The relationship between game-based performance indicators and developmental level in junior Australian football: Implications for coaching

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Abstract

Identifying performance differences between juniors at different stages of a talent pathway may assist with the development of prospective talent. This study investigated the relationship between game-based performance indicators and developmental level in junior Australian football (AF). Players were categorised into two groups according to developmental level; U16 and U18. Physical and technical skill performance indicators were collated for all U16 (*n* = 200) and U18 (*n* = 244) participants of their respective 2014 national championships. Data was acquired from all 28 games (12 U16, 16 U18); resulting in 1360 player observations (568 U16, 792 U18). Microtechnology and a commercial provider facilitated the quantification of fifteen performance indicators. Generalised estimating equations (GEEs) modelled the extent to which these performance indicators were associated with developmental level. The GEE model revealed that 'contested marks' and 'contested possessions' had the strongest association with the U16 level, while 'total marks' and 'clearances' had the strongest association with the U18 level. The remaining performance indicators were not developmentally discriminant. These results indicate that there are distinctive features of game-play more associated with the U16 and U18 level in AF. Coaches may wish to consider these results when constructing training drills designed to minimise developmental gaps.

Key words: Performance analysis; notational analytics; generalised estimating equations; youth

1. Introduction

Given the difficulty associated with the acquisition of sporting excellence, it is not uncommon for national sporting bodies, federations and team administrators to seek methods that may enhance the efficiency of athlete skill development (Abernethy, 2008). This is often reflected in the diverse evidence-based support systems elite sporting organisations put in place, such as game-based performance analyses to inform training design. However, in addition to such strategies, many national sporting organisations globally have established talent development academies that aim to facilitate the longitudinal skill progression of talent identified juniors prior to their entrance into elite senior ranks (Durand-Bush & Salmela, 2001; Reilly, Williams, Nevill, & Franks, 2000; Vaeyens, Lenoir, Williams, & Philippaerts, 2008).

The premise of these elite talent development academies is to minimise performance discrepancies between elite junior and senior competitions by affording participants with the skills needed to efficiently progress from a junior talent pathway into an elite senior environment. As such, it could be presumed that the training focus within these academies is informed by the perceived performance differences between junior and senior levels. This may create an efficient developmental transition by facilitating the design of training interventions that aim to 'bridge' performance gaps between juniors at different stages of the talent pathway. It would subsequently be important for coaches to obtain meaningful performance data on juniors at different stages of a pathway, as this may assist with the design of developmentally appropriate training interventions.

Research in Australian football (AF) has indicated that certain game-based physical performance indicators differentiate Australian Football League (AFL; premier senior AF competition) players from their elite junior Under 18 (U18) counterparts (Burgess, Naughton, & Norton, 2012). Most notably, AFL players recorded a higher relative distance per minute, sprints per minute, and spent a greater percentage of time in game-play above a high-speed velocity band when compared to their U18 counterparts (Burgess et al., 2012). Despite the ramifications this research has for the physical development of prospective AFL players, it is noteworthy that a successful performance in the game is attributed a range of multi-dimensional skill qualities (Woods, Raynor, Bruce, McDonald, &

Collier, 2015), rather than one physical element of effective play (Launder, 2013). Specifically, AF players at all development levels must possess proficient technical skills, oriented around different aspects of ball disposal (e.g. kicking or handballing under unique environmental contexts) (Robertson, Back, & Bartlett, 2015). To facilitate a comprehensive progression through a talent pathway, it has therefore been proposed that coaches should address both physical and technical skill performance indicators within their training designs (Tangalos, Robertson, Spittle, & Gastin, 2014).

Prior to progressing to the U18 level, talent identified junior AF players are selected onto an elite U16 development program, referred to as a State Academy. Thus, the U18-to-AFL progression is only one developmental transition in what is a multi-level transitional process for talent identified juniors. However, the game-based performance differences between U16 and U18 developmental levels are currently unknown. It could be presumed that the current training interventions designed to bridge these junior developmental levels are either based upon coach subjectivity or extrapolated from the findings of research conducted on developmentally advanced populations. Both assumptions, however, may mislead the training focus and in doing so, create a suboptimal developmental environment. Further research is required to investigate these differences and provide coaches in the talent pathways with critical data that could be used to orient their training and game-style designs.

Despite its scarcity within AF, physical performance indicators have demonstrated differences between talent identified juniors at different stages of a development pathway in field hockey (Nieuwenhuis, Spammer, & Rossum, 2001), and soccer (Figueiredo, Goncalves, Coelho E Silva, & Malina, 2009; Vaeyens, Malina, Janssens et al., 2006). Most notably, Vaeyens et al. (2006) identified that sprint time and maximal aerobic capacity differentiated U14 and U16 talent identified junior soccer players. Whilst these physical performance indicators were not quantified during game-play, it is reasonable to suggest they would manifest into different match activity profiles when comparing these developmental levels (Mooney, O'Brien, Cormack et al., 2011). Partially based on this, it is expected that physical game-based performance indicators may be meaningfully associated with developmental level in junior AF. Additionally, it is likely that players at the U16 level would not have been exposed to structured game-plans given their stage of development as defined by Côté

(1999). Therefore, when compared to their U18 counterparts, their relative inexperience may manifest in a more ‘congested’ technical style of play. This study aims to investigate the relationship between game-based performance indicators and developmental level in junior AF.

2. Methods

All U16 (n = 200; 15.8 ± 0.5 y) and U18 (n = 244; 17.6 ± 0.6 y) players included in this study competed within their respective 2014 national championships, and originated from one of eight different State Academy programs. In-game physical and technical performance indicators were collated from all 28 championship games, 12 of which were contributed from the U16 sample and the remaining 16 were from the U18 sample. This resulted in a total of 1360 player observations (568 U16 and 792 U18). Ethical approval was provided by the relevant Human Research Ethics Committee.

As a requirement of participation within their respective national championships, all players wore a scapula mounted global positioning system (GPS) unit (Catapult Innovations, Team Sport 5.0, Firmware 6.54, 10 Hz, Melbourne, Australia) localised to a pouch embedded beneath their playing jumper. Despite originating from different State Academies, the GPS units and corresponding Firmware did not differ. The data analysed from this microtechnology only included active playing time, with quarter breaks and individualised interchange periods being omitted prior to analysis. Following the conclusion of both the U16 and U18 national championships, data files were collated and placed in a custom design Excel (Microsoft Inc., Redmond, USA) spreadsheet for analysis. The physical performance indicators used in this study were similar to previous research (Mooney et al., 2011; Woods, Joyce, & Robertson, in-press), and consisted of relative distance per minute of game-play ($m.min^{-1}$), high speed running distance (m >4.11 $m.s^{-1}$), and low speed running distance (m <4.11$m.s^{-1}$). These physical performance indicators were chosen given their clinimetric properties (Jennings, Cormack, Coutts, Boyd, & Aughey, 2010). Specifically, Johnston et al. (2012) demonstrated an intraclass correlation coefficient of 0.89 and percent technical error of measurement of 10.9% when quantifying movements between 3.89 and 5.22 $m.s^{-1}$, respectively; deeming it an accurate representation of high speed activities.

A selection of technical skill performance indicators were retrieved from a commercial statistical provider (Champion Data©, Melbourne, Australia) following the completion of both the U16 and U18 national championships. The notations reported by this provider have been shown to be clinimetrically acceptable when analysing the technical match activity profiles of AFL players (O'Shaughnessy, 2006). The technical skill performance indicators analysed in this study are similar to previous research (Robertson et al., 2015; Woods et al., in-press), and are presented (along with their description) in Table 1. These technical skill indicators were chosen as they were the only commercially available notations for these competition levels at the time of analysis. This data was then entered into a custom design Excel (Microsoft Inc., Redmond, USA) spreadsheet for analysis.

******INSERT TABLE I ABOUT HERE******

Descriptive statistics (mean and standard deviation) were calculated for each performance indicator for both developmental levels (U16, U18) relative to game-time (per minute). The effect size of developmental level on these performance indicators was calculated using Cohen's *d* statistic, where an effect size of d = 0.20 was considered small, d = 0.50 moderate and $d \geq 0.80$ large (Cohen, 1998). All pairwise comparisons were undertaken using Excel (Microsoft, Redmond, USA).

Generalised estimating equations (GEEs) were used to model the extent to which the physical and technical skill performance indicators were associated with the main effect of developmental level (2 levels: U16, U18) given the repeated number of observations obtained for each player. GEEs are a regression-based technique used in generalised linear modelling; useful when there are potentially unknown correlations between repeated observations. The regression parameter estimates are interpreted in the same manner as linear regression, with the output used to quantify the group mean effects as opposed to that of a given individual. As such, this method is beneficial when aiming to make a population-based inference on a dataset, particularly when there is unmeasured dependence between multiple observations. Within the sport science literature, this modelling approach has been effectively used for talent identification and selection (Woods et al., in-press), and predictions regarding performance in an elite golf tournament (Robertson, Burnett, & Gupta, 2014).

To account for the potential differences in game time between each developmental level incurring misleading results, each performance indicator was divided by a player's game-time, thus generating the count of each performance indicator per minute of game-play. This was done to account for differences in game-times both between and within developmental levels (range = 60 to 80 minutes). Following this, a correlation matrix was constructed controlling for the repeated observations on each player to assess the level of collinearity between the predictor variables. A total of 1360 observations were included in the GEE model, with player observation numbers ranging from one to six; with the average being 3.3 observations per player. The fluctuation in player match participations was due largely to uncontrollable team selection strategies.

For the GEE model, an exchangeable correlation structure was used along with a binomial probability distribution. Developmental level was considered the binary dependent variable (0 = U18, 1 = U16). To describe the model fit, the quasi-Akaike Information Criterion (QIC) as described by Pan (2001) was used, where lower values indicate a better fit. The model was built using the *GEEPAK* (Højsgaard, Halekoh, & Yan, 2006) in the *R* statistical computing environment (version 2.15.1, *R* Core Team, 2015).

3. Results

Means and standard deviations for each physical and technical performance indicator relative to game time are presented in Table 2. The performance indicator reflecting the largest effect on developmental level was contested marks per min (d = -0.412), with the U16 players recording a higher count compared to their U18 counterparts (Table 2). The next largest effect was clearances per minute (d = 0.293), with the U18 players recording a higher count compared to their U16 counterparts (Table 2). This was followed by marks per minute (d = 0.258), with the U18 players recording a higher count of these actions compared to their U16 counterparts (Table 2).

******INSERT TABLE II ABOUT HERE******

Collinearity was evident for uncontested marks per minute, disposals per minute and high and low speed running per minute (r >0.8), and were thus each removed from further analyses. As shown in

Table 3, the GEE model revealed four significant predictors; two positive predictors of the U16 level, and two negative predictors of the U18 level. Total marks per minute (χ^2 = 36.77, $P \leq 0.05$) and total clearances per minute (χ^2 = 8.30, $P \leq 0.05$) were most associated with the U18 level, whilst contested marks per minute (χ^2 = 8.46, $P \leq 0.05$), and contested possessions per minute (χ^2 = 5.67, $P \leq 0.05$) were most associated with the U16 level. Comparatively, the remaining performance indicators were not meaningfully associated with developmental level (Table 3).

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4. Discussion

The aim of this study was to investigate the relationship between game-based performance indicators and developmental level in junior AF. To gain a deeper insight into the match activity demands of the U16 and U18 level, an integrated bi-dimensional approach was used, with both physical and technical performance indicators being investigated. The results demonstrated that total marks and clearances per minute were most associated with the U18 level, while contested marks and contested possessions per minute were most associated with the U16 level. Comparatively, the remaining performance indicators did not appear to be meaningfully associated with either developmental level. These findings suggest that although there are similarities with regards to game-based performance indicators, there are distinctive features of game-play more meaningfully associated with the U16 and U18 levels. This study could be of use to coaches responsible for the development of talent identified junior AF players by presenting game-based data demonstrating points of differences between developmental levels.

Noting that contested marks and contested possessions were discriminant of the U16 level suggests that per minute of game time, players within the national U16 championships are likely to record more of these contested actions when compared to their U18 counterparts. Given both of these performance indicators are underpinned by player congestion, our findings suggest that U16 game-play is less free-flowing, with a potential greater player density around the ball or ball carrier. Conversely, U18 game-play is seemingly more ‘open’ in nature; associated with fewer contests per minute of game-play. Explanatory of this, it is possible that U16 players may not have been exposed to the structured game-plans implemented by coaching staff given the stage of their development. Specifically, Côté (1999) describes that the first exposure to deliberate technical and tactical practice usually occurs within juniors aged between 13-15 years in the Developmental Model of Sport Participation. Thus, the U16 players may still potentially be familiarising themselves with the tactical requirements of elite junior AF, and as such, revert back to more congested game-styles (i.e. following the ball) during times of uncertainty. Coaches at the U16 level should continually promote and encourage the development of game-sense, while ensuring their game plans are easily interpreted by players (Launder, 2013). Additionally, it is also possible that the U16 players did not possess the same technical skill qualities as their relatively more experienced U18 counterparts, and were thus unable to perform ball disposal actions that facilitated a free-flowing style of game-play. Given the performance indicators most associated with the U18 level, it appears that U16 players may develop game-sense and technical qualities that enable free-flowing game-play through continual participation within a State Academy program. This demonstrates the importance of continual technical coaching and skill development at the junior level.

It is noteworthy that neither developmental level reflected meaningful associations with the physical performance indicators. Thus, when this finding is coupled with those from other studies (Tangalos et al., 2015; Tromp, Pepping, Lyons, Elferink-Gemser, & Visscher, 2013) it can be concluded that technical skill development should be highly prioritised by developmental coaches when attempting to efficiently develop juniors. Given that U18 game-play is more closely associated with marks and clearances, coaches at the U16 level may wish to design training drills that promote a players skill to mark the ball in a range of environmental situations, while ensuring to develop the spatial and tactical skills players require when performing clearances. Such skills may be developed through the use of small-sided games given their environmentally open and spatially constrained design (Farrow, Pyne, & Gabbett, 2008). Progressing from our findings, future work should look to include spatio-temporal metrics to the performance indicators presented in this study. This may provide additional insight into the tactical differences between developmental levels. Although the physical performance indicators were not associated with developmental level in this study, it is important to note that Burgess et al. (2012) did demonstrate that physical performance is a pertinent discriminator between an elite U18 competition and the AFL. Thus, although coaches should focus upon the development of technical skill qualities when coaching juniors, it should not necessarily be at the expense of physical development; particularly at the U18 level, as this may limit a player's capability to transition into the AFL.

Given our findings, it would now be of interest for future research to explore technical game-play differences between elite junior and senior developmental levels. Identifying key performance indicators that are more discriminant of the junior and senior level (U16, U18 and AFL) may uncover critical training considerations that could translate to the effective long-term development of talent identified juniors as they progress through a talent pathway. This future research may additionally look to examine more descriptive technical skill performance indicators that were not utilised in this study. For example, it is not uncommon for elite senior AF organisations (AFL teams) to use advanced technical skill notations inclusive of passages or patterns of play, or metres gained while in possession of the ball. The inclusion of such technical performance indicators may further identify the types of game-styles most associated with different stages of the talent pathway. It is important to note that this study did not investigate an exhaustive number of GPS-derived metrics, and as such future work may look to include additional metrics to what has been reported here. This may further describe the physical differences between developmental levels. Additionally, future work may look to investigate developmental differences at a positional-specific level. Such an approach, when coupled with the current study's findings, may provide coaches with a comprehensive insight into the differences between developmental levels both generally, and at the positional-specific level. Finally, although the reliability of the GPS metrics described in this study have been extensively investigated and deemed acceptable within the literature (Jennings et al., 2010; Johnston et al., 2012), future work should include corresponding accuracy tests to optimise the granularity of the results acquired.

5. Conclusion

The results of this study have considerable translation for the development of talent identified junior AF players. Contested performance indicators (namely contested marks and contested possessions) are discriminant of game-play at the U16 level, while total marks and clearances are discriminant of game-play at the U18 level. It is likely that the introduction of more structured and complex game-styles at the U16 level may result in periods of player uncertainty, manifesting into a higher player density and congestion around the ball. When viewing this speculation in conjunction to the discriminant performance indicators of the U18 level, coaches at the U16 level should promote simplistic, 'open' game-styles, while ensuring players are afforded opportunities to develop effective clearing actions and marking skills in a range of game-based situations.

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Table 1. The technical performance indicators and corresponding description as used in this study

Technical performance metrics	Description
Kick	Disposing of the ball with any part of the leg below the knee including kicks off the ground
Handball	Disposing of the ball by hand by striking it with a fist while it rests on the opposing hand
Disposals	Summation of kicks and handballs
Effective disposals	Disposals resulting in a positive outcome for the team in possession (i.e. correctly passed to a teammate)
Contested possessions	Possessions obtained while in congested, and physically pressured situations (i.e. obtaining possession of the ball while in dispute)
Uncontested possessions	Possessions obtained while a player is under no immediate physical pressure from the opposition
Mark	When a player cleanly catches (deemed to have controlled the ball for sufficient time by the umpire) a kicked ball that has travelled more than 15 metres without anyone else touching it or the ball hitting the ground
Contested mark	A mark recorded while engaging in a congested, physically pressured situation
Uncontested mark	A mark recorded while under no physical pressure
Inside 50	An action of moving the ball from the midfield into the forward 50 m zone.
Tackle	Using physical contact to prevent an opposition in possession of the ball from getting an effective disposal
Clearance	Disposing of the ball from a congested stoppage in play

Table 2. Between group effects for each performance indicator presented as counts per minute of game-time

Performance indicator	**U18**	**U16**	***d***
Relative distance (m.min^{-1})	126.60 ± 13.28	123.13 ± 18.07	0.028
Distance >4.11m.s^{-1}_min (m)	32.66 ± 9.15	31.42 ± 8.81	0.036
Distance <4.11m.s^{-1}_min (m)	95.34 ± 22.79	94.51 ± 30.50	0.009
Kicks_min (#)	0.098 ± 0.043	0.102 ± 0.052	-0.043
Handballs_min (#)	0.074 ± 0.039	0.068 ± 0.042	0.079
Disposals_min (#)	0.166 ± 0.067	0.170 ± 0.079	-0.021
Effective disposals_min (#)	0.114 ± 0.050	0.112 ± 0.060	0.014
Marks_min (#)	0.033 ± 0.001	0.026 ± 0.015	0.258
Contested marks_min (#)	0.008 ± 0.006	0.010 ± 0.007	-0.412
Uncontested marks_min (#)	0.036 ± 0.017	0.031 ± 0.018	0.166
Contested possessions_min (#)	0.069 ± 0.033	0.079 ± 0.040	-0.134
Uncontested possessions_min (#)	0.101 ± 0.046	0.090 ± 0.048	0.111
Inside 50_min (#)	0.028 ± 0.020	0.030 ± 0.022	-0.052
Tackles_min (#)	0.037 ± 0.022	0.036 ± 0.025	0.009
Clearances_min (#)	0.022 ± 0.001	0.017 ± 0.002	0.293

d is Cohen's effect size relative to the U18 level

Table 3. Results relating to the generalised estimating equation model

Predictor	**β (S.E.)**	**LCI**	**UCI**	χ^2	***P***
Intercept	0.136 (0.097)	-0.054	0.326	1.974	0.160
Kick_min	-0.075 (0.077)	-0.227	0.076	0.952	0.329
Mark_min	0.404 (0.066)	0.273	0.535	36.774	<0.001 *
Handball_min	0.119 (0.079)	-0.036	0.275	2.259	0.133
Tackle_min	-0.008 (0.047)	-0.100	0.084	0.029	0.865
Clearance_min	0.206 (0.071)	0.066	0.345	8.306	0.004 *
Contested marks_min	-0.420 (0.001)	-0.703	-0.137	8.463	0.004 *
Contested possession_min	-0.170 (0.071)	-0.310	-0.030	5.673	0.017 *
Effective disposals_min	<0.001 (0.045)	-0.090	0.089	<0.001	0.992
Inside 50_min	-0.032 (0.062)	-0.154	0.090	0.266	0.606
Uncontested possessions_min	-0.008 (0.076)	-0.158	0.142	0.011	0.917
Relative distance	<0.001 (<0.001)	<0.001	<0.001	0.010	0.920
Model performance	QIC [df=11] 1705.835				

β is the beta coefficient, SE is the standard error, QIC is the Quasi-Akaike Information Criterion, Wald's χ^2 is Wald's chi-square. Statistical significance accepted at ≤0.05. * denotes statistical significance