

2017

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

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This article was originally published as:

Joseph, J., Woods, C., & Joyce, C. (2017). The relationship between repeated kicking performance and maximal aerobic capacity in elite junior Australian football. *Journal of Strength and Conditioning Research, Early View (Online First)*.

Original article available here:

http://journals.lww.com/nsca-jscr/Abstract/publishahead/The_relationship_between_repeated_kicking.95790.aspx

This article is posted on ResearchOnline@ND at https://researchonline.nd.edu.au/health_article/180. For more information, please contact researchonline@nd.edu.au.

This is the author's version of an article published in the *Journal of Strength and Conditioning Research*, August 2017. This is not the final published version.

Final published version available online at

http://journals.lww.com/nsca-jscr/Abstract/publishahead/The_relationship_between_repeated_kicking.95790.aspx

Joseph, J., Woods, C., and Joyce, C. (2017) The relationship between repeated kicking performance and maximal aerobic capacity in elite junior Australian football. *Journal of Strength and Conditioning Research, Online First*. doi: 10.1519/JSC.0000000000002220

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

3

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15

16 Running Title: Aerobic capacity and kicking performance

17

18 **Abstract**

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

37

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

39 **Introduction**

40 Australian football (AF) is a dynamic team invasion sport requiring players' at all
41 developmental levels to possess unique physical, technical, and perceptual performance
42 qualities (8, 12). Gradually, game demands have evolved so that AF today is a faster and more
43 open game, particularly at the elite senior level (i.e., within the Australian Football League;
44 AFL) (12, 27). As a response, the physical demands placed on AFL players have been shown
45 to increase in terms of running velocity and intensity (24, 12). Notably, AFL players generate
46 greater physiological outputs during game-play relative to players competing within sub-elite
47 and junior competitions (5, 21). This increased physiological output during game-play may be
48 explained by superior experience and physical fitness, with Lyons et al. (13) demonstrating
49 that physiologically superior elite soccer players were better at preserving technical and
50 perceptual skills throughout the game, relative to their less physically able counterparts. The
51 negative effect of central fatigue on AF maximal kicking distance kinematics (9), as well as
52 kicking accuracy (28) supports the evidence found with soccer players (13). However, the use
53 of field-based and functional kicking (speed and accuracy) tests in AF along with a comparison
54 to kicking efficiency during competition, would have implications for both game and physical
55 demands. Pertinently, there is yet to be work that investigates the effects of maximal aerobic
56 capacity on kicking performance extracted from field and game-based means in AF.

57

58 In response to today's more open and faster flowing game (17, 27), there have been numerous
59 investigations into the physical demands of AF players during game-play (5, 8, 24). Research
60 has focused on the physical movement demands of sub-elite and elite U18 competitions for the
61 purpose of successful player development and drafting into the AFL (5, 6, 21). Coutts et al. (8)
62 reported a decrease in high intensity running (HIR) and total distance (TD) after the first quarter
63 in elite AF. Similar results are reported at the elite U18 level, with midfielders showing a

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

77

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

85

86 Indeed, work has investigated the influence of fatigue on kicking performance in AF. Notably,
87 Young et al. (28) reported that elite midfield players were able to maintain a higher kicking
88 accuracy than sub-elite players and non-nomadic position players (forwards and defenders)

89 when kicking to a target on a projected screen either side of a 2x 2 min time trial. Coventry et
90 al. (9) reported that elite and sub-elite players modify their kicking kinematics to maintain foot
91 speed, during incremented fatigue. However, despite offering insights into fatigue and its
92 impact on kicking performance in AF, neither study examined the relationship between
93 maximal aerobic capacity (as ascertained via the yo-yo IR2) and kicking performance
94 measures. Accordingly, it is currently unknown whether maximal aerobic capacity influences
95 kicking performance in elite junior AF players. Further, it is unknown if kicking performance
96 under training conditions is related to that of competition kicking performance measured
97 through kicking efficiency statistics.

98

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

103

104 **Methods**

105 *Participants & Experimental Protocol*

106 Twenty four participants competing in a state-based U18 competition were recruited to
107 participate. Selected participants were midfield players in an attempt to standardise potential
108 positional influences on the physiological characteristics of players. All participants were
109 injury free at the time of data collection, and participating in regular training sessions and/or
110 games for a minimum of four weeks prior to data collection. Accordingly, data collection was
111 undertaken during the late competition phase of the season. Participants were informed of the
112 experimental protocol during their recruitment, and informed consent was obtained from

113 parents/guardians where required. Ethical approval was granted by the relevant University
114 Human Research Ethics Committee (Reference number: XXX).

115

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

125

126 ***Data Collection***

127 *The Australian Football Kicking Test*

128 Prior to undertaking the AFK, participants specified their dominant and non-dominant kicking
129 legs. Further, the players undertook the AFK testing procedure in full in attempt to prevent a
130 scoring bias learned effect. Following the protocols described by Woods et al. (25), one kick
131 was performed at each distance (20 m, 30 m and 40 m) for the dominant leg, and then repeated
132 for the non-dominant leg. Right leg dominant participants would kick to the ‘dominant’ targets
133 on the left side of their body, then to the right side of their body for the non-dominant, left leg
134 (25). The test commenced with the participant facing away from the targets. They would then
135 run to the turn cone, pick up a stationary football, before turning 180°, and run to the disposal
136 line to kick to a now known target, designated by one scorer. The designated target player was
137 instructed to call for the ball, but remain inside the target circle. The test was repeated until all

138 three distances had been kicked to, then repeated for the non-dominant leg. Participants were
139 instructed to kick “as quickly and as accurately as possible”, and were allowed three seconds
140 to dispose of the ball once received from the feeder in an attempt to standardise disposal time
141 (25). A visual representation of the AFK is presented in Figure 1. Two criteria were used to
142 assess kicking performance; accuracy and speed. Kicking accuracy was assessed by elite AF
143 coaches with more than ten years’ experience coaching at state level, using the criteria
144 presented in Table 1. The score for each distance were used as the criterion value for analysis
145 for accuracy. Secondly, a radar speed gun (Bushnell Velocity Gun 101911, Kansas City,
146 Missouri) was used to assess peak ball speed for each kick and distance, which was manually
147 operated by the same user in front of kicker (Figure 1). Accuracy of the speed gun was reported
148 to be $\pm 2 \text{ km.h}^{-1}$, as well as its reliability reported to have an ICC of 0.90, and SEM of 1.48%
149 when used for baseball pitching (11).

150

151 INSERT FIGURE 1 ABOUT HERE

152 INSERT TABLE 1 ABOUT HERE

153

154 *The Yo-Yo IR2*

155 The yo-yo IR2 is a maximal aerobic capacity test that consists of repeated 2 x 20 m shuttle runs
156 that are performed at progressively increasing speeds. These workloads were interspersed with
157 10 s active rest periods in which the participant was instructed to walk around a cone 5 m away.
158 This recovery period differentiates the yo-yo IR2 from other multi-stage fitness tests, making
159 it more specific to intermittent AF movement patterns (3, 15). Participants were instructed to
160 run in time with the ‘beeps’ that occur at shorter and shorter intervals as the test progresses.
161 The test was terminated when the participant could no longer reach the cone within the ‘beep’,
162 twice in succession, or voluntarily terminated. Mooney et al. (15) reported the yo-yo IR2 is an

163 ecologically valid indicator of running performance in AF, however, the choice to perform the
164 test twice was taken to induce a cumulative load, assuming to replicate first and second halves
165 of an AF game.

166

167 *Competition Kicking Efficiency*

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

178

179 *Data Analysis*

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

185

186 *Statistical Analysis*

187 Descriptive statistics (mean \pm standard deviation) were reported for all criterion variables.
188 Further, the effect size of AFK 'test' (three levels: yo-yo IR2, post 1st yo-yo IR2 and post 2nd
189 yo-yo IR2) on each criterion variable was calculated using Cohen's *d* statistic (7), where an
190 effect size of $d < 0.2$ was considered small, $d = 0.21 - 0.50$ moderate, $d = 0.51 - 0.80$ large, and
191 $d \geq 0.80$ very large (7). The difference in yo-yo IR2 scores and actual game kicking efficiency
192 were reported also, using paired t-tests.

193

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

204

205 **Results**

206 No significant difference in yo-yo IR2 score was observed for the two tests, as well as
207 competition kicking efficiency, with the average score for the first yo-yo IR2 being 20.0 ± 0.7 ,
208 and the second being 19.5 ± 0.7 . Competition kicking efficiency difference between the first
209 and fourth quarters decreased by $9.9 \pm 32.0\%$. However, it is important to highlight the large
210 variation, suggesting that a range of diverse factors may have influenced this variable. Table
211 2a and 2b show the effect of each yo-yo IR2 test on kicking accuracy and speed for each AFK

212 over the three distances (short, medium and long) and for each leg (dominant and non-
213 dominant). The linear mixed models for kicking speed and accuracy (Tables 3a and 3b) report
214 the differences between these factors.

215

216 INSERT TABLE 2a & 2b ABOUT HERE

217

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

228

229 INSERT TABLE 3A ABOUT HERE

230

231 Table 3b shows the linear mixed model for kicking accuracy, which reported significant
232 between-level differences for factors; kicking distance, leg, and AFK number. For kicking
233 distance, post hoc pairwise comparisons showed a significant ($P < .01$) decrease in kicking
234 accuracy between short to medium and short to long, but not for medium to long kicking
235 distances. Further, a significant ($P < .01$) decrease in kicking accuracy was reported between
236 the first and second AFK, but not for the second and third AFK. The dominant kicking leg was

237 shown to be significantly ($P < .01$) more accurate, over the non-dominant kicking leg. Of the
238 two covariates, neither yo-yo IR2 score nor competition kicking efficiency were significant.

239

240 INSERT TABLE 3B ABOUT HERE

241

242

243 **Discussion**

244 The aim of this study was to determine the effect of maximal aerobic fitness on kicking
245 performance in elite junior AF, with results linked to actual game-play. Previous laboratory-
246 based investigations have reported that cumulative loading of maximal aerobic capacity
247 modifies the kicking kinematics, kicking accuracy, and number of disposals for AF players (9,
248 15, 28). Thus, based on this previous work, it was hypothesised that maximal aerobic capacity
249 would impact both kicking performance and competition kicking efficiency. Results partially
250 supported our study hypothesis, with significant associations being resolved between maximal
251 aerobic capacity and kicking speed.

252

253 Score on the yo-yo IR2 did not meaningfully change between each performance. Also, a non-
254 significant reduction of $9.9 \pm 32.0\%$ in competition kicking efficiency was reported between
255 selected competition game's first and fourth quarters. The relatively large standard deviation
256 is comparable with midfielders even at the elite (AFL) level, who often kick to more difficult
257 targets than passing backwards to an unmarked defender (18, 20). The non-significant drop in
258 yo-yo IR2 score was also reported by Mooney et al. (15), who report that elite AF players
259 produce similar exercise capacity ($\text{load}\cdot\text{min}^{-1}$) when in a fatigued state. Despite Young et al.
260 (28) using a single protocol, the repeated protocol used by Coventry et al. (9), produced a small

261 (yet significant) 0.09 s increase in 20 m sprint time, between-fatigue protocols, complementing
262 the results of this study.

263

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

274

275 Between-level differences in kicking speed were reported for covariates, with those who
276 attained a higher yo-yo IR2 score (presumed aerobically fitter) producing faster kicking speeds.
277 Mohr et al. (14) reported that elite soccer players scored higher on the yo-yo IR2 than sub-elite
278 players, which may have augmented superior technical skill shown during game-play. This is
279 supported by research in AF, where players possessing superior aerobic capabilities have been
280 shown to maintain a higher level of technical skill under a higher acute workload (HIR) (4, 28).
281 Further, AF players with a higher aerobic capacity have been shown to have a greater
282 involvement in a game, where kicking speed may be important when creating scoring
283 opportunities (19, 26). Possibly the most interesting covariate from the linear mixed model,
284 competition kicking efficiency, was reported to be higher for those who had faster kicking
285 speeds. Sullivan et al. (21) reported that effective kicking was higher in quarters which were

286 won. Accordingly, a player who is able to produce greater kicking speeds (coupled with
287 accuracy) may be able to transition the ball to a teammate faster, limiting the capability of the
288 opposition to intercept the kick or fill ‘dangerous’ space. This can also be linked to maintaining
289 kicking efficiency in the latter stages of a game through a greater aerobic capacity (26).
290 Additionally, Burgess et al. (6) suggested that U18 players who can maintain ball speed and
291 have a higher tolerance to acute cumulative loads are more likely to be talent identified.

292

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

310

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

332

333 **Conclusions**

334 This study examined the impact of maximal aerobic capacity on kicking performance in elite
335 U18 AF players. Results demonstrated that kicking speed was influenced by the level attained

336 on the Yo-Yo IR2 test, indicating that aerobically fitter players may be better equipped at
337 preserving ball speed relative to their less aerobically proficient counterparts. Coaches may
338 wish to integrate training drills that concurrently target both technical and aerobic proficiencies
339 to maximise a players kicking performance during game-play. Future work may wish to
340 investigate the association between kicking performance and competition performance at the
341 positional level, across a larger sample of game observations.

342

343 **Practical Applications**

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

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