 81-93.

Khamis, H. J., & Roche, A. F. (1994). Predicting adult stature without using skeletal age: the Khamis-Roche method. *Pediatrics, 94*(4), 504-507.

Le Gall, F., Carling, C., & Reilly, T. (2007). Biological maturity and injury in elite youth football. *Scandinavian Journal of Medicine & Science in Sports, 17*(5), 564-572.

Lovell, R., Towlson, C., Parkin, G., Portas, M., Vaeyens, R., & Cobley, S. (2015). Soccer Player Characteristics in English Lower-League Development Programmes: The Relationships between Relative Age, Maturation, Anthropometry and Physical Fitness. *PloS one, 10*(9), e0137238.

Malina, R. M. (2010). Maturity status and injury risk in youth soccer players. *Clinical Journal of Sport Medicine, 20*(2), 132.

Malina, R. M., Bouchard, C., & Bar-Or, O. (2004). *Growth, Maturation, and Physical activity*: Human Kinetics Publishers.

Malina, R. M., Chamorro, M., Serratosa, L., & Morate, F. (2007). TW3 and Fels skeletal ages in elite youth soccer players. *Annals of human biology, 34*(2), 265-272.

Malina, R. M., & Kozieł, S. M. (2014). Validation of maturity offset in a longitudinal sample of Polish boys. *Journal of Sports Sciences, 32*(5), 424-437.

Malina, R. M., Reyes, M. P., Eisenmann, J., Horta, L., Rodrigues, J., & Miller, R. (2000). Height, mass and skeletal maturity of elite Portuguese soccer players aged 11–16 years. *Journal of Sports Sciences, 18*(9), 685-693.

Malina, R. M., Silva, M. J. C. E., Figueiredo, A. J., Carling, C., & Beunen, G. P. (2012). Interrelationships among invasive and non-invasive indicators of biological maturation in adolescent male soccer players. *Journal of Sports Sciences, 30*(15), 1705-1717.

Mendez-Villanueva, A., Buchheit, M., Kuitunen, S., Douglas, A., Peltola, E., & Bourdon, P. (2011). Age-related differences in acceleration, maximum running speed, and repeated-sprint performance in young soccer players. *Journal of Sports Sciences, 29*(5), 477-484.

Mendez-Villanueva, A., Buchheit, M., Kuitunen, S., Poon, T., Simpson, B., & Peltola, E. (2010). Is the relationship between sprinting and maximal aerobic speeds in young soccer players affected by maturation. *Pediatric Exercise Science, 22*(4), 497-510.

Mendez-Villanueva, A., Buchheit, M., Simpson, B., & Bourdon, P. (2012). Match Play Intensity Distribution in Youth Soccer. *International Journal of Sports Medicine*.

Mirwald, R. L., Baxter-Jones, A., Bailey, D. A., & Beunen, G. P. (2002). An assessment of maturity from anthropometric measurements. *Medicine and Science in Sports and Exercise, 34*(4), 689.

Mooney, M. G., Cormack, S., O'brien, B. J., Morgan, W. M., & McGuigan, M. (2013). Impact of neuromuscular fatigue on match exercise intensity and performance in elite Australian football. *The Journal of Strength & Conditioning Research, 27*(1), 166-173.

Moore, S. A., McKay, H. A., Macdonald, H., Nettlefold, L., Baxter-Jones, A. D., Cameron, N., & Brasher, P. M. (2015). Enhancing a somatic maturity prediction model. *Medicine & Science in Sports & Exercise, 47*(8), 1755-1764.

Mujika, I., Spencer, M., Santisteban, J., Goiriena, J. J., & Bishop, D. (2009). Age-related differences in repeated-sprint ability in highly trained youth football players. *Journal of Sports Sciences, 27*(14), 1581-1590.

Mujika, I., Vaeyens, R., Matthys, S. P., Santisteban, J., Goiriena, J., & Philippaerts, R. (2009). The relative age effect in a professional football club setting. *Journal of Sports Sciences, 27*(11), 1153-1158.

Philippaerts, R. M., Vaeyens, R., Janssens, M., Van Renterghem, B., Matthys, D., Craen, R., . . . Malina, R. M. (2006). The relationship between peak height velocity and physical performance in youth soccer players. *Journal of Sports Sciences, 24*(3), 221-230.

Preece, M., & Baines, M. (1978). A new family of mathematical models describing the human growth curve. *Annals of Human Biology, 5*(1), 1-24.

Quatman-Yates, C. C., Quatman, C. E., Meszaros, A. J., Paterno, M. V., & Hewett, T. E. (2012). A systematic review of sensorimotor function during adolescence: a developmental stage of increased motor awkwardness? *British Journal of Sports Medicine, 46*(9), 649-655.

Reilly, T., Williams, A. M., Nevill, A., & Franks, A. (2000). A multidisciplinary approach to talent identification in soccer. *Journal of Sports Sciences, 18*(9), 695-702.

Romann, M., & Fuchslocher, J. (2013). Relative age effects in Swiss junior soccer and their relationship with playing position. *European Journal of Sport Science, 13*(4), 356-363.

Ryan, D., McCall, A., Fitzpatrick, G., Hennessy, L., Meyer, T., & McCunn, R. (2018). The influence of maturity status on movement quality among English Premier League academy soccer players. *Sport Performance Science Reports, 32*, 1-3.

Santos, S., Jiménez, S., Sampaio, J., & Leite, N. (2017). Effects of the Skills4Genius sports-based training program in creative behavior. *PloS One, 12*(2), e0172520.

Schorer, J., Cobley, S., Büsch, D., Bräutigam, H., & Baker, J. (2009). Influences of competition level, gender, player nationality, career stage and playing position on relative age effects. *Scandinavian Journal of Medicine & Science in Sports, 19*(5), 720-730.

Sherar, L. B., Mirwald, R. L., Baxter-Jones, A. D., & Thomis, M. (2005). Prediction of adult height using maturity-based cumulative height velocity curves. *The Journal of Paediatrics, 147*(4), 508-514.

Stewart, A. (2002). Physiological Tests for Elite Athletes (Second ed.). Australian Institute of Sport Taylor & Francis.

Stewart, A., Marfell-Jones, M., Olds, T., & Ridder, H. (2011). *International Standards for Anthropometric Assessment*: International Society for the Advancement of Kinanthropometry.

Tanner, J. M., Whitehouse, R., & Takaishi, M. (1966). Standards from birth to maturity for height, weight, height velocity, and weight velocity: British children, 1965. I. *Archives of Disease in Childhood, 41*(219), 454.

The English Premier League. (2011). *Elite Player Performance Plan*.

The Football Association (Ed.) (2010). *The Future Game: The Football Association Technical Guide for Young Player Development*.

Till, K., Cobley, S., O'Hara, J., Cooke, C., & Chapman, C. (2014). Considering maturation status and relative age in the longitudinal evaluation of junior rugby league players. *Scandinavian Journal of Medicine & Science in Sports, 24*(3), 569-576.

Till, K., Cobley, S., Wattie, N., O'Hara, J., Cooke, C., & Chapman, C. (2010). The prevalence, influential factors and mechanisms of relative age effects in UK Rugby League. *Scandinavian Journal of Medicine & Science in Sports, 20*(2), 320-329.

Till, K., & Jones, B. (2015). Monitoring anthropometry and fitness using maturity groups within youth rugby league. *The Journal of Strength & Conditioning Research, 29*(3), 730-736.

Towlson, C., Cobley, S., Midgley, A., Garrett, A., Parkin, G., & Lovell, R. (2017). Relative Age, Maturation and Physical Biases on Position Allocation in Elite-Youth Soccer. *International Journal of Sports Medicine*.

Towlson, C., Cobley, S., Parkin, G., & Lovell, R. (2018). When does the influence of maturation on anthropometric and physical fitness characteristics increase and subside? *Scandinavian Journal of Medicine & Science in Sports, 28*(8), 1946-1955.

Towlson, C., Perry, J., Levett, N., Court, D., & Cope, E. (2019). Practitioners' perspectives of soccer talent according to playing position and the FA's four-corner model in academy soccer. Under Review. *International Journal of Sport Science and Coaching, Accepted*.

UEFA Club Licensing and Fiancial Fair Play Regulations, (2012).

Unnithan, V., White, J., Georgiou, A., Iga, J., & Drust, B. (2012). Talent identification in youth soccer. *Journal of Sports Sciences, 30*(15), 1719-1726.

Vaeyens, R., Malina, R. M., Janssens, M., Van Renterghem, B., Bourgois, J., Vrijens, J., & Philippaerts, R. M. (2006). A multidisciplinary selection model for youth soccer: the Ghent Youth Soccer Project. *British Journal of Sports Medicine, 40*(11), 928-934.

Vaeyens, R., Philippaerts, R. M., & Malina, R. M. (2005). The relative age effect in soccer: A match-related perspective. *Journal of Sports Sciences, 23*(7), 747-756.

Vincent, W. (1993). Statistics in Kinesiology. 3rd Edition, Washington DC; Human Kinetics.

Votteler, A., & Höner, O. (2014). The relative age effect in the German Football TID Programme: Biases in motor performance diagnostics and effects on single motor abilities and skills in groups of selected players. *European Journal of Sport Science, 14*(5), 433-442.

Wattie, N., Baker, J., Cobley, S., & Montelpare, W. J. (2007). A historical examination of relative age effects in Canadian hockey players. *International Journal of Sport Psychology, 38*(2), 178-186.

Wattie, N., Cobley, S., & Baker, J. (2008). Towards a unified understanding of relative age effects. *Journal of Sports Sciences, 26*(13), 1403-1409.

Williams. (2010). Relative age effect in youth soccer: analysis of the FIFA U17 World Cup competition. *Scandinavian Journal of Medicine & Science in Sports, 20*(3), 502-508.