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The effects of maturational variation on the performance of young Australian footballers and their selection into the Australian Football League's Talent Pathway

Ashley Cripps
University of Notre Dame Australia

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The effects of maturational variation on the performance of young Australian footballers and their selection into the Australian Football League's Talent Pathway

by

Mr Ashley John Cripps
B. Sci. (Hons) Exercise and Sport Science
(University of Notre Dame Australia)

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2016

SIGNED DECLARATION

I declare that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university of higher education, and that to the best of my knowledge it does not contain any materials previously published or written by another person except where due reference is made in the text.

Signature: ……………………………………. **Date: 24/11/2016**

Ashley John Cripps

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DEFINITION OF TERMS AND ABBREVIATIONS

AFL	Australian Football League
AFL TP	Australian Football League Talent Pathway
CPQ	Coaches' perception questionnaire
Development	Performance changes associated with maturation and/or training
DVJD	Dynamic vertical jump off dominant foot
DVJND	Dynamic vertical jump off non-dominant foot
Growth	The change in size of anthropometric measures
Maturation	The timing and tempo of progress towards a mature biological state
PHV	Peak height velocity
SVJ	Standing vertical jump
U	Under
Y-PHV	Years to/from Peak Height Velocity

THESIS OVERVIEW

Traditional player development pathways share a common goal, to identify and accelerate the development of talented adolescent players for senior competition. Players who gain selection into development programs gain greater access to experienced coaches, training facilities, support staff and competition. However, despite such advantages, research has shown that few players who gain initial selection into development pathways progress into professional senior competition. A major factor which potentially contributes to poor player retention in development pathways is the initial misidentification of talented athletes due to variations in biological maturity.

Earlier maturing individuals have been shown to be at a physical advantage over their later maturing counterparts in traditional talent identification testing measures. While inconclusive, some research has also indicated that more mature individuals also demonstrate technical skill advantages. It is currently unknown if coaches' perceptions of skill and potential favour earlier biologically maturing adolescent players. Performance advantages experienced by earlier maturing adolescent players likely results in selection advantages in highly competitive player development pathways, such as the Australian Football League's Talent Pathway (AFL TP). The broad aim of this thesis was to examine the impact of maturational variation on player performance and selection in the Under 16 (U16) stage of the AFL TP.

Chapter two of this thesis investigated the developmental efficiency of the AFL TP by examining retrospective pathway involvement of players drafted into professional teams between the 2006-2012 seasons. A secondary analysis was conducted to examine the relative age of players selected into each stage of the AFL TP (U16, U18 and Draft). The results from chapter two revealed that only 27.7% of players drafted to professional teams had participated in the initial U16 stage of the AFL TP. Further, only half of the professionally selected players had any involvement in either underage level of the AFL TP. Birth distributions at every pathway stage was biased towards relatively older players however, relatively older players were also more likely to be de-selected as the pathway progressed. Results of this study demonstrate that variations in relative age between players in the AFL TP are likely to impact on pathway efficiency and long-term development outcomes.

The results of chapter two demonstrated that selection into the AFL TP may be biased by advantages associated with the relative age of the athletes and a potential effect of maturational variation. In Australian football, maturational variation in age matched players has been shown to impact on anthropometric and physical performance measures however, the effects of maturational variation on technical skill has yet to be explored. Further, the effects of maturational variation on coaches' perceptions of skill and potential is unknown. Chapter three investigated the inter-rater reliability and validity of two technical skill assessments commonly used by the AFL. Results from this study led to the conclusion that the AFL's skill tests were appropriate for use in subsequent studies within this thesis.

The results of chapter four highlight that earlier maturing U16 Australian footballers are significant taller and heavier than their later maturing counterparts. Earlier maturing players also possessed greater vertical jump and sprint capacities. Interestingly, no difference was found between maturational groups and performance in technical skill tests. Chapter four and five also explored the links between maturational variation and coaches' perceptions of skill and long-term potential. The results of the analyses in chapter four demonstrate that earlier maturing individuals are perceived to possess better marking and ball winning abilities, as well as superior overall technical skills. Chapter five highlighted that coaches' perceptions of later maturing players were significantly lower than earlier maturing individuals, with 72% of the later maturing individuals perceived by coaches to not progress further than adolescent competition. Thus, the findings of chapter four and five suggest that because of physical advantages and favourable coaches' perceptions, earlier maturing Australian footballers are likely to be at a selection advantage at the U16 level of the AFL TP.

Chapter six sought to compare biological maturation, anthropometric, physical and technical skill measures between talent identified and non-talent identified junior Australian footballers at the U16 stage of the AFL TP. Twenty-five talent identified (selected into the U16 stage of the AFL TP), and twenty-five non-talent identified players (non-selected) were examined. Results demonstrated that talent identified players were more mature than their non-talent identified counterparts. Further, talent identified players were also taller, performed better in dynamic vertical jump tests and scored higher in the AFL's handball test. Predictive modelling correctly identified 84% of the talent identified and 76% of the non-talent identified players and included the measures of standing height, dynamic vertical jump off the non-dominant foot and handball test performance. The results of chapter six further highlight the problem maturational variation presents to talent identification in adolescent Australian football, as the key discriminators of height and jumping measures have been shown in chapter four to be influenced by biological maturity.

In conclusion, this thesis highlights the poor developmental efficiency of the AFL TP which may in-part be attributed to the selection of more mature adolescent athletes in early stages of the pathway. Results from chapters four and five demonstrate that as well as being at a physical advantage, coaches also perceived earlier maturing adolescent Australian footballers to possess superior technical skills and greater long-term potential. Methods to minimise the impact of maturational variation and promote greater developmental efficiencies in the AFL TP, such as the mandatory inclusion of maturational assessments and other performance tests unaffected by maturational variation, are discussed in the concluding chapter of this thesis.

LIST OF PUBLICATIONS AND PRESENTATIONS

Publications forming part of this thesis

Chapter Two

Cripps, A. J., Hopper, L., Joyce, C., & Veale, J. (2015). Pathway efficiency and relative age effects in the Australian Football League's Talent Pathway. *Talent Development and Excellence*, *7*(1), 3-11.

Chapter Three

Cripps, A. J., Hopper, L., & Joyce, C. (2015). Inter-rater reliability and validity of the Australian Football League's kicking and handball tests. *Journal of Sport Science and Medicine, 14,* 675-680.

Chapter Four

Cripps, A. J., Hopper, L., & Joyce, C. (2016a) Maturity, physical ability, technical skill and coaches' perception of semi-elite adolescent Australian footballers. *Paediatric Exercise Science,* http://dx.doi.org/10.1123/pes.2015-0238.

Chapter Five

Cripps, A. J., Hopper, L., & Joyce, C. (2016b). Coaches' perceptions of long-term potential are biased by maturational variation. *International Journal of Sport Science and Coaching*. Accepted 18th November 2015.

Chapter Six

Cripps, A. J., Hopper, L., Woods, C.T., & Joyce, C. Biological maturity and the anthropometric, physical and technical assessment of talent identified U16 Australian footballers. *International Journal of Sport Science and Coaching,* Accepted 25th July 2016.

Scientific conference presentations related to this thesis

Cripps, A., Hopper, L. & Veale, J. (2014). *Player turnover and selection priorities in the AFL Talent Pathway.* Paper presented at the 20th Sports Management Australia and New Zealand Conference, Melbourne, Australia.

Cripps, A., Hopper, L. & Joyce, C. (2015). *Anthropometric, fitness and coaches' perceptions of technical skill favour early maturing adolescent Australian footballers*. Poster presented at the 8th World Congress on Science and Football, Copenhagen, Denmark.

CHAPTER ONE: INTRODUCTION AND LITERATURE REVIEW

1.1 Chapter overview

This chapter contains a review of literature relating to three broad sections focusing on;

i. Australian football and its talent development pathway (Section 1.2),
ii. development pathways and player retention rates in sports world-wide (Section 1.3),
iii. the assessments of maturity and the role maturational variation plays in adolescent performance and talent identification (Section 1.4)

The relationships between these factors are also discussed throughout. The opening section (Section 1.2) introduces the game of Australian football and the development pathways established to ensure talented players continue to progress into the professional Australian Football League. Section 1.3 describes the common processes used in player development pathways and the efficiency of these programs in developing professional senior players. Factors which potentially impact on pathway efficiency will also be discussed. Section 1.4 discusses commonly used assessments of biological maturity and potential practical limitations of the assessment measures. This section also describes changes that occur throughout adolescence and the potential for these changes to influence individual performance and talent identification in development pathways. This section will discuss how maturational variation influences anthropometric, physical and skill measures. Further, the potential for coaches' perceptions of skill and potential to be effected by maturational variation is also presented. A succinct description of literature presented previously and the gaps in current literature is presented in Section 1.5.

The overarching objective of the thesis and specific aims of each of the five studies within are presented in Section 1.6. Finally, the chapter concludes with a statement of the significance of the thesis (Section 1.7).

1.2 Overview of Australian football

The first Australian football competition was established in Victoria in 1886 (Victorian Football League), since then competitions have spread to all Australian states and territories. A national league (Australian Football League (AFL)) was officially established in 1990, which since has expanded to a competition comprising of 18 teams from 5 Australian states. Since the inception of the professional AFL, Australian football has grown to become one of the most popular sports in Australia with 938,069 registered participants in 2013 (AFL, 2014). The game itself consists of two opposing teams attempting to outscore each other by kicking goals; with players required to execute skilful movements, while exposed to heavy physical contact and high running volumes across varying running intensities (Brewer, Dawson, Heasman, Stewart, & Cormack, 2010; Coutts, Quinn, Hocking, Castagna, & Rampinini, 2010; Dawson, Hopkinson, Appleby, Stewart, & Roberts, 2004; Norton, Craig, & Olds, 1999). Australian football has adopted many characteristics from internationally played football codes and can be described as a mix between American and Gaelic football, Soccer and both Rugby codes (Douge, 1988). However, despite its links to other football codes, Australian football is unique in that the playing area, game time (typically ~120 minutes) and number of players on the field (18) at any one time is greater than that of other football codes. Although specific positions exist; generally roles on the field can be defined as 'defenders', 'forwards', and 'midfielders', who move freely around the ground during play. Minor format changes exist (game length, field size, bench numbers and rules to limit physical contact) across Australia depending on age, location and level of experience which are all designed to ensure participant safety and competition equity. Figure 1 depicts the playing dimensions and positions in a typical Australian football match.

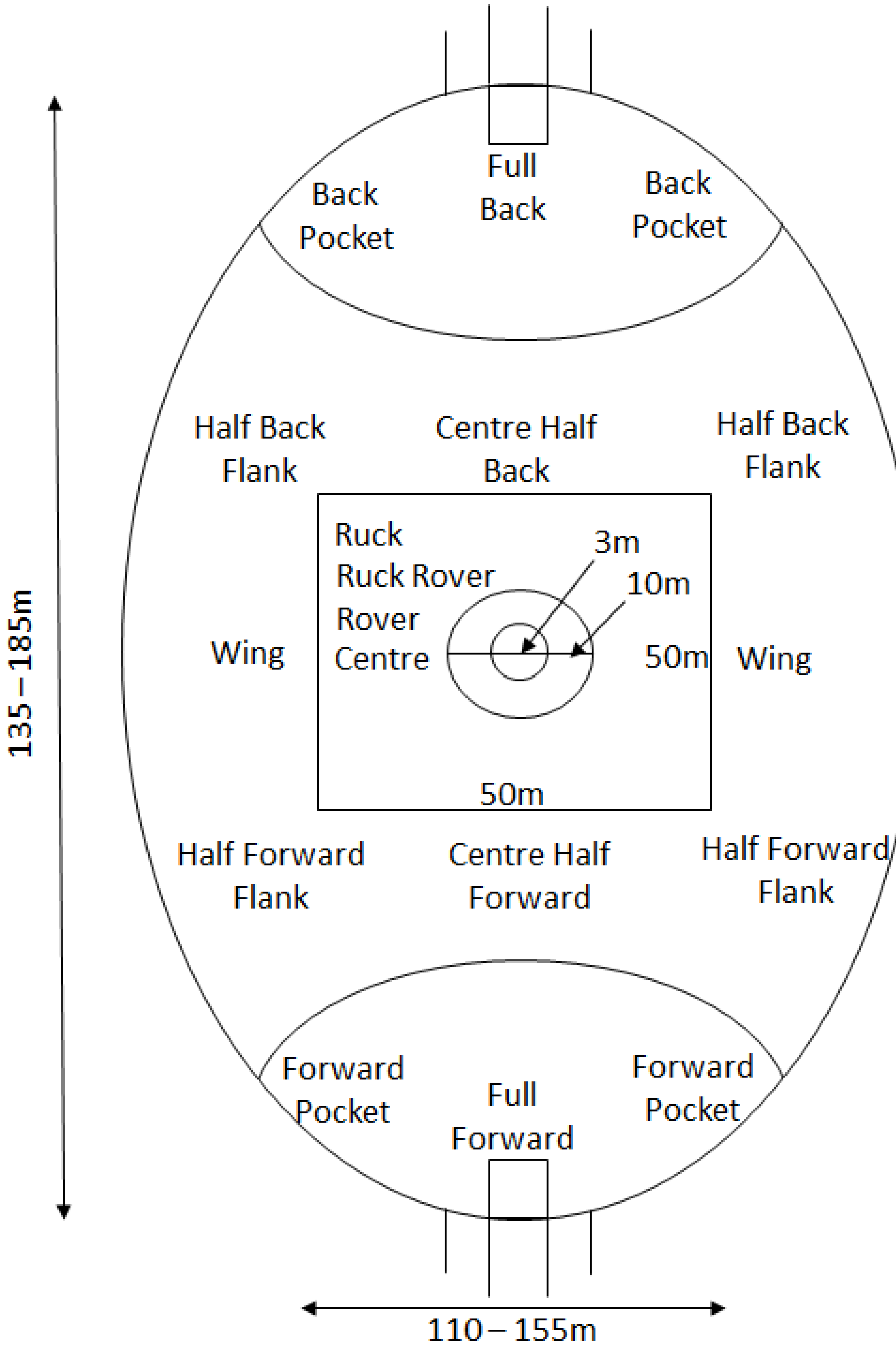


Figure 1. The playing dimensions and player positions typically used in Australian football matches

The AFL has developed two specific pathways for children wishing to play Australian football (see Figure 2), these are referred to as the participation and talent pathways (AFL, 2004). The structure of these programs ensures that any child wishing to play Australian football has the opportunity to participate at a level that is appropriate to their abilities, needs and aspirations (AFL, 2004). The participation pathway is primarily focused on engaging participants in community and school based football programs. These programs generate a combined 76.9% of the sport's total playing population (AFL, 2014). Players in the participation pathway identified as being talented or with potential are encouraged to trial for and participate in state league competitions, such as the Western Australian Football League, or South Australian National Football League. Players competing in state league competitions are eligible for selection into the AFL Talent Pathway (AFL TP).

The AFL TP is the primary development pathway for talented junior Australian footballers to develop and progress into the professional AFL. The talent pathway itself is similar to that of other sports such as English Rugby League (Till, Cobley, O'Hara, Chapman, & Cooke, 2010), where regional coaches select players from state league competitions to train and compete within an age-stratified national championship. This selection process typically involves regional coaches making selections based on training observations, match performance and talent identification testing. The AFL TP is considered the pinnacle of the underage development pathway, with player's selection to represent their respective states at age restricted (under 16s [U16s] and under 18s [U18s]) national championships. The AFL provides significant funding to the talent pathway to ensure the development of selected players by increasing access to experienced coaches and support staff, as well as access to better training resources and competitions. To compete in the senior professional competition, players must first be selected in the draft, the final stage of the AFL TP. The draft is similar to that of American basketball and American football, where players are selected from semi-professional, or underage competitions into professional clubs. Players must be 18 years of age but do not need to have participated in the underage stages of the AFL TP to be eligible for the draft. In fact, players can be selected into or out of the talent pathway at any stage, resulting in a non-linear progression of players at all levels of the pathway. However, considering the AFL provide significant resources to the talent pathway, player drop out at any stage of the AFL TP represents an inefficient use of invested resources. Currently there is a lack of research available examining the efficiency of the AFL TP in development players for the professional AFL.

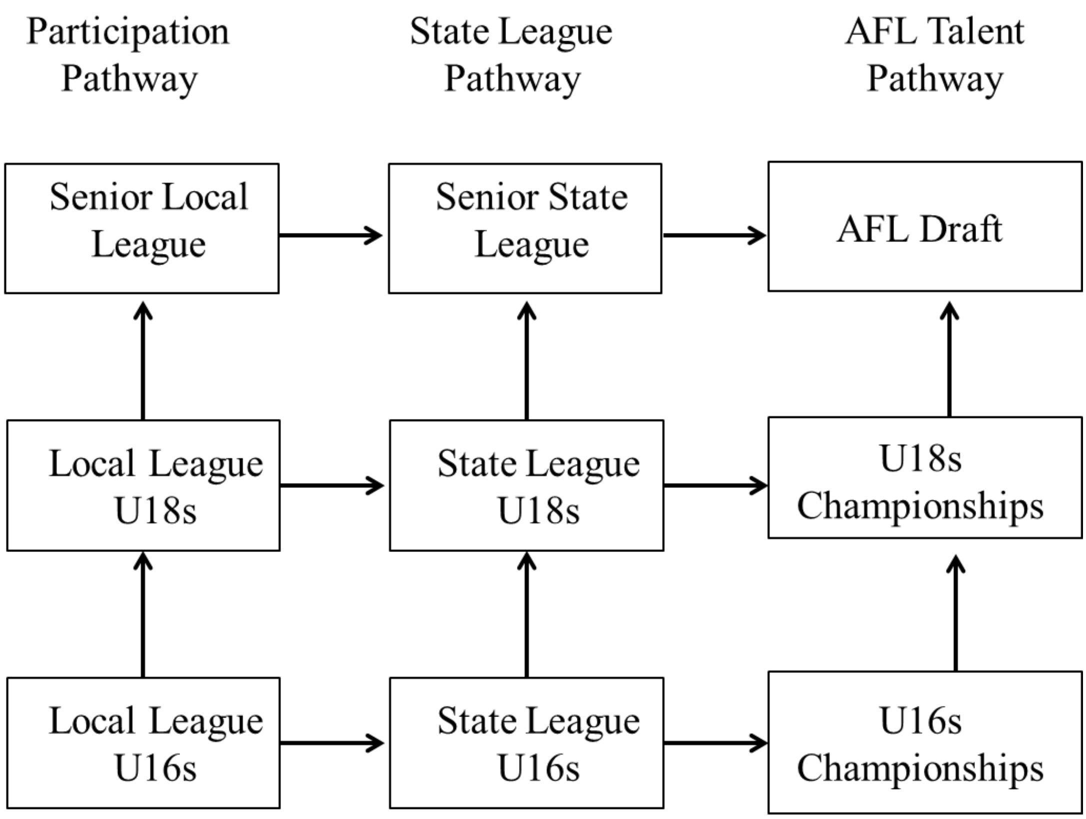


Figure 2. Schematic representation of the Australian Football League's Participation and Talent Pathways

1.3 Player development pathways

Traditional adolescent player development pathways share a common goal, to identify and accelerate the development of talented adolescent players for senior competition. To achieve this, traditional pathways such as the AFL TP are typically exclusive rather than inclusive. Pathway exclusivity is largely the result of time and financial limitations, with the progressive exclusion of players as the pathway progresses enabling greater centralisation of developmental resources and greater tuition time for players with experienced coaches (Vaeyens, Gullich, Warr, & Philippaerts, 2009). The identification and development processes used in typical sporting pathways, such as soccer, rugby and Australian football, utilise a four stage player development process similar to that depicted in Figure 3 (Williams & Reilly, 2000).

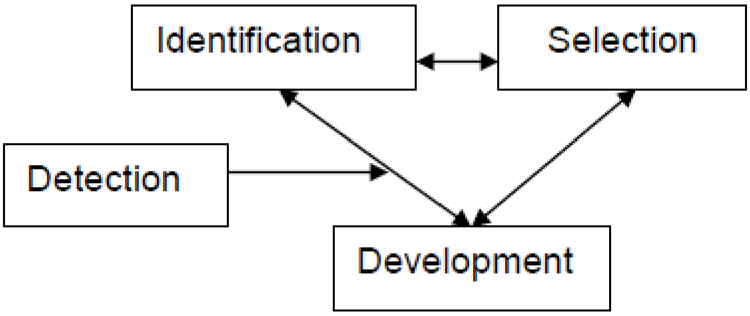


Figure 3. Key stages in the talent and identification process. Adapted from Williams and Reilly (2000).

In the four stage model proposed by Williams and Reilly (2000) talent detection refers to the discovery of potential elite performers who do not currently participate in the relevant sport. The detection process often utilises anthropometric, physical and psychological measures to profile players from other sports to predict if they have the characteristics required to potentially excel within the particular sport. Talent identification on the other hand, refers to the recognition of players currently participating in the sport in question, who potentially have the capacity to excel in adult competitions (Williams & Reilly, 2000). The identification process also uses testing to profile anthropometric, physical and psychological attributes, but unlike detection, can also extend to the assessment of technical skills. The acknowledgement and utilisation of coaches' subjective opinions is also an important component of this identification process. Selection in the model proposed by Williams and Reilly (2000) is similar to that of identification, but refers to the ongoing process of continual assessment at various levels for inclusion into higher stages of the development pathway. Development refers to the provision of appropriate resources and the environment necessary to accelerate development and ensure player's reach their sporting potential (Williams & Reilly, 2000). Development pathways provide players with access to experienced coaches, training resources and competition. The player development process is designed to optimise the development outcomes of talented players. However, there is limited longitudinal evidence suggesting development pathways are an efficient means of producing elite adult players (Vaeyens et al., 2009).

1.3.1 Efficiency of development pathways

Achieving selection into elite development pathways should ensure junior players are provided the best opportunity to reach their sporting potential. However, there is limited scientific literature examining the effectiveness of development pathways (Vaeyens et al., 2009). The limited research that has been published consistently reports poor retention rates when examining players progressing from elite junior development programs to elite senior competitions (Vaeyens et al., 2009). For example Ljach (1997) found that only 0.1% of talented Russian players training at elite sport schools attained excellence at a senior level. While Barreiros, Côté, and Fonseca (2014) explored the retention of pre-junior Portuguese National representatives (≤16 years) in the sports of soccer, volleyball, swimming and judo. Male retention into junior competitions (17-19 years) was reported to average 55.4% indicating that talented pre-junior players were likely to be re-selected into subsequent underage competitions. However, only 34.6% of pre-junior players were re-selected into national senior squads. The retention of elite pre-junior females into junior competitions were similar to males at 55.7%, however fewer were selected into senior competition (28.3%). Recently, McCarthy and Collins (2014) found that only 33 (28%) adolescent rugby union players in a professional team's development academy (n=118) received a professional contract with the senior team. However, an issue with reporting pathway retention in this manner is that results may be misleading, as junior development pathways are typically larger than senior squads making 100% retention impossible.

A more appropriate assessment of development pathway efficiency would be to examine the percentage of senior listed players who originated from junior development squads. Fewer studies have examined pathway efficiency using this model. Schumacher, Mroz, Mueller, Schmid, and Ruecker (2006) examined both pathway efficiency and retention and reported that 29.7% of elite adult cyclists had previously participated in junior World Championships. Barreiros and Fonseca (2012), also conducted a retrospective analysis of adult Portuguese representatives in both team and individual sports. The study found that 38% of national soccer and volleyball representatives had participated in pre-junior (≤16 years) competitions. However, the results from both these studies may under-estimate the true number of successful junior players as participation in junior World Championships and International squads represents a limited inclusion criteria, with a small number of players eligible for such selection. Examination of elite development pathways across entire sporting codes is needed to provide greater scope to previous findings and to potentially highlight problems which effect the efficiency of talent development pathways.

1.3.2 Factors affecting efficiency of development pathways

Understanding what factors contribute to poor pathway efficiency in adolescent development programs may enable coaches and key pathway administrators to increase the developmental outcomes of these pathways. There are a multitude of factors which potentially contribute to poor efficiency in adolescence development programs; for example injury, players transitioning between sports, or the de-selection of players from development pathways (Bergeron et al., 2015). However, it is unlikely that injury or player withdrawal can account for the inefficiencies demonstrated in well-resourced development pathways. For example in the AFL TP players are closely monitored by sport scientists and coaches to reduce the impact and likelihood of overload, injury and burn-out (Burgess &

Naughton, 2010). Scase et al. (2012) examined injury rates of elite junior Australian footballers across a single year and reported occurrence rates of 17.1 new injuries per club (95% confidence interval (CI) 14.9–19.4) with an average of 3.3 matches missed per injury (95% CI 3.1-3.6). While injuries in adolescent sport are common, they are unlikely to have a substantial impact on the long-term efficiency of a development pathway.

Similarly, player withdrawal is likely to contribute to pathway inefficiencies. Studies examining adolescent player withdrawal rates in the sports of Ice Hockey and soccer have reported participant withdrawal rates between 19.9-26.9% (Delorme, Boiche, & Raspaud, 2010; Figueiredo, Gonçalves, Coelho E Silva, & Malina, 2009a; Lemez, Baker, Horton, Wattie, & Weir, 2014). Lemez et al. (2014) tracked player (n=14,325) withdrawal from adolescent Canadian Ice Hockey across 5 years and reported that 26.9% of players withdrew from competition during this period. Player withdrawal in the previously mentioned studies was defined as a hiatus of either one or two years from sporting competition however, the specific reasons for withdrawal where not explored. The withdrawal of talented players from the sport in question would undoubtable reduce the efficiency of developmental pathways however, a third factor is also likely to contribute to the poor pathway efficiencies previously reported, coach derived selection/de-selection of players from the pathway.

Like most traditional development pathways, the AFL TP is exclusive rather than inclusive and follows the basic pyramid model of player participation (Green, 2005). In this developmental continuum, a broad base of participation at a community stage is progressively narrowed as the competition or developmental level increases, until eventually a small number of elite players remain (Bailey et al., 2010). In efficient development pathways, a high number of players selected into the elite senior stage of the pathway should progress from the elite lower levels of the development pathway. However, studies examining pathway efficiency in this manner report efficiency rates of less than 56% (Barreiros & Fonseca, 2012; Schumacher et al., 2006; Vaeyens et al., 2009). It has previously been suggested that elite under-age selection is biased by current performance capacities, rather than long-term adult potential (Vaeyens et al., 2009). A result of such acute selections priorities is that those who achieve selection are likely to be relatively or biologically more mature.

The relative age effect is a well-established phenomenon in many age-stratified sports whereby, chronologically older players are more likely to gain selection than their relatively younger counterparts (Baker, Schorer, & Cobley, 2010; Cobley, Baker, Wattie, & McKenna, 2009; Deaner, Lowen, & Cobley, 2013, McCarthy, & Collins, 2014; Till, Cobley, Morley, et al., 2016). It is hypothesised that relatively older players gain selection advantage because of physical and physiological advantages associated with increased relative age (Carling, Le Gall, Reilly, & Williams, 2009; Musch & Grondin, 2001). Relative age affects are apparent in many individual sports for example; tennis (Edgar & O'Donoghue, 2005; O'Donoghue, 2009), athletics (Hollings, Hume, & Hopkins, 2014), and swimming (Baxter-Jones, 1995; Costa, Marques, Louro, Ferreira, & Marinho, 2013) and team sporting contexts for example; handball (Schorer, Cobley, Busch, Brautigam, & Baker, 2009), soccer (Baxter-Jones, 1998; Helsen, van Winckel, & Williams, 2005), rugby (McCarthy, & Collins, 2014; Till, Cobley, Morley, et al., 2016), and ice hockey (Barnsley, & Thompson, 1988; Deaner, Lowen, & Cobley, 2013). Typically the relative age effect is strongest in early stages of development pathways where maturational variation is often greatest, around 14 to 16 years of age (Helsen, van Winckel, & Williams, 2005; McCarthy & Collins, 2014; Schorer, Cobley, Busch, et al., 2009; Till, Cobley, Wattie, et al., 2010). The strength of relative age effects often reduce as the pathway progresses, and into adulthood. The reduced strength of relative age effects reported are likely a result of the reduced maturational variation evident between players as they approach full adult status (Armstrong, 2007). The reduction of relative age effects with age may highlight that those initially selected are at risk of subsequent de-selection as relatively younger or less mature player physically "catch up" with age. As such, age biased selections into junior development pathways may provide a mechanism for player turnover, as the initial selection and subsequent de-selection of relatively older players would reduce the efficiency of a development pathway. Despite suggesting relationships between relative age effects and development pathways, no concurrent observation between pathway efficiency and relative age effects exist across an entire sporting code's development pathway.

1.4 Assessment of changes throughout adolescence and effects on performance.

Growth and physical development are terms often used interchangeably. For the purpose of this thesis, growth is defined as an increase in the size of the body whilst physical development refers to physical performance changes with maturation (Armstrong, 2007). Both growth and physical development during adolescence are age-influenced, but not necessarily age-dependent (Gallahue & Ozmun, 2006). The timing and magnitude of changes during this time is regulated by both genetic and environmental factors that stimulate hormonal changes within the body (Rowland, 2005). The main hormonal regulators of growth during adolescence is the Growth Hormone (GH)/ Insulin-like Growth Factors I (IGF-I) Axis. The GH/IGF-I axis has an obvious link with somatic growth throughout adolescence, as Serum IGF-I levels rising steadily from 5-15 years of age (Rowland, 2005). These hormones promote; anabolic; epiphyseal and osteoblastic activity in bones, lean muscle tissue development, and metabolic reactions in the adolescent body (Rowland, 2005). A unique depiction of how growth and sexual development are altered by variations in maturity can be seen in work by Shuttleworth (1949), where later and earlier maturing boys of similar chronologically are compared between 11 to 17 years of age. The up-regulation of testosterone during this time also plays an important role in somatic and strength development (Armstrong, 2007). As previously mentioned, these hormonal regulators of growth and physical development are influenced by both genetic predisposition and environmental factors.

Environmental factors such as nutrition and exercise serve to regulate hormone production rates (Ames & Flory, 1944). Appropriate nutrition is required to encourage the normal anabolic effects of growth facilitating hormones. Under and over-nutrition have both been suggested to depress normal hormonal activity in adolescent children (Jensen, 1950). Exercise has been suggested to play both a stimulatory and inhibitory role on the hormones that regulate growth, as it is seen as key to balancing energy expenditure and dietary intake. The impact of genetics on development also should not be understated. It is estimated that about 60% of height and 40% of weight change throughout adolescence is attributed to genetic predisposition (Malina, Holman, & Harper, 1970). Further, genetic predisposition also plays a significant role in athletic endowment (aerobic and anaerobic capacity, and strength have been shown to be linked to hereditary genetic variables) (Puthucheary et al., 2011) and maturational tempo (earlier maturing parents tend to have earlier maturing children, and vice versa) (Rowland, 2005). The physical and physiological changes that occur during adolescence as a result of these genetic predispositions can impact directly on their ability to perform in a competitive sporting environment.

Adolescent sporting competitions are typically age-stratified by one or two years in an attempt to ensure competition equity and player safety (Cobley et al., 2009). This process of age stratification is designed to ensure adolescent players compete with and against players of a similar physical capacity. However, despite this process maturational variation in age stratified sporting populations can be large (Buchheit & Mendez-Villanueva, 2014; Figueiredo, Gonçalves, Coelho E Silva, & Malina, 2009b; Gastin, Bennett, & Cook, 2013; Malina, Bouchard, & Bar-Or, 2004). For instance, Gastin et al. (2013) examined a population of under 15 community Australian footballers (n=52) and found that self-reported pubertal stage, using Tanner’s description of sexual development, ranged from pubertal stage 2 to pubertal stage 5. An independent case was highlighted, of two boys of similar chronological age (15.1 years v 15.2 years) who demonstrated marked variation in biological maturity, with 1.4 years of maturational difference between the two age matched players. Biological maturity is associated with a number of anthropometric, physical and motor skill changes (Armstrong & Welsman, 2005), with maturational variation potentially providing competitive advantage or disadvantage to competing players.

1.4.1 Assessments of maturity

The measurement of biological maturity during adolescence is typically assessed in relation to one of three biological markers; skeletal, sexual or somatic maturity (Malina, Bouchard, et al., 2004). Assessments of skeletal maturity most commonly uses x-ray imaging to examine the progression of bones in the wrist and/or hand from initial ossification to adult morphology (Greulich & Pyle, 1959; Roche, Chumlea, & Thissen, 1988). The assessment of sexual maturity is based on the maturation of secondary sex characteristics. Specifically in girls this refers to the development of breasts and menarche, and for boys, penis and testicular development is examined, the development of pubic hair can also be used in both sexes (Tanner, 1962). The third measure used to assess maturity in adolescence examines somatic growth. Somatic changes in height and weight throughout adolescence are used to estimate the individual's age at peak height velocity (PHV) or predicted adult stature (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002). Generally during puberty assessments of sexual and somatic maturity of individuals demonstrate moderate to high correlations (Bielicki, Koniarek & Malina 1984; Malina, Bouchard, & Bar-Or, 2004).

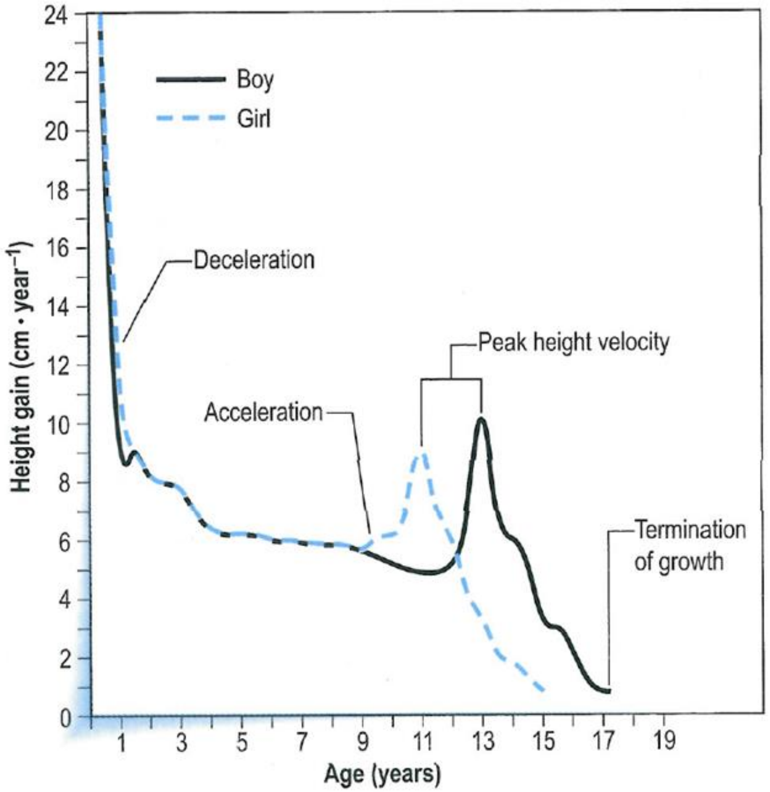
There are several practical limitations associated with the assessment of skeletal and sexual maturity which restricts their utilisation in adolescent development pathways. Specifically, to assess skeletal maturity expensive imaging equipment is required, with assessment time consuming and logistically difficult to coordinate for large groups. Issues with the examination of secondary sex characteristics are associated with the perceived invasive nature of such assessments. Estimates of maturity from somatic assessments are non-invasive and logistically simple to collect as sex-specific equations are used which incorporate chronological age, height, weight, sitting height and estimates of leg length to predict age at PHV and maturity offset (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002). Maturity offset is estimated as age at PHV minus chronological age. This method was originally developed using a sample of Canadian children aged 8-16 years who were longitudinally tracked through adolescence. Cross-validation was conducted using a combined sample of Canadian and Flemish children, with mean ages of 13.4, 14.0 and 14.2 years. The predictive equation developed was found to provide a reliable and practical means of assessing biological maturity, with a coefficient of determination 0.92, a standard error of measurement 0.59 years, and a mean difference of 0.24 ± 0.65 years between a verified sample of boys actual and predicted age at PHV (Mirwald et al., 2002). It should be noted that the validity of the predictive equation for estimating PHV in adolescent athletes has been questioned. Malina and Koziel (2014) explored the validity of the predictive model using longitudinal data of male Polish boys (n=193) collected between 1961 and 1972. The authors suggested the predictive equation has limitations due to estimating error in early maturing participants and suggests specifically the limitations of the tests when applying to adolescent sporting populations. The validity of the predictive measure has been explored longitudinally in female gymnasts (n=13), with the maturity offset equation appearing to overestimate age at PHV. However the small sample size of this study limits the application of the findings to gymnastics and female athletes (Malina et al., 2006). Currently the predictive equation has yet to be validated longitudinally using male athletic adolescent populations (Malina, Rogol, Cumming, Coelho E Silva, & Figueiredo, 2015).

Despite the lack of longitudinal data validating the age at PHV equation in athletic adolescent samples, cross-sectional studies have demonstrated strong correlations between the predictive equation and assessments of sexual and skeletal maturity (Buchheit & Mendez-Villanueva, 2014; Gastin et al., 2013). For instance, Gastin et al. (2013) examined a sample of adolescent Australian footballers (n=52) using both the predictive equation and participants subjective rating of actual biological maturity (using Tanners criteria for sexual development) and reported very large correlations between the two measures (r=0.80). While, work by Buchheit and Mendez-Villanueva (2014) demonstrated that peak height velocity estimates were well correlated (r = 0.69) with skeletal maturity (estimated from a hand and wrist radiograph) in highly trained Middle Easter adolescent soccer players (n = 36; age range: 12.1–17.3 years). Due to the ease of assessment the age at PHV equation has also been adopted as the standard maturity assessment in various development pathways such as the Player Performance Pathway in UK rugby league (Till et al., 2013). Given the methods applicability to practical talent identification testing and previous research reporting strong correlations between the predictive equation and other assessments of biological maturity, the predictive equation presents as a valid tool for assessing biological maturity in the athletic sample recruited for this thesis.

1.4.2 Anthropometric growth

Anthropometric changes during childhood and adolescence are perhaps the easiest to identify and most commonly measured due to their ease of assessment. There are four phases which typify anthropometric growth during this period; rapid growth during infancy and early childhood, steady gains during middle childhood, another period of rapid growth during adolescence and finally slowed increases until the cessation of growth at adult stature (Malina, Bouchard, et al., 2004). Whilst growth throughout childhood and adolescence usually follows this four phase process, the timing and magnitude of growth through each phase can vary greatly between individuals, due to the genetic and environmental factors previously outlined in section 1.4. The various phases of anthropometric growth throughout childhood and adolescence are best depicted via height and weight velocity charts (Figure 4). The fastest period of growth in any individual's life is during the first two years, during this time the rate of growth is so great that by 2 years of age children will have attained nearly 50% of their full adult stature (Malina, Bouchard, et al., 2004). After this period the rate of growth decreases markedly until the onset of peak height velocity, the peak velocity of height growth during adolescence. The onset of PHV typically occurs around 10.0-12.1 years with PHV attained between 13.3-14.4 years of age in males. In females, the onset of PHV is much earlier at around 8.2-10.3 years with PHV reached around 11.3-12.2 years of age (Malina, Bouchard, et al., 2004). Increases in weight throughout adolescence follows a similar trend to stature, though peak weight velocity generally occurs around 0.2-0.4 years after PHV (Armstrong, 2007). During adolescence, variation in biological maturity between individuals of a similar chronological age can result in large anthropometric growth discrepancies, though once full adult status is attained, these associated differences in maturational variation disappear (Malina, Bouchard, et al., 2004). In both youth soccer (Vandendriessche et al., 2012) and rugby (Till, Cobley, O'Hara, et al., 2011) higher level selection and performance has previously been shown to be biased towards athletes of greater maturity and stature. In Australian football the effects of maturational variation on growth in the underage stages of the AFL TP may consequently effect sporting performance and selection opportunities.

Players with greater height and weight are at a selection advantage at both senior and junior levels of Australian football (Keogh, 1999; Robertson, Woods, & Gastin, 2015; Veale, Pearce, Koehn, & Carlson, 2008; Woods, Raynor, Bruce, McDonald, & Collier, 2015). This selective advantage infers that due to the combative nature of Australian football being taller and heavier is potentially advantageous in match situations, particularly in marking, ruck and contested ball situations. However few studies have examined how anthropometric variables impact directly on match performance outcomes in adolescent Australian football. Young and Pryor (2007) assessed the number of disposal, marks and hit-outs attained by adolescent Australian footballers by grouping players into a high or low performance group. They found significant (p=.05) anthropometric differences when grouping adolescent footballers based on the number of marks (high group >3; low group <3) and hit-outs attained within matches (high group >6; low group <6). The high performance marking group was significantly heavier (p<.05, Effect Size (ES) =0.54) while the high performance hit-out group was significantly taller (p<.05, ES=1.51). Studies examining anthropometric measures and selection outcomes have exclusively studied players in U18 elite/semi-elite squads and drafted players. To date no research has examined the impact of stature and higher selection in U16 Australian footballers.



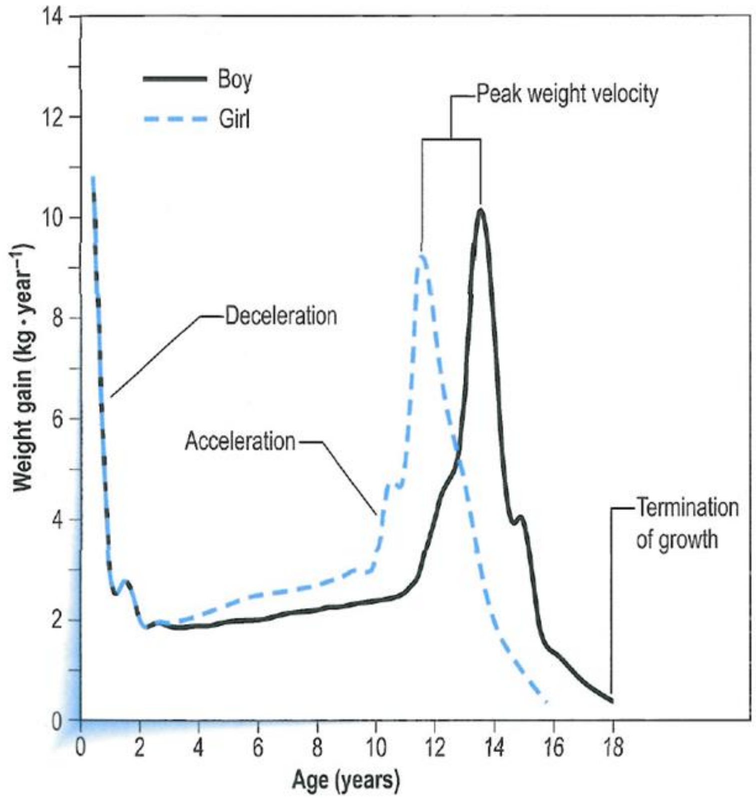


Figure 4. Height and weight velocity changes from birth to adulthood. Adapted from (Armstrong, 2007) with permission from Elsevier

1.4.3 Physical development

Assessment of a player's physical capacities, and the development of these physical capacities is common in talent identification for development pathways, such as the AFL TP (Hoare, 2000; Sierer, Battaglini, Mihalik, Shields, & Tomasini, 2008; Till, Cobley, O'Hara, et al., 2010; Williams & Reilly, 2000). These assessments are used to predict if players have the physical capacities required to successfully perform in a particular sport. Attributes typically examined include measures of speed, power, agility and aerobic capacity. However, performance in physical testing can vary greatly depending on the relative maturity of the player (Armstrong & Welsman, 2005; Pearson, Naughton, & Torode, 2006). Physical performance advantages or disadvantages associated with maturational variability has been documented in many commonly used physical testing measures and match performance outcomes.

1.4.3.1 Speed development

Speed is considered a critical component of team sports like Australian football (Veale, 2011), and can be broken into three specific sub-fields; acceleration (Duthie, Pyne, Marsh, & Hooper, 2006), maximum running speed (Jeffreys, 2013; Little & Williams, 2005), and repeated-sprint ability (Pyne, Saunders, Montgomery, Hewitt, & Sheehan, 2008; Rampinini et al., 2007). While all three aspects of speed are inter-related and often show large correlations (Harris, Cronin, Hopkins, & Hansen, 2008; Mendez-Villanueva et al., 2011; Pyne et al., 2008), different morphological, physiological and biochemical variables can affect the development of each individual aspect of speed. Maximal acceleration is largely influenced by concentric force production, impulse and knee extensor activity (Dorn, Schache, & Pandy, 2012), whereas maximum speed appears to be influenced the stretch-shortening cycle efficiency, hip extensor activity and lower limb stiffness (Harris et al., 2008; Sleivert & Taingahue, 2004). While, the capacity for players to repeatedly produce high intensity running efforts is associated with biochemical capacities, phosphocreatine degradation/resynthesis, pH buffering capacities and oxygen kinetics (Girard, Mendez-Villanueva, & Bishop, 2011). During adolescence a number of morphological, physiological and biochemical changes occur which serve to increase the capacity of a player to produce speed in each of the three specific sub-fields.

Factors effecting the development of acceleration and maximum speed include increases in muscle mass and strength, neurological control and motor coordination (Malina, Bouchard, et al., 2004; Pearson et al., 2006). A number of studies have shown that both acceleration and maximal sprint speed performance in field tests significantly improve *(p*<.05) with increased biological age (Gastin & Bennett, 2013; Gastin et al., 2013; Malina, Eisenmann, Cumming, Ribeiro, & Aroso, 2004; Mendez-Villanueva et al., 2011; Papaiakovou et al., 2009; Philippaerts et al., 2006). For instance, Mendez-Villanueva et al. (2011) examined the acceleration and maximal running speed capacities of highly trained young male soccer players (n=61) between the age of 12.0-17.8 years. Acceleration was assessed as the time through the first 10 meters of a 40 metre sprint test. Maximum sprint speed was assessed as a flying start 20 metre sprint, which represented the time through the final 20 metres of the 40 metre test. The results showed significant differences with large effect (*p*<.05, ES 0.93-3.02) between U14s and U16s, U16s and U18s, and U14s and U18s for both acceleration and maximal sprint speed. These results are supported by Gastin et al. (2013) who found a large significant negative correlation (r=-0.77, *p*<.01) with increased maturational status and decreased 20 m sprint time, in male community adolescent Australian footballers (n=52). It was also observed that players grouped into similar chronological age categories demonstrated performance variability, potentially due to intra-group variations in maturation. Gastin and Bennett (2013) conducted a follow up study to examine performance outcomes in age-matched U15 community Australian football players (n=87). A large, significant negative correlation (r= -0.53, *p*<.01) between 20 metre sprint performance and biological maturity was again reported. To date no examination has been conducted to examine the impact of maturational variation on sprint measures in semi-elite U16 Australian footballers.

The considered importance of maximum speed and acceleration to Australian football, has led a number of studies to examining whether speed plays a role in team selection outcomes (Pyne, Gardner, Sheehan, & Hopkins, 2006; Robertson et al., 2015; Veale et al., 2008; Woods, Raynor, Bruce, McDonald, et al., 2015). Results, however have been mixed and as a result the relationship with sprint speed and team selection is inconclusive. For instance, Veale et al. (2008) conducted a case study assessing players competing for selection into an U18s state representative side. The results showed no difference (*p*=.16) in maximal sprint values and selection. These results were mirrored by Woods, Raynor, Bruce, McDonald, et al. (2015) who examined selection of U18s players into a state representative team and found no significant relationship between acceleration or maximal sprint performance and higher team selection. In comparison, Robertson et al. (2015) reported moderate differences in sprint performance between players selected into state or regional representative teams and into the AFL draft. Given the inconclusive nature of the available studies and that all explore the link between sprint performance and U18 team or draft selection, further exploration of the relationship between sprint performance and elite team selection in U16 Australian football is warranted.

1.4.3.2 Power development

Muscular power can be defined as the rate of force produced through a range of motion (Peterson, Alvar, & Rhea, 2006). The development of power in players enables them to produce an increased magnitude of force in the same relative time or the same magnitude of force in less time, with both considered to be important factors in sporting environments (Peterson et al., 2006). In team sport environments, assessments of lower limb power is usually conducted by examining a player's capacity to produce power in a singular maximal effort, which often takes the form of a vertical jump test (Young, Macdonald, Heggen, & Fitzpatrick, 1997). Vertical jump tests commonly require players to perform either a maximal countermovement jump or maximal running vertical jump (generally with a single leg take off) (Sierer et al., 2008; Till, Cobley, O'Hara, et al., 2010; Vila et al., 2012; Woods, Raynor, Bruce, McDonald, et al., 2015). Vertical jump tests are commonly adopted to assess lower limb power because of the considered importance of maximal jumps performance in many sporting contexts, for example in Australian football to compete in a marking or ruck contest or in soccer when trying to head the ball. Vertical jump tests are also commonly adopted due to the ease and reliability of assessment (Young et al., 1997). Performance in vertical jump tests can be determined by a number of biological (e.g. muscle size, fibre type and muscle architecture) and mechanical (e.g. muscle and lever length, stretch-shortening speed and neuromuscular control) factors (Fitts, McDonald, & Schluter, 1991; Rowland, 2005), many of which develop throughout adolescence.

Vertical jump performance doubles between the ages of 5-13 years (Malina, Bouchard, et al., 2004), and continues to progress from around the time of puberty into adulthood (Philippaerts et al., 2006; Rowland, 2005; Thomas & French, 1985; Valente-dos-Santos, Coelho E Silva, Severino & Duarte, 2012). In adolescent soccer, vertical jump performance has been shown to improve significantly ($p<.01$) with age throughout adolescence, with 13-14 year old players jumping on average 5.7 cm higher than 11-12 year old players (Figueiredo, Gonçalves, Coelho E Silva, et al., 2009b). Further longitudinal research examining power development in Portuguese adolescent soccer players reported that from between 11-16 years of age counter movement jump height increased by between 2-3cm per year (Valente-dos-Santos, Cobley, O'Hara, et al., 2012). Similar performance differences have been reported in youth basketball, with players 15 years of age jumping on average 4.4 cm ($p\leq.01$) higher than their 14 year old counterparts (Coelho E Silva, Figueiredo, Moreira Carvalho, & Malina, 2008). Despite strong links to chronological age the impact of maturational variation on jump performance in age matched adolescent subjects has been less clear.

Studies examining normal healthy populations and community level sporting groups (Beunen et al., 1997; Malina et al., 2011; Quatman, Ford, Myer, & Hewett, 2006) have shown that earlier maturing participants are at a significant performance advantage over later maturing individuals. However, in adolescent players, the effects of maturation on vertical jump performance has been varied. For instance a number of studies have reported significant difference between players of different maturational stages (Malina, Eisenmann, et al., 2004; Matthys, Vaeyens, Coelho E Silva, Lenoir, & Philippaerts, 2012). While other similar comparisons have been inconclusive or non-significant (Coelho E Silva et al., 2008; Figueiredo et al., 2009b; Till, Cobley, Cooke, & Chapman, 2014). For example, Malina, Eisenmann, et al. (2004) examined vertical jump performance in U15 youth soccer players (n=69) and reported significant (*p*=.05) differences between pubertal stages and jump height performances, with athletes of advanced pubertal development jumping on average 7 cm higher than the youngest athletes. In contrast Till et al. (2014) found no significant difference between vertical jump performances in age matched 14, 15 and 16 year old rugby league players when maturational status was considered. The inconclusive results in adolescent team sports may be associated with selected players being required to demonstrate relatively homogenous fitness characteristics (Till et al., 2014). However, given the inconclusive nature of the findings further assessment of the effects of maturational variation on vertical jump performance is warranted.

Possessing the ability to jump high in Australian football is likely to put players at a performance advantage in matches. For instance in match activities such as marking and ruck contests, where players try to either catch the ball or tap the ball to the advantage of a teammate. As a result of the perceived importance of jumping ability in Australian football, a number of studies examining talent identification testing and team selection, career success or progression have included a measure of vertical jump performance (Burgess, Naughton, & Hopkins, 2012; Keogh, 1999; Pyne, Gardner, Sheehan, & Hopkins, 2005; Robertson et al., 2015; Veale et al., 2008; Woods, Raynor, Bruce, McDonald, et al., 2015; Young et al., 2005; Young & Pryor, 2007). Studies specifically examining adolescent team selection have consistently shown that players who possess greater vertical jump capacities are more likely to gain team selection (Keogh, 1999; Robertson et al., 2015; Veale et al., 2008; Woods, Raynor, Bruce, McDonald, et al., 2015; Young & Pryor, 2007). For instance, Woods, Raynor, Bruce, McDonald, et al. (2015) reported that in a sample of U18 Australian footballers, higher selection into a state representative team was strongly correlated with vertical jump performance. Athlete selection was associated with superior standing ($p<.05$, ES=0.53), running dominant ($p<.05$, ES=0.80), and non-dominant foot ($p<.05$, ES=0.97) take off performances. Further, Woods, Raynor, Bruce, McDonald, et al. (2015) also reported that the best individual predictor of selection was running non-dominant vertical jump performance, with 78.2% of players selected into the elite team jumping ≥ 74.5 cm. Despite a large body of work examining vertical jump performance and selection in adolescent

Australian footballers, research has focused on either adult or players in U18s competitions. To date no examination of vertical jump performance and team selection has been conducted on U16 Australian footballers.

1.4.3.3 Aerobic development

Aerobic capacity is defined as an individual's ability to deliver oxygen and generate energy in the working muscles during exercise (Armstrong, 2007). Movement patterns in team sports are often intermittent in nature and require players to not only have well established anaerobic capacities but also well-developed aerobic systems (Abdelkrim, El Fazaa, & El Ati, 2007; Bangsbo, Mohr, & Krustrup, 2006; Chelly et al., 2011; Cunniffe, Proctor, Baker, & Davies, 2009; Gray & Jenkins, 2010). The commonly accepted gold standard for assessing aerobic capacity is the estimation of maximal oxygen uptake (VO_2max). However, to attain a true estimate of VO_2max expensive laboratory equipment is required and experienced scientists are needed to implement the test (Malina, Bouchard, et al., 2004). Further, it is often not possible to test multiple players at the same time. Therefore, the estimation of a player's aerobic capacity in team sport environments is normally undertaken using one of a number of field based tests, which are used to predict a player's VO_2max (Buchheit, 2008; Grant, Joseph, & Campagna, 1999; Krustrup et al., 2003; Piggott, McGuigan, & Newton, 2014; Ramsbottom, Brewer, & Williams, 1988). These tests either involve intermittent or incremental running to a timed beep over a set distance, as is the case with the 20 m multistage fitness test (Ramsbottom, et al., 1988), or are continuous time trial. In Australian football, the tests most commonly used to assess aerobic capacity of players are the 20 m multistage fitness test and a single 3km time trial (Piggott, McGuigan, & Newton, 2014).

Aerobic capacity estimated via timed or incremental field tests have generally been shown to increase with chronological age (Armstrong & Welsman, 1994; Beunen, Ostyn, Simons, Renson, & Van Gerven, 1981; Coelho E Silva et al., 2008; Elferink-Gemser, Visscher, Lemmink, & Mulder, 2007; Gastin et al., 2013; Malina, Eisenmann, et al., 2004; Till, Cobley, O'Hara, Chapman, & Cooke, 2013; Vaeyens et al., 2006). Improvements in aerobic capacity throughout adolescence is associated with physiological, anatomical and biomechanical changes such as; increased cardiac output, muscle mass, aerobic enzyme activity, stride length/frequency and running economy (Rowland, 2005). Longitudinal research involving adolescent field hockey players found that aerobic performance in the interval shuttle run test improved significantly (p<.05) between the ages of 12-16 years of age, with elite players increasing the average number of shuttles completed from 68.8 to 101.1 (Elferink-Gemser et al., 2007). These findings were supported by other longitudinal research into adolescent rugby league with estimated VO_2max, calculated using the multistage fitness test. It was found that estimated VO_2max significantly (p<.01) increased from 47.90 $ml \cdot kg^{-1} \cdot min^{-1}$ to 51.30 $ml \cdot kg^{-1} \cdot min^{-1}$ between U13 to U15 competition (Till et al., 2013). Similar longitudinal research in Portuguese adolescent soccer players reported that between 12-15 years of age performance in the multistage shuttle test improved by on average around 200m per year, whilst between 16-17 years of age performance improved by an average of around 100m per year (Valente-dos-Santos, Cobley, O'Hara, et al., 2010). Despite longitudinal research suggesting performance improvements with chronological age, improvements in aerobic field test performance in more mature age matched players are less apparent.

The effects of maturation variation on aerobic field test performance in age matched players have been inconclusive, for example Malina, Eisenmann, et al. (2004) reported youth soccer players of advanced maturity significantly outperformed their less mature counterparts in the yo-yo intermittent endurance test (level 1). Several other studies examining aerobic test performance have shown non-significant differences between age matched players of lesser and greater biological maturity (Buchheit & Mendez-Villanueva, 2014; Coelho E Silva et al., 2008; Gastin & Bennett, 2013; Matta, Figueiredo, Garcia, & Seabra, 2014; Till et al., 2014). A number of these studies showed trends towards more mature players demonstrating non-significant performance advantages (Buchheit & Mendez-Villanueva, 2014; Gastin & Bennett, 2013; Till et al., 2014), while in other studies results were mixed (Coelho E Silva et al., 2008; Figueiredo et al., 2009b; Matta et al., 2014). Interestingly, Figueiredo et al. (2009b) examined youth soccer and found that in 11-12 year olds, later maturing individuals significantly (p<.05) outperformed their more mature counterparts in the endurance shuttle run test. The authors suggested that such results may be attributed to the advantages of lower body mass in the later maturing individuals (Figueiredo et al., 2009b). Limited research has examined the impact of maturational variation on aerobic fitness testing in youth Australian football. The limited work available has focused on community level participants and reporting non-significant results (Gastin & Bennett, 2013; Gastin et al., 2013). Gastin and Bennett (2013) recruited community level U15 Australian footballers (n=87) and found there was little relationship between maturity and endurance shuttle performance (r=0.12).

In Australian football, the links between performance in aerobic endurance tests and adolescent team selection have largely focused on selection into U18s competitions or draft outcomes. These studies have either examined selection into state league teams (Keogh, 1999; Veale, Pearce, & Carlson, 2010; Veale et al., 2008; Young & Pryor, 2007), selection into the U18 stages of the AFL TP (Woods, Raynor, Bruce, McDonald, et al., 2015) or draft outcomes (Burgess et al., 2012; Pyne et al., 2005; Robertson et al., 2015). Results from these studies generally suggest that players who perform better in aerobic testing measures are at a selective advantage. For instance recent work by Woods, Raynor, Bruce, McDonald, et al. (2015) found that players selected into an elite state U18 representative team performed significantly (p<.05, ES=0.59) better in the multi-stage fitness test than their non-selected, state league counterparts. Further, recent work by Robertson et al. (2015) examined performance differences between drafted, state representative and stage league players, using the Hedges *d* statistic. Small differences were evident between drafted and state representatives (Hedges d=0.27), and state representatives and state league players (Hedges d=0.36), with moderate differences reported between drafted and state league individuals (Hedges d=0.64). Whilst similar results may be expected for younger players, to this point no research has examined the influence of aerobic testing measures on selection in U16 Australian footballers.

1.4.4 Skill development

Australian football is a multidimensional team sport where talented players are required to possess both well-developed physical capabilities and technical skills (Woods, Raynor, Bruce, & McDonald, 2015; Woods, Raynor, Bruce, McDonald, et al., 2015). In Australian football, players can either dispose of the ball by foot (kick) or by hand (handball). The skill of kicking involves the player dropping the ball from the hands at approximately waist height so that the ball drops towards the kicking foot. Ball-foot contact typically occurs around 0.1-0.3 m from the ground (Ball, 2008). Handballing is a skill unique to Australian football and involves the player holding the ball in one hand and striking the ball, using a clenched fist, with the opposite hand (Parrington, Ball, & MacMahon, 2013). Senior AFL players often perform kicks on both their dominant and non-dominant legs, over various short (~25m), medium (~35m) or long (~45m) distances (Appleby & Dawson, 2002). Handballs are more commonly performed under high opposition pressure, with players typically executing handballs across distances of less than 15 m (Parrington et al., 2013). To test the technical skill of potential draftees the AFL introduced a kicking efficiency test to the AFL National Draft Combine in 2009, with the tests assessing dominant and non-dominant foot kicking skills across three distances; short (20 m), medium (30 m) or long (40 m) (see Figure 5). In 2010, the skills tests were expanded to include a handball efficiency test, in which the player receives the ball either in the air or on the ground and then were required to handball to a target, either on their dominant and non-dominant hand. Targets in the handball test are set at 6 m, 8 m, and 10 m (see Figure 6). Both tests were designed for use at the annual National Draft Combine, as well as in other levels of the development pathway. As such, the tests were designed to be easy to implement and replicate. However it is surprising that despite the tests being extensively used in the AFL TP and the implication for performance on potential career progression that no assessment of reliability or validity has yet been conducted on either skill test.

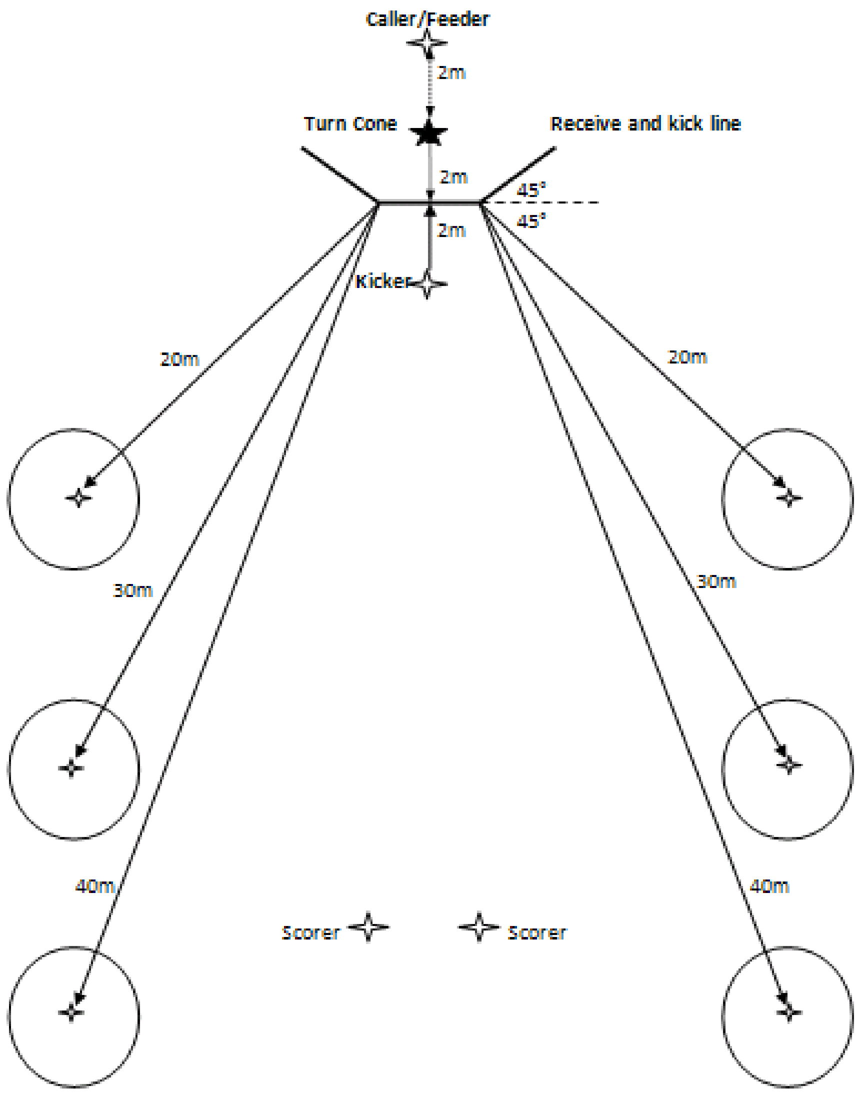


Figure 5. Layout of the AFL's kicking test. The player receives the ball before pivoting around the turn cone. At the same time as the ball is received a randomly selected target will be called with the player required to deliver the ball before the kick line to the target. Targets are set on the left and right sides at 20 m, 30 m and 40 m (adapted from Sheehan (2010) with permission from the AFL).

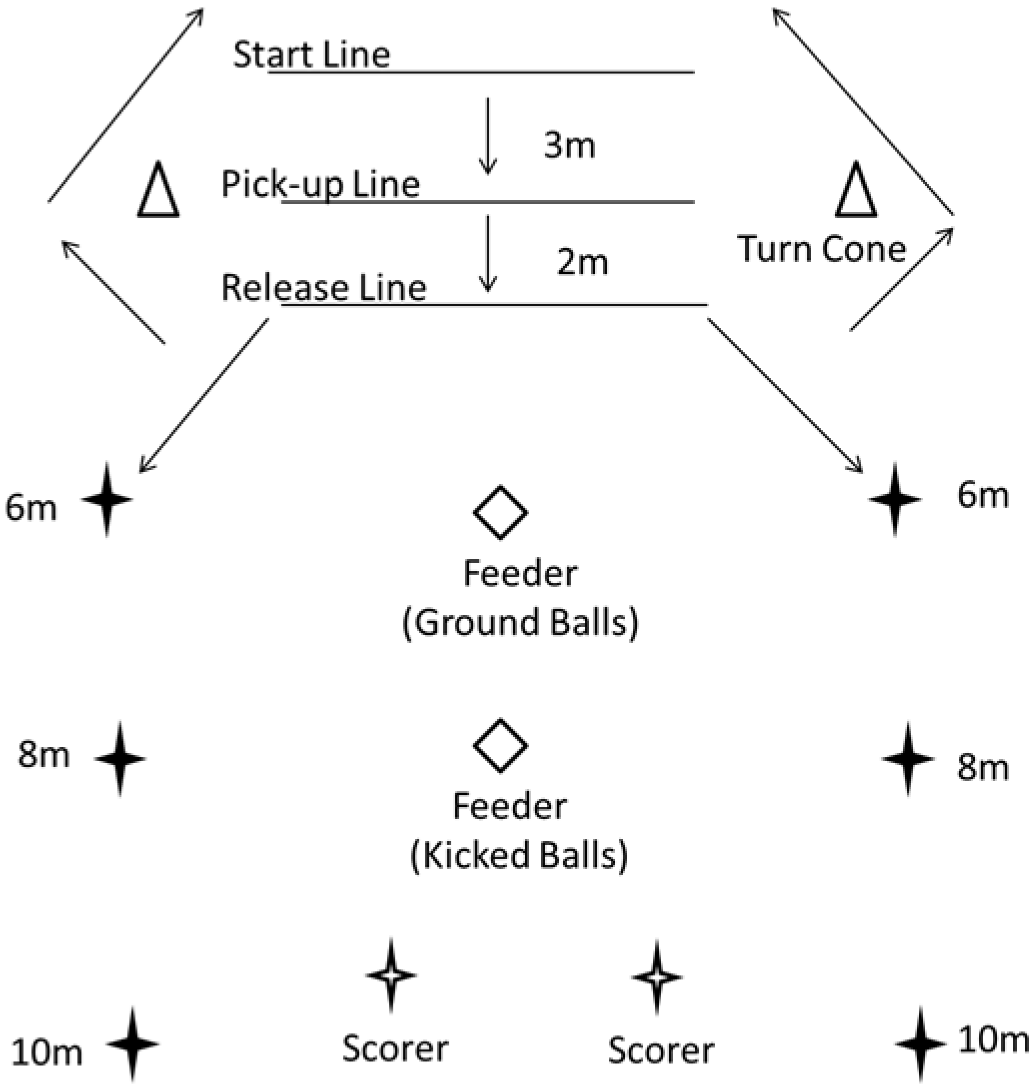


Figure 6. Layout of the AFL's handball test. The player receives the ball at the pick-up line. At the same time as the ball is received a randomly selected target will be called with the player required to deliver the ball before the release line to the target. Targets are set on

Longitudinal research into the sports of hockey, soccer and handball have shown that sport specific skills progressively improve with age (Elferink-Gemser et al., 2007; Huijgen, Elferink-Gemser, Ali, & Visscher, 2013; Matthys, Vaeyens, Fransen, et al., 2012; Vaeyens et al., 2006). For instance, Vaeyens et al. (2006) demonstrated that the soccer skills of lobbing, dribbling and juggling all improved between 13-16 years of age. However, research examining the effect maturational variation has on age matched players and technical performance has been inconclusive (Coelho E Silva et al., 2008; Figueiredo et al., 2009b; Malina, Eisenmann, et al., 2004; Matta et al., 2014; Vandendriessche et al., 2012). For instance, age matched soccer players appear to demonstrate no significant difference between players of varying maturation status and skill (Figueiredo et al., 2009b; Malina et al., 2005; Matta et al., 2014). Soccer skill tests commonly involve assessments of ball control, dribbling, passing and shooting performance. In the study by Malina et al. (2005), only a single skill variable, dribbling speed with a pass, differed between pubertal stages in 13 to 15 year old soccer players (n=69). In this study maturity was found to have a small effect on the skill tests, explaining 8-21% of observed variance. However, other studies have consistently shown no significant difference between groups of different maturational status and soccer skill performance (Figueiredo et al., 2009b; Matta et al., 2014; Vandendriessche et al., 2012). In other sports of basketball and handball maturational variation appears to have little effect on sport specific skill (Coelho E Silva et al., 2008; Matthys, Vaeyens, Coelho E Silva, et al., 2012). Matthys, Vaeyens, Coelho E Silva, et al. (2012) reported no significant difference in handball specific skills and maturation, while Coelho E Silva et al. (2008) reported significant performance disadvantage to late maturing 14 year old basketball players in dribbling and defensive skills, however the small sample (n=31) of players in this group limit these findings. To date no research has explored the effect of maturational variation has on the kicking and handball skills specific to Australian football.

It is suggested that talented team sport players are required to possess a composite of physical, technical and tactical skill (Launder, 2001). In Australian football there is a plethora of evidence available supporting the theory that talented players also have superior physical capacities however, examination of sport specific skill and selection has scarcely been undertaken. To date only one study has examined the link between technical skill and talent identification in Australian football. Woods, Raynor, Bruce, and McDonald (2015), created two skill tests with similar technical requirements to the AFL's skills test with players required to perform kicks or handballs on their dominant and non-dominant hand or foot. Talent identified U18 state representative players were significantly (p<.05) more accurate on their dominant and non-dominant hands and foot than their non-talent identified counterparts (Woods, Raynor, Bruce, et al., 2015). Further predictive modelling included all the technical variables examined (dominant and non-dominant limb accuracy and kicking ball speed) and correctly detected 80% of the talent identified players. This study provides the first evidence that skill differences exist between talent identified and non-talent identified junior Australian footballers. Given the relative lack of research examining skill efficiency and selection in Australian football further research should explore if the findings of Woods, Raynor, Bruce, and McDonald (2015) are replicated in other levels of the AFL TP and if the tests developed by the AFL demonstrate a discriminatory capacity.

1.4.5 Coaches' perceptions of skill

Effective talent identification systems utilise both objective performance assessments of physical ability and skill, as well as subjective assessment, such as coaches' perceptions of a player's ability and potential (Williams & Reilly, 2000). In Australian football, coaches and talent identification officers of high level underage and professional teams routinely observe players train and compete in order to gain a more complete understanding of a player's ability and potential. Despite coaches' subjective assessments of performances and technical skills being an essential component of talent identification, subjective assessments of players are innately open to bias. For example, a "halo effect" may occur, whereby a coach makes an inappropriately generalisation about a player's ability, based on impressions of another characteristic (Thorndike, 1920). Evidence of how perceptions of height can bias judgement have been documented in adults impressions of authority (Dannenmaier & Thumin, 1964), job status (Egolf & Corder, 1991) and career success (Judge & Cable, 2004). However no research has explored the link between maturity and perceptions of technical skill or potential. Previous research has demonstrated that the physical stature of a hypothetical goal keeper can impact on perceptions of athletic prowess (Masters, Poolton, & Van Der Kamp, 2010). However, the findings of this study were limited and lack practical application as soccer players were required to rate the perceived athletic prowess of size adjusted images of goal keepers. However, despite its limitations the study by Masters et al. (2010) highlights that perceptions of skill or potential may be biased by anthropometric and/or physical performance capacities. As discussed previously both anthropometric and physical measures are likely to be influenced by maturation and advanced in players of greater biological maturity. Given that coaches' perceptions of skill and potential have implications for selection outcomes in sporting pathways such as the AFL TP, research should establish if in fact coaches' perceptions are biased by maturational variation.

1.5 Conclusions

The selection and subsequent development of talented junior players is critical to ensuring the long-term success of professional sport teams and codes (Vaeyens, Lenoir, Williams, & Philippaerts, 2008). As such, significant investment is made into the player identification and development process, however there is limited longitudinal evidence to suggest that players initially selected into development pathways are retained into senior professional teams (Vaeyens et al., 2009). A number of factors can impact on a player's progression from elite junior development programs into professional senior teams or competition, such as injury, burnout or withdrawal from the sport. Another factor which is likely to influence retention rates is the progressive de-selection of those initially selected as player's progress towards senior competition.

Variations in biological maturity may present as a major confound when identifying adolescent players for development pathways. Typically competition and development pathways are stratified by chronological age groups in an attempt to ensure competition equity and participant safety. However during adolescence, especially around the time of PHV, large variations in biological maturity can occur in players of a similar chronological age (Armstrong, 2007). In Australian football, variations in maturity of U15 community level players have been associated with significant anthropometric and physical performance advantage (Gastin & Bennett, 2013). While the impacts of maturational variation on Australian football specific technical skills and coaches perceptions of skill and potential are unknown.

Research into measures predictive of selection in Australian football has focused on players at an U18 or draft level. For example Woods (2015) recently conducted multidimensional examination of measures which predicted selection into an elite U18 Australian football team and reported that selected players possessed greater technical skill, and tactical, height, vertical jump and aerobic capacities. To date no examination of factors which predict U16 talent identification has been conducted despite initial identification into the AFL TP occurring at this age.

1.6 Overall objectives and specific aims of the thesis

The overarching objective of this thesis is to explore the effects of maturational variation on player retention, performance and progression throughout the AFL TP. Particular reference was given to the initial stage of the pathway (U16) due the lack of research exploring this age group. Chapter two set out to longitudinally explore the AFL TP retention rates and relative age effects. Chapter three examined the reliability and validity of the AFL skill tests. Chapter four and five examined the influence of maturity on performance measures, coaches' perceptions of skill and potential. The final study of the thesis (chapter six) explored differences between talent identified and non-talent identified adolescent Australian footballers and measures predictive of talent identification into the AFL TP. The titles of each of each chapter and their specific aims are below.

Chapter two- Pathway efficiency and relative age in the Australian Football League Talent Pathway.

Aims:

i) To longitudinally explore the player retention rates of AFL TP.

ii) To determine if a relative age effect exists in the AFL TP.

Chapter three- Inter-rater reliability and validity of the Australian Football League's kicking and handball tests.

Aims:

i) To determine if the skill tests developed by the AFL demonstrated acceptable levels of inter-rater reliability.

ii) To determine if the skill tests developed by the AFL demonstrated content and concurrent validity.

Chapter four- Maturity, physical ability, technical skill and coaches' perception of semi-elite adolescent Australian footballers.

Aims:

i) To explore if maturational status impacts anthropometric and physical testing, technical skill efficiency, and coaches' perceptions of skill in talented young Australian footballers.

ii) To determine if anthropometric, maturational or age factors are predictive of performance in physical and skill tests commonly used by the AFL.

Chapter five- Coaches' perceptions of long-term potential are biased by maturational variation.

Aims:

i) To examine if maturational variation in talented young Australian footballers influence coaches' perceptions of long-term potential.

***Chapter six* –** Biological maturity and the anthropometric, physical and technical assessment of talent identified U16 Australian footballers.

Aims:

i) To compare biological maturation, anthropometric, physical and technical skill measures between talent and non-talent identified U16 junior Australian footballers.

ii) To determine if the aforementioned measures could discriminate between talent identified and non-identified U16 players.

1.7 Significance of the thesis

Significant resources are invested into the identification and subsequent development of talented junior players. However longitudinal evidence suggests that few players initially selected into adolescent development pathways progress into professional adult competition (Barreiros & Fonseca, 2012; McCarthy & Collins, 2014; Schumacher et al., 2006). Poor retention of elite junior players into professional senior competition wastes development pathway resources and potentially reduces the standard of competition at the professional level. One explanation for the poor retention of players may be that players initially selected into talent pathways are simply more mature and therefore may be at a performance and selection advantage over their younger counterparts. To date, no examination has been conducted exploring the retention rates of the AFL TP, the primary development pathway for junior Australian footballers seeking to progress into the professional AFL. Further, no study has examined relative age effects across the pathway from initial identification at 16 years of age through to draft selection. The exploration of pathway retention rates and relative age effects may provide first empirical evidence that variations in age impact on long-term player retention outcomes.

Numerous studies across a range of sports have reported that age matched players of advanced biological age are at an anthropometric and physical performance advantage (Buchheit & Mendez-Villanueva, 2014; Gastin & Bennett, 2013; Till et al., 2014). However, there is a relative lack of research exploring the effects of maturational variation in Australian football with previous studies only assessing players from the participation pathway (Gastin & Bennett, 2013; Gastin et al., 2013). The effects of maturational variation on technical skill performance is yet to be examined in Australian football, though previous research in other sports has been inconclusive (Coelho E Silva et al., 2008; Malina et al., 2005; Matthys, Vaeyens, Coelho E Silva, et al., 2012). Further, despite coaches' perceptions of potential and skill proposed to play a key role in the player selection process (Williams & Reilly, 2000) it is unclear if coaches' perceptions are influenced by variations in biological maturity. This research will explore if maturational variation impacts on anthropometric, physical and technical measures used in the AFL TP. The influence of maturation on coaches' perceptions of potential and skill will also be investigated. Finally this thesis examines if maturity, anthropometric, physical and technical skill measures differ between talent identified and non-talent identified U16 players. Results of this thesis will help identify issues within current talent identification processes and provide recommendations to help improve identification processes used in the AFL TP.

CHAPTER TWO: PATHWAY EFFICIENCY AND RELATIVE AGE EFFECTS IN THE AUSTRALIAN FOOTBALL LEAGUE'S TALENT PATHWAY

This chapter is presented in the pre-publication format adapted from:

Cripps, A. J., Hopper, L., Joyce, C., & Veale, J. (2015). Pathway efficiency and relative age effects in the Australian Football League's Talent Pathway. *Talent Development and Excellence*, *7*(1), 3-11.

2.1 Introduction

Selection and development of talented, upcoming generations of junior players is of great importance for the ever increasing professionalism of elite sport (Vaeyens et al., 2008). Talent identification programs aim to ensure selection of talented junior players into development pathways in order to accelerate development towards their sporting potential (Ericsson, Krampe, & Tesch-Römer, 1993; Ford et al., 2011; Williams & Reilly, 2000). Development pathways provide selected players developmental advantages due to greater access to experienced coaches, training resources and competition levels (Helsen, Starkes, & Van Winckel, 1998). However, there is limited longitudinal evidence that suggests that development pathways are an efficient means of producing elite adult players (Vaeyens et al., 2009).

Substantial financial and human resources are invested into the identification and subsequent development of talented junior players (Williams & Reilly, 2000). However, low retention of junior players into professional, senior competition represents significant inefficiencies within development pathways (Barreiros et al., 2014; McCarthy & Collins, 2014). The retention of players progressing from junior development pathways have ranged from 28.10-55.60% (Barreiros et al., 2014; McCarthy & Collins, 2014). However, this definition of retention can be misleading as junior squads are typically larger than senior squads and therefore 100% retention is often not possible. Conversely, Barreiros and Fonseca (2012) explored the developmental efficiency of Portuguese national soccer and volleyball teams and found that only 38% of national representatives were previously involved in elite pre-junior competitions. These studies provide the first insights into player retention in development pathways, however they are restricted to participation in national squads, which only represent a small percentage of a sporting code’s talent population. Considering that high financial and human resourcing costs are associated with providing elite player development pathways, the poor pathway retention previously documented (Barreiros et al., 2014; Barreiros & Fonseca, 2012; McCarthy & Collins, 2014) represents a significant waste of investment made by the sporting codes. Low retention further highlights that a substantial proportion of elite players develop the required skillset to compete at a professional level outside development pathways in subsidiary competitions. Wholesale examination of elite development pathways across entire sporting codes is needed to provide greater scope to previous findings and to highlight problems which effect the efficiency of talent development pathways.

Australian football is unique blend of international football codes, such as rugby and soccer, however it is only played professionally in Australia. The AFL TP is the primary development pathway for talented junior Australian football players to progress into the AFL (see Figure 2). The AFL TP is conducted alongside the subsidiary state league competitions. The AFL funds the state representative teams which comprise the AFL TP and compete at a national level. The AFL funding provides players in the AFL TP with greater access to training resources, and the opportunity to train under the tutelage of more experienced coaches. This approach theoretically accelerates player development when selected to the AFL TP. The AFL TP has two underage selection stages and a draft. The underage stages are structured similar to other major football codes for example, England’s rugby league’s development pathway (Till, Cobley, Wattie, et al., 2010). Here, representative coaches select players from regional competitions to represent their region at age restricted U16s and U18s national championships. In the AFL TP, the draft is similar to that of American basketball and American football, where players are selected from semi-professional, or underage competitions into the professional clubs. Players can be selected into the AFL TP at any stage of the pathway. That is, involvement in a prior stages of the AFL TP is not a prerequisite for inclusion into subsequent stages. This attribute of the AFL TP allows a flux of players to drop out and be recruited into every stage of the pathway. Drop out represents wasted resources from the AFL and pathway inefficiency. To date no examination of pathway efficiency has been conducted on the AFL TP. Considering the similarities of Australian football to other international sporting codes, the AFL TP can provide a unique precedent for wholesale examination of pathway efficiency across an entire sporting code.

There are various mechanisms which may affect player drop out and development pathway efficiency, such as injury, players moving out of the sport, or deselection from development pathway stages. These factors can be largely outside the control of sporting codes. However, in the interests of efficiency, sporting codes would ideally select players that will participate through junior, senior and professional competition. Relative age effects refer to age biased selection of players, are evident in many sporting codes and represent a mechanism for player dropout and pathway inefficiency (Schorer et al., 2009; Sherar, Baxter-Jones, Faulkner, & Russell, 2007; Till, Cobley, Wattie, et al., 2010). Selection into junior development pathways, such as the AFL TP, is often dependent on a player's ability to perform in short term age restricted competitions (Vaeyens et al., 2009). Adolescent players who are chronologically older are also likely to be more physically mature than their competitors and have greater physical stature, physiological capacities, motor control and cognitive aptitude (Armstrong, 2007). These attributes are advantageous for performance in the age restricted competitions that are used in their respective development pathways (Buchheit & Mendez-Villanueva, 2014; Gastin et al., 2013; Gil et al., 2013). However, over time, players who may have been selected into the initial stages of a development pathway as a result of advanced physical capacities may be at risk of de-selection, as the advantages associated with earlier maturation diminish into late adolescence and adulthood (Malina, Bouchard, et al., 2004). This initial selection and subsequent de-selection of relatively older players would contribute to player drop out and efficiency of development pathways such as the AFL TP. Despite the suggested relationship between relative age effects and development pathway efficiency, no concurrent observation between pathway efficiency and relative age effect exists across a sporting code.

Conflicting reports of relative age effects have been reported in Australian football by studies focusing only on players participating at single levels of the AFL TP (U18s, draft) (Coutts, Kempton, & Vaeyens, 2014; Pyne et al., 2006; Robertson et al., 2015). The conflicting results are likely a result of the methodological differences used to compare birth distributions. No research has investigated relative age effects at the U16s stage of the AFL TP, nor longitudinally across the entire pathway (U16s, U18s and draft). Examination of fluctuations of relative age effects across the AFL TP stages would provide greater insight into the relationship between relative age effects and the developmental efficiency of the AFL TP.

The primary aim of this study was to examine the efficiency of the AFL TP by examining the participation of players across the different AFL TP stages (U16s, U18s and draft). A secondary aim was to examine if a concurrent relative age effect exists across the AFL TP from the U16s level through to the draft.

2.2 Methods

2.2.1 Participants

The involvement and birth dates of 2519 players across the 2006-2012 seasons and stages of the AFL TP were collated. This enabled the tracking of five individual cohorts of players across the three AFL TP stages (U16s, U18s & draft). All players included in this study participated at least once in the U16s (n=1331) or U18s (n=1454) national championships, or were drafted (n=911) during this time. The 2006, U18s and draft datasets were removed, as were the 2012 U16s participants, as the dataset did not enable these players to be tracked through the entirety of the AFL TP. All information was provided by the AFL. Ethical approval for the study was granted by the University's Human Research Ethics Committee (013113F).

2.2.2 Data management

Efficiency of the AFL TP was assessed for the U18s teams and the draft. Efficiency was defined as the percentage of senior listed players that had been involved in the AFL TP junior development squads. Player involvement at each stage of the pathway (U16s, U18s, and draft) were recorded. Some players participated multiple times in the same stage of the pathway, however the analysis for this study was delimited to a player's first appearance at each level.

To assess the existence of relative age effects in the AFL TP, players' birth dates were re-coded into birth quartiles (Q1: Jan–Mar; Q2: Apr–Jun; Q3: Jul–Sep; Q4: Oct–Dec). The AFL TP birth quartiles were then compared to all births in

Australia between 1988 and 1993 (Australian Bureau of(Statistics, 1994). Player de-selection was defined as the percentage of players that did not progress from one stage of the AFL TP into a subsequent stage. Birth quartiles of de-selected players were also compared across the AFL TP pathway stages. Whereby the birth distributions of the de-selected players at the U18s and draft stages were compared against the birth distributions of all players involved in the U16s and U18s respectively.

2.2.3 Statistical analyses

To examine pathway efficiency, analysis was conducted in SPSS version 22 (IBM, Chicago, IL, USA) with a binary coding system used to track involvement or exclusion from pathway stages. relative age effects were assessed using chi-squared ($\chi 2$), odds ratios (OR) and associated 95% confidence intervals (CI) to test the birth quartile distribution for each stage of the pathway, as well as for player de-selection across the pathway stages. When comparing birth distributions, the relatively youngest group (Q4) was used as the reference group for odds ratio analysis (Coutts et al., 2014). Chi-squared, OR and 95% CI were calculated in Microsoft Excel (Microsoft, Redmond, WA, USA). SPSS was used to calculate descriptive statistics examining retention rates between pathway stages. Significance for all analyses was set at $p<.05$.

2.3 Results

Of the drafted players, 50.5% had participated in at least one stage of the AFL TP. Further, 27.7% of drafted players had participated in the U16s, 47.9% of drafted players were involved in U18s, and 25.1% were selected for both the U16s and U18s teams. Of the players selected into the U18s, 47.5% had been selected into the U16s.

Table 1 shows the quartile distribution, chi-squared, OR and 95% CI for all levels of the AFL TP when compared to Australian national birth distributions. Odds ratios revealed a consistent bias towards the relatively oldest participants at every stage of the pathway. Chi-squared analyses reported significantly ($p<.001$) uneven birth date distributions (biased towards relatively older players) at every stage of the pathway. However the strength of these relative age effects reduced at each subsequent stage; U16s ($\chi2=254.3$, $p<.001$), U18s ($\chi2=99.6$, $p<.001$), and for the draft ($\chi2=19.1$, $p<.001$).

Chi-squared analyses showed a significant relative age effect for players de-selected between U16s to U18s ($\chi2=168.8$, $p<.001$) and from the U18s to the draft ($\chi2=161.2$, $p<.001$). Players de-selected from the U18s and born in the first quartile were 1.96 times more likely to be de-selected than players born in the fourth quartile. A similar trend was seen for players de-selected between the U18s to the draft, with players born in the first quartile 1.61 times more likely to miss selection than players born in the fourth quartile.

Table 1. Birth-date distribution, chi-squared (χ2), odds ratio (OR) and confidence intervals (CI) of selected adolescent and drafted players.

	Q1 (% Total)	Q2 (% Total)	Q3 (% Total)	Q4 (% Total)	Total	χ2	*p*-value	OR (CI) Q1 v Q4	OR (CI) Q2 v Q4	OR (CI) Q3 v Q4
U16s	549 (41.2%)	364 (27.3%)	254 (19.1%)	164 (12.3%)	1331	245.3	<.001	3.34 (2.81-3.98)	2.18 (1.82-2.63)	1.50 (1.23-1.82)
U18s	501 (34.5%)	397 (27.3%)	311 (21.4%)	245 (16.9%)	1454	99.6	<.001	2.04 (1.76-2.39)	1.61 (1.37-1.89)	1.23 (1.04-1.45)
Draft	256 (28.1%)	258 (28.3%)	221 (24.3%)	176 (19.3%)	911	19.1	<.001	1.30 (1.07-1.59)	1.38 (1.14-1.67)	1.21 (0.99-1.48)
Australian Population	379086 (24.7%)	384749 (25.1%)	391680 (25.5%)	378316 (24.7%)	1533831					

Table 2. Birth-date distribution, chi-squared (χ2), odds ratio (OR) and confidence intervals (CI) of de-selected players. Reference groups for χ2 are the total number of players in the U16s and U18s teams as shown in Table 1.

Transition	Q1 (% Total)	Q2 (% Total)	Q3 (% Total)	Q4 (% Total)	Total	χ2	*p*-value	OR (CI) Q1vQ4	OR (CI) Q2vQ4	OR (CI) Q3vQ4
U16s-U18s	289 (45.2%)	162 (25.3%)	117 (18.3%)	72 (11.2%)	640	168.86	<.001	1.96 (1.45-2.65)	1.39 (1.01-1.91)	1.28 (0.91-1.80)
U18s-Draft	380 (37.3%)	262 (25.7%)	214 (21.0%)	162 (15.0%)	1018	161.29	<.001	1.61 (1.23-2.10)	1.10 (0.84-1.45)	1.05 (0.79-1.40)

2.4 Discussion

There were two main aims of this study: (i) to assess the efficiency of the AFL TP, by examining the involvement of drafted players in the underage stages of the pathway; and (ii) to concurrently examine the presence of relative age effects across the entire AFL TP. Half of the players drafted had previous involvement in the underage stages of the AFL TP. However, only 25.1% of drafted players had participated in the U16s and U18s stages of the AFL TP. Strong relative age effects were evident in each level of the pathway. This relative age effect weakened as the pathway progressed with relatively older players significantly less likely to transfer between stages than their relatively younger counterparts.

This research confirms that a substantial proportion of elite players across an entire sporting code, develop the required skillset to compete at a professional level in subsidiary development pathways and competitions. Such findings have direct implications for elite development pathways similar to the AFL TP. For instance, development pathways are typically funded to a greater extent than subsidiary pathways, with players gaining greater access to training facilities, experienced coaches and support staff. It appears that additional resourcing provided to the AFL TP by the AFL results in little benefit by way of professional senior selection as half of the players drafted in this study came from subsidiary state league competitions. This finding highlights an inefficient use of development pathway resources, as half the players drafted into the AFL did not benefit from the additional resourcing provided to the AFL TP.

Pathway inefficiencies can impact the standard of players drafted into the AFL. It may take longer for players with limited or no exposure to the AFL TP to reach the tactical, technical and physiological standards required to compete at the senior level. Ericsson et al. (1993) suggested that gifted players will only attain their full adult potential when appropriate and stimulating development opportunities are provided. Further, providing these appropriate training stimuli during maturational “windows of opportunity” may accelerate and enhance physical development (Ford et al., 2011). Achieving this potential after these periods may take longer or be harder to attain (Balyi & Hamilton, 2004). Therefore the standard of the professional

AFL competition may be reduced as a result of the selection of players that drop out from the AFL TP or non-selection of players into the AFL TP that are drafted later in adulthood.

This is the first paper to examine the efficiency of an entire development pathway and the concurrent relative age effect. Strong relative age effects were evident in every stage of the pathway, with relatively older players significantly more likely to be de-selected as the pathway progressed. The strong relative age effect evident, especially in the initial stage of the pathway support the argument that player selection focused on acute physical capacities or performance outcomes rather than long term player potential occurs in junior age restricted competitions such as in the AFL TP (Cobley et al., 2009; Schorer et al., 2009; Sherar et al., 2007; Till, Cobley, Wattie, et al., 2010). During adolescence, relatively older players are more likely to benefit from advanced physical and psychological capacities (Gil et al., 2013; Thompson, Barnsley, & Battle, 2004). In Australian football, these advantages are likely to translate into greater performance in matches, as advanced maturity is linked to increased match running intensities (Gastin & Bennett, 2013) potentially resulting in greater match involvements (e.g. number of disposals) (Mooney et al., 2011). However such advantages may not reflect true adult potential, as the advantages associated with greater relative age reduce with age (Malina, Bouchard, et al., 2004). The strong relative age effect in players de-selected between pathway stages would support the notion that relatively older players at a performance advantage in initial stages of the AFL TP are at risk of subsequent de-selection, as relatively younger players mature, catch up, and ultimately take their place in the later stages of the pathway (Cobley et al., 2009; Schorer et al., 2009; Sherar et al., 2007; Till, Cobley, Wattie, et al., 2010).

Relative age effects are one of several mechanisms that can influence player drop out and pathway inefficiency. The retrospective nature of this study only allows for observation of the concurrent relative age effect and inefficiencies of the AFL TP and cannot establish causation. This is a result of the inability to prospectively quantify the cause of player turnover in the study. Whilst it is suggested that player turnover is performance based, it is possible that players missed selection due to injury or for other unknown reasons. Further prospective examination of the various factors which influence selection into the AFL TP may provide further insight into factors affecting the efficiency of the pathway.

In this study we suggest selection may be associated with biological maturity, which is linked to relative age (Gil et al., 2013). Players who are chronologically older are likely to also be biologically older however, without direct assessments of biological maturity such assumptions are speculative. Another potential limitation of this investigation is a potential methodological bias associated with comparing sporting population data to population norms. Previously it has been suggested that athletic populations may already demonstrate relative age effects, thereby potentially confounding results when comparing to population norms (Delorme, Boiché, & Raspaud, 2010). The present investigation lacked access to the birth distribution data of all registered Australian footballers, therefore we followed the method of comparing to national population distributions outlined in previous studies (Coutts et al., 2014; Helsen et al., 1998; McCarthy & Collins, 2014).

2.5 Conclusions

This study concurrently examined the efficiency and birth date distribution of adolescent players selected into the AFL TP between 2006 and 2012. Poor efficiency was observed across the pathway, with only 50.5% of players selected in the draft involved in previous stages of the AFL TP. Strong relative age effects were also observed in every stage of the AFL TP, with the strength of these relative age effects reducing with age. The weakening relative age effect with age was in part the result of relatively older players being more likely to be de-selected at subsequent stages. This is the first study to concurrently observe poor pathway efficiency and relative age effects across an entire development pathway. The results of this study suggest a relationship exists between relative age effects and development pathway inefficiencies, however further research is required to confirm this link. Coaches of adolescent development pathways should be aware of performance advantages associated with relative age, as failing to do so may reduce the efficiency of sporting development programs.

CHAPTER THREE: INTER-RATER RELIABILITY AND VALIDITY OF THE AUSTRALIAN FOOTBALL LEAGUE'S KICKING AND HANDBALL TESTS

This chapter is presented in the pre-publication format adapted from:

Cripps, A. J., Hopper, L., & Joyce, C. (2015). Inter-rater reliability and validity of the Australian Football League's kicking and handball tests. *Journal of Sport Science and Medicine*, 14, 675-680.

Research Synthesis:

The results of chapter two demonstrated that selection into the AFL TP may be biased by advantages associated with increased chronological age and potentially maturity. In Australian football, maturational variation in age matched players has been shown to impact on anthropometric and physical performance measures however the effects on technical skills had yet to be explored. The AFL developed two skill tests for use within the AFL TP however no examination of the tests' inter-rater reliability or validity had been conducted. Chapter two therefore examined if the skills tests used in the AFL TP demonstrate acceptable levels of inter-rater reliability and validity in order to enable inclusion of the tests in subsequent chapters of the thesis.

3.1 Introduction

Australian football matches are characterised by high running volume and intensities, heavy physical contact and skill executions by both hand and foot (Dawson et al., 2004). The AFL coordinates an annual National Draft Combine in order to ascertain if talented players have the physical, psychomotor, and psychological capacities required to compete at a professional level (Woods, Raynor, Bruce, McDonald, et al., 2015). Since the combine's inception in 1994, physical characteristics of speed, power and aerobic endurance have been examined using a series of physical tests. However, other factors such as technical skill are likely to impact on performance and selection in Australian football (Woods, Raynor, Bruce, & McDonald, 2015). Technical skills specific to Australian football include kicking (the player drops the ball from the hands at approximately waist height so that the ball drops towards the kicking foot. Ball-foot contact typically occurs around 0.1-0.3 m from the ground (Ball, 2008)) and handballing (the player holds the ball in one hand and strikes the ball, using a clenched fist, with the opposite hand (Parrington et al., 2013)).

In 2009 the AFL introduced a kicking test designed to assess the dominant and non-dominant kicking efficiency of players across a range of Australian football specific distances. In 2010, a handball test was added to the combine test battery which was designed to assess the capacity of players to receive the ball cleanly, either on the ground or in the air, and handball efficiently to a target at various distances. Unlike the physical testing measures, such as the vertical jump tests, 20 metre sprint, agility and Multi-Stage Fitness test, which use objective time or distance measures for assessment, the kicking and handball tests are scored subjectively. Assessors subjectively rate skill outcome of both tests using a simple 0-5 Likert scale. However, there are potential limitations when using subjective measures to quantify performance, such as biasing, which may reduce the accuracy or reliability of the skill tests (Thomas, Nelson, & Silverman, 2011). To date, no examination has been conducted to assess the inter-rater reliability of either the AFL's kicking or handball tests.

Physical test results from the AFL combine are used in conjunction with the subjective observations and perceptions of the AFL recruiters, to guide selection in the annual AFL National Draft Combine. Links have been made between physical test performance, professional selection and career success (Burgess et al., 2012; Pyne et al., 2005; Robertson et al., 2015) Physical tests used have demonstrated both reliability and validity, no such evidence exists for the AFL's skills tests. A simple means of assessing the partial content validity of the kicking and handball tests procedures may be to assess the tests' sensitivity to laterality and distance. Kinematic differences exist between dominant and non-dominant limb kicks (Ball, 2011) and handballs (Parrington, Ball, & MacMahon, 2015) in professional Australian footballers and these differences are likely to result in accuracy discrepancies. Such dominant and non-dominant limb discrepancies are likely to be further highlighted when the distance to the target increases. Scoring outcomes sensitivity to laterality and distances would indicate partial content validity of the skill tests.

Whilst the skill tests were originally designed for use at the National Draft Combine, they are also commonly used in adolescent development pathways to assess skill efficiency and for talent identification purposes. Test assessors in development pathways are likely to have varying levels of exposure to the test and so scoring variability may occur. Examination of inter-rater reliability using assessors with limited experience scoring the test would provide first evidence that the subjective scoring procedures are reliable when used in this context.

In Australian football coaches have great insight into a player's ability to perform sport specific skills, due to the time spent training and coaching the players. As such, examining coaches' perceptions of a players' skill may provide a unique means of assessing the concurrent validity of the kicking and handball test procedures. This study aimed to examine the inter-rater reliability, content and concurrent validity of the AFL's skill efficiency tests in adolescent Australian footballers. It was hypothesised that both tests would demonstrate acceptable levels of inter-rater reliability, that laterality and distance would have a significant effect on technical skill outcomes and that coaches' perceptions of skill would correlate with test score outcomes.

3.2 Methods

3.2.1 Participants

Male players (n= 121, age=15.7 ± 0.3 years, height=177.35 ± 7.05 cm, weight= 69.17 ± 8.08 kg) were recruited from seven semi-elite U16 Western Australian Football League teams. Players and their guardians were given written information sheets detailing the potential risks associated with the study and subsequently provided written informed consent. Coaches (n=7) from each of the teams were also recruited to give a subjective assessment of the skill efficiencies for players within their team. The coaches' assessments rated the skills of each players in their team on a 1-5 Likert scale. Further detail regarding the coaches' perceptions of skill is provided later. Assessors for the test were all university students with varying levels of exposure to Australian football. Assessors were given a briefing on the tests purpose and scoring criterion prior to commencement. To further familiarise the assessor with the test they were also required to watch the test conducted at least once prior to being allowed to score the test. Ethics approval was granted by the University's Human Research Ethics Committee.

3.2.2 Procedures

The test procedures for both skill tests are provided by the AFL (Sheehan, 2010). Figure 5 illustrates the layout of the kicking test. Players were required to perform three right and three left footed kicks. Players ran towards the feeder and received the ball around chest height on the kick line. At the same time as receiving the ball, the feeder instructed the participant to kick to one of six randomly assigned targets. The player then circled the turn cone and kicked to the appropriate target (the targets are other players at the designated points). The first (20 m) target was set on a 45° angle from the intersect of the kick lines in Figure 5; the second (30 m) and third (40 m) targets were then set directly back from the first target. The target circles were four metres in diameter. Once the kick was delivered, the player returned to the starting point and repeated until all six targets had been called.

Two student assessors stood approximately 35 m from the kick line in order to best assess the kicks. The assessors stood two metres apart aside the designated scoring position and were instructed not to communicate results to each other. Assessors were instructed to judge the kick on the criteria outlined in Table 3.

One point was removed from the possible five points for each kick if; the kick execution took longer than 3 seconds (monitored by the assessors using a stop watch from time of hearing the call from the feeder to skill execution), the kick was executed beyond the kick line, or the kick was executed incorrectly (unconventional flight and or spin). If the participant kicked to the wrong target, a score of zero was given.

The handball test is depicted in Figure 6. Players received the ball six times and completed six handballs. The player received the first three balls from the ground and the second three were thrown to the receiver around chest height. The player was required to perform three right and three left-handed handballs. Players ran towards the feeder and received the ball on the pick-up line. At the same time as receiving the ball, the feeder instructed the participant to handball to one of six randomly selected target players standing in designated positions. The first (6 m) target was set on a 45° angle from the release line; the second (8 m) and third (10 m) targets were then set straight back from the first target. The participant was required to handball to the appropriate target, before the release line. Once the handball was delivered, the player jogged around the turn cone and returned to the start point and repeated until all six targets had been called.

Two student assessors stood 5 m behind the feeder to assess the handballs. The assessors stood two metres apart aside the designated scoring position and were instructed not to communicate results to each other. Assessors were instructed to judge the take and handball based on the criteria outlined in Table 3.

One point was subtracted if; the ball gather and handball took longer than 3 seconds to be executed (monitored by the assessors using a stop watch from time of hearing the call from the feeder to skill execution), or the handball was completed beyond the release line. The delivery was given a score of zero if the participant handballed to the wrong target.

Table 3. Scoring protocols for the AFL's kicking and handball tests.

Points	Rating	Kicking Test	Handball Test
5	Excellent	Target didn't move & ball travelled quickly with low trajectory & perfect spin.	Clean take, quick execution with perfect spin & target not moving receiving ball at chest height
4	Very Good	Target receives within one step of the cone, low trajectory & good spin.	Clean take, quick execution and good spin with target moving slightly to receive
3	Effective	Target receives with a foot inside circle, good trajectory & spin.	Clean take, satisfactory execution with target able to take the ball after moving
2	Ineffective	Target had to leave circle to mark ball, good trajectory & spin.	Fumble but recovers to reach target with good technique
1	Poor	Target unable to mark football, poor trajectory & spin.	Fumbles and gets ball to target with poor technique
0	Fail	Misses target or delivers to wrong target.	Fumbles and misses the target completely

3.2.3 Coaches' perceptions of the players

Prior to receiving the results of the tests, the players' coaches were asked to rate players from their team on a 1-5 Likert Scale for kicking and handball efficiency, and clean hands (their ability to take the ball cleanly either in the air or on the ground) with rating listed as; 5 rare, 4 excellent, 3 good, 2 marginal and 1 poor in accordance with the AFL Youth Coaching Manual (2004). Outcome descriptors were attached to the 1-5 rating scale. For example, when assessing kicking and handball ability: a 5 mark was given if the player was considered very accurate on both dominant, and non-dominant sides, and when under pressure; the player was also required to be a very good decision maker. Coaches were also asked to categorise players as right (n=102) or left (n=19) side dominant. If they were unsure they were instructed to leave the field blank. These players (n=8) were then excluded from the analysis.

3.2.4 Data analyses

The kicking and handball tests were assessed for inter-rater reliability, content and concurrent validity. Inter-rater reliability was examined using the subjective scores provided by two independent assessors, who both rated every disposal using the scoring procedure developed by the AFL.

Content validity was assessed by examining the scoring outcomes sensitivity to laterality across a range of Australian football specific distances. Concurrent validity was assessed by comparing the scores from both tests to coaches' perception of skill efficiency. For the kicking test, the coaches' perceptions of kicking ability was directly compared to their testing score. For the handball test, because the test examines both the ability to receive the ball cleanly and handball efficiently, the coaches' perception of both clean hands and handball efficiency was summated and compared to the testing outcome.

3.2.5 Statistical analyses

Statistical analyses were carried out using SPSS software (Version 22.0, SPSS Inc., USA). Inter-rater reliability was assessed as relative and absolute measures. Relative reliability was calculated by comparing the total score given by both assessors using intra-class correlation coefficients (ICC). Absolute reliability was calculated using the 95% limits of agreement method developed by Bland and Altman (1986).

Scores were reported as means and standard deviations. Multivariate analysis was used to examine the main effect of "laterality" (two levels: dominant and non-dominant) on the skills test variables. Cohen's d effect sizes (ES) were calculated, with an ES of 0.20 considered small, 0. 50 medium, and 0.80 large (Cohen, 1998). The correlation between actual testing outcomes and coaches' perceptions of skill was assessed using Pearson’s correlation coefficients (r). Significance was set at $p<.05$.

3.3 Results

Inter-rater reliability for both the kicking (ICC=0.96, $p<.01$) and handball tests (ICC=0.89, $p<.01$) were strong and within the limits of agreement demonstrating acceptable levels of absolute reliability (Figure 7).

The Pillai’s trace (*V*) revealed a significant effect of laterality on the kicking (*V*= 0.10, F(3, 252) =9.63, $p<.01$) and handball (*V*= 0.06, F(3, 252) =2.85, p =.04) tests. Follow-up univariate analysis revealed dominant leg kicks scored significant higher for all distances ($p<.01$) with medium effects demonstrated. Dominant hand disposals in the handball test only significantly outscored the non-dominant on the long target (ES= 0.30, $p<.01$) with small to medium effects demonstrated. Short (ES= 0.26, p=.09) and medium (ES= 0.21, p=.16) handballs showed non-significant differences between dominant and non-dominant limbs. Summary of the tests results can be seen in Table 4. There was no significant correlation between coaches’ perceptions of skill and kicking (r=-0.13, p=.75) or handball (r=0.04, p=.63) test scores.

A number of delivery errors were made in both tests by the players, whereby the player passed to the wrong target. A total of 25 errors made in the kicking test (3.23%) and 95 made in the handball test (12.27%).

Figure 7. Bland-Altman Limits of Agreement analysis for the kicking (a) and handball (b) tests

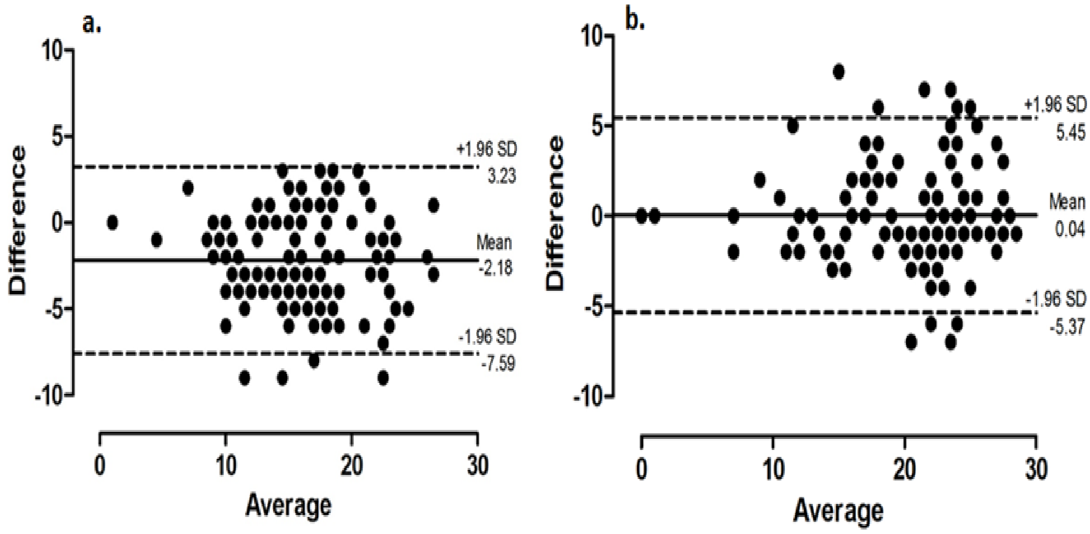


Table 4. Scoring outcomes (mean and standard deviation) for dominant and non-dominant limb disposals for the kicking and handball tests.

Disposal Distance	Kicking Test			Handball Test		
	Dominant	Non-Dominant	Cohen's *d*	Dominant	Non-Dominant	Cohen's *d*
Short	3.21 ± 1.39	2.43 ± 1.47*	0.55	3.77 ± 1.50	3.38 ± 1.52	0.26
Medium	2.74 ± 1.39	2.17 ± 1.29*	0.43	3.34 ± 1.46	3.02 ± 1.65	0.21
Long	2.40 ± 1.26	1.90 ± 1.07*	0.43	3.54 ± 1.54	3.09 ± 1.50*	0.30

* Significantly (p<.01) less than dominant limb score

3.4 Discussion

3.4.1 Inter-rater reliability

Relative and absolute inter-rater reliability for both the kicking and handball tests was shown to be strong. The results of this study therefore suggest that the use of inexperienced assessors to administer the AFL's skills tests will not affect the reliability of the tests scoring outcomes. Further, considering the assessors came from a varied and somewhat inexperienced football background, it is reasonable to assume that employing assessors with greater assessment experience, such as those used at the National Draft Combine, would further improve the reliability outcomes of the tests. There were a high number of delivery errors in the handball test. The higher number of errors in the handball test may have slightly elevated the test's reliability measures, as it removed the opportunity for scoring variability. However given the strength of the findings in the reliability analysis, these effects are likely to be minimal.

3.4.2 Validity of the AFL's skills tests

The results of this study demonstrates mixed results when assessing content validity. Scoring outcomes for the kicking test shows a significant ability to differentiate between accuracy on dominant and non-dominant foot kicks, across varying Australian football specific distances. While the handball test was only able to significantly differentiate between laterality, with inconsistent results apparent when examining effects of distance.

As with most skill tests, the AFL's skills tests are closed-skill tests and are unable to examine every component of the complex task assessed (Robertson, Burnett, & Cochrane, 2014). Coaches or scientists designing skill tests are therefore required to select the components of a specific skill they wish to examine, with the intended use of the protocols and results in mind. The two AFL skill tests are designed to be used for both elite and sub-elite talent identification and to provide feedback to players for development purposes. Specifically the skills test seek to assess the player's capacity to accurately dispose of the ball on their dominant and non-dominant limbs, across varying Australian football specific distances. Therefore the kicking test in this context demonstrates partial content validity, as the scoring outcomes can differentiate between both laterality and target distance. The AFL's kicking test provides an appropriate means of assessing and providing feedback to development players regarding their kicking skills. However, further research is required to determine if the kicking test can differentiate between players of higher and lower playing abilities or if kicking test outcomes change with age.

The AFL's handball test did not show the same level of content validity demonstrated by the kicking test. Whilst the test was able to differentiate between dominant and non-dominant disposals, it failed to consistently differentiate between target distances. This may be due to the short (6 m) and medium (8 m) distances not being long enough or the task itself being too simple to elicit meaningful accuracy changes. Further research is needed to confirm the use of the handball test for providing a valid means of handball skill assessment.

Both the kicking and handball tests demonstrated poor concurrent validity, suggesting the AFL skills tests results are not representative of coaches' perceptions of players kicking and handball skills. The poor concurrent validity of the skill tests is likely due to the tests inability to replicate all match related skill demands. In matches other factors are likely to influence a player's skill efficiency by both hand and foot include, opposition pressure, decision making, and fatigue. The poor concurrent validity demonstrated by both tests suggests that coaches should be cautious when using test results to predict match related skill outcomes.

An identified weakness of the handball test is that the test examines two independent skill outcomes but only reports a single score. This means when examining the scoring outcomes it is impossible to tell which of the two skills in the test the player may have excelled or scored poorly in. For example, a player may have fumbled the ball, but executed an excellent handpass; or taken the ball cleanly but executed a poor handpass. In both cases the scoring outcome would not identify which skill the player performed well in and which they did not. A simple suggestion to eliminate this issue is to incorporate two scoring protocols, one for the clean-hands component of the test and a second for the disposal outcome. A further suggestion to reduce delivery errors in the test may be to adopt a pre-determined delivery pattern. This may reduce any errors associated with the player miss-hearing calls or decision making errors.

This study was limited to assessments of partial content and concurrent validity, further validity assessments, such as the tests ability to discriminate between players of higher and lower playing abilities is necessary to confirm the utility of the skills tests. Another limitation of this study was that the kicking and handball tests were originally designed to be used at the AFL National Draft Combine with players of eligible draft age (at least 18 years of age before 31st December of the relevant selection year). Whereas, the players we recruited were around two years younger than the players who would typically perform the test. Further assessments of the tests validity should therefore be conducted with players of eligible draft age.

3.5 Conclusions

Both the AFL's kicking and handball tests demonstrated acceptable levels of relative and absolute inter-rater reliability. The kicking tests was also shown to demonstrate partial content validity, with the tests able to discriminate between dominant and non-dominant disposals, across a range of Australian football specific distances. The AFL's handball test was also able to discriminate between laterality, however it could not consistently discriminate between disposal distances. Both tests demonstrate poor concurrent validity, when compared to coaches' perceptions of skill. The AFL's kicking test may provide an appropriate means of assessing and providing feedback to development players regarding their kicking skills, with further research required to establish if the handball test is appropriate to do the same. Future research should establish if both tests can differentiate between players of higher or lower playing abilities and if performance in the skill tests improve with age.

CHAPTER FOUR: MATURITY, PHYSICAL ABILITY, TECHNICAL SKILL AND COACHES' PERCEPTION OF SEMI-ELITE ADOLESCENT AUSTRALIAN FOOTBALLERS.

This chapter is presented in the pre-publication format adapted from:

Cripps, A. J., Hopper, L., & Joyce, C. (2016a). Maturity, physical ability, technical skill and coaches' perceptions of semi-elite adolescent Australian footballers. *Paediatric Exercise Science*, http://dx.doi.org/10.1123/pes.2015-0238.

Research Synthesis:

Chapter one highlighted that selection into the AFL TP is likely biased by advantages associated with increased chronological age and potentially maturity. Selection biasing is likely due to performance advantages associated with greater biological age. In Australian football, maturational variation has previously been shown to impact on anthropometric and physical performance measures in U15 community level Australian footballers. However no examination had yet explored the effects of maturational variation on U16 Australian footballers. Further the effects of maturational variation on technical skills outcomes and coaches' perceptions of skill had yet to be explored. Chapter four was therefore designed to assess the impact of maturational variation on U16 Australian footballers, using the technical skill tests examined in chapter three, as well as commonly assessed physical measures and coaches' perceptions of skill.

4.1 Introduction

Adolescent sporting competitions are typically age-stratified by one or two years in the interests of competition equity and player safety (Cobley et al., 2009). However, these age stratifications do not consider the large differences in biological maturity that are common in athletes of the same chronological age (Armstrong, 2007). During early to mid-adolescence, biological maturity can differ by as much as three years (Malina, Bouchard, et al., 2004). Athletes of greater biologically maturity are likely to demonstrate advanced physical performance characteristics. Typical maturation related advantages include; increased physical stature (Malina et al., 2000), muscle strength and power (Till, Cobley, O'Hara, et al., 2010), and running capacities (Buchheit & Mendez-Villanueva, 2014; Gastin et al., 2013; Matthys, Vaeyens, Coelho E Silva, et al., 2012). Previously maturational differences have been shown to affect performance in community level adolescent Australian footballers, with earlier maturing individuals demonstrating lower 20 m sprint times as well as; greater match running speeds (m/min^{-1}), high intensity running (m/min^{-1}) and high intensity efforts (number/min^{-1}) (Gastin & Bennett, 2013). It is unknown if the physical performance advantages evident in more mature athletes at the community level are also evident in adolescent athletes selected into higher level semi-elite competitions.

In Australian football matches, increased running intensities have been shown to result in athletes gaining a higher number of disposals (i.e. gaining possession of the ball and subsequently performing a kick or handball) (Mooney et al., 2011). However, unless these disposals are effective (i.e. to another teammate or resulting in a score), the value of the disposal to the team is minimal (Heasman, Dawson, Berry, & Stewart, 2008). Whilst more mature adolescent athletes may demonstrate greater running capacities within competition such advantages may be of little benefit without matched technical skill efficiency. Previous research into skill performance and maturation has been largely inconclusive. In soccer, technical skill efficiency has been shown to be linked to biological maturity (Malina et al., 2005). However, conversely in the sports of basketball (Coelho E Silva et al., 2008) and handball (Matthys, Vaeyens, Coelho E Silva, et al., 2012), maturity appears to have limited effect on sport specific skills. Examination of how maturation affects skill efficiency in Australian football has yet to been conducted.

Effective talent identification systems utilise both objective performance assessments of physical ability and skill as well as subjective athlete assessments, such as coaches' perceptions of athlete ability (Williams & Reilly, 2000). The multidimensional nature of team sports means that objective performance assessments are unlikely to comprehensively quantify an athlete's ability and should be used to support the subjective opinions and assessments of coaches or talent identification officers (Vaeyens et al., 2008). However, given that earlier maturing athletes are likely to be at a performance advantage in testing and match situations, coaches' perceptions of player's ability may also be biased towards more mature athletes. Previously it has been shown that coaches' perceptions of long-term potential are influenced by maturational differences in semi-elite U16 Australian footballers (Cripps, Hopper, & Joyce, 2016b) which may be represented by the continuous selection of relatively older athletes into development pathways (Cripps, Hopper, Joyce, & Veale, 2015; Till, Cobley, Wattie, et al., 2010). To date no research has assessed how maturational differences impact on coaches' perceptions of an athlete's technical abilities.

The aim of this study was to confirm the impact of maturational differences on anthropometric and physical testing and explore the effects of maturation on technical skill efficiency, and coaches' perceptions of skill in a sample of semi-elite Australian footballers. It was hypothesised that athletes classified as earlier maturing would out-perform their later maturing peers in all assessed variables.

4.2 Methods

4.2.1 Study design

Ninety-four athletes (age 15.7 ± 0.3 years) were recruited from seven teams involved in the state-wide West Australian Football League U16 competition. This study was conducted over a 3 month period prior to the commencement of the competition season and took place in three stages; the first stage assessed anthropometric and physical measures, specifically assessing; stature, maturation, and fitness characteristics. In the second stage, athletes completed two Australian football specific skill tests; the kicking and handball tests. The final stage of the data collection involved coaches rating each of the athletes' technical skills. Coaches (n=7, age 39.68 ± 7.43 years, coaching experience 11.50 ± 3.65 years) were required to complete the coaches' perception questionnaire (CPQ)(AFL, 2004) prior to receiving testing data previously collected. Further explanation of the CPQ is provided later in methods. Informed consent was obtained from both the athletes and their parents/guardians and the study protocols were approved by the Universities Human Research Ethics Committee.

4.2.2 Maturity assessment

Biological maturity was estimated using an age at peak height velocity predictive equation (Mirwald et al., 2002). The regression equation uses the non-invasive anthropometric measures of body weight, standing and sitting height to predict age at PHV.

$$\text{Age at PHV} = -9.326 + (0.002708 \times [\text{leg length} \times \text{sitting height}]) - (0.001663 \times [\text{age} \times \text{leg length}]) + (0.007216 \times [\text{age} \times \text{sitting height}]) + (0.02292 \times ((\text{weight}/\text{height}) \times 100))$$

Height and weight measures were assessed to the nearest 0.1 cm and 0.01 kg using a stadiometer (PE, Sportforce, Australia) and electric scales (Model UC-321, A&D Mercury Pty. Ltd., Australia). Sitting height was measured by sitting athletes on a 0.42 m seat with their buttocks and shoulders against the stadiometer. This method provides a reliable and practical means of assessing biological maturation, with a coefficient of determination 0.92, a standard error of measurement 0.59 years, and a mean difference of 0.24 ± 0.65 years between a verified sample of actual and predicted boys (Mirwald et al., 2002). A-PHV was subtracted from chronological age at prediction to calculate years from PHV (Y-PHV).

Adolescent male athletes are typically of advanced biological maturity when compared to normal age matched adolescent children (Matthys, Vaeyens, Coelho E Silva, et al., 2012; Sherar et al., 2007; Till, Cobley, O'Hara, et al., 2010). As such examining maturational status in reference to population norms may be inappropriate. Maturational groups were therefore defined in reference to the studies sample average Y-PHV. Commonly research using this method to define earlier and later maturational groups use a definition of ±1-year from sample averages (Baxter-Jones, Maffulli, & Mirwald, 2003; Matthys, Vaeyens, Coelho E Silva, et al., 2012) however taking into account the age of the athletes such groupings were determined to be too large. Subsequently maturational groups were set to ±0.5-year in accordance with methods previously used resulting in at least one year maturational difference between the later and earlier maturing groups (Till et al., 2014). Maturational groups were therefore calculated by adding or subtracting 0.50 years from the samples average Y-PHV (1.67 ± 0.59 years). As a result athletes were classified as later (Y-PHV below 1.17 years, n=19) average (Y-PHV between 1.18 and 2.16 years, n=55) or earlier (Y-PHV above 2.17 years, n=20) maturing.

4.2.3 Assessment protocols

Prior to testing, a standardised warm up was completed by all athletes, involving light jogging, unilateral and bilateral countermovement jumps and dynamic stretching. Lower-body power was assessed using vertical jump tests. Athletes were requested to stand under a Vertec vertical jump device (Swift Performance Equipment, Lismore, Australia), with both feet flat on the ground reach up and displace the highest vane possible. This process was repeated three times, with the highest vane displaced representing the individuals reach height. Athletes were then asked to perform three counter-movement jumps and three running vertical jumps (dominant and non-dominant leg take-offs). For the running vertical jumps athletes were allowed a 5 m run up. Jump height was measured to the nearest 1 cm with the standing and running vertical jumps measures recorded as the difference between the jump height and the standing reach height. The largest of the three measures was recorded and used for analysis. Sprint performance was evaluated by 20 m sprint time using infra-red timing gates (Smartspeed, Fusion Sport Pty Ltd, Queensland, Australia). Athletes were instructed to self-start the test to remove the effects of reaction time. Athletes were given three attempts with the fastest of the three trials recorded to the nearest 0.01 of a second. Strong intra-individual correlations were evident between trials for the jumping and sprint tasks ($r=0.80-0.88$). Aerobic fitness was assessed using the multi-stage fitness test. Athletes were required to run back and forth along a 20 m track, keeping time with a series of audio beeps. The frequency of beeps increased as the test progressed. The tests stopped when the athlete reached voluntary exhaustion or could no longer keep up with the timing of the beeps. The stage and level achieved by each athlete was recorded. For analysis, the total distance was used which was calculated from the athletes recorded shuttle stage and level.

Skill efficiency was assessed using the AFL's two skill efficiency tests; the kicking and handball tests. Athletes were required to perform six repeated skill executions, on their dominant and non-dominant sides, across a range of Australian football specific distances (Cripps, Hopper, & Joyce, 2015). For the kicking test these distances were short (20 m), medium (30 m) and long (40 m); whilst the handball test was short (6 m), medium (8 m) and long (10 m). As per methods previously outlined (Cripps, Hopper, & Joyce, 2015), examiners rated each of the six skill execution from 0-5 based on accuracy and trajectory outcomes. The sum of the six executions represented the individuals test score. Previous research has reported strong levels of inter-rater reliability for both the kicking (ICC=0.96, $p<.01$) and handball tests (ICC=0.89, $p<0.01$).

Subjective coaches' perceptions of athletes were assessed using the AFL CPQ (AFL, 2004). The head coach from each U16 teams was asked to rate their athletes on the technical competencies of; kicking, marking, and handball efficiency, clean hands (ability to take the ball from the ground or in the air cleanly) and ball winning ability (the ability to gain possession of the ball when the ball is in a contested situation). The CPQ uses a simple 1-5 Likert scale, with rating listed as; 5 rare, 4 excellent, 3 good, 2 marginal and 1 poor (AFL, 2004). Outcome descriptors were attached to the 1-5 rating scale for each skill. For example, when assessing kicking and handball ability; a 5 mark was given if the athlete was considered very accurate on both dominant, and non-dominant sides, and when under pressure; the athlete was also required to be a very good decision maker.

4.2.4 Statistical analyses

Statistical analysis was undertaken using SPSS version 22 (IBM, Chicago, IL, USA). Mean and standard deviation scores were calculated for all independent variables (i.e. anthropometric, fitness characteristics, skill efficiencies and coaches' perception). One-way between group analysis of variance (ANOVA) were used to assess differences between maturational groups. Post-hoc comparisons using Gabriel's methods were used to compare the differences between maturational groups. This post-hoc test was selected as it is offers greater statistical power when examining groups with different sample sizes (Field, 2013). To measure the effect size comparing maturational groups, Hedge's d statistic and effect size confidence intervals were calculated. The magnitude of the effect sizes were interpreted using a scale where values <0.2 are deemed trivial, 0.2–0.6 small, 0.6–1.2 moderate, 1.2–2.0 large and >2.0 very large (Hopkins, Marshall, Batterham, & Hanin, 2009). Multiple linear regressions were run to explore the relative contribution of body size, age, and maturation on the seven dependent variables of fitness and skill. Given the high level of inter-relatedness between height and weight, a height x weight interaction based on residuals (individual value minus the mean) was also used in the regression. This height x weight interaction term was calculated as a product of the residuals for height and weight. This method reduces the collinearity among the independent variables making them more stable predictors of fitness and skill variables. A backwards-elimination protocol was used which entered all variable in the equation and then sequentially removed the variables which met the criterion for elimination (p >.10). This process was repeated until all variables which met the exclusion criterion were removed. Level of statistical significance for analyses was set at p<.05. Bonferroni adjustment was applied for the post-hoc comparisons in the analysis of variance with a corrected alpha level of .017 used for the pair-wise comparisons.

4.3 Results

Hedges effect size showed generally very large to moderate (range= 1.19-6.26) differences between each maturational group for height, sitting height and weight measures (Table 5). Large to moderate (range= -0.74-1.26) differences were also found between the earlier and later maturing athletes for all fitness assessments, with the exception of the multi-stage fitness test. Small to trivial (range= 0.06-0.56) difference were reported between maturation groups and skill test results (Table 6).

Results from the CPQ revealed earlier maturing individuals had a significantly higher overall technical rating when compared to later maturing individuals, with small to moderate between group differences (range= 0.26-0.90). However, of the independent components of the CPQ, only marking and ball winning abilities were found to demonstrate significant between group effects. Comparison between earlier and later maturing athletes demonstrated generally moderate differences (range= 0.16-1.10) for all CPQ ratings, with the earlier maturing athletes scoring higher. Generally small to trivial differences were reported when comparing CPQ scores of the average v later and earlier v average groups (range=0.17-0.32and -0.03-0.70, respectively).

Table 5. Anthropometric measure comparisons for later, average and earlier maturational groups (mean ± standard deviation).

	Maturation Status			ANOVA	Average vs Later	Earlier vs Later	Earlier vs Average
	Later	Average	Earlier	F-value (df:2,93)		Hedge's *d* (CI)	
Anthropometric							
Age (years)	15.41 ± 0.26	15.64 ± 0.29	15.81 ± 0.21	12.27**	0.81 (0.28-1.33)	1.65 (0.93-2.38)	0.62 (0.09-1.15)
Height (cm)	170.73 ± 4.57	177.19 ± 5.22 [a]	184.09 ± 5.99[a,b]	34.46**	1.19 (0.64-1.73)	2.74 (1.87-3.62)	1.58 (1.00-2.16)
Sitting Height (cm)	85.81 ± 1.64	90.66 ± 2.00[a]	96.48 ± 5.73 [a,b]	107.28**	2.97 (2.27-3.67)	4.90 (3.64-6.15)	1.98 (1.37-2.59)
Weight (kg)	61.43 ± 5.10	68.61 ± 6.05 [a]	77.29 ± 6.84 [a,b]	33.75**	1.22 (0.67-1.77)	2.59 (1.73-3.44)	1.42 (0.85-1.99)
Y-PHV	0.83 ± 0.26	1.68 ± 0.28 [a]	2.46 ± 0.25 [a,b]	174.32**	3.06 (2.35-3.77)	6.26 (4.73-7.78)	2.83 (2.14-3.52)

Notes: ANOVA= analysis of variance, df = degrees of freedom, *p<.05; **p<.01. Post hoc comparison with groups to the left: [a] significantly different (p<.017; Bonferroni adjusted) from Later; [b] significantly different from Average. Y-PHV= years to and from peak height velocity

Table 6. Physical and skills measure comparisons for later, average and earlier maturational groups (mean ± standard deviation).

	Maturation Status			ANOVA	Average vs Later	Earlier vs Later	Earlier vs Average
	Later	Average	Earlier	F-value (df:2,93)	Hedge's *d* (CI)		
Fitness and Skill							
SVJ (cm)	47.69 ± 6.91	52.78 ± 5.81 [a]	56.7 ± 7.13 [a]	8.47**	0.63 (0.11-1.15)	1.26 (0.57-1.95)	0.79 (0.25-1.33)
DVJD (cm)	54.62 ± 8.09	59.77 ± 8.81	62.45 ± 7.92 [a,b]	5.44**	0.57 (0.05-1.09)	0.98 (0.32-1.64)	0.34 (-0.19-0.86)
DVJND (cm)	57.93 ± 8.52	62.10 ± 6.58 [a]	66.15 ± 9.86 [a]	5.61**	0.75 (0.23-1.28)	0.98 (0.31-1.64)	0.55 0.02-1.08
20m Sprint (sec)	3.20 ± 0.13	3.14 ± 0.11	3.10 ± 0.14 [a]	3.26*	-0.51 (-1.03-0.00)	-0.74 (-1.37-0.08)	-0.33 (-0.86-0.19)
Shuttle Distance (m)	2200.00 ± 259.95	2139.63 ± 288.01	2116.00 ± 296.90	0.45	-0.21 (-0.73-0.3)	-0.30 (-0.93-0.34)	-0.08 (-0.6-0.44)
Kicking Test	14.89 ± 3.70	14.27 ± 3.85	16.50 ± 4.48	2.32	-0.16 (-0.67-0.35)	0.38 (-0.25-1.02)	0.56 (0.02-1.08)
Handball Test	22.42 ± 4.26	22.62 ± 2.90	23.15 ± 3.00	0.22	0.06 (-0.45-0.57)	0.19 (-0.44-0.82)	0.18 (-0.35-0.70)

Notes: ANOVA= analysis of variance, df = degrees of freedom, *p<.05; **p<.01. Post hoc comparison with groups to the left: [a] significantly different (p<.017; Bonferroni adjusted) from Later; [b] significantly different from Average. SVJ= standing vertical jump, DVJD = Dynamic vertical jump off dominant foot, DVJND = Dynamic vertical jump off non-dominant foot

Table 7. Comparison of coaches' perceptions of skill for later, average and earlier maturational groups (mean ± standard deviation).

	Maturation Status			ANOVA	Average vs Later	Earlier vs Later	Earlier vs Average
	Later	Average	Earlier	F-value (df:2,93)	Hedge's *d* (CI)		
Kicking	2.63 ± 0.60	2.78 ± 0.92	2.75 ± 0.85	0.22	0.17 (-0.38-0.69)	0.16 (-0.47-0.79)	-0.03 (-0.55-0.49)
Marking	2.37 ± 0.50	2.58 ± 0.79 [a]	3.15 ± 0.85[a,b]	6.36**	0.29 (-0.23-0.80)	1.10 (-0.47-0.79)	0.70 (0.16-1.23)
Handball	2.63 ± 0.50	2.76 ± 0.79	3.10 ± 0.85	2.10	0.18 (-0.34-0.69)	0.68 (0.02-1.31)	0.42 (-0.11-0.94)
Clean Hands	2.68 ± 0.58	2.82 ± 0.84	3.25 ± 0.91	2.79	0.18 (-0.34-0.69)	0.74 (0.09-1.39)	0.50 (-0.03-1.02)
Ball Winning	2.63 ± 0.68	2.91 ± 0.91	3.40 ± 1.05[a]	3.74*	0.32 (-0.19-0.84)	0.86 (0.20-1.51)	0.51 (-0.02-1.04)
Overall Technical Rating	12.95 ± 2.20	13.85 ± 3.69	15.65 ± 3.62 [a]	3.25*	0.26 (-0.25-0.78)	0.90 (0.23-1.55)	0.48 (-0.04-1.01)

Notes: ANOVA= analysis of variance, df = degrees of freedom, * p<.05; **p<.01. Post hoc comparison with groups to the left: [a] significantly different (p<.017; Bonferroni adjusted) from Later; [b] from Average

Results from the regression analysis for the physical tests are summarised in Table 8. The predictor variables explained 6-18% of the variance in all the fitness measures, with maturation a significant predictor of performance in all fitness test except the multi-stage fitness. The performance predictor for the multi-stage fitness test was weight, which had a negative beta coefficient indicating that lighter athletes performed better in the test. The only significant predictor of kicking test performance was age which again had a negative beta coefficient and explain 10% of the variance reported. There were no significant performance predictors in the handball test.

Table 8. Predictors of performance in physical and skill tests using multiple regression analysis

Performance Task	Predictor	Standardized beta coefficients	R^2	Adjusted R^2	*p*
SVJ (cm)	Y-PHV	0.43	0.19	0.18	<.01
Dominant RVJ (cm)	Y-PHV	0.29	0.08	0.07	<.01
Non-Dominant RVJ (cm)	Y-PHV	0.32	0.11	0.10	<.01
20m Sprint (sec)	Y-PHV	0.28[a]	0.08	0.07	<.01
Shuttle Distance (m)	Weight	-0.26	0.07	0.06	.01
Kicking Test	Age	-0.25	0.10	0.07	.03
Handball Test	No significant predictor				

[a] The signs of the beta coefficient were reversed because a lower time represents a better performance

4.4 Discussion

This study tested the hypothesis that semi-elite earlier maturing U16 Australian footballers will have superior anthropometric, physical, technical and perceived technical skills, when compared to their later maturing counterparts. Results from this study further highlight potential issues that maturational differences presents to age-stratified competitions. Commonly, large maturational differences are seen in adolescent boys around the time of PHV, which typically occurs around 14 years of age (Armstrong, 2007). In this study, athletes were recruited from a semi-elite U16 competition. It was found that biological age differed by as much as 3.51 years, despite the least mature boy being only 0.43 years younger than the most mature. This study confirms that earlier maturing athletes are significantly taller and heavier and outperform their later maturing counterparts in sprint and jumping tasks. Investigation into how maturity effects skill and coaches' perceptions of skill found that earlier maturing athletes are also perceived by coaches' to have superior technical abilities, despite no congruent technical skill advantage evident in technical skills testing.

The earlier maturing group was significantly taller, heavier, could jump higher and sprint faster when compared to the average and later maturing groups. These findings reinforce and build from Gastin and Bennett (2013) study examining a cohort of community level adolescent U15 Australian footballers, as analysis was expanded to include a counter-movement jump and running dominant and non-dominant foot jumps. It is important to include vertical jump performance in talent identification testing for Australian football, as vertical jump performance has been shown to be an important predictor of selection into junior teams (Veale et al., 2008; Woods, Raynor, Bruce, McDonald, et al., 2015). In all three jumping tests, earlier maturing athletes significantly out-performed their later maturing counterparts. Further, maturity assessed as Y-PHV was found to be the one consistent predictor of performance in four of the five fitness tests, accounting for 8-19% of performance variability. This agrees with research examining youth soccer and basketball players of a similar age which has reported maturity to be a key predictive value in jump and sprint performance (Coelho E Silva et al., 2008; Malina, Eisenmann, et al., 2004). The only fitness test not influenced by maturity was the multi-stage fitness test, with no difference between maturational groups, supporting previous research into adolescent Australian football (Gastin & Bennett, 2013). As with other research, we found performance in the multi-stage fitness test to be inversely related to the weight of the individual, with lighter individuals performing better in the test (Coelho E Silva et al., 2008). In Australian football smaller players typically play in more nomadic positions which require greater distances to be covered within matches. The inverse relationship demonstrated between weight and performance in the multi-stage fitness test may therefore be associated with fitness adaptions linked to key physical performance requirements of smaller players within matches.

This is the first study to examine the impact of maturation on technical skill efficiencies in Australian football. These results conform to previous research in which weak or non-significant differences were seen with maturational differences and technical skill (Coelho E Silva et al., 2008; Figueiredo et al., 2009b; Matthys, Vaeyens, Coelho E Silva, et al., 2012). Small to trivial differences of no significant effect were found between maturational groups for either technical skills test, nor was there any significant predictors of performance for the handball test. Chronological age presented as the only significant predictor of performance in the kicking test accounting for 10% of the variability in performances. Interestingly a negative beta coefficient was reported indicating that chronologically younger athletes performed better in the kicking test. One explanation for this finding may be the compensation phenomenon suggested by Tranckle and Cushion (2006) whereby athletes account for deficiencies in one area of performances by demonstrating higher levels of performance in another. The results may suggest that younger athletes develop superior technical skills to compensate for inferior physical performances in order to remain competitive against older and physically more superior athletes. The development of superior technical skill to compensate for physical disadvantage may in fact prove advantageous longitudinally to individuals as physical capacities have been shown to ‘catch up’ as athletes mature (Till et al., 2014), potentially resulting in more rounded athletes .

Given the strong link between team selection and relative age in the elite junior AFL TP (Cripps, Hopper, Joyce, et al., 2015), it was hypothesised that greater maturational age would result in advantageous coaches' perception of technical skills. When compared to later maturing players, earlier maturing individuals had significantly higher overall technical rating, as well as perceived marking and ball winning abilities. Biologically, older athletes have already been shown to be at a physical performance advantage in adolescent soccer and Australian football matches (Buchheit & Mendez-Villanueva, 2014; Gastin & Bennett, 2013) however, it has been unclear whether these maturational advantages transitioned into technical performance. The results of this study suggest that biologically older individuals are perceived by coaches to possess superior technical skill sets, despite no congruent advantage in skill demonstrated. Interestingly previous research has demonstrated that coaches' perceptions of long-term potential is advanced in earlier maturing athletes indicating that a maturation related biasing may occur (Cripps et al., 2016b). The combination of advanced physical capacities and perceived technical skill demonstrated in this study may result in selection biases towards athletes of greater biological maturity.

A limitation of the predictive A-PHV protocols used in this study is that the equation was originally developed using a non-athletic population (Mirwald et al., 2002). Currently this equation has not been validated longitudinally using samples of adolescent athletes to compare predicted A-PHV results against established maturity indicators. However recent cross-sectional research by Gastin et al. (2013) examined a sample of adolescent Australian footballers using both the A-PHV predictive equation and participants subjective rating of actual biological maturity (Tanners criteria of pubertal development) and reported very large correlations between the two measures ($r=0.80$). Finally, the lack of agreement of actual and perceived technical skills is a novel finding and highlights a need for further examination. For instance research should explore if coaches' perceptions of skill are supported by match related skill outcomes.

4.5 Conclusions

The study findings supports previous research demonstrating that earlier maturing Australian footballers are significantly taller, heavier and perform better in all physical tests, with the exception of the multistage fitness test. No significant differences exist between maturational groups when examining technical skills, however coaches' perceptions of overall technical skill, marking and ball winning abilities were advanced in the earlier maturing group. The combination of anthropometric, physical and perceived skill advantages afforded to earlier maturing athletes are likely to result in significant competition and team selection advantages. Interestingly chronologically younger athlete performed better in the kicking test potentially highlighting a compensation phenomenon. Greater technical proficiency to compensate for physical disadvantage, may in fact provide longitudinal benefit to younger athletes as they mature and physically 'catch up' to older athletes, potentially resulting in more rounded athletes. Key sporting administrators, coaches and parents should therefore be made aware of the large maturational differences present in athletes of this age, and should attempt to develop appropriate training, competition and selection policies so as not to inadvertently discriminate against later maturing adolescent athletes.

CHAPTER FIVE: COACHES' PERCEPTIONS OF LONG-TERM POTENTIAL ARE BIASED BY MATURATIONAL VARIATION

This chapter is presented in the pre-publication format adapted from:

Cripps, A. J., Hopper, L., & Joyce, C. (2016b). Coaches' perceptions of long-term potential are biased by maturational variation. *International Journal of Sport Science and Coaching*. Accepted 18th November 2015.

Research Synthesis:

Chapter four demonstrated that both physical performance measures and coaches' perceptions of skill are biased in favour of earlier maturing players. In development pathways often coaches are required to make selection decisions based on their perceptions of a players long-term potential, with such decisions informed by current performance capabilities. Chapter four therefore sought to expand on the findings in chapter three by examining if coaches' perceptions of potential are also biased by maturational variation.

5.1 Introduction

The identification and subsequent development of talented young players is paramount in ensuring players attain their full potential and provide continuous elite players through to senior competition (Williams & Reilly, 2000). However, development pathways are typically expensive to run (Vaeyens et al., 2008) and are associated with poor player retention into senior professional competition (Barreiros & Fonseca, 2012; Güllich & Emrich, 2012; McCarthy & Collins, 2014). Development pathway coaches play a critical role in talent identification and the player development processes (Williams & Reilly, 2000). Coaches often select or de-select players from development pathways based on their perceptions of a player's long-term sporting potential (Gee, Marshall, & King, 2010). Understanding factors that affect coaches' perceptions of players would enable greater coaching education and potentially modify selection outcomes in the interests of improving development pathway efficiency.

Coaches of young players have the difficult task of assessing player's long-term potential and make subsequent selecting decisions for inclusion or exclusion into development pathways (Bergeron et al., 2015). However, in adolescent players, variations in biological maturity can be large (Armstrong, 2007) which, directly impact on match (Buchheit & Mendez-Villanueva, 2014; Gastin et al., 2013) and physical performance outcomes (Coelho E Silva et al., 2008; Malina et al., 2000). Earlier maturing players are at a significant performance advantage over their later maturing counterparts, with advanced vertical jump, sprint, strength and aerobic capacities seen in players of greater biological age (Armstrong & Welsman, 2005; Meylan, Cronin, Oliver, & Hughes, 2010; Pearson et al., 2006). Advantages associated with greater maturational age have also been linked to match running performance in both adolescent soccer (Buchheit & Mendez-Villanueva, 2014) and Australian football (Gastin et al., 2013), demonstrating that physical advantages translate to performance benefits in matches. However, these maturational advantages reduce with age, as variations in biological maturity become less pronounced and completely diminish once full adult status is attained (Armstrong, 2007). Adolescent differences in stature and performance due to maturational variation may confound coaches' perceptions of a player's long-term potential.

Coaches' perceptions of players may be biased by factors associated with size or maturational advantage. In adolescent competition where stature (height and weight) and physical performance is influenced by maturity (Armstrong, 2007), coaches may develop biased perceptions of long-term potential due to the advantages associated with greater biological age. Previously, it has been shown that stature can influence perceptions of athletic ability (Masters et al., 2010). However, this study was limited to soccer players rating the perceived athletic prowess of a size adjusted image of a goalkeeper, and so may lack practical and coaching application. Despite perceptions of potential guiding coaches' selection decisions in adolescent development pathways, no research has yet explored the link between perceptions of potential and maturational variation. This study aimed to examine if maturational variation in youth Australian footballers influenced coaches' perceptions of long-term potential.

5.2 Methods

Male players (n= 264, age 15.62 ± 0.28 years) and coaches (n= 9, age 40.88 ± 7.59. years, coaching experience 12.50 ± 3.74 years) recruited for this study were from nine teams involved in the U16s Western Australian Football League competition. Player participants attended a screening day where the basic anthropometric variables of height, sitting height and weight where measured. Height and weight measures were assessed to the nearest 0.1 cm and 0.01 kg using a stadiometer (PE, Sportforce, Australia) and electric scales (Model UC-321, A&D Mercury Pty. Ltd., Australia). Sitting height was measured by sitting participants on a 42 cm seat with their buttocks and shoulders against the stadiometer. These variables were then input into a regression equation to estimate maturity, using the predicted age at PHV method developed by Mirwald et al. (2002). The equation used was as followed.

$$Age\ at\ PHV = -9.326 + (0.002708 \times [\text{leg length} \times \text{sitting height}]) - (0.001663 \times [\text{age} \times \text{leg length}]) + (0.007216 \times [\text{age} \times \text{sitting height}]) + 0.02292 \times ((\text{weight}/\text{height}) \times 100))$$

This method provides a reliable and non-invasive means of assessing biological maturation, with a coefficient of determination 0.92, a standard error of measurement 0.59 years, and a mean difference of 0.24 ± 0.65 years between a verified sample of actual and predicted boys (Mirwald et al., 2002). A-PHV was subtracted from chronological age at prediction to calculate years from PHV (Y-PHV). Players were then classified as later (Y-PHV below 1.16 years, n=58) average (Y-PHV between 1.17 and 2.15 years, n=154) or earlier (Y-PHV above 2.16 years, n=52) maturing. These groups were constructed by adding or subtracting 0.50 years from the average Y-PHV (1.66 ± 0.62 years), resulting in at least one year maturational difference between later and earlier maturing groups (Till et al., 2014).

The coaches were asked to rate the perceived long-term potential of players in their team, via a questionnaire. The questionnaire asked what level of competition they thought the player would ultimately attain (1, semi-elite adolescent competition; 2, semi-elite senior competition; 3, professional senior competition).

Anthropometric variables were reported using mean and standard deviation. Perceptions of long-term potential were examined using chi-squared ($\chi 2$) analysis. Statistical analyses were carried out using SPSS software (Version 22.0, SPSS Inc., USA). Statistical significance was set at $p<.05$.

5.3 Results

At the time of assessment, the average years from PHV was 1.66, with a range of 0.27 years before peak height velocity to 3.73 years after PHV, resulting in a biological age differential of 4 years. Anthropometric information collected is reported in Table 9.

Table 9. Anthropometric variables for each of the different maturational groups (mean ± standard deviation).

	Maturational Status		
	Later	Average	Earlier
Height (cm)	171.08 ± 4.08	178.83 ± 4.47	186.23 ± 5.65
Sitting Height (cm)	84.43 ± 2.88	91.20 ± 1.72	96.50 ± 2.30
Weight (kg)	59.54 ± 5.65	68.15 ± 7.04	76.68 ± 7.78

Fisher's exact chi-squared test was used as both the later and earlier maturing groups had less than 5 players with perceived AFL potential. The chi-squared analysis revealed a significant between group difference when comparing maturational groups and perceived potential ($\chi2=9.99$, $p=.04$). As show in Figure 8, the differences appeared to be between the later-maturing group compared to both the average and earlier-maturing groups. A sub-group chi-squared analysis confirmed this, with the later maturing group having a significantly different distribution compared to the average ($\chi2=9.42$, $p<.01$) and earlier ($\chi2=5.86$, $p=.04$) groups. No significant difference was evident between the average and later maturing groups.

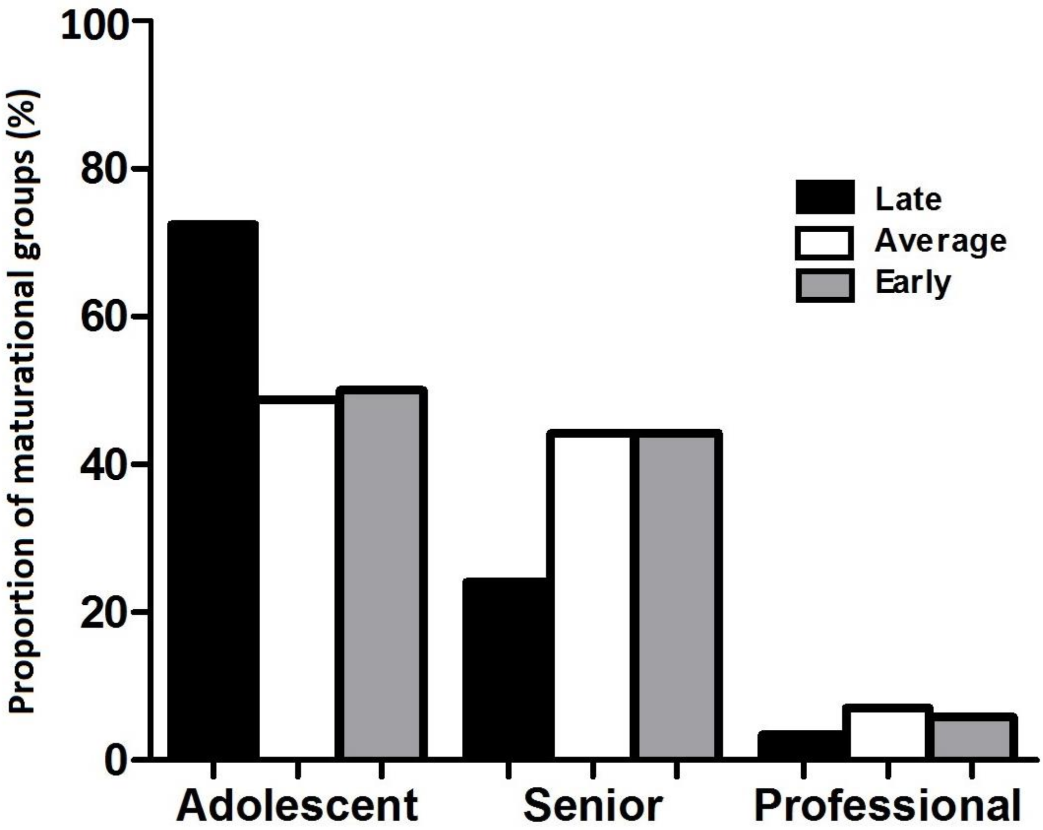


Figure 8. Proportional breakdown (%) of each maturational group and the coaches' perceptions of the player's potential.

The proportional breakdown of maturational groups and coaches' perceptions of long-term potential can be seen in Figure 8. Of those in the later maturing group, 42 (72.4%) were expected to progress no further than adolescent selection, 14 (24%) were expected to make senior teams, and 2 (4%) were predicted to make professional teams. Coaches' perceptions of the average maturing group were; 76 (49%), 69 (45%), and 9 (6%), respectively. Coaches' perceptions of the earlier maturing group were 26 (50%), 23 (44%) and 3 (6%); for adolescent, senior, and professional competition respectively.

5.4 Discussion

The aim of this study was to explore if coaches' perceptions of a player's long-term potential are associated with variations in biological maturity. Results from this study demonstrate that coaches perceive later-maturing players to have a lower long-term potential, than their more biologically mature counterparts. No concurrent bias was evident between the average and earlier maturing groups.

Development pathways are tasked with the role of ensuring the development of talented junior individuals for senior competition. Within these pathways, it often falls to coaches to make inclusion or exclusion decisions of players, based on both objective data collected (i.e. anthropometric measures, fitness testing and match statistics) and subjective opinions of skill and potential. However, research has consistently shown that maturational variation can significantly impact on objective measures commonly used, with those of advanced maturation likely to perform better in testing (Meylan et al., 2010) and match situations (Buchheit & Mendez-Villanueva, 2014; Gastin et al., 2013). This study demonstrates that subjective bias also occurs, with coaches' perceiving later maturing players to have a lower long-term potential than their average and later maturing counterparts.

Previously it has been shown that stature can influence perceptions of athletic ability (Masters et al., 2010). However, the results of this study lack application to real-world coaching environments because it used soccer players to rate the hypothetical goalkeeping ability when viewing several size adjusted images of a goal keeper. To the authors' knowledge, this is the first study to explore how coaches' perceptions of players within their own team can be influenced by maturational variation.

The results of this study have direct implications for coaches of development pathways, especially those who coach players around 15-16 years of age. For instance, since selection and de-selection decisions are often based on coaches' perceptions of long-term potential, the lower perceptions coaches have of late maturing players long-term potential may reduce their likelihood of selection into development pathways. Whilst the selection of more mature players may contribute to success in adolescent competition (Augste & Lames, 2011), such selection biases may prove erroneous longitudinally as performance advantages associated with maturational variations diminish once full adult status is attained (Malina, Bouchard, et al., 2004). Coaches should therefore be aware that when assessing the long-term potential of players, maturational variation within the playing population can greatly affect performances. Acknowledgment of these maturational and subsequent performance variations may then serve to moderate opinions and reduce perceptual biases.

A limitation of this study was that actual long-term potential of the players used in this study was not undertaken, to validate coaches' perceptions. Further, the results of this study are also limited to Australian football. Future research is required to establish if such perceptual biases exist in sports with different physical demands. Future research should also seek to longitudinally explore how accurate coaches' perceptions of a player's potential are and what factors contribute to players attaining or failing to reach these expectations.

5.5 Conclusions

The findings of this study demonstrate that coaches' perceptions of player long-term potential are associated with maturational variation. Coaches in this study perceived later maturing players to have a lower long-term potential, when compared to their earlier and average-maturing counterparts. Maturational differences in age matched players can be as large as 4 years, which is likely to contribute to performance variations. Coaches should be aware that performance variations associated with delayed maturity can impact the perception coaches have on a player's long-term potential. Given that coaches' selection and de-selection decisions are likely to be based on their perceptions of a player's long-term potential, later maturing players may be at an increased risk of de-selection. Coaches should therefore seek to moderate their perceptions of a player's potential, by at least considering the players maturity in reference to other age matched players.

CHAPTER SIX: BIOLOGICAL MATURITY AND THE ANTHROPOMETRIC, PHYSICAL AND TECHNICAL ASSESSMENT OF TALENT IDENTIFIED U16 AUSTRALIAN FOOTBALLERS.

This chapter is presented in the pre-publication format adapted from:

Cripps, A. J., Hopper, L., Woods, C.T., & Joyce, C. Biological maturity and the anthropometric, physical and technical assessment of talent identified U16 Australian footballers. *International Journal of Sport Science and Coaching,* Submitted for peer-review on 11th March 2016.

Research Synthesis:

Chapter two highlighted that few professional players had been selected into the initial U16 stage of the AFL TP suggesting poor pathway efficiency. The proposed reason for the poor pathway efficiency is that players originally selected are advantaged by greater biological maturity, which diminishes as the pathway progresses. Chapter four and five demonstrated advantages associated with greater biological maturity included anthropometric measures, physical measures and coaches' perceptions of technical skill and potential. These findings and the lack of research exploring talent identification in U16 Australian football teams highlighted the need for a final study to explore if maturational, physical and technical measures differed between talent identified and non-talent identified U16 players.

6.1 Introduction

The assessment of anthropometric and physical capacities for talent identification in team sports is common as successful team sport players require a range of well-developed physical attributes (Matthys, Vaeyens, Fransen, et al., 2012; Pyne et al., 2005). Considerable research has explored the link between physical testing performance and talent identification in Australian football at an under 18 (U18) level (Robertson et al., 2015; Veale et al., 2008; Woods, Raynor, Bruce, McDonald, et al., 2015). However, Australian football research has highlighted that only 47.5% of athletes selected into elite U18 squads had previously been selected into elite under 16 (U16) squads, highlighting issues with the talent identification process at the U16 level (Cripps, Hopper, Joyce, et al., 2015). Recent research in adolescent team sports demonstrates that differences in maturity are likely to contribute to anthropometric and physical performance variation (Buchheit & Mendez-Villanueva, 2014; Gastin & Bennett, 2013) and coaches perceptions of player skill and potential (Cripps et al., 2016a; Cripps et al., 2016b), which in turn are likely to impact on talent identification outcomes. Effects of maturational differences on performance outcomes are strongest in younger players around the time of peak height velocity (Armstrong, 2007). However, there is a lack of research examining factors which explain the talent identification of young (< 17 years) Australian footballers. Educating coaches as to the potential influence of biological maturation on physical performance outcome assessments may assist with the reduction of talent misclassification. Specifically, this education process may make coaches cognisant of avoiding acute selection bias associated with superior physical and/anthropometric measures underpinned by biological maturation.

The Australian Football League Talent Pathway (AFL TP) is the primary developmental pathway for talent identified junior Australian footballers seeking to compete in elite senor competitions (i.e., within the AFL) (Cripps, Hopper, Joyce, et al., 2015). The AFL TP is designed to accelerate the development of talented juniors to ensure the sustained supply of senior talent to the AFL. The AFL TP provides talent identified player’s access to experienced coaches, advanced training resources, support staff and participation in elite junior competitions. The AFL TP has three selection stages which are associated with; U16 and U18 state representative teams, and into the professional AFL teams. Recent research exploring the effectiveness of the AFL TP reported that only 27.7% of drafted players had previously been selected onto elite U16 teams (Cripps, Hopper, Joyce, et al., 2015). Further, only 47.5% of athletes selected at the U16 level were retained onto U18 squads. Poor retention of juniors may be linked to the relative age effect repeatedly reported in adolescent competitions (Cripps, Hopper, Joyce, et al., 2015; Till, et al., 2014; Schorer, Cobley, Busch, et al., 2009), which suggests that older players are looked upon more favourably in the initial identification process due to maturational advantage. This suggestion is supported by recent findings that Australian football coaches' perceive earlier maturing individuals to possess advanced technical skills and greater long-term potential (Cripps et al., 2016a; Cripps et al., 2016b). However, despite these findings there is no available research exploring factors which drive identification into the AFL TP at the U16 level. It may be postulated that earlier maturing athletes at the U16 level could experience identification advantage as they have been shown to possess both superior physical attributes and be perceived by coaches' to have greater long-term potential (Cripps et al., 2016a; Cripps et al., 2016b). Whilst later maturing players may fail to be identified due to acute performance disadvantages associated with being less mature. Such identification outcomes may negatively affect pathway efficiency as physical performance advantages and disadvantages associated with maturity reduce with age, which may result in later maturing players catching up and replacing those initially talent identified at the U16 level.

The poor retention of players initially identified onto the AFL TP may represent an inefficient use of pathway resources and may reduce the developmental capacity of the pathway. However to date, no research has explored if biological maturity or other measures such as anthropometric, physical or technical skill impact on talent identification of elite U16 Australian footballers, making it unclear what factors drive identification at the initial stage of the AFL TP. Therefore, the aims of this study were twofold, firstly to identify if maturational, anthropometric, physical or technical skill measures differ between junior Australian footballers according to status (talent identified / non-talent identified). A secondary aim of this study was to explore which measures could explain talent identification into the AFL TP at the U16 level.

6.2 Methods

6.2.1 Participants

Participants (n=282, age 15.7 ± 0.3 years) were recruited from the U16 Western Australian Football League competition. From this sample, two groups were examined; a talent identified group (n=25, age 15.7 ± 0.3 years; defined as representatives of the 2015 Western Australian State U16 Academy) and a non-talent identified group (n=25, age 15.6 ± 0.4 years; defined as players not identified on the 2015 West Australian State U16 Academy). The non-talent identified players were randomly selected from the remaining 257 players not selected into the Academy using the random sample function in SPSS version 22 (IBM, Chicago, IL, USA). In accordance with Woods et al. (2016), this randomisation process was implemented in order to generate a representative sample of the larger cohort for comparative reasons. This randomly selected non-talent identified group was representative of the larger non-randomly selected group of players (Appendix A). Further, between group differences were analysed to ensure the included randomly selected non-talent identified sample were representative of the larger non-talent identified sample, with no between-group differences evident ($p > .05$). To participate in the testing, players were required to declare themselves to be injury free at the time of testing. The relevant Human Research Ethics Committee provided ethical approval for the study with players and their guardians required to provide informed consent prior to testing.

6.2.2 Procedures

Upon arriving at the testing session, the players initially had anthropometric information recorded, being followed by the completion of two technical skill tests, and a series of five physical tests. Anthropometric variables collected were standing and sitting height and body mass. All players were then required to complete a standardised warm-up prior to the skills tests; the AFL’s kicking and handball efficiency test. Physical test completed included; a 20 m sprint, a stationary vertical jump (SVJ), a dynamic vertical jump on both the dominant (DVJD) and non-dominant foot (DVJND), and the 20 m multistage fitness test. A maximum of 40 players were tested at a time in three hour testing sessions during the preseason phase of training.

Both standing and siting height and body mass values were measured to the nearest 0.1 cm and 0.01 kg using a stadiometer (PE, Sportforce, Australia) and electric scales (Model UC-321, A&D Mercury Pty. Ltd., Australia), respectively. To measure sitting height, players sat on a 42 cm seat, with their buttocks and shoulders against the stadiometer. For all anthropometric measures players removed their footwear. Biological maturity was estimated using the anthropometric measures collected, with years to and from peak height velocity calculated using a standardised predictive equation (Mirwald et al., 2002). This method of assessment provides a reliable and practical method of assessing biological maturity and has been used in a number of studies with similar populations (Cripps et al., 2016a; Cripps et al., 2016b; Gastin & Bennett, 2013; Gastin et al., 2013).

The warm-up conducted prior to the skills testing included a light jog, a series of dynamic stretches, and a basic handballing and kicking drill. The skills tests were conducted outside on an outdoor playing field. All players were directed to wear their regular football boots. Both skills tests used in this study were developed by the AFL and required the players to deliver a handball or kick to a series of six targets across a range of Australian football specific distances. A reliable score of 0-5 was given by assessors (Cripps, Hopper, & Joyce, 2015) to rate each disposal for accuracy and trajectory. Previous research using athletes and assessors of a similar demographic reported strong levels of inter-rater reliability for both the kicking ($ICC=0.96$, $p<.01$) and handball tests ($ICC=0.89$, $p<.01$) (Cripps, Hopper, & Joyce, 2015). Disposal distances for the kicking test were short (20 m), medium (30 m) and long (40 m); whilst the handball test was short (6 m), medium (8 m) and long (10 m). For each distance a disposal was completed on the player’s dominant and non-dominant hand or foot, with skill executions to be completed in succession. Prior to testing players nominated their preferred hand and foot, with players performing each test once.

After completion of the skill testing the group was taken inside to a gymnasium with hardwood floors to complete the physical testing. Players wore standard running shoes for all physical assessments. The physical tests were complete in a circuit fashion, with players randomly sub-divided into four groups of approximately 10 and assigned to one of the four vertical jump or 20m sprint tests stations. The 20 m multistage fitness test was conducted after the completion of all other tests, with the players split into two equal groups to complete the test. Vertical jump tests were completed to assess lower limb power. Prior to each jump, players were required to stand under a Vertec vertical jump device (Swift Performance Equipment, Lismore, Australia), with both feet flat on the ground, then reach up and displace the highest vane possible. This process was repeated three times, with the highest vane displaced representing the individuals reach height. Players were asked to perform three counter-movement jumps and three running vertical jumps on their dominant and non-dominant feet. Foot dominance was defined as the players preferred kicking foot. For the running vertical jumps, players were allowed a 5 m run up. Standing reach height was subtracted from each of the individual jumps to give a relative jump height. Jump height was measured to the nearest 1 cm, with the largest of each jump reported.

Sprint performance was evaluated by 20 m sprint time using infra-red timing gates (Smartspeed, Fusion Sport Pty Ltd, Queensland, Australia). Players were instructed to self-start the test to remove the effects of reaction time. Players were given three attempts with the fastest of the three trials recorded to the nearest 0.01 of a second.

Aerobic fitness was conducted last to prevent fatigue in other tests and assessed via the multi-stage fitness test. Players were required to run back and forth along a 20 m track, keeping time with a series of audio beeps, with the frequency of beeps increasing as the test progressed. The test stopped when the player reached voluntary exhaustion, or could no longer keep up with the beep frequency. The stage and level achieved by each player was recorded. For analysis, the total distance was used which was calculated from the players recorded shuttle stage and level.

6.2.3 Statistical analyses

Statistical analysis was undertaken using SPSS version 22 (IBM, Chicago, IL, USA). Mean and standard deviation scores were calculated for all dependent variables (i.e. anthropometric, physical, and technical skill measures). Prior to analysis, all data was screened for normality. A multivariate analysis of variance (MANOVA) was used to explore the main effect of 'status' (two levels: talent identified, non-talent identified) on the biological maturity, anthropometric, physical and technical skill variables. The effect size (ES) of status on all measures was calculated using Cohen's d statistic. The magnitude of the effect sizes were interpreted using a scale where values <0.2 are deemed trivial, 0.2–0.6 small, 0.6–1.2 moderate, 1.2–2.0 large and >2.0 very large (Hopkins et al., 2009). For all analyses, the Type-I error rate was set at $\alpha<0.05$.

Binary logistic regression was used to determine which measures best explained the main effect of selection (two levels: 1 =talent identified and 0 =non-talent identified). The full model was created using all significant measures from the MANOVA. Subsequent models were constructed using a backwards elimination method with the measure affecting the model the least subsequently removed until only significant measures remained. Model fit was determined using the Akaike information criterion (AIC). Odds ratio (OR) and 95% confidence intervals (95% CI) were reported for each significant measure. Additionally, a receiver operator curve (ROC) was built to examine the discriminative capability of the most parsimonious model by examining the area under the curve (AUC). In accordance with recommendations provided by Woods, Raynor, Bruce, McDonald, et al. (2015), the point on the curve at which the sum of the talent identified and non-talent identified scores were maximised was considered the value of which a "cut off" score can be considered for identifying players.

6.3 Results

According to Pillai's trace (V), the MANOVA revealed a significant effect of status ($V = 0.57$, $F(11, 38.000) = 4.56$, $p<.01$). Follow up univariate analysis revealed a significant effect of status on biological maturity, standing and sitting height, DVJD foot, DVJND foot and the handball test (Table 10).

Table 10. Between group differences for anthropometric, physical and technical skill measures (mean ± standard deviation).

Measure	Talent Identified	Non-talent Identified	Effect size (Cohen's *d*)
Height (cm) [b]	183.06 ± 9.75	176.39 ± 6.05	0.82
Sitting Height (cm) [a]	92.65 ± 4.45	90.04 ± 4.04	0.61
Weight (kg)	72.21 ± 7.84	67.79 ± 9.40	0.52
Y-PHV [a]	1.98 ± 0.66	1.55 ± 0.68	0.65
SVJ (cm)	60.20 ± 5.28	57.80 ± 6.18	0.42
DVJD (cm) [a]	66.00 ± 7.36	61.00 ± 8.50	0.63
DVJND (cm) [b]	73.40 ± 8.11	66.72 ± 6.58	0.91
20m Sprint (s)	3.04 ± 0.11	3.09 ± 0.10	0.48
Shuttle Distance (m)	2282.88 ± 320.96	2167.64 ± 214.73	0.42
Kicking Test	14.44 ± 3.04	13.60 ± 3.14	0.27
Handball Test [a]	24.84 ± 3.26	21.04 ± 4.68	0.94

[a] p <.05. [b] p <.01

Table 11. Model summary relating to the binary logistic models run.

	Model 1				Model 2			
Measure	β (SE)	χ^2	*p*	OR (95%CI)	β (SE)	χ^2	*p*	OR (95%CI)
Constant	12.57 (26.64)	0.22	0.64		4.86 (23.93)	0.04	0.84	
Standing Height (cm)	-0.19 (0.11)	3.21	0.07	0.82 (0.67-1.02)	-0.17 (0.10)	2.97	0.08	0.84 (0.69-1.02)
Handball	-0.34 (0.13)	6.61	0.01	0.71 (0.55-0.92)	-0.34 (0.13)	7.18	0.01	0.71 (0.55-0.91)
DVJD (cm)	-0.12 (0.06)	3.63	0.06	0.88 (0.78-1.00)	-0.13 (0.06	4.62	0.03	0.88 (0.78-0.99)
Sitting Height (cm)	0.49 (0.39)	1.59	0.21	1.63 (0.76-3.48)	0.53 (0.38)	1.94	0.16	1.70 (0.81-3.57)
Y-PHV	-2.15 (2.09)	1.09	0.30	0.12 (0.01-7.01)	-2.57 (1.99)	1.67	0.20	0.076 (0.01-3.77)
DVJND (cm)	-0.05 (0.07)	0.46	0.49	0.96 (0.84-1.01)				
AIC		55.89				54.34		
	Model 3				Model 4			
Measure	β (SE)	χ^2	*p*	OR (95%CI)	β (SE)	χ^2	*p*	OR (95%CI)
Constant	33.07 (11.37)	8.47	<0.01		34.97 (11.08)	9.96	0.02	
Standing Height (cm)	-0.15 (0.09)	2.66	0.10	0.86 (0.72-1.03)	-0.10 (0.52)	3.94	0.04	0.90 (0.81-1.00)
Handball	-0.32 (0.12)	7.07	0.01	0.73 (0.57-0.92)	-0.31 (0.12)	6.95	<0.01	0.73 (0.58-0.92)
DVJD (cm)	-0.12 (0.06)	4.41	0.04	0.88 (0.79-0.99)	-0.13 (0.06)	4.93	0.03	0.88 (0.78-0.98)
Sitting Height (cm)	0.11 (0.18)	0.39	0.54	1.12 (0.79-1.58)				
AIC		54.14				52.52		

Abbreviations: β, beta coefficient; SE, standard error; χ^2, Wald chi-squared; AIC, Akaike information criterion. Statistical significance accepted at $p<0.05$

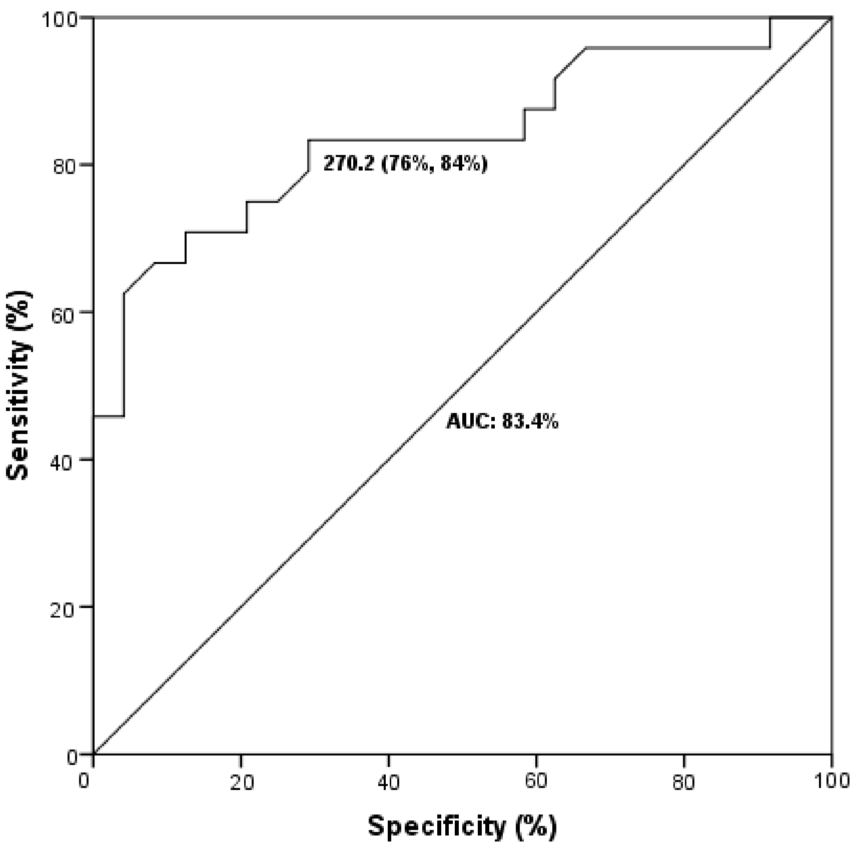


Figure 9. Receiver operating curve for the most parsimonious model which included standing height, DVJND foot and handball parameters.

The six significant variables from the MANOVA were then included in the full logistic regression model. A total of four models were developed (see Table 11. Model summary relating to the binary logistic models run.), however the best reduced model (AIC=52.52) included only standing height (OR=0.90, CI= 0.81-1.00, *p*=.04), DVJND foot (OR=0.73, CI= 0.58-0.92, *p*=.03) and handball score (OR=0.88, CI= 0.78-0.98, *p*<.01) as the strongest model of status (AUC=83.4%, CI= 72.1%-95.1%). The ROC was maximised when a cut-off score of 270.2 was applied, with the final reduced model correctly identified 84% of the talent identified and 76% of the non-talent identified players (Figure 9). According to the AUC the most robust single measure to explain status was handball score (AUC=76.0%, CI= 62.5%-89.5%), with a value of 24.5/30 found to optimise the ROC and correctly explain 60% of the talent identified and 80% of the non-talent identified players. A standing height (AUC=72.8%, CI= 57.8%-87.8%) with a cut-off value of 179.9cm correctly identifying 20 (80%) of the talent identified and 15 (60%) of the non-talent identified players. The weakest measure from the most parsimonious model was the DVJND foot (AUC=72.6%, CI= 58.5%-86.6%) with a cut-off value of 68.5 cm correctly classifying 16 (64%) of the talent identified and 17 (68%) of the non-talent identified players.

6.4 Discussion

Talent identified junior Australian footballers were biologically more mature than non-talent identified players, and in addition were taller, and performed better in the DVJD foot, DVJND foot and handball tests. Gastin and Bennett (2013) reported maturational differences between community U15 Australian footballers, however this is the first study to demonstrate that age-matched talent identified U16 Australian footballers are more mature than their non-talent identified counterparts. Between group variations in maturity reported in this study are likely to contribute to the anthropometric and physical performance differences demonstrated between the talent identified and non-talent identified groups, as players of advanced maturational age are typically taller, heavier and have been shown to possess greater vertical leaps than their less mature counterparts (Cripps et al., 2016a; Gastin & Bennett, 2013; Malina, Eisenmann, et al., 2004). Maturational variation has previously been shown to account for between 8-19% of physical performance variability and affect coaches' perceptions of skill and potential in U16 Australian footballers (Cripps et al., 2016a; Cripps et al., 2016b). The greater anthropometric and vertical jump measures reported in this study conforms to previous results examining U18 Australian footballers who were talent identified (Veale et al., 2008; Woods, Raynor, Bruce, McDonald, et al., 2015). However at a U16 level this may be problematic as performance advantages are likely related to biological maturity, rather than raw talent and long term potential. Identification resulting from advanced maturity may negatively affect pathway efficiency as physical advantages due to maturity have been shown dissipate with age (Till et al., 2014), elevating the risk of subsequent de-selection.

Handball performance was found to differ between talent identified and non-identified players confirming the importance of technical skills to talent identification and selection in Australian football (Woods, Raynor, Bruce, & McDonald, 2015; Woods, Raynor, Bruce, McDonald, & Robertson, 2016). Currently it is unclear if performance in the AFL skill tests associate with skilful performance in matches, which presents as a limitation to this study. However unlike anthropometric and physical measures, performance in Australian football skill tests do not appear to be influenced by biological maturity (Cripps et al., 2016a). Coaches at an U16 level may therefore consider prioritising performance in skills tests over anthropometric and physical measures during talent identification due to its unbiased nature. Greater consideration of measures unaffected by maturity may improve talent identification processes and development pathway efficiency. For example measures may also be extended to include examination of psychological markers and decision-making tasks which have been shown to discriminate between talent identified and non-talent identified U18 Australian footballers (Woods, Raynor, Bruce, & McDonald, 2016). However, the effects of maturational variance on new identification assessments need to be explored before including in the talent identification processes.

Australian football is a multidimensional team sport which requires players to possess well developed physical, technical and tactical skills to perform at a high level (Woods et al., 2016). As such, several studies have examined if physical (Keogh, 1999; Robertson et al., 2015; Woods, Raynor, Bruce, McDonald, et al., 2015), skill (Woods, Raynor, Bruce, & McDonald, 2015) and decision making (Woods et al., 2016) measures can explain talent identification in U18 Australian football. The results of this study demonstrate a combined set of physical and technical measures can explain talent identification into an elite U16 Australian football team. The strongest model correctly identified 84% of the talent identified and 76% of the non-talent identified players, with this model including the measures of standing height, DVJND foot and handball efficiency. Using this model and the ROC a score of 270.2 was determined to be an acceptable cut-off value for identifying potentially elite U16 Australian footballers. This study, when coupled with the findings of Woods, Raynor, Bruce, et al., (2016) further highlights the need for a multidimensional approach to talent identification in junior team sports, such as Australian football. However when considered in conjunction with the low retention of players from U16 to U18 squads (Cripps, Hopper, Joyce, et al., 2015), this study highlights a clear need to factor assessments of biological maturity in identification measures of U16 players. Consideration of maturity and prioritisation of tests unbiased by maturation may help improve long-term pathway outcomes by ensuring later developing adolescent players are not misidentified early in development pathways due simply to disadvantages associated with being biologically younger.

6.5 Conclusions

This research provides first evidence that players identified onto the AFL TP at the U16 level are likely to be more biologically mature than their non-talent identified counterparts. Further, differences were evident between talent identified and non-talent identified players in measures of standing and sitting height, DVJD foot, DVJND foot and handball test scores. The results of this research have implications for current talent identification methods as both standing height and DVJND foot have previously been shown to be influenced by maturational variation (Cripps et al., 2016a). The strongest measures able to define status where reduced to three variables, standing height, DVJND foot and handball score. Given that handball test performance is unaffected by maturational variation (Cripps et al., 2016a), coupled with the results of this study, coaches should prioritise performance in technical skill assessments over physical testing measures during the talent identification process. The consideration of biological maturity and prioritisation of talent identification measures unbiased by maturation such as technical skills tests, may improve athlete retention outcomes in the AFL TP by preventing the initial misidentification of players potentially physically advantaged or disadvantaged at 16 years of age.

CHAPTER SEVEN: GENERAL THESIS SUMMARY AND CONCLUSIONS

7.1 Introduction

Talent identification and development programs are considered critical to ensuring the continued supply of elite talented players to professional senior sporting competitions (Vaeyens et al., 2008). As a result sporting bodies invest heavily into talent identification and development programs however, programs are largely inefficient as few players originally included in development programs progress into senior competition (Vaeyens et al., 2009). The multidimensional and unpredictable nature of player development means some level of player turnover is logically expected. Factors such as injury, burnout or withdrawal are likely to also contribute to some level of player turnover in development pathways (Bergeron et al., 2015). The well-researched phenomenon termed the 'relative age effect' may provide evidence of another factor likely to contribute to poor retention outcomes. Specifically if players initially selected into development pathway are more mature than their non-selected counterparts due to greater chronological age or earlier maturation. Player turnover may be a result of older players initially selected being surpassed as the development pathway progresses.

Adolescent sporting teams and development pathways are typically stratified by chronological age groups which generally span one or two years. However maturational variation in age matched adolescent players at or around the time of PHV can be as large as three years (Armstrong, 2007). A by-product of maturational variation may be that earlier maturing players are selected into development programs due to advantages associated with greater biological age. Variations in biological maturity have direct implications for sporting performance as anthropometric and physical performance measures such as running and jumping capacities are all typically advanced in more mature players (Gastin & Bennett, 2013; Malina, Eisenmann, et al., 2004). In contrast, the effects of maturational variation on technical skill performance in the sports of soccer, basketball and handball has been ambiguous, with no previous research examining the impacts of maturation on Australian football specific skills. Further despite the importance of subjective coaches' opinions in the player selection process (Gee et al., 2010), examination of how maturational variation impacts on coaches' perceptions of technical skill and potential had yet to been explored in any sport.

Research exploring measures which predict selection in Australian football has previously focused on adolescent players competing in U18 competitions or draft selection. However the AFL TP begins with identification onto U16 representative teams, with identification hypothetically setting the players up for progression into the professional AFL. Despite other levels of the AFL TP being explored no multidimensional examination had yet been conducted exploring measures predictive of identification into the initial stage of the AFL TP.

7.2 Chapter summary and conclusions

This doctoral thesis aimed to explore the effects of maturational variation on player retention, performance and progression throughout the AFL TP. Particular reference was given to the initial stage of the pathway (U16) due the lack of research exploring this age group. Chapter two longitudinally explored the AFL TP retention rates and relative age effects. Chapter three examined the reliability and validity of the AFL skill tests. Chapter four and five examined the influence of maturity on performance measures, coaches' perceptions of skill and potential. The final study of the thesis (chapter six) explored differences between talent identified and non-talent identified adolescent Australian footballers and measures predictive of talent identification into the AFL TP. Key findings from each study are outlined below.

7.2.1 Chapter two - Pathway efficiency and relative age effects in the Australian Football League's Talent Pathway

Previous research examining player progression from elite junior competition or development programs into senior competition has repeatedly reported poor retention outcomes (Vaeyens et al., 2009). A common methodological flaw to a number of these studies is that retention was assessed as the number of players progressing from junior pathways into professional senior competition or teams.

Assessment of retention in such a manner will inevitably result in low retention outcomes as the pyramid model of participation adopted by most development pathways means there are more junior players than there are spots available at the senior level. As such 100% retention is impossible to attain. The retrospective analysis of senior player involvements in adolescent development pathways provides a better representation of the developmental efficiency of talent pathways.

Chapter two therefore retrospectively examined the AFL TP involvement and birth quartile distribution of drafted players across six seasons. The results of this study demonstrated that only 27.7% of drafted players had previously been selected into the initial U16 stage of the AFL TP. Further, a significant relative age effect existed in all levels of the AFL TP with relatively older players also significantly more likely to be de-selected as the pathway progressed. Results of this study highlight that chronologically older and potentially more mature players are more likely to be selected into the AFL TP. However given that de-selected players also demonstrated significant relative age effects, it is likely that such selections will negatively impact on long-term developmental efficiency of the AFL TP.

7.2.2 Chapter three - Inter-rater reliability and validity of the Australian Football League's kicking and handball tests

The results of chapter two demonstrated that selection into the AFL TP may be biased by advantages associated with increased chronological age and maturity. In Australian football maturational variation in age matched players has been shown to impact on anthropometric and physical performance measures however the effects on technical skills had yet to be explored. In 2009 and 2010 the AFL developed two skill tests to assess the skill efficiency of potential draftees. These tests were originally developed for use at the AFL Draft Combine, however the simplicity of the assessments has resulted in the widespread use of the tests at lower levels of the AFL TP. Chapter th9ee therefore set out to explore if the skills tests commonly used in the AFL TP demonstrate acceptable levels of inter-rater reliability and validity enabling the tests inclusion in subsequent chapters within the thesis.

Reliability assessments from chapter three demonstrated that both the AFL's kicking (ICC=0.96, $p<.01$) and handball (ICC=0.89, $p<.01$) tests provided acceptable levels of relative and absolute inter-rater reliability. Both tests also demonstrated partial content validity, with the tests able to differentiate between laterality, with scores on the dominant hand ($p=.04$) and foot ($p<.01$) significantly higher compared to the players non-dominant side. Results from chapter three led to the conclusion that the AFL's skill tests were appropriate for use in subsequent chapters within this thesis.

7.2.3 Chapter four - Maturity, physical ability, technical skill and coaches' perception of semi-elite adolescent Australian footballers.

Chapter two highlighted that selection into the AFL TP is likely biased by advantages associated with increased chronological age and maturity. Selection biasing is likely due to performance advantages associated with advanced maturity. In Australian football maturational variation has previously been shown to impact on anthropometric and physical performance measures in U15 community level Australian footballers (Gastin & Bennett, 2013). However performance in team sport environments is considered multidimensional, with other factors such as technical skill able to differentiate between talent identified and non-talent identified players at a U18 level (Woods, Raynor, Bruce, & McDonald, 2015). Unlike physical performance, the impact of maturational variation on technical skill has been inconclusive (Figueiredo et al., 2009b; Malina et al., 2005) and had not yet been examined in skills specific Australian football. Another important but previously unexamined factor was coaches' perceptions of skill. The talent identification process utilises objective data from testing and matches to support subjective perceptions coaches have of players. Given the potential for objective performance to be influenced by maturity, it was important to examine if coaches' perceptions were influenced by maturation.

Chapter four was therefore designed to assess the impact of maturational variation on U16 Australian footballers, using the technical skill tests examined in chapter three, as well as commonly assessed physical measures and coaches' perceptions of skill. The results of chapter four highlighted very large to moderate differences between earlier and later maturing groups for height, weight, vertical leap and sprint capacities (Hedge's d range -0.74-6.26). Interestingly, no difference was found between maturational groups and performance in technical skill tests. Chapter four also demonstrates that earlier maturing individuals are perceived to possess better marking and ball winning abilities, as well as superior overall technical skills, when compared to later maturing counterparts. The combination of anthropometric, physical and perceived skill advantages afforded to earlier maturing players are likely to result in significant competition and team selection advantages.

7.2.4 Chapter five - Coaches' perceptions of long-term potential are biased by maturational variation.

Chapter four highlighted that earlier maturing players are not only physically advanced but also perceived to possess better developed technical skills when compared to later maturing players. Talent pathways such as the AFL TP are designed to ensure athletes selected into the pathway receive the support and guidance required to fulfil their potential. Therefore players selected into these pathways should be those with the greatest long-term potential. However given the advantages afforded earlier maturing players highlighted in chapter four, it is possible that coaches' may perceive earlier maturing adolescent players to have greater long-term potential. Chapter five therefore sought to explore if maturational differences influenced coaches' perceptions of long term potential.

Results from chapter five highlight that coaches' perceptions of later maturing players are significantly lower than earlier maturing individuals, with 72% of the later maturing individuals perceived to progress no further than adolescent competition. This is in contrast to the average and earlier maturing groups, with 49% and 50% not expected to progress beyond adolescent competition respectively. In summarising results from chapter one, three and four, few professional players are selected into the initial U16 stage of the AFL TP demonstrating poor pathway efficiency. The proposed reason for the poor pathway efficiency is that athletes originally selected have advantages associated with earlier biological maturity at the time of selection, as represented by the relative age effects reported, which diminishes as the pathway progresses. Chapter three and four highlighted that advantages associated with greater biological maturity includes anthropometric measures, physical measures and coaches' perceptions of technical skill and potential. These findings and the lack of research exploring talent identification in U16 Australian footballers highlighted the need for chapter six which explored if maturational, physical and technical measures differed between talent identified and non-talent identified U16 players.

7.2.5 Chapter six - Biological maturity and the anthropometric, physical and technical assessment of talent identified U16 Australian footballers

Chapter six demonstrated that U16 Australian footballers who are talent identified onto AFL TP squads are more mature than their non-talent identified counterparts. Increased biological maturity is likely to contribute to the anthropometric and physical performance variances demonstrated between the talent identified and non-talent identified players. Performance in the handball test was also advanced in talent identified players. Predictive modelling used in chapter six correctly identified 84% of the talent identified and 76% of the non-talent identified players, with the best reduced model including assessments of standing height, DVJND foot and handball efficiency. The results of chapter six further highlight the problem maturational variation presents to talent identification in adolescent Australian football, as height and jumping measures used in the predictive model have been shown in chapter four to be influenced by biological maturity. Given the significant investment and considered importance of gaining selection into the AFL TP the findings in this thesis have considerable practical recommendations for coaches and sport scientist charged with talent identification in the initial stages of the AFL TP. The following section will discuss in detail these broader practical recommendations.

7.3 Implications and practical recommendations for talent identification in Australian football

This thesis highlights the issues that maturational variation presents to the developmental efficiency of the AFL TP. Large maturational variations were evident between players of similar chronological ages, with maturational variations linked to performance advantages and favourable coaches' perceptions of skill and potential. Such favourable outcomes are likely to result in the talent identification of more mature players, which is likely to influence the developmental efficiency reported in chapter two. This thesis therefore can provide a framework for talent identification processes used in the U16 stage of the AFL TP. Specifically, talent identification processes should: 1) include assessments of biological maturation and 2) include testing measures unaffected by biological maturity.

7.3.1 Include assessments of biological maturation

The assessment of biological maturation is not typically included in the talent identification assessment battery at the U16 stage of the AFL TP. The large maturational variation evident in age matched players included in this thesis highlights the need for maturational assessment. Assessments of biological maturity are often seen as impractical due to assessment costs or the invasive nature of the tests. However the maturational assessment developed by Mirwald et al. (2002) provides an accurate, non-invasive and simple means of conducting such assessments in players 16 years and younger. This method of assessment has previously been used successfully in the Player Performance Pathway developed for the United Kingdom's Rugby Football League (Till, Cobley, O'Hara, et al., 2010). Inclusion of maturational assessment would provide coaches and sport scientists charged with talent identification and selection greater insight into the current performance capacities of players by enabling results to be referenced against the biological maturity of the player.

Previous research has demonstrated that later maturing players have a greater potential to increase anthropometric and physical measures as they mature with age when compared to earlier maturing individuals (Till et al., 2014). Inclusion of maturational assessments may therefore also help with making selection decisions based on future potential. For instance, consider a scenario where two players are competing for selection into an elite U16 squad with both demonstrating similar physical performance and skill measures. However player A is determined to be earlier maturing whilst player B is later. Whilst not guaranteed, it is feasible to assume that the potential physical development of player B could be greater than player A and therefore may justify player B's inclusion in the squad. The inclusion of the maturational assessment used in this thesis would therefore ensure that later maturing players are identified and that their performances and potential are considered in relation to their biological maturity.

The inclusion of non-invasive maturational assessments to talent pathways coupled with greater coach education about the physical effects of maturation may improve player development outcomes. The Long Term Athlete Development model developed by Balyi & Hamilton (2004) suggest that the planning and implementation of training stimuli throughout adolescence should be specific to the maturity level of the individual. Whilst all energy systems are always trainable (Balyi & Hamilton, 2004), there appear to be phases particularly around PHV where there are periods of accelerated power (Beunen & Malina, 1988), speed (Philippaerts et al., 2006) and aerobic (Payne & Morrow, 1993) development. Educating coaches about how maturity and training can effects the development of these energy systems may improve the developmental outcomes of talent pathways.

7.3.2 Include testing measures unlikely to be affected by biological maturity

Effective talent identification processes in team invasion sports should be multi-dimensional and assess the physical, technical and tactical attributes required of players to perform at an elite level (Gabbett, Jenkins, & Abernethy, 2011; Vaeyens et al., 2006; Woods, 2015). Also critical to the talent identification process are subjective assessment of player's ability and potential made by coaches (Williams & Reilly, 2000). In Australian football, talent identification processes begin around 16 years of age meaning the assessment of such measures occur during periods of high maturational variation. Maturational variation in players at this age is likely to result in mature players being advantaged in physical testing measures and subjective assessments made by coaches, which in turn is likely to result in selective advantages towards more mature players. Selections biased by maturational performance advantages may result in the subsequent de-selection of the previously advantaged players as later maturing individuals themselves mature and physically catch up.

To reduce selection biasing resultant from maturational advantage, coaches and sport scientists should ensure the inclusion of testing measures which are unbiased by the effects of biological maturity. Chapter four demonstrated that performance in both the AFL's handball and kicking test are unaffected by maturational variation. However these tests are primarily used in the U18 and draft levels of the AFL TP. Neither skill test is included as a standard talent identification measures at an U16 level, largely due to time and resourcing constraints. As a result, physical performance measures dominate talent identification testing at the youngest stage of the AFL TP. Inclusion of the AFL skill's tests as standard assessments when performing talent identification testing at an U16 level would ensure that assessment measures are not completely biased towards earlier maturing players, potentially preventing the exclusion of talented but later maturing players.

Other non-physical performance measures may be unaffected by maturational variation and therefore warrant inclusion in Australian football talent identification processes. For example, video-based tactical decision making tests developed by Woods et al. (2016) have shown an ability to discriminate between talent identified and non-talent identified U18 Australian footballers. These tests require players to watch specific attacking plays unfold on a television screen and choose the correct passing option. Previous research has demonstrated that decision-making outcomes are similar between video-based and in situ tasks when quantifying decision making skill (Bruce, Farrow, Raynor, & Mann, 2012). The video-based tactical assessment developed by Woods et al. (2016) may therefore be appropriate for inclusion in the talent identification of young Australian footballers as it has the capacity to quantify decision making skills. However due to the lack of physical/motor requirements of the test it may be less likely than in situ tests to be biased by maturational advantage.

Psychological evaluation may provide further insight into the potential of a junior player to excel in Australian football. Players involved in competitive development pathways are constantly exposed to physically challenging situations and mentally stressful environments. Examination of the player's psychological constitution or more specifically factors such as intrinsic motivation, self-confidence, mental toughness and commitment to attaining excellence in the sport may provide insight into the long-term potential of a player. It is unclear whether traits such as mental toughness are influenced by maturational variation, however changes in mental toughness with age have been inconclusive (Crust, Nesti, & Littlewood, 2010; Gucciardi, Gordon, & Dimmock, 2009). Whilst further research is need to confirm the effects of maturational variation on psychological measures, the inclusion of these measures may provide further opportunity for later maturing players to demonstrate their potential without maturational bias occurring.

7.4 Limitations

This thesis aimed to examine the effects of maturational variation on player selection, progression and performance in the AFL TP. While rigorous scientific processes were employed throughout, several limitations of the thesis that should be acknowledged are:

7.4.1 Methodological issues and assumptions associated with the use of relative age

In chapter two it is suggested that pathway inclusion is associated with selected players being biological more maturity than those who missed selection. This conclusion was based on the knowledge that biological maturity is linked to the chronological age of an individual, with players of advanced chronological age also likely to be biologically older (Armstrong, 2007; Gil et al., 2013). However simple examination of chronological age cannot account for potential variations associated with earlier or later biological maturation. Therefore without direct assessments of biological maturity such assumptions made in chapter two should be treated as speculative.

Another potential limitation of this investigation is a potential methodological bias associated with comparing sporting population data to population norms. Previously it has been suggested that athletic populations may already demonstrate relative age effects, thereby potentially confounding results when comparing to population norms (Delorme, Boiché, et al., 2010). Unfortunately the present investigation lacked access to the birth distribution data of all registered Australian footballers, therefore we followed the method of comparing to national population distributions outlined in previous studies (Coutts et al., 2014; Helsen et al., 1998; McCarthy & Collins, 2014).

7.4.2 Limitations with the peak height velocity protocols

A limitation of the predictive peak height velocity protocols used in this thesis is that the equation was originally developed using a non-athletic population (Mirwald et al., 2002). Currently this equation has not been validated longitudinally using samples of male adolescent athletes to compare predicted peak height velocity results against established maturity indicators (Malina et al., 2015). Malina and Koziel (2014) explored the validity of the predictive model using longitudinal data of male Polish boys (n=193) with finding demonstrating the predictive equation had limitations due to estimating error in early maturing participants. The author subsequently suggested the predicative equation has specifically limitations when being applied to adolescent sporting populations. Currently the only study to longitudinal explore sporting populations and the validity of the predictive equation used a small sample (n=13) of female gymnasts with the maturity offset equation appearing to overestimate age at PHV (Malina et al., 2006). However the small sample size of this study limits the application of the findings to gymnastics and female athletes (Malina et al., 2006). Whilst the predictive maturity offset equation is not without limitation recent cross-sectional research by Gastin et al. (2013) examined a sample of adolescent Australian footballers (n=52) using both the predictive equation and participants subjective rating of actual biological maturity (using Tanners criteria of pubertal development) and reported very large correlations between the two measures (r=0.80). Further, work by Buchheit and Mendez-Villanueva (2014) demonstrated that peak height velocity estimates were well correlated (r = 0.69) with skeletal age (estimated from a hand and wrist radiograph) in highly trained Middle Easter adolescent soccer players (n = 36; age range: 12.1–17.3 years). Therefore while it is acknowledged that the equation developed by Mirwald et al. (2002) is not the “gold standard’ for measuring biological maturity, the method enables the objective comparison of maturity between adolescent players relative to their peers. As such this method of maturational assessment is particularly relevant when assessing large samples of adolescent players and has been used as the standardised assessment for biological maturity in development pathways such as the Player Performance Pathway in UK rugby league (Till et al., 2013). Given the methods applicability to practical talent identification testing and previous research reporting strong correlations between the predictive equation and other measures of biological assessment, it was determined that the predictive equation was a valid tool for assessing biological maturity in the thesis.

7.4.3 Exclusion of other multi-dimensional measures

Skilful performance in team sports is considered to consist of a composite of physical, technical and tactical elements (Launder, 2001). The psychological constitution of a player is also likely to influence a players long-term potential. Effective talent identification processes should therefore include assessments of each of these measures. The research within this thesis examined how two of these factors, physical and technical skill measures, can be influenced by maturation and predictive of talent identification. The thesis did not examine the tactical or psychological traits. Video-based tactical decision making test have recently been developed for Australian football and have demonstrated an ability to discriminate between talent identified and non-talent identified U18 players (Woods et al., 2016). Psychological assessments of mental toughness have also previously been developed for Australian football and used in talent identified and non-talent identified players (Gucciardi et al., 2009). However currently neither the tactical decision making test nor psychological assessment are currently included in the standard talent identification protocols used in the AFL TP. It is acknowledged that the inclusion of such measures within the thesis would have added a further novel element to the thesis and potentially strengthened the predictive model developed in chapter six. However primarily the thesis sought to investigate current and commonly applied talent identification protocols used in the AFL TP and so tactical and psychological measures were not considered necessary for inclusion in the context of this thesis.

7.4.4 Inability to longitudinally track performance measures and potential

Unfortunately due to time constraints, player development was not longitudinally tracked as they progressed through the pathway. The inclusion of longitudinal changes would have significantly added to the thesis. This limitation is particularly an issue in chapter five, where without the longitudinal tracking of the players through the pathway we are unable to ascertain how accurate coaches' perceptions of potential are. However, this leaves an enticing window for future research to exploring the long-term accuracy of coaches' perceptions of potential and the development of players as the pathway progresses.

7.5 Future research directions

This thesis has explored the impact of maturational variation on performance, selection and progression of Australian footballers through the AFL TP. However, the continued examination of the AFL TP and talent identification within the pathway provides an exciting and continued line of research for future studies. Specifically;

1. Tactical and psychological measures have the potential to advance talent identification processes used in Australian football. However, there is a lack of research examining how either factor is affected by maturational variation. Future research should seek to explore if/how maturational variation affects performance in tactical and psychological measures. Further to this research should also examine if including tactical and psychological measures can further strengthen the predictive model developed in chapter six.

2. Longitudinal research in Australian football is limited. While the longitudinal tracking of players has been identified as a limitation of this thesis, the inclusion of such longitudinal data was not feasible given the time constraints of the doctoral thesis. Future projects will endeavour to longitudinally track the

developmental trajectories of players of differing maturational statuses. Further longitudinal research is also proposed to establish the predictive accuracy of coaches' perceptions of potential in chapter four. Such longitudinal investigations would significantly add to the current body of research into talent identification in Australian football.

3. While player de-selection is likely to be a major influence on the efficiency of the AFL TP, other factors such as injury and player withdrawal are also likely to have some impact. Injury incidence and the effects on matches missed have been investigated in junior Australian football (Scase et al., 2012). However no research has examined the impact of injury on player turnover in the AFL TP. Examination of the timing, type and severity of injury and the subsequent effects on pathway efficiency would provide valuable information to key pathway stakeholders. Further investigation of player withdrawal rates and factors which promote withdrawal from the talent pathway would provide key stakeholders with information critical to improving the efficiency of the AFL TP.

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APPENDIX A

Table 12. The anthropometric, physical and technical skill profiles of the entire sample, the randomly included sub-elite sample in comparison to the remaining sub-elite sample in chapter six.

Measurement	Entire Sample (n=282)	Included Non-Talent Identified Sample (n=25)	Remaining Non-Talent Identified Sample (n=232)
Height (cm)	178.78 ± 7.33	176.39 ± 6.05	178.18 ± 6.74
Sitting Height (cm)	90.67 ± 5.74	90.04 ± 4.04	90.75 ± 3.81
Weight (kg)	68.67 ± 8.99	67.79 ± 9.40	67.81 ± 8.82
Y-PHV	1.70 ± 0.64	1.55 ± 0.68	1.55 ± 0.60
SVJ (cm)	56.16 ± 6.65	57.80 ± 6.18	55.67 ± 6.79
Dominant RVJ (cm)	61.47 ± 8.45	61.00 ± 8.50	60.39 ± 8.03
Non-Dominant RVJ (cm)	66.54 ± 7.56	66.72 ± 6.58	66.05 ± 7.31
20m Sprint (sec)	3.12 ± 0.13	3.09 ± 0.10	3.12 ± 0.11
Shuttle Distance (m)	2104.32 ± 284.24	2167.64 ± 214.73	2062.80 ± 270.46
Kicking Test	13.52 ± 3.52	13.60 ± 3.14	13.55 ± 3.31
Handball Test	22.08 ± 4.33	21.04 ± 4.68	22.68 ± 3.75

Note: No significant difference were noted between either sample

APPENDIX B

THE UNIVERSITY OF NOTRE DAME AUSTRALIA

19 Mouat Street (PO Box 1225)
Fremantle, Western Australia 6959
Telephone: +61 8 9433 0555
Facsimile: +61 8 9433 0544
Email: enquiries@nd.edu.au
Internet: www.nd.edu.au

ABN: 69 330 643 210
CRICOS PROVIDER CODE: 01032F

6 August 2013

Dr Luke Hopper
School of Health Sciences
The University of Notre Dame Australia
Fremantle Campus

Dear Luke,

Reference Number: 013113F

Project Title: "An examination of the AFL talent development pathway, testing validity and associated selection outcomes."

Your response to the conditions imposed by a sub-committee of the university's Human Research Ethics Committee, has been reviewed and based on the information provided has been assessed as meeting all the requirements as mentioned in *National Statement on Ethical Conduct in Human Research* (2007). Therefore, I am pleased to advise that ethical clearance has been granted for this proposed study.

All research projects are approved subject to standard conditions of approval. Please read the attached document for details of these conditions.

On behalf of the Human Research Ethics Committee, I wish you well with what promises to be a most interesting and valuable study.

Yours sincerely,

Dr Natalie Giles
Executive Officer, Human Research Ethics Committee
Research Office

cc: Professor Naomi Trengove, Dean, School of Health Sciences;
A/Prof Gerard Hoyne, SRC Chair, School of Health Sciences.

APPENDIX C

Factors affecting selection into the WA state academies: Assessments of maturation, AFL talent identification tests and coach's perceptions.

Dr Luke Hopper

Mr Ashley Cripps

Dear Participant,

You are invited to participate in the research project described below.

What is the project about?

This research project will take part in two stages. The first stage will investigate the selection outcomes associated with the AFL talent pathway, with particular reference to talent identification testing, maturation and coaches' perception questionnaires. Stage one aims to identify areas of weakness within the talent selection process and provide coaches with practical information about what factors are predictive of selection into various stages of the AFL talent pathway. The second component of this study will track late maturing players through the talent pathway, with the aim of assessing player turnover, progression and development over time. Identifying weaknesses and predictors within the pathway may ultimately result in a more efficient and effective development system, with greater selection accuracy and player development outcomes.

Who is undertaking the project?

This project is being conducted by Ashley Cripps and will form part of the primary researcher's candidacy for Doctor of Philosophy at The University of Notre Dame Australia, under the supervision of Dr Luke Hopper.

What will I be asked to do?

The first stage of this project will examine if the player assessment methods used within the AFL talent pathway predict representative team selection. All participants recruited are part of AFL talent pathway and such participants will not be required to perform or participate in anything that would not normally be a requirement of this pathway. Information that will be collected of participants will include:

- AFL talent identification tests results
- Anthropometric measures for the estimation of biological maturity
- Coach-based player assessments

Talent identification testing and anthropometric measures will be taken at a single testing session during the pre-season phase of the training cycle; this session will take around 2 hours. Coaches' assessments will be collected prior to the selection of the state representative teams.

The second stage of this project will involve the tracking of late maturing players across a year. A late maturing participant will be defined as a player who is deemed to have a peak height velocity- a maturational benchmark for males- >0.5 years behind population average. The researchers will call players who are deemed late maturing and are no longer in the pathway to ascertain reasons for de-selection or retirement. The researcher will specifically ask about the impact of injury, other sport, social or educational commitments and any other factors which may have impacted on the player's de-selection/retirement from the talent pathway. Late maturing individuals still within the talent pathway will be re-tested at the yearly colts combine to assess the player's development over the year.

Are there any risks associated with participating in this project?

The risks to participants associated with this project are the same risks that players within the talent pathway accept when competing and testing. Prior to testing participants will be required to perform a standardised warm-up, implemented by the researcher, in an attempt to reduce the risk of injury. It should also be noted that only participants who are injury free at the time of testing will perform the testing. Risks while competing are outside the limits of control of the study and as such will fall to the relevant clubs to monitor and control.

What are the benefits of the research project?

This research project stands to provide valuable information about the selection processes associated with AFL talent pathway. The project will attempt to identify weaknesses within the current selection process, which may potentially increase the selection accuracy and development outcomes of the pathway. There is no direct benefit for participants who are included in this project; however participants will not be exposed to any greater or lesser risks then otherwise would be assumed by participating in the talent pathway.

Can I withdraw from the study?

Participation in this study is completely voluntary. You are not under any obligation to participate and failing to participate will have no adverse effects on potential selection outcomes. If you agree to participate, you can ask to have your information withdrawn from the study at any time without adverse consequences.

Will anyone else know the results of the project?

Information gathered at the testing sessions will only be seen by yourself, the researchers, your coaches and the relevant state team selectors.

For those involved in the second component of this study any information given upon follow-up will be treated as strictly confidential and remain between the player and the researcher.

Data will be stored securely in the School of Health Sciences at The University of Notre Dame Australia for a period of five years.

De-identified results will be published in relevant scientific journals.

Will I be able to find out the results of the project?

Participants will be provided with a written report of testing results upon completion. This report will document participant's scores, population averages and positional averages.

Who do I contact if I have questions about the project?

Any questions about the project can be directed to the primary researcher Ashley Cripps via email (ashley.cripps1@my.nd.edu.au) or phone (0429341454). Or alternatively you can contact the School of Health Science (9433 0200).

What if I have a complaint or any concerns?

The study has been approved by the Human Research Ethics Committee at The University of Notre Dame Australia (approval number 013113F). If participants have any complaint regarding the manner in which a research project is conducted, it should be directed to the Executive Officer of the Human Research Ethics Committee, Research Office, The University of Notre Dame Australia, PO Box 1225 Fremantle WA 6959, phone (08) 9433 0943, research@nd.edu.au

Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

I want to participate! How do I sign up?

Each of the WAFL clubs will be issued with plain language statements and a consent forms which they will be asked to distribute to potential participants. All interested participants will be required to read the plain language statement and have the consent form signed and returned to the researcher on the day of testing. Both the participant and their legal guardians will be required to have signed the consent form for participants to be included in the study.

Yours sincerely,

Dr Luke Hopper
(08) 9433 0974

Mr Ashley Cripps
+61 429 341 454

If participants have any complaint regarding the manner in which a research project is conducted, it should be directed to the Executive Officer of the Human Research Ethics Committee, Research Office, The University of Notre Dame Australia, PO Box 1225 Fremantle WA 6959, phone (08) 9433 0943, research@nd.edu.au

APPENDIX D

An examination of the AFL talent development pathway, testing validity and associated selection outcomes.

Dr Luke Hopper

Mr Ashley Cripps

Dear Participant,

You are invited to participate in the research project described below.

What is the project about?

This research project will investigate the selection outcomes associated with the AFL talent pathway, with particular reference to talent identification testing, maturation and coaches' perception questionnaires. The project aims to identify areas of weakness within the talent selection process and provide coaches with practical information about what factors are predictive of selection into various stages of the AFL talent pathway. Identifying these weaknesses predictors within the pathway may ultimately result in a more efficient and effective development system, with greater selection accuracy and player development outcomes.

Who is undertaking the project?

This project is being conducted by Ashley Cripps and will form part of the primary researcher's candidacy for Doctor of Philosophy at The University of Notre Dame Australia, under the supervision of Dr Luke Hopper and Dr James Veale.

What will I be asked to do?

This project will examine if the player assessment methods used within the AFL talent pathway predict representative team selection. All participants recruited are coaches in the AFL talent pathway. Coaches will be asked to complete and email a coaches' perception questionnaire to the researcher for players in their development squads.

Are there any risks associated with participating in this project?

The risks associated with this project are very low. Players participating in this study will be issued with a similar plain language statement and be required to sign and return consent forms prior to being included in the study. Coaches will only complete and email the questionnaire for consenting player participants to the researcher, the questionnaires will be irreversibly numerically coded to ensure full confidentiality.

What are the benefits of the research project?

This research project stands to provide valuable information about the selection processes associated with AFL talent pathway. The project will attempt to identify weaknesses within the current selection process, which may potentially increase the selection accuracy and development outcomes of the pathway. There is no direct benefit for participants who are included this project; however participants will not be exposed to any substantial risk.

Can I withdraw from the study?

Participation in this study is completely voluntary. You are not under any obligation to participate and failing to participate will have no adverse effects on coaching outcomes. If you agree to participate, you can ask to have any information you provide to be withdrawn from the study at any time without adverse consequences.

Will anyone else know the results of the project?

Information gathered about you will only be seen by yourself and the researchers.

Data will be stored securely in the School of Health Sciences at The University of Notre Dame Australia for a period of five years.

De-identified results will be published in relevant scientific journals.

Will I be able to find out the results of the project?

Coaches will be provided with a team report detailing the results of the questionnaire. This report will document individual scores, population averages and positional averages.

Who do I contact if I have questions about the project?

Any questions about the project can be directed to the primary researcher Ashley Cripps via email (ashley.cripps1@my.nd.edu.au) or phone (0429341454). Or alternatively you can contact the School of Health Science (9433 0200).

What if I have a complaint or any concerns?

The study has been approved by the Human Research Ethics Committee at The University of Notre Dame Australia (approval number 013113F). If participants have any complaint regarding the manner in which a research project is conducted, it should be directed to the Executive Officer of the Human Research Ethics Committee, Research Office, The University of Notre Dame Australia, PO Box 1225 Fremantle WA 6959, phone (08) 9433 0943, research@nd.edu.au

Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

I want to participate! How do I sign up?

All coaches will be issued with plain language statements and a consent forms. All interested participants will be required to read the plain language statement and have the consent form signed and returned to the researcher prior to receiving the questionnaire.

APPENDIX E

An examination of the AFL talent development pathway, testing validity and associated selection outcomes.

INFORMED CONSENT FORM

I, *(guardian's name)* ________________________________hereby give consent for

(*participant's name*) ________________________________to participate in the above research project.

- I have read and understood the Information Sheet about this project and any questions have been answered to my satisfaction.
- I understand that my son may withdraw from participating in the project at any time without prejudice.
- I understand that all information gathered by the researcher will be treated as strictly confidential, except in instances of legal requirements such as court subpoenas, freedom of information requests, or mandated reporting by some professionals.
- I understand that the protocol adopted by the University Of Notre Dame Australia Human Research Ethics Committee for the protection of privacy will be adhered to and relevant sections of the *Privacy Act* are available at http://www.nhmrc.gov.au/
- I agree that any research data gathered for the study may be published provided my son's name or other identifying information is not disclosed.

GUARDIANS SIGNATURE:		**DATE:**	
RESEARCHER'S FULL NAME:			
RESEARCHER'S SIGNATURE:		**DATE:**	

If participants have any complaint regarding the manner in which a research project is conducted, it should be directed to the Executive Officer of the Human Research Ethics Committee, Research Office, The University of Notre Dame Australia, PO Box 1225 Fremantle WA 6959, phone (08) 9433 0943, research@nd.edu.au

An examination of the AFL talent development pathway, testing validity and associated selection outcomes.

INFORMED CONSENT FORM

I, *(participant's name)* ________________________________hereby agree to being a participant in the above research project.

- I have read and understood the Information Sheet about this project and any questions have been answered to my satisfaction.
- I understand that I may withdraw from participating in the project at any time without prejudice.
- I understand that all information gathered by the researcher will be treated as strictly confidential, except in instances of legal requirements such as court subpoenas, freedom of information requests, or mandated reporting by some professionals.
- I understand that the protocol adopted by the University Of Notre Dame Australia Human Research Ethics Committee for the protection of privacy will be adhered to and relevant sections of the *Privacy Act* are available at http://www.nhmrc.gov.au/
- I agree that any research data gathered for the study may be published provided my name or other identifying information is not disclosed.

PARTICIPANT'S SIGNATURE:		**DATE:**	
RESEARCHER'S FULL NAME:			
RESEARCHER'S SIGNATURE:		**DATE:**	

If participants have any complaint regarding the manner in which a research project is conducted, it should be directed to the Executive Officer of the Human Research Ethics Committee, Research Office, The University of Notre Dame Australia, PO Box 1225 Fremantle WA 6959, phone (08) 9433 0943, research@nd.edu.au