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The relationship between repeated kicking performance and maximal aerobic capacity in elite junior Australian football

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Running Title: Aerobic capacity and kicking performance

Abstract

Australian football (AF) is a physically demanding game, requiring players to engage in a range of anaerobic activities interspersed with prolonged aerobic exercise. Coupled, players have to perform a range of technical skills, the most fundamental of which being to effectively kick (dispose) the ball. The aim of this study was to ascertain the extent to which aerobic capacity influenced kicking performance in AF. Twenty four elite U18 players competing in the same U18 competition performed the Australian Football Kicking test (AFK) three times with the yo-yo IR2 completed twice (between each AFK), with no rest between all three AFKs. Linear mixed models (LMM) reported the extent to which kicking speed and accuracy scores were influenced by the level reached on the yo-yo IR2. Results indicated that players who recorded a higher level on the yo-yo IR2 produced a faster average kicking speed following each AFK (P <0.01), while for all players, kicking speed was faster and more accurate on their dominant kicking leg regardless of score on the yo-yo IR2 (P <0.01). The LMMs also reported that those who maintained kicking speeds following two yo-yo IR2 also had higher competition kicking efficiency than those who reported reduced kicking speeds. These results show that aerobically proficient U18 AF players who attain a relatively higher score on the yo-yo IR2 may be better equipped at preserving their kicking speed. Thus, coaches may wish to integrate both technical and aerobic drills in an attempt to preserve a player's capability to execute ball disposals with a high velocity.

Key Words: aerobic capacity, kicking speed, kicking accuracy, Australian football

Introduction

Australian football (AF) is a dynamic team invasion sport requiring players' at all developmental levels to possess unique physical, technical, and perceptual performance qualities (8, 12). Gradually, game demands have evolved so that AF today is a faster and more open game, particularly at the elite senior level (i.e., within the Australian Football League; AFL) (12, 27). As a response, the physical demands placed on AFL players have been shown to increase in terms of running velocity and intensity (24, 12). Notably, AFL players generate greater physiological outputs during game-play relative to players competing within sub-elite and junior competitions (5, 22). This increased physiological output during game-play may be explained by superior experience and physical fitness, with Lyons et al. (13) demonstrating that physiologically superior elite soccer players were better at preserving technical and perceptual skills throughout the game, relative to their less physically able counterparts. The negative effect of central fatigue on AF maximal kicking distance kinematics (9), as well as kicking accuracy (28) supports the evidence found with soccer players (13). However, the use of field-based and functional kicking (speed and accuracy) tests in AF along with a comparison to kicking efficiency during competition, would have implications for both game and physical demands. Pertinently, there is yet to be work that investigates the effects of maximal aerobic capacity on kicking performance extracted from field and game-based means in AF.

In response to today's more open and faster flowing game (17, 27), there have been numerous investigations into the physical demands of AF players during game-play (5, 8, 24). Research has focused on the physical movement demands of sub-elite and elite U18 competitions for the purpose of successful player development and drafting into the AFL (5, 6, 21). Coutts et al. (8) reported a decrease in high intensity running (HIR) and total distance

(TD) after the first quarter in elite AF. Similar results are reported at the elite U18 level, with midfielders showing a reduced number of HIR bouts after the first quarter (22). Coutts et al. (8) suggested the increased number of HIR bouts and TD covered during the first quarter influenced the onset of fatigue in the following quarters. Similar reductions have been reported in sub-elite players relative to their elite counterparts (4). Although no differences in technical skill were reported, a reduction in physical game performance (HIR), did not have a detrimental effect on technical skill. Sub-elite midfield players have shown to cover more distance at higher running speeds than other playing positions, however, these physical traits are shown to be inferior to midfield players at the elite level (5, 22). It was interesting to note Burgess et al. (6) reported that elite U18 midfielders exhibit less total game time than their elite counterparts, indicating that elite players work harder per minute, and are capable of executing accurate ball disposals at an increased game speed. However, it is unclear to what effect the role of aerobic fitness has on elite U18 midfielders, based on the differences reported between them and their elite counterparts when considering accurate ball disposals.

Research has shown that the use of a yo-yo IR2 is a strong indicator of HIR in AF (15). The yo-yo IR2 is used to evaluate maximal aerobic capacity (3), and comparisons with game physical movement patterns has reported an indirect influence on number of disposals when players perform HIR (15). However, although Mooney et al. (15) reported that playing experience influenced the relationship between HIR and disposals in elite senior AF players, it is currently unclear if disposals were effective, and if similar results would exist for elite U18 players.

Indeed, work has investigated the influence of fatigue on kicking performance in AF. Notably, Young et al. (28) reported that elite midfield players were able to maintain a higher kicking accuracy than sub-elite players and non-nomadic position players (forwards and defenders) when kicking to a target on a projected screen either side of a 2x 2 min time trial. Coventry et al. (9) reported that elite and sub-elite players modify their kicking kinematics to maintain foot speed, during incremented fatigue. However, despite offering insights into fatigue and its impact on kicking performance in AF, neither study examined the relationship between maximal aerobic capacity (as ascertained via the yo-yo IR2) and kicking performance measures. Accordingly, it is currently unknown whether maximal aerobic capacity influences kicking performance in elite junior AF players. Further, it is unknown if kicking performance under training conditions is related to that of competition kicking performance measured through kicking efficiency statistics.

The aim of this study was to determine the effect of maximal aerobic capacity on kicking performance in elite junior AF players. Given the work of others (28), it was hypothesised that those with a greater maximal aerobic capacity would be better equipped at preserving both speed and accuracy elements, and this would transfer to competition.

Methods

Participants & Experimental Protocol

Twenty four participants competing in a state-based U18 competition were recruited to participate. Selected participants were midfield players in an attempt to standardise potential positional influences on the physiological characteristics of players. All participants were injury free at the time of data collection, and participating in regular training sessions and/or games for a minimum of four weeks prior to data collection. Accordingly, data collection was undertaken during the late competition phase of the season. Participants were informed of the experimental protocol during their recruitment, and informed consent was obtained from parents/guardians where required. Ethical approval was granted by the relevant University Human Research Ethics Committee (Reference number: XXX).

A single data collection session was undertaken on an outdoor AF oval, under standardised environmental conditions. Prior to data collection, a standardised warm-up was completed, consisting of light jogging and dynamic stretches. Participants then performed the Australian Football Kicking Test (AFK), as reported by Woods et al. (25). The AFK was completed three times with the yo-yo IR2 completed twice (between each AFK), with no rest between all three AFKs. The testing was performed in pre-determined groups of three, with the coaches classing participants as either high, moderate or low aerobic fitness level in an attempt to minimise the rest periods. Three separate yo-yo IR2 (one per participant), and one AFK were set up to help standardise testing conditions.

Data Collection

The Australian Football Kicking Test

Prior to undertaking the AFK, participants specified their dominant and non-dominant kicking legs. Further, the players undertook the AFK testing procedure in full in attempt to prevent a scoring bias learned effect. Following the protocols described by Woods et al. (25), one kick was performed at each distance (20 m, 30 m and 40 m) for the dominant leg, and then repeated for the non-dominant leg. Right leg dominant participants would kick to the 'dominant' targets on the left side of their body, then to the right side of their body for the non-dominant, left leg (25). The test commenced with the participant facing away from the targets. They would then run to the turn cone, pick up a stationary football, before turning 180°, and run to the disposal line to kick to a now known target, designated by one scorer. The designated target player was instructed to call for the ball, but remain inside the target circle. The test was repeated until all three distances had been kicked to, then repeated for the non-dominant leg. Participants were instructed to kick "as quickly and as accurately as possible", and were allowed three seconds to dispose of the ball once received from the feeder in an attempt to standardise disposal time (25). A visual representation of the AFK is presented in Figure 1. Two criterions were used to assess kicking performance; accuracy and speed. Kicking accuracy was assessed by elite AF coaches with more than ten years' experience coaching at state level, using the criteria presented in Table 1. The score for each distance were used as the criterion value for analysis for accuracy. Secondly, a radar speed gun (Bushnell Velocity Gun 101911, Kansas City, Missouri) was used to assess peak ball speed for each kick and distance, which was manually operated by the same user in front of kicker (Figure 1). Accuracy of the speed gun was reported to be ± 2 $km.h^{-1}$, as well as its reliability reported to have an ICC of 0.90, and SEM of 1.48% when used for baseball pitching (11).

INSERT FIGURE 1 ABOUT HERE

INSERT TABLE 1 ABOUT HERE

The Yo-Yo IR2

The yo-yo IR2 is a maximal aerobic capacity test that consists of repeated 2 x 20 m shuttle runs that are performed at progressively increasing speeds. These workloads were interspersed with 10 s active rest periods in which the participant was instructed to walk around a cone 5 m away. This recovery period differentiates the yo-yo IR2 from other multi-stage fitness tests, making it more specific to intermittent AF movement patterns (3, 15). Participants were instructed to run in time with the 'beeps' that occur at shorter and shorter intervals as the test progresses. The test was terminated when the participant could no longer reach the cone within the 'beep', twice in succession, or voluntarily terminated. Mooney et al. (15) reported the yo-yo IR2 is an ecologically valid indicator of running performance in AF, however, the choice to perform the test twice (and without rest) was taken to induce a cumulative load, assuming to replicate first and second halves of an AF game.

Competition Kicking Efficiency

To investigate the relationship between kicking performance under testing conditions and competition, a commercial statistical provider; namely Champion Data© (Champion Data©, Melbourne, Australia), was used to extract the midfield players kicking efficiency. The reliability of the notations reported by Champion Data© in an U18 competition have been shown to be comparable to that of those at the elite senior level (18). Averaged kicking efficiency statistics from five randomly chosen games per participant was acquired. Kicking efficiency was reported as number of *completed* kicks (%), i.e. a kick reaching an intended teammate, who was not dispossessed, or had the kick intercepted by an opposing player. Competition kicking efficiency was reported as the difference in kicking efficiency between the first and fourth quarters of a game.

Data Analysis

For each AFK performed, the average accuracy score of the two scorers was reported for each kick (18 kicks total), for each participant. A single ball speed value was reported, corresponding to each individual AFK kick score. The two yo-yo IR2 scores were also recorded for each participant. A single value per participant was reported as the difference in competition kicking efficiency between the first and fourth quarters of five randomly selected games.

Statistical Analysis

Descriptive statistics (mean ± standard deviation) were reported for all criterion variables. Further, the effect size of AFK 'test' (three levels: yo-yo IR2, post 1st yo-yo IR2 and post 2nd yo-yo IR2) on each criterion variable was calculated using Cohen's *d* statistic (7), where an effect size of $d < 0.2$ was considered small, $d = 0.21 – 0.50$ moderate, $d = 0.51 – 0.80$ large, and $d \geq 0.80$ very large (7). The difference in yo-yo IR2 scores and actual game kicking efficiency were reported also, using paired t-tests.

Two linear mixed models were produced, one for kicking speed and one for kicking accuracy, where these two variables were entered as the dependant (response) variables. For each model, kicking distance (short, medium and long), leg (dominant and non-dominant), and AFK number were entered as factors, while the yo-yo IR2 score and competition kicking efficiency were entered as covariates. Post-hoc pairwise comparisons were performed using a Bonferroni correction, to assess differences across all levels of kick distance (i.e. short to medium, medium to long, and short to long) and AFK. IBM SPSS Statistics for Windows, Version 22.0 (Armonk, NY: IBM Corp.) was used to generate the linear mixed models. Residual tests for normality on each final model was used to ensure the assumption for each model was met. Statistical significance was set at $\alpha < 0.05$.

Results

No significant difference in yo-yo IR2 score was observed for the two tests, as well as competition kicking efficiency, with the average score for the first yo-yo IR2 being 20.0 ± 0.7, and the second being 19.5 ± 0.7. Competition kicking efficiency difference between the first and fourth quarters decreased by 9.9 ± 32.0%. However, it is important to highlight the large variation, suggesting that a range of diverse factors may have influenced this variable.

Table 2a and 2b show the effect of each yo-yo IR2 test on kicking accuracy and speed for each AFK over the three distances (short, medium and long) and for each leg (dominant and non-dominant). The linear mixed models for kicking speed and accuracy (Tables 3a and 3b) report the differences between these factors.

INSERT TABLE 2a & 2b ABOUT HERE

Table 3a shows the linear mixed model for kicking speed, which reported significant (P < .01) between-level differences for factors; kicking distance, leg, but not for AFK number. For kicking distance, post hoc pairwise comparisons showed significantly (P < .01) faster kicking speeds between all three comparisons (i.e. short to medium, medium to long, and short to long). The dominant kicking leg was shown to have produced significantly (P < .01) faster kicking speeds, over the non-dominant kicking leg. For the covariates, it was reported that those who attained a higher yo-yo IR2 score (higher aerobic capacity) across the two yo-yo IR2 tests were able to produce significantly (P < .01) faster kicking speed. Also, those who had a higher competition kicking efficiency were also shown to produce significantly (P < .01) faster kicking speeds.

INSERT TABLE 3A ABOUT HERE

Table 3b shows the linear mixed model for kicking accuracy, which reported significant between-level differences for factors; kicking distance, leg, and AFK number. For kicking distance, post hoc pairwise comparisons showed a significant (P < .01) decrease in kicking accuracy between short to medium and short to long, but not for medium to long kicking distances. Further, a significant (P < .01) decrease in kicking accuracy was reported between the first and second AFK, but not for the second and third AFK. The dominant kicking leg was shown to be significantly ($P < .01$) more accurate, over the non-dominant kicking leg. Of the two covariates, neither yo-yo IR2 score nor competition kicking efficiency were significant.

INSERT TABLE 3B ABOUT HERE

Discussion

The aim of this study was to determine the effect of maximal aerobic fitness on kicking performance in elite junior AF, with results linked to actual game-play. Previous laboratory-based investigations have reported that cumulative loading of maximal aerobic capacity modifies the kicking kinematics, kicking accuracy, and number of disposals for AF players (9, 15, 28). Thus, based on this previous work, it was hypothesised that maximal aerobic capacity would impact both kicking performance and competition kicking efficiency. Results partially supported our study hypothesis, with significant associations being resolved between maximal aerobic capacity and kicking speed.

Score on the yo-yo IR2 did not meaningfully change between each performance. Also, a non-significant reduction of 9.9 ± 32.0% in competition kicking efficiency was reported between selected competition game's first and fourth quarters. The relatively large standard deviation is comparable with midfielders even at the elite (AFL) level, who often kick to more difficult targets than passing backwards to an unmarked defender (18, 20). The non-significant drop in yo-yo IR2 score was also reported by Mooney et al. (15), who report that elite AF players produce similar exercise capacity (load.min^{-1}) when in a fatigued state. Despite Young et al.

(28) using a single protocol, the repeated protocol used by Coventry et al. (9), produced a small (yet significant) 0.09 s increase in 20 m sprint time, between-fatigue protocols, complementing the results of this study.

Linear mixed models (kicking speed and kicking accuracy) were used to investigate the effect of maximal aerobic capacity from two yo-yo IR2 tests (cumulative load), specific to AF kicking performance on both the dominant and non-dominant leg. Firstly, the *kicking speed* linear mixed model reported between-level differences for factors, with the dominant kicking leg producing higher ball speeds than the non-dominant leg, and kicking speed reported to increase from both short to medium, and medium to long kicking distance. These results correspond to those reported by Woods et al. (25), who utilised the AFK test to identify talent. Faster kicking speeds on the dominant kicking foot were reported by Woods et al. (25) to be associated with talent identified players. These results are also explained by Ball (1, 2), who reported that the dominant kicking foot produces faster kicking speeds, dependant on required kicking distance.

Between-level differences in kicking speed were reported for covariates, with those who attained a higher yo-yo IR2 score (presumed aerobically fitter) producing faster kicking speeds. Mohr et al. (14) reported that elite soccer players scored higher on the yo-yo IR2 than sub-elite players, which may have augmented superior technical skill shown during game-play. This is supported by research in AF, where players possessing superior aerobic capabilities have been shown to maintain a higher level of technical skill under a higher acute workload (HIR) (4, 28). Further, AF players with a higher aerobic capacity have been shown to have a greater involvement in a game, where kicking speed may be important when creating scoring opportunities (19, 26). Possibly the most interesting covariate from the linear mixed model, competition kicking efficiency, was reported to be higher for those who had faster kicking speeds. Sullivan et al. (21) reported that effective kicking was higher in quarters which were won. Accordingly, a player who is able to produce greater kicking speeds (coupled with accuracy) may be able to transition the ball to a teammate faster, limiting the capability of the opposition to intercept the kick or fill 'dangerous' space. This can also be linked to maintaining kicking efficiency in the latter stages of a game through a greater aerobic capacity (26). Additionally, Burgess et al. (6) suggested that U18 players who can maintain ball speed and have a higher tolerance to acute cumulative loads are more likely to be talent identified.

The *kicking accuracy* linear mixed model reported between-level differences for factors, with kicking accuracy reported to decrease with kicking distance, the dominant leg kicking more accurately than the non-dominant leg, and kicking accuracy decreasing with each AFK. Neither of the covariates (yo-yo IR2 score or competition kicking efficiency) were associated with kicking accuracy. Results for the above factors can be explained in a similar way in which they are explained in the *kicking speed* linear mixed model. The use of the AFK by Woods et al. (25) suggested that U18 players had reduced accuracy when kicking to further targets, irrespective of being talent identified or non-talent identified. This is further explained by Ball (2) who reported kicking kinematics are less efficient when kicking to further targets, as well as when kicking on the non-dominant foot; potentially impacting subsequent accuracy. Although score on the yo-yo IR2 score did not directly influence kicking accuracy, a decrease in kicking accuracy was reported between the first and second AFK, but not between the second and third AFK. While speculating, this may indicate that the acute load induced by the initial yo-yo IR2 test influenced the players kicking performance to a greater extent than the second yo-yo IR2 test. As Coutts et al. (8) suggests, player movement demands including HIR and TD decrease after the first quarter, yet technical skill in even sub-elite players is seemingly maintained (4).

Despite our promising findings, the study is not without limitations. With regards to the ecological validity and application of this study, the reported values for competition kicking efficiency were taken from five random games where the score or final outcome were not reported. Further, although the standard deviation for competition kicking efficiency was high, similar results have been reported at the professional (AFL) level (20). Sullivan et al. (21) reports an increase in player movement patterns (HIR) and physiological demands for games in which the selected team are losing, or eventually go on to lose. Therefore, the linear mixed model for kicking speed that reported players who had a higher competition kicking efficiency were also shown to produce faster kicking speeds, may have had games selected in which the team was winning, and possibly had lower movement patterns and physiological demands. Further, the use of five games does limit the representation of the results, thus, future work may wish to quantify kicking performance throughout the entirety of an AF season. Secondly, although players were recruited from the same elite junior competition, external factors not quantified within this study, such as training history, may have influenced the observed results. Thirdly, although the AFK has been shown to be a discriminately valid test of kicking skill in junior AF (25), it is important to note that the targets were stationary, whereas during game-play, it is likely that targets would be dynamic (i.e., kicking to a teammate running in space). Thus, future work may wish to incorporate dynamic targets when integrating tests of kicking performance in AF to increase the specificity of the results. Lastly, data collection was undertaken in the latter stages of the competition season, so it is possible that yo-yo IR2 score, functional kicking performance, and influence of current playing form influenced results.

Conclusions

This study examined the impact of maximal aerobic capacity on kicking performance in elite U18 AF players. Results demonstrated that kicking speed was influenced by the level attained on the Yo-Yo IR2 test, indicating that aerobically fitter players may be better equipped at preserving ball speed relative to their less aerobically proficient counterparts. Coaches may wish to integrate training drills that concurrently target both technical and aerobic proficiencies to maximise a players kicking performance during game-play. Future work may wish to investigate the association between kicking performance and competition performance at the positional level, across a larger sample of game observations.

Practical Applications

The fundamental practical application from this work indicates that AF coaches and conditioning staff may wish to integrate training drills that target both the development of maximal aerobic capacity and technical skill (kicking) proficiency. By doing so, kicking performance (namely kicking speed) may be persevered through the concurrent development of a player's maximal aerobic capacity.

References

1. Ball, K. Biomechanical considerations of distance kicking in Australian Rules football. *Sport Biomech* 7: 10-23, 2008.

2. Ball, K. Kinematic comparison of the preferred and non-preferred foot punt kick. *J Sport Sci* 29: 1545-1552, 2011.

3. Bangsbo, J, Iaia F, and Krustrup, P. The Yo-Yo Intermittent Recovery Test: a useful tool for evaluation of physical performance in intermittent sports. *Sport Med* 38: 37-51, 2008.

4. Black, G, Gabbett, T, Naughton, and McLean, B. The effect of intense exercise periods on physical and technical performance during elite Australian Football match-play: A comparison of experienced and less experienced players. *J Sci Med Sport* 19: 506-602, 2016.

5. Brewer, C, Dawson, B, Heasman, J, Stewart, G, and Cormack, S. Movement pattern comparisons in elite (AFL) and sub-elite (WAFL) Australian football games using GPS. *J Sci Med Sport* 13: 618-623, 2010.

6. Burgess, D, Naughton, G, and Norton, K. Quantifying the gap between under 18 and senior AFL football: 2003 and 2009. *Int J Sports Physiol Perform* 7: 53-58, 2012.

7. Cohen J. *Statistical power analysis for the behavioural sciences (2nd ed.)*. Hillsdale, NJ: Lawrence Erlbaum, 1988.

8. Coutts, A, Quinn, J, Hocking, J, Castagna, C, and Rampinini, E. Match running performance in elite Australian Rules Football. *J Sci Med Sport* 13: 543-548, 2010.

9. Coventry, E, Ball, K, Parrington, L, Aughey, R, and McKenna, M. Kinematic effects of a short-term fatigue protocol on punt-kicking performance. *J Sports Sci* 33: 1596-1605, 2015.

10. Dawson, B, Hopkinson, R, Appleby, B, Stewart, G, and Roberts, C. Comparison of training activities and game demands in the Australian Football League. *J Sci Med Sport* 7: 292-301, 2004.

11. English, T, and Howe, K. The effect of pilates exercise on trunk and postural stability and throwing velocity in college baseball pitchers: Single subject design. *N Am J Sports Phys* 2: 8-21, 2007.

12. Gray, A, and Jenkins, D. Match Analysis and the Physiological Demands of Australian Football. *Sport Med* 40: 347-360, 2010.

13. Lyons, M, Al-Nakeeb, Y, and Nevill, A. Performance of Soccer Passing Skills Under Moderate and High-Intensity Localized Muscle Fatigue. *J Strength Cond Res* 20: 197, 2006.

14. Mohr, M, Krustrup, P, and Bangsbo, J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci* 21: 519-528, 2003.

15. Mooney, M, O'Brien, B, Cormack, S, Coutts, A, Berry, J, and Young, W. The relationship between physical capacity and match performance in elite Australian football: A mediation approach. *J Sci Med Sport* 14: 447-452, 2011.

16. Mooney, M, Cormack, S, O'Brien, B, Morgan, W, and McGuigan, M. Impact of neuromuscular fatigue on match exercise intensity and performance in elite Australian football. *J Strength Cond Res* 27: 166-173, 2013.

17. Norton, K, Craig, N, and Olds, T. The evolution of Australian Football. *J Sci Med Sport* 2: 389-404, 1999.

18. O'Shaughnessy, D. Possessions versus position: Strategic evaluation in AFL. *J Sports Sci Med* 5: 533-540, 2006.

19. Piggott, B, McGuigan, M., and Newton, M. Relationship between physical capacity and match performance in semi-professional Australian rules football. *J Strength Cond Res* 29: 478-482, 2015.

20. Robertson, S, Back, N, and Bartlett, J. Explaining match outcome in elite Australian rules football using team performance indicators. *J Sports Sci* 34: 637-644, 2016.

21. Sullivan, C, Bilsborough, J, Cianciosi, M, Hocking, J, Cordy, J, and Coutts, A. Match score affects activity profile and skill performance in professional Australian Football players. *J Sci Med Sport* 17: 326-331, 2014.

22. Veale, J, Pearce, A, and Carlson, J. Player movement patterns in an elite junior Australian Rules Football team: an exploratory study. *J Sports Sci Med* 6: 254-260, 2007.

23. Vourimaa, T, Vasankari, T, and Rusko. H. Comparison of Physiological Strain and Muscular Performance of Athletes During Two Intermittent Running Exercises at the Velocity Associated with V˙O2max. *Int J Sports Med* 21: 96-101, 2000.

24. Wisbey, B, Montgomery, P, Pyne, D, and Rattray, B. Quantifying movement demands of AFL football using GPS tracking. *J Sci Med Sport* 13: 531-536, 2010.

25. Woods, C, Raynor, A, Bruce, L, and McDonald, Z. The use of skill tests to predict status in junior Australian football. *J Sports Sci 33*: 1132-1140, 2015.

26. Woods, C, Raynor, A, Bruce, L, McDonald, Z, and Collier, N. Predicting playing status in junior Australian Football using physical and anthropometric parameters. *J Sci Med Sport* 18: 225-229, 2015.

27. Woods, C, Robertson, S, and Collier, N. Evolution of game play in the Australian Football League 2001-2015. *J Sports Sci.* 2016. In Press.

28. Young, W, Gulli, R, Rath, D, Russell, A, O'Brien, B, and Harvey, J. Acute effect of exercise on kicking accuracy in elite Australian football players. *J Sci Med Sport* 13: 85-89, 2010.

Table 1. Scoring criteria for the AFK (25)

Points	Criteria
3	The ball reached the target player on the full and they did not have to leave the target circle to receive possession
2	The ball reached the target player on the full; however, they were required to place one foot outside of the target circle to receive possession
1	The ball reached the target player on the full, but they had to place both feet outside of the target circle to receive possession
0	The target player did not receive possession of the ball on the full

Table 2a. Descriptive statistics for kicking speed ($\bar{x}$ ± SD, and between-AFK effect sizes)

		AFK[1]	AFK[2]	ES[1]	AFK[3]	ES[2]	ES[3]
Short							
	Dom	56.0 ± 7.6	56.0 ± 8.2	0.00	54.9 ± 7.5	0.14	0.15
	Non Dom	52.2 ± 10.2	49.2 ± 6.3	0.36	47.5 ± 11.1	0.19	0.44
Medium							
	Dom	63.8 ± 8.4	66.7 ± 7.0	-0.38	62.6 ± 8.8	0.52	0.14
	Non Dom	56.3 ± 8.5	57.9 ± 9.2	-0.18	55.6 ± 9.7	0.24	0.08
Long							
	Dom	68.5 ± 6.2	71.1 ± 4.7	-0.47	70.1 ± 4.7	0.21	-0.29
	Non Dom	61.8 ± 8.8	66.5 ± 8.5	-0.54	62.3 ± 10.4	0.44	-0.05

Speed – $m.s^{-1}$, ES[1] – between AFK[1&2] effect size, ES[2] – between AFK[2&3], ES[3] – between AFK[1&3]

Table 2b. Descriptive statistics for kicking accuracy ($\bar{x}$ ± SD, and between-AFK effect sizes)

		AFK[1]	AFK[2]	ES[1]	AFK[3]	ES[2]	ES[3]
Short							
	Dom	2.5 ± 0.9	2.1 ± 1.2	0.38	2.3 ± 1.2	-0.17	0.19
	Non Dom	1.8 ± 1.3	1.6 ± 1.1	0.17	1.3 ± 1.3	0.25	0.38
Medium							
	Dom	2.1 ± 1.1	2.1 ± 1.0	0.00	2.0 ± 1.2	0.09	0.09
	Non Dom	1.6 ± 1.3	1.7 ± 1.2	-0.08	1.2 ± 1.3	0.40	0.31
Long							
	Dom	1.8 ± 1.2	2.0 ± 1.1	-0.17	1.2 ± 1.2	0.69	0.50
	Non Dom	1.0 ± 1.1	1.3 ± 1.2	-0.26	0.9 ± 1.2	0.33	0.09

Accuracy – points, ES[1] – between AFK[1&2] effect size, ES[2] – between AFK[2&3], ES[3] – between AFK[1&3]

Table 3a. Linear mixed model for kicking speed

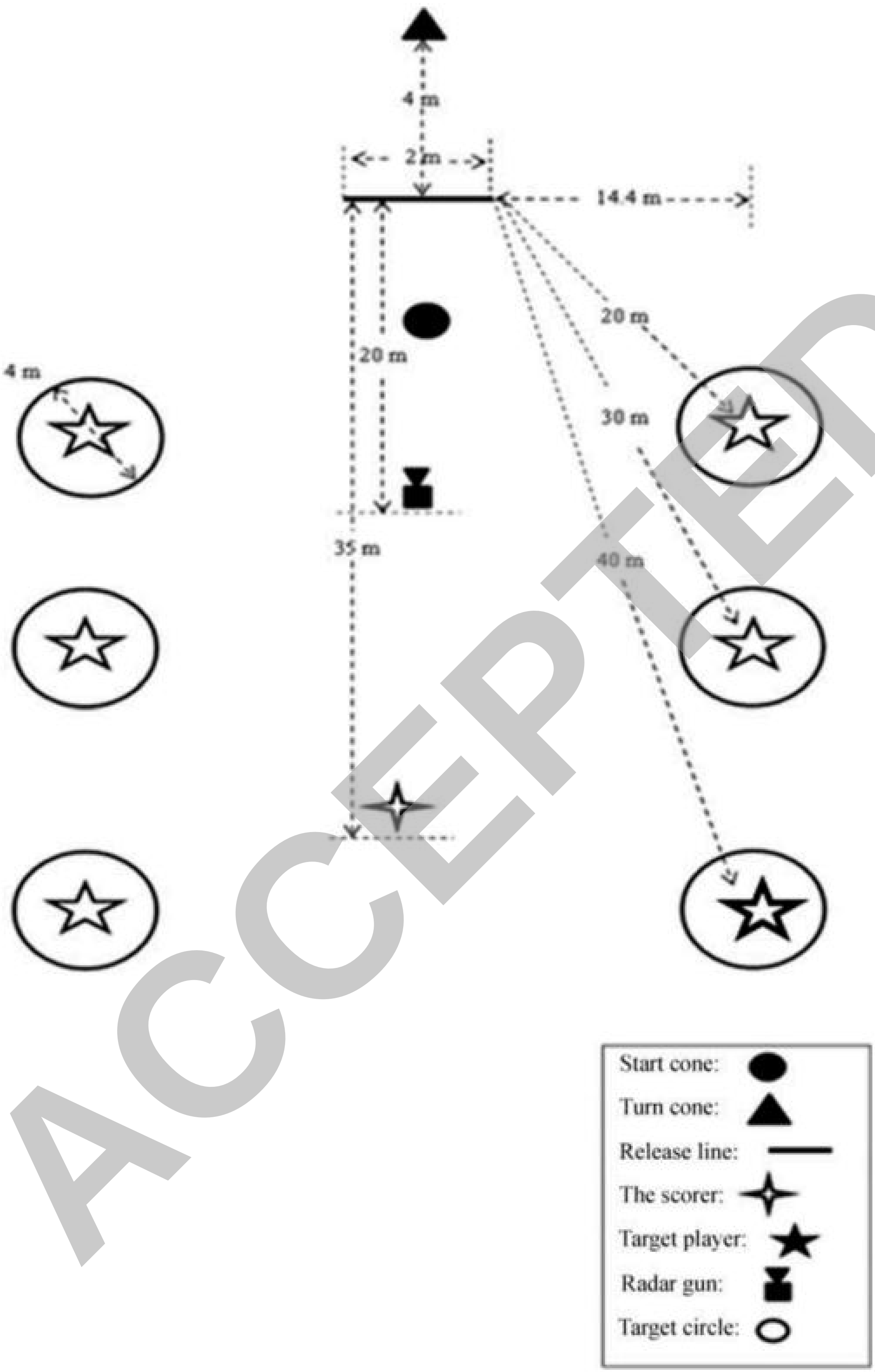
Variable	Estimate	SE	95% Lower-Upper CI	*P* value
[1] **YYIRT2 score**	0.046	0.554	2.153 – 4.331	.000*
[1] **Comp kicking efficiency**	3.242	0.121	0.023 – 0.070	.000*
[2] **Leg**				
Dominant	6.704[a]	0.764[a]	5.202 – 8.206	.000[a]*
Non dominant				
[2] **Kick distance**				
Short^	-15.609[a]	0.972[a]	-17.520 – -13.699	.000[a]*
Medium^	-7.755[a]	0.972[a]	-9.666 – -5.844	.000[a]*
Long^				
[2] **AFK**				
Pre YYIRT2	-0.924[a]	0.934[a]	-2.763 – 0.916	.324[a]
Post 1st YYIRT2	1.472[a]	0.934[a]	-0.367 – 3.312	.116[a]
Post 2nd YYIRT2				

[1] covariate, [2] factor, ^ pairwise between-test difference, [a] between-test estimate, error or significance, CI – confidence interval, *sig to < .01 level

Table 3b. Linear mixed model for kicking accuracy

Variable	Estimate	SE	95% Lower-Upper CI	*P* value
[1] **YYIRT2 score**	0.001	0.082	-0.160 – 0.163	0.989
[1] **Comp kicking efficiency**	0.002	0.002	-0.001 – 0.006	0.190
[2] **Leg**				
Dominant	0.644[a]	0.114[a]	0.420 – 0.867	0.000[a]*
Non dominant				
[2] **Kick distance**				
Short^	-0.576[a]	0.145[a]	0.291 – 0.860	0.000[a]*
Medium	-0.423[a]	0.145[a]	0.139 – 0.707	0.004[a]*
Long^				
[2] **AFK**				
Pre YYIRT2	-0.326[a]	0.139[a]	-0.600 – 0.005	0.020[a]*
Post 1st YYIRT2^	-0.278[a]	0.139[a]	-0.302 – 0.246	0.842[a]
Post 2nd YYIRT2				

[1] covariate, [2] factor, ^ pairwise between-test difference, [a] between-test estimate, error or significance, CI – confidence interval, *sig to < .01 level


4 m
2 m
14.4 m
20 m
4 m
20 m
30 m
35 m
40 m
Start cone:
Turn cone:
Release line:
The scorer:
Target player:
Radar gun:
Target circle: