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Sprint acceleration characteristics across the Australian football participation pathway

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Force-Velocity-Power Characteristics of Maximal Sprint Acceleration across the Australian Football Participation Pathway

Running head: Sprint acceleration characteristics of junior Australian footballers

Submission type: Original Investigation

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ABSTRACT

The aim of this study was to compare the force, velocity and power profiles of a maximal sprint acceleration through different competition levels of the Australian Football (AF) participation pathway. 162 junior AF athletes across five competition levels including State under 18's (ST 18), State under 16's (ST 16), local under 18's (LOC 18), local under 15's (LOC 15), and local under 14's (LOC 14) participated in this cross-sectional study. Velocity-time data from maximal sprint accelerations were analysed to derive athlete's sprint acceleration characteristics and split times. ST 18 showed a more force orientated profile than the LOC 18 with *moderate* differences in relative theoretical maximal force (F_0) (7.54%), absolute F_0 (10.51%), and slope of the force-velocity relationship (S_{f-v}) (9.27%). Similarly, *small* differences were found between ST 18 and ST 16 in relative F_0 (4.79%) and S_{f-v} (6.28%). *Moderate* to *extremely large* differences were observed between players competing in older (ST 18, LOC 18, ST 16) compared to younger (LOC 15, LOC 14) competition levels highlighting the potential influence of biological maturation. It is recommended that practitioners working with junior AF players to consider developing a force orientated sprint acceleration profile to improve sprinting performance.

Key Words: sprinting, talent identification, kinetics, kinematics, inverse dynamics

INTRODUCTION

High speed running actions and maximal acceleration efforts are critical in Australian Football (AF) (Johnston et al., 2018). At the elite level (Australian Football League [AFL]), players can perform 22 ± 9 high intensity sprints (> 7 m/s) and accumulate up to 328 ± 128 metres (m) in sprint distance during a game (Varley et al., 2014). Furthermore, players can perform 82 ± 26 high intensity accelerations (> 2.78 m/s/s) in addition to these high intensity sprints (Varley et al., 2014). The sprinting and acceleration match demands also increase with competition level when elite, sub-elite and youth levels have been compared (Johnston, et al., 2018). Crucially, faster sprint performances over 20 m (< 2.99 s) have been shown to increase the likelihood of being drafted to the AFL (Robertson et al., 2015), as well as playing a greater number of AFL games over a five year period (Burgess et al., 2012; Pyne et al., 2005). Therefore, quantifying and developing maximum acceleration and sprinting speed qualities in AF players is of importance to strength and conditioning professionals working with these cohorts.

Whilst split time data provides a basic analysis of sprint performance, it cannot provide insight into the underlying biomechanical properties of sprinting. A method to quantify sprinting performance based on the force-velocity (F-v) profile has increased in popularity amongst researchers and practitioners in recent years (Samozino et al., 2016). This method is based on instantaneous speed changes during a maximal sprint acceleration and uses an inverse dynamics approach applied to the body's centre of mass (Samozino et al., 2016). The technique allows for the determination of individual F-v variables during a maximal sprint acceleration: theoretical maximal force (F_0), theoretical maximal velocity (V_0), slope of the F-v relationship (S_{fv}), and maximal horizontal power (P_{max}) (Cross et al., 2017; Samozino et al., 2016). In addition to these variables, the mechanical effectiveness of force application during a maximal sprint acceleration (identified as the maximal ratio of horizontal force to resultant force

[RF_{max}]), as well as the decrease in the ratio of horizontal to resultant force (D_{RF}) as velocity increases (Morin et al., 2011, Samozino et al., 2016, Cross et al., 2017). Collectively these sprint acceleration characteristics allow the practitioner to derive F-v and power-velocity relationships, reflecting the neuromuscular system's ability to apply force and power during a maximal sprint acceleration (Morin & Samozino, 2016).

Sprint acceleration characteristics have been reported across several team sports and levels of competition including elite rugby union and rugby league (Cross et al., 2015), male and female soccer and futsal (Baumgart et al., 2018; Jiménez-Reyes et al., 2018a), and male youth soccer (Buchheit et al., 2014). Overall, findings from other sports indicate that substantial differences in sprint acceleration characteristics exist across sports (Jiménez-Reyes et al., 2018b) and within and between competition levels (Haugen et al., 2019). For example, players competing at higher competition levels presented with higher sprint acceleration characteristics than their lower level counterparts in both soccer and futsal (Jiménez-Reyes et al., 2018a). Specifically, first division soccer and futsal players produced greater F_0 , V_0 , P_{max} , and RF_{max} than players competing in second, third, and fifth divisions. Furthermore, group differences in sprint acceleration characteristics were found when comparing different aged male soccer players (U12 – U23) with older players producing superior F_0 , V_0 , P_{max} and V_{max} (Baumgart et al., 2018). Together, these results suggest that maximal sprint acceleration characteristics can help discriminate between competition levels and different ages across various talent development pathways. Given the increasing acceleration demands through the competition levels in the AF talent pathway (Johnston et al., 2018) and the relationship between accelerative ability, career success and draft outcome (Burgess et al., 2012; Pyne, et al., 2005; Robertson et al., 2015) the identification of sprint acceleration characteristics of junior AF players has implications for talent identification and long-term player development.

The AF participation pathway consists of the local participation pathway and the talent pathway, the latter being the primary development pathway to progress into the AFL (see Figure 1) (Cripps, et al., 2015; Haycraft et al., 2018). Selection into the State under 16s (ST 16) or State under 18s (ST 18) team is the first major talent identification point in the talent pathway where talented players are recruited from local under 15s (LOC 15) into ST 16 and local under 18s (LOC 18) into ST 18 to represent their State at a national level (Cripps et al., 2015; Haycraft et al., 2018). Players entering the talent pathway at the ST 16 competition level will progress to the ST 18 competition level allowing them to accelerate the athlete development of talent identified players through superior training resources and coaching staff who are able to develop player skill and physical conditioning (Cripps et al., 2015; Haycraft et al., 2018).

****** INSERT FIGURE 1 ABOUT HERE ******

In order for practitioners and strength and conditioning coaches to develop and improve sprint acceleration performance in players through the AF talent pathway the identification of underlying sprint acceleration characteristics need to be investigated. Since high speed running actions and maximal acceleration are crucial for performance in AF, it is expected that those competing at a higher competition level will present with higher force, velocity and power sprint acceleration characteristics compared to their lower level counterparts. Therefore, this study assessed several research aims including: (1) to identify if any differences in sprint acceleration characteristics existed between age matched elite (ST 18) and sub-elite (LOC 18) competition levels; (2) to identify if any differences existed between ST 18 and ST 16 level AF athletes; and, (3) to identify if sprint acceleration characteristics are improving at each

competition level throughout the AF participation pathway. We hypothesise that the ST 18 players will be faster and display superior relative force and power characteristics compared to LOC 18 (aim 1) and ST 16 (aim 2) players. Lastly, we hypothesised that sprint acceleration characteristics will improve at each competition level of the AF participation pathway, as players' progress from lower to higher competition levels (aim 3).

METHODS

Participants

A total of 162 participants were recruited from five AF participation pathway levels that included LOC 14 ($n = 73$; age: 13.4 ± 0.5 y; height: 166.4 ± 7.7 cm; body mass: 55.9 ± 9.6 kg), LOC 15 ($n = 38$; 14.1 ± 0.5 y; 176.1 ± 8.3 cm; 66.8 ± 10.5 kg), LOC 18; ($n = 15$; 17.5 ± 0.9 y; 182.6 ± 7.8 cm; 76.2 ± 6.7 kg), ST 16 ($n = 15$; 15.7 ± 0.5 y; 187.5 ± 7.2 cm; 74.5 ± 10.2 kg) and ST 18 ($n = 21$; 17.6 ± 0.7 y; 186.7 ± 7.7 cm; 78.2 ± 8.4 kg). The competition levels for all groups were of the highest calibre available for the respective age bracket in the state of Western Australia. All participating athletes were free from any musculoskeletal or neuromuscular injuries that would have affected their ability to perform the required test. This research was approved through the University Human Research Ethics Committee (Reference Number 018162F).

Experimental Design

This investigation was an observational cross-sectional analysis of the AF participation pathway in Western Australia. Sprint performance data were collected over a total of four days (day one – ST 18 and ST 16; day two – LOC 18; day three – LOC 15; day four – LOC 14) across a one month in-season period. Each testing session occurred after a minimum 24 hours of rest. All testing occurred on an outdoor grassed surface at the same time of day with

participants wearing their normal football boots to control for ecological validity. Environmental conditions including wind speed and direction, air temperature and humidity were quantified using a hand held multi-function weather meter (WeatherHawk WindMate – 350) with the latter two conditions included in the derivation of sprint acceleration characteristics.

Sprint Profiling

Each testing session commenced with a dynamic warmup that included low intensity running, plyometrics, joint mobility exercises, and athletic drills followed by three incremental sprints of 30 – 40 m at 70%, 80%, and 90% of maximal velocity. Following this, each participant performed two maximal 30 m sprints from a two-point standing position with a three minute recovery period between trials. Participants were instructed that no backward movement was allowed prior to the start of the sprint, and to begin each sprint at their own convenience with their front foot immediately behind the 0 m start line. Verbal encouragement was given to all participants to sprint through the 30 m distance. Instantaneous velocity-time data for each trial was measured at 46.7 Hz via a Stalker Acceleration Testing System (ATS) II radar device (Stalker ATS II; Applied Concepts, Dallas, TX, USA). The radar device was positioned 10 m behind the starting line on a tripod 1 m above the ground corresponding approximately to the participant's centre of mass. The radar device was operated remotely via connection to a laptop to limit the possible variability introduced by manual operation.

****** INSERT TABLE 1 ABOUT HERE ******

All data were collected using commercially available software (STATS; Stalker ATS II Version 5.0.2.1; Applied Concepts, Dallas, TX, USA) provided by the radar device

manufacturer. The raw data files were manually processed in the STATS software. The processed data file for each trial were imported together with the height, body mass and environmental conditions into a custom-made Microsoft Excel spreadsheet that was used to derive all outcome variables (F_0 , V_0 , $P_{\max}$, S_{Fv} , $RF\%$, D_{RF}) and split times (5 m, 10 m, 15 m, 20 m, 25 m, 30 m) consistent with reliable procedures (Perez et al., 2019; Samozino et al., 2016; Simperingham et al., 2019). The average of the two maximal sprint trials for each participant was used for statistical analysis.

**** INSERT TABLE 2 ABOUT HERE ****

Statistical Analysis

The mean and standard deviation (SD) were calculated for all outcome variables and split times. Trial to trial reliability analysis was assessed using coefficient of variation (CV) calculated using a custom-made spreadsheet available online (Hopkins, 2017). A Shapiro-Wilk test of normality confirmed all variables were normally distributed. A one-way multivariate analysis of variance (MANOVA) was performed to identify significant main effects between competition level and sprint acceleration characteristics. In the event of significant main effects and interactions, univariate ANOVA's were performed to determine how sprint acceleration characteristics differed for competition level. Significant ANOVA's were followed up with Tukey's HSD post-hoc analysis to control for type 1 error and assess multiple comparisons between competition level. Statistical significance was set at $p < 0.05$. Finally, Hedge's g effect sizes and 90% confidence intervals were used to determine the differences between groups. Threshold values of > 0.2 , > 0.6 , > 1.2 , and > 2.0 were used to represent small, moderate, large, and very large effects, respectively (Hopkins et al., 2009).

**** INSERT FIGURE 2 ABOUT HERE ****

RESULTS

Descriptive results of all sprint acceleration characteristics and split times for each competition level are presented in Table 1. The MANOVA revealed a statistically significant differences in sprint acceleration characteristics based on participants competition level ($F=4.83$, $p<0.01$, $\eta^2=0.36$). The univariate ANOVA's showed that competition level has a statistically significant effect on all sprint acceleration characteristics. Tukey's HSD post-hoc analysis revealed statistically significant differences in several sprint acceleration characteristics and split times between the ST 18, ST 16, LOC 18, and LOC 15 and LOC 14 competition levels (Table 2). The effect size analysis of the differences in sprint acceleration characteristics between competition levels are reported in Figures 2 and 3.

**** INSERT FIGURE 3 ABOUT HERE ****

DISCUSSION AND IMPLICATIONS

This is the first study to investigate the sprint acceleration characteristics of junior AF players and their differences across competition levels in the AF participation pathway. The first aim was to identify differences in sprint acceleration characteristics between age matched elite (ST 18) and sub-elite (LOC 18) players. The findings supported our hypothesis that players competing at the ST 18 competition level will be faster and produce a more force orientated sprint acceleration profile compared to the LOC 18 competition level. This is highlighted by *moderate* differences in absolute and relative F_0 and S_{f-v} . The second aim was to compare sprint acceleration characteristics between ST 18 and ST 16 players. Similarly, this finding supported our hypothesis that ST 18 players will produce a more force orientated profile that the ST 16

players, however the effect size differences were less with only *small* differences observed. Lastly the third aim was to identify if sprint acceleration characteristics improved with each competition level, and if so through what characteristic. We found large and *extremely large* increases in sprint acceleration characteristics and split times, specifically the greatest magnitude of differences were seen between older competition levels (ST 18, ST 16, LOC 18) compared to younger competition levels (LOC 15, LOC 14) supporting our hypothesis that sprint acceleration characteristics will improve at each competition level. This finding also suggests that sprint acceleration characteristics may be influenced by biological maturation status. These findings of the three aims of this study are somewhat expected as it has been previously demonstrated that physical characteristics differ throughout the AF participation pathway competition levels (Cripps et al., 2015; Cripps et al., 2020; Haycraft et al., 2018). However, the results of such research provide valuable information for coaches and practitioners aiming to progress players through the AF participation pathway and respective competition levels by highlighting the important sprint acceleration characteristics that need to be developed.

An important finding of this study was that ST 18 players displayed *moderately* greater relative $P_{\max}$ through a more force orientated sprint acceleration profile than LOC 18 players. In particular, *moderate* differences were observed in relative F_0 , and S_{f-v} between the ST 18 and LOC 18 competition levels indicating a superior force producing ability in the earlier phases of acceleration (Morin & Samozino 2016). This is further highlighted through ST 18 players recording *moderately* faster split times over 5, 10, and 15 m than the LOC 18 with only *small* differences in split times > 20 m (Figure 3). The increasing sprint acceleration demands throughout competition levels in the AF participation pathway (Johnston et al., 2018) and the relationship between sprint acceleration ability, career success and draft outcome (Cripps et al.,

2020; Pyne, et al., 2005; Burgess et al., 2012) suggest there may be a selection bias towards players with superior acceleration qualities (Woods et al., 2017), or that players within the State academy are exposed to superior strength, speed and power programmes (Cripps et al., 2015; Haycraft et al., 2018), aiding horizontal force and power production during sprinting.

Interestingly, despite having spent a longer period of time within the State academy program with access to superior training resources and coaching staff to accelerate physical and skill development, only *small* differences were observed between ST 18 and ST 16 players in all sprint acceleration characteristics and split times (Figures 2 and 3). The findings support a recent longitudinal study identifying that whilst sprint acceleration performance at ST 16 and ST 18 competition levels is a significant identifier of professional career attainment, it is also developmentally stable with only *trivial* improvements reported as athletes move from ST 16 to ST 18 competition level (Cripps et al., 2020). Given the multidimensionality of AF game-play, the amount of time allocated to the development of sprint acceleration performance in the State academy programs may be limited which could explain the *small* differences between ST 18 and ST 16 competition levels in the current study and *trivial* improvements longitudinally (Cripps et al., 2020). Collectively these results highlight the importance of early assessment of sprint acceleration performance for identifying athletes for selection into State academies and long-term career attainment. Further research is warranted to determine if sprint acceleration characteristics improve longitudinally in athletes within the State academy program.

Lastly, most sprint acceleration characteristics and split times were significantly superior in older competitions (ST 18, ST 16, LOC 18) when compared to the younger levels (LOC 15, LOC 14) (Table 2). These results are consistent with those from top level German soccer players where differences in sprint acceleration characteristics existed between under 12 to

under 17 players (Baumgart et al, 2018). This is not overly surprising given the age range of the participants in each competition level may have led to a substantial influence of biological maturation on sprint acceleration characteristics and split times. Interestingly however, the results of the current study show that the *large* to *very large* significant differences in $P_{\max}$ between the higher and lower competition levels is a result of *large* to *very large* significant differences in V_0 with only *trivial* to *small* differences in relative F_0 (except ST 18). This suggests that the increases in maturational related physical and physiological characteristics such as increases in neuromuscular function (Malina et al., 2004), muscle cross-sectional area (Granacher et al., 2011) and maximal strength (Lloyd et al., 2016) may not transfer to better relative force production (at low velocities) during sprinting. Further research is warranted to investigate the influence of biological maturation on the underlying sprint acceleration characteristics and split times in order to better explain the changes in sprinting performance through maturation.

The findings have important training considerations for strength and conditioning practitioners working with athletes in the AF participation pathway who should focus on improving force producing capabilities at low velocities. To develop a more force orientated profile and improve force producing capacities the prescribed sprint and resistance training programme needs to include exercises where force is applied against heavy external resistance, >85% of 1 repetition-maximum to target maximal strength qualities (Hicks et al., 2020). It is also important to consider the specificity and transference of exercises to sprinting performance as the F-v profile during maximal sprints does necessarily match the F-v profile in other tasks such as vertical jumps (Jimenes-Reyes et al., 2018b; Marcote-Pequeno et al., 2019). In this instance, exercises that target maximal strength qualities and specifically improve force producing capacity during sprinting include heavy prowler marches, resisted sprinting, and sled

pulls should be used in conjunction with traditional exercises such as heavy back squats (Hicks et al., 2020).

Limitations of this study include the exclusion of a local under 16 competition group which would have allowed for direct comparison of age matched elite and local competition similar to ST 18 and LOC 18 in the current study. The data collection also occurred during the in-season period and whilst all testing sessions occurred within one month and with a minimum of 24 hours of no activity this may have influenced sprint acceleration performance (Jimenez-Reyes et al., 2020). Specifically, research in elite male soccer players has demonstrated sprint acceleration variables relating to early acceleration (F_0 and RF_{max}) were significantly higher in season than pre-season (Jimenez-Reyes et al., 2020). Lastly, whilst environmental conditions were recorded and controlled for as much as possible, they may have impacted the results. Future research should address these limitations and consider longitudinal studies to investigate the progress of individual players through both the talent and local pathways. Research is also warranted to investigate the influence of maturation status on sprint acceleration characteristics and training interventions to improve sprint performance.

CONCLUSION

The progressive approach to assess sprint performance through identifying the underlying sprint acceleration characteristics appears sensitive enough to identify differences in junior AF players competing at different competition levels through the AF participation pathway. Specifically, age matched players competing in a higher competition level (ST 18) demonstrated a superior ability to apply high amounts of relative force during the early acceleration period leading to greater relative P_{max} than in lower competition levels (LOC 18). Due to the observational nature of this study it is uncertain whether the ST 18 players have

developed a more force orientated profile through the training undertaken within the State academy or coaches are unconsciously bias to selecting players with this profile. Another key finding was that all sprint acceleration characteristics appeared to improve through the AF participation pathway. Whilst speculative, these improvements may be due to biological maturation such as increased neuromuscular function, muscle cross-sectional area, and maximal strength occurring during boys in this age. Finally, the results of this study show that the increases in relative $P_{\max}$ from lower to higher competition level is related to greater ability to apply forces at higher velocity (V_0) with no differences in the force production at the beginning of the sprint (low velocity) (F_0). It is recommended that practitioners and strength and conditioning coaches working with players and teams within the AF participation pathway aim to improve force and power generating capacities that transfer to sprint acceleration performance.

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Table 1. Sprint Acceleration Characteristics and Radar-Derived Split Times of Competition Levels in the Australian Football Participation Pathway.

Mechanical Sprint Variables	State Under 18's	State Under 16's	Local Under 18's	Local Under 15's	Local Under 14's	CV ± 90% CI
Absolute F ₀ (N)	626 ± 75	568 ± 101	566 ± 51	491 ± 82	414 ± 87	7.9 ± 0.8
F ₀ (N/kg)	8.03 ± 0.67	7.66 ± 1.05	7.46 ± 0.63	7.37 ± 0.66	7.41 ± 0.80	7.9 ± 0.8
V ₀ (m/s)	8.85 ± 0.26	9.04 ± 0.49	9.03 ± 0.46	8.15 ± 0.63	7.49 ± 0.60	2.9 ± 0.2
Absolute P _{max} (W)	1386 ± 182	1278 ± 201	1276 ± 116	1000 ± 186	776 ± 175	13.7 ± 1.2
P _{max} (W/kg)	17.7 ± 1.5	17.2 ± 1.8	16.8 ± 1.3	15.0 ± 1.7	13.8 ± 1.8	13.7 ± 1.2
S _{fv} (N/m/s/kg)	-0.91 ± 0.08	-0.85 ± 0.15	-0.83 ± 0.10	-0.91 ± 0.11	-1.00 ± 0.14	1.2 ± 0.1
RF _{max} (%)	45.5 ± 1.6	44.5 ± 2.3	44.2 ± 1.5	42.3 ± 2.0	40.9 ± 2.3	0.2 ± 0.1
DRF (%)	-8.37 ± 0.73	-7.89 ± 1.38	-7.67 ± 0.89	-8.51 ± 1.07	-9.40 ± 1.31	0.1 ± 0.1
Max Speed (m/s)	8.35 ± 0.21	8.42 ± 0.27	8.42 ± 0.33	7.71 ± 0.51	7.15 ± 0.51	1.9 ± 0.1
Split Times						
5 m (s)	1.33 ± 0.05	1.36 ± 0.07	1.37 ± 0.04	1.40 ± 0.06	1.43 ± 0.07	0.6 ± 0.1
10 m (s)	2.07 ± 0.06	2.10 ± 0.09	2.11 ± 0.06	2.19 ± 0.09	2.25 ± 0.11	0.7 ± 0.1
15 m (s)	2.73 ± 0.08	2.76 ± 0.10	2.78 ± 0.07	2.90 ± 0.12	3.00 ± 0.14	0.8 ± 0.1
20 m (s)	3.35 ± 0.09	3.38 ± 0.10	3.40 ± 0.08	3.58 ± 0.15	3.73 ± 0.18	0.8 ± 0.1
25 m (s)	3.96 ± 0.10	3.99 ± 0.11	4.01 ± 0.10	4.24 ± 0.19	4.44 ± 0.23	0.9 ± 0.1
30 m (s)	4.57 ± 0.11	4.59 ± 0.11	4.61 ± 0.12	4.89 ± 0.24	5.13 ± 0.27	1.1 ± 0.1

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Note: Data are presented as mean ± standard deviation. Abbreviations: CV, coefficient of variation; F₀, theoretical maximum force; V₀, theoretical maximum velocity; P_{max}, maximum power; S_{fv}, slope of the force-velocity relationship; RF_{max}, maximum ratio of force; DRF, decrease in ratio of force.

487

488 **Table 2.** Changes in Sprint Acceleration Characteristics and Radar-Derived Split Times between Playing Levels in the Australian Football Participation
489 Pathway

Mechanical Sprint Variables	ST18 vs ST16 %Δ ± 90%CI	ST18 vs LOC18 %Δ ± 90%CI	ST18 vs LOC15 %Δ ± 90%CI	ST18 vs LOC14 %Δ ± 90%CI	ST16 vs LOC18 %Δ ± 90%CI	ST16 vs LOC15 %Δ ± 90%CI	ST16 vs LOC14 %Δ ± 90%CI
Absolute F ₀ (N)	10.16 ± 8.75	10.51 ± 6.72	27.53 ± 7.42*	51.05 ± 8.41*	0.32 ± 8.78	15.76 ± 9.16*	37.11 ± 10.18*
F ₀ (N/kg)	4.79 ± 6.33	7.54 ± 4.98	8.90 ± 4.08*	8.33 ± 4.28*	2.63 ± 7.21	3.92 ± 5.46	3.38 ± 5.37
V ₀ (m/s)	-2.08 ± 2.34	-1.96 ± 2.23	8.64 ± 2.93*	18.18 ± 3.00*	0.13 ± 3.25	10.95 ± 3.70*	20.69 ± 3.68*
Absolute P _{max} (W)	8.50 ± 8.51	8.63 ± 7.09	38.59 ± 8.39*	78.55 ± 9.39*	0.12 ± 8.01	27.74 ± 9.73*	64.56 ± 10.94*
P _{max} (W/kg)	3.15 ± 5.51	5.65 ± 4.97	18.34 ± 5.01*	28.08 ± 5.25*	2.43 ± 5.90	14.72 ± 5.93*	24.17 ± 6.21*
S _{fv} (N/m/s/kg)	6.28 ± 7.73	9.27 ± 6.05	-0.26 ± 5.10	8.88 ± 5.22*	2.81 ± 9.44	-6.16 ± 6.93	-14.26 ± 6.56*
RF _{max} (%)	2.08 ± 2.53	2.82 ± 2.09	7.25 ± 2.06*	10.93 ± 2.23*	0.72 ± 2.78	5.07 ± 2.57*	8.67 ± 2.71*
D _{RF} (%)	6.16 ± 7.59	9.19 ± 5.96	-1.63 ± 5.15	-10.92 ± 5.27*	2.85 ± 9.37	-7.35 ± 6.96	-16.09 ± 6.61*
Max Speed (m/s)	-0.88 ± 1.59	-0.86 ± 1.80	8.27 ± 2.52*	16.78 ± 2.65*	0.01 ± 2.21	9.22 ± 3.01*	17.82 ± 3.15*
Split Times							
5 m (s)	-2.22 ± 2.44	-2.98 ± 1.90	-5.45 ± 1.71*	-7.20 ± 1.88*	-0.78 ± 2.66	-3.31 ± 2.19	-5.09 ± 2.30*
10 m (s)	-1.43 ± 2.05	-2.16 ± 1.66	-5.58 ± 1.63*	-8.21 ± 1.81*	-0.74 ± 2.21	-4.21 ± 2.02*	-6.88 ± 2.18*
15 m (s)	-1.18 ± 1.78	-1.81 ± 1.52	-5.93 ± 1.63*	-9.22 ± 1.81*	-0.64 ± 1.90	-4.81 ± 1.96*	-8.14 ± 2.16*
20 m (s)	-0.95 ± 1.58	-1.49 ± 1.43	-6.27 ± 1.91*	-10.06 ± 1.86*	-0.54 ± 1.69	-5.37 ± 1.98*	-9.20 ± 2.20*
25 m (s)	-0.69 ± 1.45	-1.20 ± 1.39	-6.48 ± 1.73*	-10.67 ± 1.93*	-0.51 ± 1.59	-5.83 ± 2.03*	-10.06 ± 2.28*
30 m (s)	-0.50 ± 1.35	-0.99 ± 1.49	6.72 ± 1.91*	-11.00 ± 1.96*	-0.49 ± 1.53	-6.25 ± 2.24*	-10.55 ± 2.31*

490 Note: Data is presented as mean difference (%Δ) with 90% confidence intervals. Abbreviations: F₀, theoretical maximum force; V₀, theoretical maximum
491 velocity; P_{max}, maximum power; S_{fv}, slope of the force-velocity relationship; RF_{max}, maximum ratio of force; D_{RF}, decrease in ratio of force. * denotes p < 0.05

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493 **Table 2.** Changes in Sprint Acceleration Characteristics and Radar-Derived Split Times between Playing Levels in the Australian Football Participation
494 Pathway (continued)

Mechanical Sprint Variables	LOC18 vs LOC15 %Δ ± 90%CI	LOC18 vs LOC14 %Δ ± 90%CI	LOC15 vs LOC14 %Δ ± 90%CI
Absolute F ₀ (N)	15.40 ± 7.83*	36.68 ± 9.37*	18.44 ± 6.85*
F ₀ (N/kg)	1.27 ± 4.50	0.74 ± 4.91	-0.52 ± 3.37
V ₀ (m/s)	10.81 ± 3.66*	20.53 ± 3.65*	8.78 ± 2.70*
Absolute P _{max} (W)	27.58 ± 8.68*	64.36 ± 10.17*	28.83 ± 7.66*
P _{max} (W/kg)	12.00 ± 5.51*	21.23 ± 5.98*	8.24 ± 4.28*
S _{fv} (N/m/s/kg)	-8.73 ± 6.01	-16.61 ± 6.17*	-8.64 ± 4.27*
RF _{max} (%)	4.32 ± 2.32*	7.89 ± 2.58*	3.42 ± 1.83*
D _{RF} (%)	-9.91 ± 6.12	-18.42 ± 6.25*	-9.44 ± 4.34*
Max Speed (m/s)	9.21 ± 3.08*	17.80 ± 3.19*	7.87 ± 2.36*
Split Times			
5 m (s)	-2.54 ± 1.92	-4.34 ± 2.17*	-1.85 ± 1.51*
10 m (s)	-3.50 ± 1.84	-6.18 ± 2.10*	-2.78 ± 1.48*
15 m (s)	-4.20 ± 1.85*	-7.55 ± 2.11*	-3.50 ± 1.49*
20 m (s)	-4.86 ± 1.93*	-8.70 ± 2.18*	-4.04 ± 1.55*
25 m (s)	-5.34 ± 2.01*	-9.59 ± 2.27*	-4.49 ± 1.61*
30 m (s)	-5.79 ± 2.25*	-10.11 ± 2.31*	-4.59 ± 1.69*

513 Note: Data is presented as mean difference (%Δ) with 90% confidence intervals. Abbreviations: F₀, theoretical maximum force; V₀, theoretical maximum
514 velocity; P_{max}, maximum power; S_{fv}, slope of the force-velocity relationship; RF_{max}, maximum ratio of force; D_{RF}, decrease in ratio of force. * denotes p < 0.05

Figure 1. Australian football participation pathway.

Figure 2. Effect size and inference of differences in sprint accelertaion characteristics between competition levels in the Australian football participation pathway

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564 **Figure 3.** Effect size and inference of differences in radar-derived split times between
565 competition levels in the Australian football participation pathway.

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