Profiling the kicking and handballing accuracy of female Australian football players across five competition levels

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Abstract

Objectives: To profile the kicking and handballing accuracy of female Australian football (AF) players and investigate potential differences across five competition levels.

Methods: Altogether, 205 female players were classified into five competition levels: elite senior (≥18 years) (n=35), non-elite senior (≥18 years) (n=58), high-level junior (<18 years) (n=32), non-elite junior (14-17 years) (n=38), and non-elite junior (10-13 years) (n=42). Modified AF kicking and handballing tests examined accuracy outcomes (dominant kicking leg and dominant/non-dominant handballing disposal). Differences in accuracy between the five competition levels were modelled using multivariate analysis of variance.

Results: A large, significant difference between the competition levels was noted ($F = 11.508$, $p < 0.001$, Wilk's $\Lambda = 0.462$, $\eta^2_p = 0.227$), with significant differences ($p < 0.001$) observed in the modified AF kicking ($\omega^2 = 0.514$) and handballing (dominant hand: $\eta^2_p = 0.250$; non-dominant hand: $\eta^2_p = 0.150$) tests. Specifically, elite seniors and high-level juniors performed the modified AF kicking test more accurately than non-elite senior, non-elite junior (14-17 years), and non-elite junior (10-13 years) competition levels ($p \leq 0.001$). The elite seniors were also more accurate on the dominant side when performing the modified AF handballing test compared to all non-elite competition levels ($p \leq 0.001$).

Conclusions: This study is the first to report technical skill characteristics in female AF across a broader participation pathway. These exploratory findings could be used as reference data to set benchmarks for player development and inform training designs, namely by incorporating non-dominant handballing competitive play situations to develop this skill in female AF players.

Keywords: Technical skill, women, talent identification, team sports

1. INTRODUCTION

Australian football (AF) is a dynamic, team invasion sport played on a large oval field that requires the combination of physical fitness, technical skill, and perceptual capabilities [1]. Successful performance of various athletic movements, such as direction change, acceleration, and jumping, as well as technical skills to move the football down-field (namely by kicking and handballing) are integral to the sport [1]. Female participation rates in AF have been on the rise since the inauguration of the Australian Football League Women's (AFLW) competition in 2017 [2]. Female players can participate in AF nationwide through various participation pathways, including community competitions, school clubs, and talent programs [3]. To support participation pathways, understanding and advancing expertise development, including physical capacities, skilfulness, and perceptual abilities, is often at the forefront of research innovation given the accolades associated with its attainment. However, the acquisition of sporting expertise can be a highly perplexing process for both the practitioner and athlete given its innate non-linearity and number of contributing factors, such as the specificity of the sport and practice environment [4]. Nonetheless, various theoretical models and frameworks have been developed by researchers in attempts to understand this progression [5].

Successful performance in team ball sports is often attributed to a unique combination of physical, technical, tactical, and psychosocial characteristics [6, 7]. Therefore, measuring these qualities using a multidimensional testing battery is likely to offer coaches and sport practitioners insight into prospective performance potential (i.e., talent identification), fundamental qualities that are important at the senior level, and capturing an individual's ability to learn (i.e., talent development) [8]. While each of these qualities may be important to achieving sport expertise, understanding sport-specific technical skill profiles can assist talent identification and development practices by influencing testing batteries, training, and/or competition design considerations for aspiring players across the participation pathway [9].

Technical skills specific to AF include kicking and handballing, which are the game's two modes of ball disposal between players [10]. Combining these actions through a series of optimal events allow a team to maintain possession of the ball, gain inside 50-m entries (a common AF game statistic occurring when the ball is within 50-m of the opponent's goal), and attempt to kick a goal through the two centre posts at the opposition's end of the field [10]. One study reported the technical demands of AFLW match play, indicating there were no positional differences regarding the number of kicks, handballs, contested possessions, uncontested possessions, or marks [11]. However, positional differences did exist regarding running or passing the ball into (i.e., inside 50) and outside of (i.e., rebound 50) the opposition's defensive end, number of tackles, and number of goals [11]. As no positional differences existed for kicking and handballing, these findings likely highlight these technical skill attributes are important for all players in the sport. While this research provided initial insight into understanding skill execution at the elite senior competition level [11], assessment of technical proficiency and examining technical skill attributes at the junior and non-elite senior levels is imperative to enhance talent development and participation pathways for female players. For example, the use of kicking and handballing technical skills tests have been demonstrated to be predictive of elite versus sub-elite status in male junior players [12]. Additionally, differences in technical skill performance between developmental stages in male compared to female youth soccer players has been demonstrated [13], highlighting the need for research to support female sporting environments. Despite the expansion of female participation in AF, limited research exists to support the emergence of talent development and participation pathways specific to female players. Therefore, the aims of this study were to: (i) profile the technical skill characteristics (namely kicking and handballing accuracy) of female AF players across five competition levels, and (ii) determine if competition level differences existed in these attributes. It was hypothesised that as developmental experience increased, AF kicking and handballing proficiency would also increase.

2. Materials and Methods

Study Design and Participants

A descriptive, cross-sectional research design was used to examine the kicking and handballing accuracy of 205 female AF players. Players were recruited from southeast Queensland and classified into one of the five competition levels outlined in Table 1.

Table 1: Competition level classifications and number of players recruited

Competition Level	Sample size (n)	Description
Elite Senior	n = 35	Players aged ≥18 years participating in the AFLW competition or selected into a state representative team or talent academy program.
Non-elite Senior	n = 58	Players aged ≥18 years participating in one of the state community competitions.
High-level Junior	n = 32	Players aged <18 years and selected into a state representative team or talent academy program.
Non-elite Junior (14-17 years)	n = 38	Players aged 14 to 17 years who were playing for a school or community club.
Non-elite Junior (10-13 years)	n = 42	Players aged 10 to 13 years who were playing for a school or community club.

To be eligible for inclusion in this study, participants were required to be participating in regular training sessions on an all-female AF team for at least two weeks. All players received an explanatory statement of the study, volunteered to participate, and provided informed consent prior to participation. Parent (or guardian) consent was also obtained for those players under 18 years of age. The study was approved by the Bond University Human Research Ethics Committee (16116).

Age, dominant arm / hand and leg (determined by handballing and kicking limb preference), years of AF experience, total number of other sports (other than AF) concurrently being played at time of testing, standing height, body mass, body mass index (BMI), and primary playing position (forward, midfielder, or defender) were collected to describe the sample. The coach supplied information on the player's most likely playing position for the upcoming season for those individuals who were in their first year of playing AF. Standing height and body mass were measured utilizing standardised protocols [14] via a stadiometer (Harpenden, Holtain Limited, Crymych, UK) and an electronic scale (WM204, Wedderburn, Ingleburn, NSW, Australia), both recorded to the nearest 0.1 cm and 0.1 kg, respectively.

Procedures

From preseason 2018 to preseason 2019, all players completed two technical skills tests: the AF kicking test and the AF handballing test [12]. Based on feedback provided by AFLW coaches, the distances used in the technical skills tests as described by Woods and colleagues [12] were adapted for female players and only the dominant kicking leg was assessed. Therefore, from herein, these tests will be referred to as the *modified* AF kicking and handballing tests. Prior to testing, players performed a 10-15-minute self-directed warm-up typical to that of their training environment, inclusive of dynamic movements, kicking, and handling. As the nature of varying competitions in the region extended across different times of the calendar year, the cohorts did not complete testing at the same time. The majority of players completed the two technical skill tests within one week or less of each other. Given the observational nature of this study, no dietary or exercise restrictions were applied. Prior to data collection, all assessors attended a familiarisation training session with the primary researcher to ensure accurate and standardised data collection for the skills tests.

Modified Australian football kicking test

Given the applied nature of this research, where possible, the modified AF kicking test was conducted on an outdoor grass field, with players being instructed to wear their typical training gear (i.e., shorts, top, and boots; refer to Figure 1 for set up of the modified AF kicking test). Due to challenges associated with data collection in applied settings and time-poor environments, no familiarisation session prior to data collection was conducted. However, to familiarise themselves with the modified AF kicking test, players performed three warm-up trials by kicking the football once to each distance (short, 15-m; medium, 20-m; long, 25-m) on one side of the field [12]. To conduct the test, the kicker stood at a start cone while holding a football (AFLW match standard size pertinent to each competition level) facing away from the target players [12]. A target player was then allocated by the assessor without knowledge of the kicker [12]. The assessor then blew a whistle to cue the kicker to run to the turn cone to make a self-directed 180-degree turn [12]. As the kicker manoeuvred around the turn cone, the allocated target player called for the ball within their designated circle perimeter [12]. The kicker then disposed the ball from behind the release line to the designated target player within three seconds of commencing the trial [12]. Players were instructed to *"kick the ball to the target player as quickly and as accurately as*

possible" [12]. Players used their dominant leg only to kick the football once to each of the six target players (for a total of six kicks assessed), with the selection order determined by a randomised computer generator prior to test commencement. Kicking accuracy was assessed using the scoring criteria described in Table 2, with a maximum test score of 18 points. This kicking scoring criteria has demonstrated strong correlations (intraclass correlation coefficient = 0.91) at three distances for both sides of the field and substantial inter-rater reliability (kappa-statistic = 0.80) [12].

*** Insert Figure 1 about here. ***

Figure 1. The modified Australian football kicking test set-up, as adapted from Woods and colleagues [12].

Modified Australian football handballing test

Consistent with the protocol used by Woods and colleagues [12], the modified AF handballing test was conducted in an indoor gymnasium with players instructed to wear their typical indoor training gear (i.e., shorts, top, and runners). A laptop computer and projector were placed on a solid box (98-cm in height), which projected a 3 x 3 grid (150-cm x 150-cm) consisting of nine small squares (each 50-cm by 50-cm) numbered one to nine onto a solid, plain wall [12]. A release line was positioned 5-m from the wall. To conduct the test, players stood at the release line holding a football (AFLW match standard size pertinent to each competition level) and were instructed to *"handball as quickly and as accurately as possible"* to the allocated target indicated by the numbered square [12]. Players first used their dominant hand to handball the football once to each of the nine targets (a total of nine handballs assessed) [12], with the selection order determined by a randomised computer generator. Participants then conducted the test using their non-dominant hand [12]. Handballing accuracy was assessed using the scoring criteria described in Table 2, with a maximum test score of 9 points for each hand.

Table 2: Technical skill tests scoring criteria [12]

Australian football kicking test	Australian football handball test

3 points	The football reached the target player within the target circle on the full.	Not applicable.
2 points	The football reached the target player with one foot outside of the target circle to receive possession on the full.	Not applicable.
1 point	The football reached the target player with both feet outside of the target circle to receive possession on the full.	The football landed anywhere within the correct target number square perimeter.
0 points	The target player did not receive possession of the football on the full.	The football landed on the line (i.e., "line-ball") of the correct target number square or the football landed anywhere but the correct target number square.

Statistical Analysis

Descriptive statistics (means, standard deviations (SD), medians, interquartile range (IQR), range, frequencies, and percentages, as appropriate) were conducted to describe the sample and the technical skill attributes of the players across each competition level. Additionally, the modified AF kicking and handballing test score quartile ranges were calculated to demonstrate the range of skills across the playing competitions. To investigate the differences in technical skill characteristics between the five competition levels, a multivariate analysis of variance (MANOVA) was conducted on cases with complete data for both the modified AF kicking and handballing tests, after preliminary MANOVA assumptions were explored. Univariate analyses of variance (ANOVA) (classic or Welch ANOVA depending on homogeneity of variance assessed using Levene's statistic), and post-hoc analyses, as appropriate, were performed pending a statistically significant MANOVA result (p <0.01). The magnitude of differences was determined using partial eta squared (η^2_p) or estimated omega squared (ω^2) effect sizes, as appropriate, in reference to 0.01 (small), 0.06 (medium), and 0.14 (large) thresholds [15]. As competition levels were defined by age, and subsequently, height, body mass, and BMI, differences in these variables were expected across these competition levels, and therefore were not considered as covariates in the MANOVA. However, competition level differences regarding player position and arm / hand and leg dominance were explored by chi-square analysis or Fisher's Exact tests, as appropriate, for consideration as potential covariate(s). The p-values were adjusted using Bonferroni correction for multiple comparisons. All data were analysed using SPSS statistic software (Version 26), with statistical significance set at p <0.05, except for the quartile ranges, which were calculated using the *stats* package in the statistical computing software R (Version 3.6.3) [16].

3. RESULTS

Table 3 presents the demographic data for players across the five competition levels included in the study. Chi-square analysis and Fisher's Exact tests revealed no significant differences in the proportions of players regarding playing position or arm / hand and foot dominance across competition levels, and therefore, these variables were not applied as covariates in further analysis.

1 Table 3: Sample demographics

Demographic data	n	Elite Senior (≥18 years)	n	Non-elite Senior (≥18 years)	n	High-level Junior (<18 years)	n	Non-elite Junior (14-17 years)	n	Non-elite Junior (10-13 years)
Age (years)	35	21.89 (6.61)	58	23.01 (5.36)	32	17.32 (1.07)	38	15.89 ± 0.91	42	12.50 ± 1.02
AF experience (years)	35	6.23 ± 4.47	58	2.00 (2.75)	32	3.50 (3.00)	34	1.84 ± 1.14	37	1.00 (1.00)
Number of other sports played concurrently (n)	24	0.00 (1.00)	55	0.00 (1.00)	26	0.85 ± 0.88	31	1.00 (1.00)	34	1.00 (1.50)
Height (cm)	32	170.82 ± 7.75	52	169.94 ± 7.00	30	168.18 ± 5.56	30	167.32 ± 5.73	40	158.56 ± 9.85
Body mass (kg)	32	69.00 ± 9.43	52	65.70 (12.80)	30	64.02 ± 6.63	30	62.91 ± 9.01	40	51.72 ± 10.89
BMI (kg/m^2)	32	23.58 ± 2.13	52	22.48 (4.04)	30	22.62 ± 2.00	30	22.49 ± 3.20	40	20.39 ± 3.01
Hand dominance										
Right (%)	33	94.3	53	91.4	30	93.8	36	94.7	40	95.2
Left (%)	2	4.8	5	8.6	2	6.2	2	5.3	2	4.8
Foot dominance										
Right (%)	31	88.6	56	96.6	27	84.4	35	92.1	40	95.2
Left (%)	4	11.4	2	3.4	5	15.6	3	7.9	2	4.8
Primary Position										
Forward (%)	10	28.6	15	25.9	6	18.8	10	26.3	17	40.5
Midfielder (%)	14	40.0	25	43.1	15	46.9	19	50.0	18	42.9
Defender (%)	11	31.4	18	31.0	11	34.4	9	23.7	7	16.7

Continuous data presented as mean ± standard deviation if normally distributed and as median (interquartile range) if not normally distributed. Categorical data reported as frequencies and percentages. AF = Australian football; BMI = body mass index.

2

A total of 161 female AF players completed both the modified AF kicking and AF handballing tests. Data from the remaining 44 players included completion of only one of the technical skill tests (either modified AF kicking or modified AF handballing test). As testing occurred in an applied setting, constraints enforced by some of the teams, such as time and load monitoring restrictions, or barriers regarding the teams' environments, limited complete data collection from all participants. The data from these 44 players were included in the demographic and descriptive profiling and quartile calculation results, however, were not considered in the MANOVA. No significant differences in age (p = 0.330), years AF experience (p = 0.455), height (p = 1.00), body mass (p = 1.00), or BMI (p = 0.655) existed between players that were and were not included in the MANOVA.

Regarding the first study aim, the technical skill profiles of the players across the five competition levels are presented in Table 4. Figure 2 and

Figure **3** provide visualisations of the distributions of the modified AF kicking and AF handballing (dominant hand) test scores grouped by competition level, respectively, with the competition level means plotted within the study sample's quartile ranges for each technical skill test. The percentage of players from each competition level that fell within the identified quartile ranges for each technical skill test are reported in Table 5. As non-dominant test scores for the modified AF handballing were not normally distributed, quartile ranges were not computed.

Table 4: Kicking and handballing profiles of female Australian football players

Modified Australian football kicking test - dominant leg (maximum score 18 points)				
Competition Level	**n**	**Mean ± SD**	**Median (IQR)**	**Range**
Elite Senior	33	12.61 ± 2.28	13.00 (3.00)	8.00-18.00
Non-elite Senior	52	8.96 ± 4.00	9.00 (6.00)	0.00-17.00
High-level Junior	28	12.29 ± 3.25	12.00 (4.50)	6.00-18.00
Non-elite Junior (14-17 years)	38	7.61 ± 2.57	7.00 (4.00)	2.00-13.00
Non-elite Junior (10-13 years)	41	5.00 ± 3.14	4.00 (4.00)	0.00-13.00
Modified Australian football handball test - dominant hand (maximum score 9 points)				
Competition Level	**n**	**Mean ± SD**	**Median (IQR)**	**Range**
Elite Senior	24	4.25 ± 1.33	4.50 (2.00)	1.00-6.00
Non-elite Senior	52	2.90 ± 1.36	3.00 (2.00)	1.00-7.00
High-level Junior	32	3.62 ± 1.56	3.00 (2.00)	0.00-7.00
Non-elite Junior (14-17 years)	27	2.67 ± 1.18	3.00 (2.00)	0.00-4.00
Non-elite Junior (10-13 years)	38	1.97 ± 1.28	2.00 (1.75)	0.00-5.00
Modified Australian football handball test – non-dominant hand (maximum score 9 points)				
Competition Level	**n**	**Mean ± SD**	**Median (IQR)**	**Range**
Elite Senior	27	2.62 ± 1.50	2.00 (2.25)	0.00-5.00
Non-elite Senior	54	1.83 ± 1.54	2.00 (2.00)	0.00-6.00
High-level Junior	32	1.97 ± 1.47	2.00 (1.25)	0.00-6.00
Non-elite Junior (14-17 years)	29	1.15 ± 1.35	1.00 (2.00)	0.00-4.00
Non-elite Junior (10-13 years)	38	0.89 ± 1.06	0.50 (2.00)	0.00-3.00

***Insert Figures 2 and 3 about here. ***

Figure 2. Modified Australian football kicking test score distributions in female Australian football players across five competition levels.

Figure 3. Modified Australian football handballing (dominant hand) test score distributions in female Australian football players across five competition levels.

Table 5: Proportion of players for each competition level across the four quartiles for the modified AF kicking and handballing tests (n (%))

Competition Level	*1st Quartile (<24.9 percentile)*		*2nd Quartile (25-49.9 percentile)*		*3rd Quartile (50-74.9 percentile)*		*4th Quartile (>75 percentile)*	
	mAFK score <6	**mAFHB-D score <2**	**mAFK score 6-9**	**mAFHB-D score 2**	**mAFK score 10-11**	**mAFHB-D score 3**	**mAFK score ≥12**	**mAFHB-D score ≥4**
Elite Senior	0 (0)	1 (4.17)	2 (6.06)	1 (4.17)	9 (27.27)	5 (20.83)	22 (66.67)	17 (70.83)
Non-elite Senior	11 (21.15)	10 (19.23)	16 (30.77)	9 (17.31)	10 (19.23)	17 (32.69)	15 (28.85)	16 (30.77)
High-level Junior	0 (0)	2 (6.25)	7 (25.00)	6 (18.75)	4 (14.29)	7 (21.87)	17 (60.71)	17 (53.13)
Non-elite Junior (14-17 years)	8 (21.05)	5 (18.52)	18 (47.37)	6 (22.22)	10 (26.32)	8 (29.63)	2 (5.26)	8 (29.63)
Non-elite Junior (10-13 years)	25 (60.98)	13 (34.21)	12 (29.27)	15 (39.47)	3 (7.32)	4 (10.53)	1 (2.44)	6 (15.79)

mAFK = modified Australian football kicking test (maximum total score 18 points); mAFHB-D = modified Australian football handballing (dominant hand) test (maximum total score 9 points). Percentages based on number of players who completed the test for each competition level.

In reference to the second study aim, preliminary MANOVA assumptions were explored and revealed no extreme univariate outliers in the data, as assessed by inspection of boxplot, and there were no multivariate outliers, as assessed by Mahalanobis distance (p >0.001). Modified AF kicking and handballing (dominant hand) test scores were determined as approximately normally distributed for each competition level, as assessed by Shapiro-Wilk's tests (p >0.05) and visualisation of histograms and Q-Q plots; however, non-dominant modified AF handballing test scores were not normally distributed for some competition levels. Despite this, a MANOVA has been shown to be robust to deviations from normality [17]. There was no multicollinearity (r = 0.324-0.393, p <0.001); there were approximate linear relationships, as assessed by scatterplot; and there was homogeneity of variance-covariance matrices, as assessed by Box's M test (p = 0.012). Therefore, the MANOVA revealed a large, statistically significant difference between the competition levels on the combined kicking and handballing accuracy variables (F = 13.022, p <0.001, Wilk's Λ = 0.462, η^2_p = 0.227). Follow-up univariate ANOVAs and post-hoc analyses results are shown in Table 6. Only significant competition level differences are reported.

Table 6: Differences in technical skill characteristics represented in the MANOVA between female Australian football players across five competition levels (mean ± SD)

Technical Skill Outcome	n	**GROUP 1** Elite Senior (≥18 years)	n	**GROUP 2** Non-elite Senior (≥18 years)	n	**GROUP 3** High-level Junior (<18 years)	n	**GROUP 4** Non-elite Junior (14-17 years)	n	**GROUP 5** Non-elite Junior (10-13 years)	*p*-value (effect size)	Significant group differences using post-hoc tests
Modified AF kicking test (score 0-18)*	22	12.41 ± 2.11	47	8.77 ± 3.99	28	12.29 ± 3.25	27	6.85 ± 2.05	37	4.86 ± 3.12	**<0.001** (0.514-large)	1>2: $p < 0.001$ 1>4: $p < 0.001$ 1>5: $p < 0.001$ 2<3: $p = 0.001$ 2>5: $p < 0.001$ 3>4: $p < 0.001$ 3>5: $p < 0.001$ 4>5: $p = 0.026$
Modified AF handballing test (dominant hand) (score 0-9)	22	4.41 ± 1.26	47	3.02 ± 1.36	28	3.57 ± 1.60	27	2.67 ± 1.18	37	1.97 ± 1.30	**<0.001** (0.250-large)	1>2: $p = 0.001$ 1>4: $p < 0.001$ 1>5: $p < 0.001$ 2>5: $p = 0.005$ 3>5: $p < 0.001$
Modified AF handballing test (non-dominant hand) (score 0-9)	22	2.55 ± 1.54	47	1.91 ± 1.59	28	2.07 ± 1.51	27	1.15 ± 1.35	37	0.86 ± 1.06	**<0.001** (0.150-large)	1>4: $p = 0.007$ 1>5: $p < 0.001$ 2>5: $p = 0.008$ 3>5: $p = 0.008$

Competition level means and differences analysed on complete cases. **Statistically significant ANOVA *p*-value (< 0.05).** Only significant post-hoc tests results are reported. 1 = elite senior; 2 = non-elite senior; 3 = high-level junior; 4 = non-elite junior (14-17 years); 5 = non-elite junior (10-13 years).

* Indicates Welch ANOVA with estimated ω^2 and Games-Howell post-hoc tests were performed.

4. DISCUSSION

The aims of this study were firstly to profile the kicking and handballing accuracy of female AF players, and secondly, to examine if competition level differences existed in kicking and handballing accuracy. The results confirmed the hypothesis that elite seniors and high-level juniors predominantly scored in the 4th quartile for the modified AF kicking test, demonstrating significantly better kicking accuracy compared to all non-elite competition levels. Elite seniors also significantly outperformed all non-elite players on the modified AF handballing test (dominant hand), primarily scoring in the 4th quartile. Conversely, the hypothesis was not confirmed regarding non-dominant handballing accuracy, as minimal differences were observed between competition levels. Given the novelty of this study, the kicking and handballing test results could offer reference values for athletes, coaches, and/or other practitioners responsible for talent development specific to female AF players. Additionally, the competition level differences found in this study may provide potential implications for coaches regarding talent identification across a developmental pathway.

Kicking accuracy

Elite seniors and high-level juniors primarily scored in the highest (4th) quartile amongst this sample (Table 5) with significantly better kicking accuracy compared to all non-elite competition levels (Table 6), emphasising the importance of accurate kicking skill in elite level match play. While these competition levels had similar mean modified AF kicking test scores, elite seniors were highly distributed around the 75th percentile, compared to the greater variability seen in outcome scores amongst the high-level juniors (Figure 2). Research has demonstrated performance in sport-specific technical skills can help discriminate between selected talented and non-selected juniors in AF (men's) [12], volleyball [18], rugby [19], and soccer [20]. Interestingly, research has demonstrated that match success in the AFLW competition is contributed greater by skilled performance of key players, rather than the collective effort of the team [21]. As research in junior male AF players has demonstrated combined physical and technical skill qualities are associated with effective performance during match play [22], utilising technical skill tests may be beneficial in talent identification and tactical coaching

strategies in female AF. While the findings from this study are limited by the skill tests' parameters, future research is needed to explore the relationship between physical fitness and technical skill and their implications on game performance.

While the use of technical skill tests may be beneficial in talent identification, biological maturity is a challenging confounder of perceiving sports performance in junior players [23]. The youngest players in this study clustered around the 25th percentile for kicking and handballing accuracy (Figures 2 and 3). Recent research has demonstrated motor competence tests were not strongly affected by maturity in junior male AF players [23]. Therefore, inclusion of non-sport specific skill tests may be beneficial for talent identification and development in younger players, which may increase the talent pool and encourage retention of girls in the sport. Future research is warranted to investigate appropriate multidimensional testing batteries to support female AF talent pathways.

It is of note that the non-elite seniors in this study were spread evenly across the kicking accuracy quartiles (Table 5), demonstrating a greater variation in outcome scores (Figure 2). This could be explained by the infancy of opportunities available to participate on an all-female team in southeast Queensland. Namely, these results may reflect the surge of participation rates seen with new teams forming across all competition levels [2], providing new opportunities for senior and junior players to participate in AF. This is somewhat supported by similar years' experience seen in the non-elite senior (median (IQR): 2.00 (2.75) years) and non-elite junior (14-17 years) (mean ± SD: 1.84 ± 1.14) competition levels, despite these groups having significant age differences (Table 3). Further research is needed to see how these technical skill profiles change over time as the current juniors make progress and begin to participate at a senior level.

Handballing accuracy

Regarding dominant handballing accuracy, elite seniors largely scored in the 4th quartile (Table 5) and demonstrated better handballing accuracy than all non-elite competition levels (Table 6). Contrary to the hypothesis, minimal differences between competition levels were found in non-dominant

handballing accuracy scores (Table 6). High-level junior and sub-elite junior male AF players demonstrated greater dominant and non-dominant handballing accuracy scores compared to all female competition levels in this study [12]. Of note, the males demonstrated more symmetrical results compared to the female scores in the present study. These differences may reflect the relative infancy of female participation in AF, and thereby less experience developing handballing skill globally. For example, the elite senior players in this study started playing AF on average at 15 years of age, prior to which they may have been participating in other team ball sports that required predominantly foot skills (e.g. soccer) or hand dominant throwing or shooting sports (e.g. netball, basketball). This lack of exposure may have contributed to their relatively underdeveloped non-dominant handballing skill and possibly explain the partially met hypothesis. In elite male AF players, kinematic differences between dominant and non-dominant handballing techniques have been demonstrated [24], as well as key kinematic movement patterns emerged in accurate players [25]. As performing handballs using either hand has been deemed an integral attribute in AF [26], coupled with the 45% increase in the average number of handballs made per team per game over a 14-year period in male AF match play [27], this research reflects an evolution of game-play in men's AF [28]. Given the infancy of the elite female competition, further research could investigate handballing technical skill in female AF, particularly regarding how it develops over time as the game evolves, as well as in the future with juniors being exposed to AF technical skills at a younger age than those in this study sample.

Competition level differences were more distinct in kicking versus handballing accuracy in this study. As the years of AF experience was low across all competition levels in this sample, this may be explained by the transfer of training, which occurs when prior experiences in one situation can influence performance in another [29]. Therefore, AF kicking technique may be influenced by prior learning opportunities during childhood, as it is a universal movement pattern that can be developed using different ball shapes and sizes in many games and sports, whereas exposure to AF handballing technique is commonly experienced primarily during AF play. These results highlight the need for female AF players to be exposed to training opportunities which emerge non-dominant handballing actions to enhance the development of this key sport attribute. As such, a multidisciplinary approach is encouraged

to support the talent development of female AF players. Coaches can use the results from this study to influence training designs by incorporating competitive play situations [30] to develop players' non-dominant handballing technique. For example, varying rules, such as bonus points allotted when using non-dominant handballing in small-sided games or only using their non-dominant hand during warm-ups, to challenge players to make new actions. To provide more opportunities for skilled behaviour to emerge, coaches could also diversify where junior players play so they experience a variety of scenarios, such as handballing under pressure in the midfield or kicking with more space from the defence. The findings from this study also provide competition level benchmarks to support sport practitioners in the technical skill proficiency of female AF players. Quartile data can assist with identifying areas for improvement, setting individual goals, and tracking player development over time.

General Limitations

An important limitation of this study is the use of measuring sport-specific technical skills using closed tasks and environments, thereby lacking some aspects of representative experimental design [31]. The methods used to assess kicking and handballing accuracy were not completely representative of the intended behavioural setting where these skills occur (i.e., game play) [31]. For example, factors affecting set shot goal-kicking accuracy in AF have been described, including task, environment, and personal constraints, that can influence performance, and thereby the outcome of scoring a goal or not [32]. A number of these constraints presented in match play conditions were not represented in the modified AF kicking or handballing tests used in this study, therefore the findings from this study may only differentiate between skilled and less skilled performers on the test performance [33]. Additionally, due to the challenges associated with data collection in constrained environments, no familiarisation session occurred prior to testing. Despite this, the use of closed tasks and environments allowed for easier or more feasible implementation in an applied setting. Given the infancy of female AF, this method provided initial insight into kicking and handballing accuracy in female AF players across a developmental pathway. While research has demonstrated a link between technical skill tests and competitive performance [22], future research is needed to investigate this in female AF. Therefore, as the skills tests used lack some level of representativeness, generalisability regarding the findings from

this study may be limited [34]. Recent research has been published on new AF kicking tests aimed to capture more representative tasks [35, 36] and using small-sided games [37]; however, to the author's knowledge, these have yet to be conducted in female players or designed with constraints specific to the female game. This offers an enticing platform for future research by sport scientists and researchers to incorporate representative learning designs [34], thereby extending our findings. Additionally, future research should investigate the use of technical skills and non-sport specific skills in combination with other expertise dimensions, such as physical fitness and perceptual abilities, to determine multidimensional testing batteries specific to the female AF talent pathway.

Secondly, it is important to note that the maximum handballing score achieved for any player in the current study with their dominant and non-dominant hands, were seven and six, respectively, out of nine possible points each. As such, the competition level mean scores for handballing accuracy were clustered towards the bottom of the scale, which differed to that seen in male elite senior AF players [12]. This suggests a potential floor effect indicating that the test may not be adequate to capture handballing accuracy in this population. Therefore, while it appears that elite seniors demonstrate better handballing accuracy compared to the non-elite groups, these mean differences are based on only one or two points, indicating that handballing skill is under-developed in female AF players globally.

Practical Recommendations

- Sport practitioners can use the quartile results from this study as benchmarks when developing technical skill pertinent to female AF participation pathways.
- Coaches should include training designs that incorporate competitive play situations, such as altering rules during small-sided training games, to develop contextually relevant non-dominant handballing techniques in female AF players.
- Sport scientists and researchers can further explore the findings from this study through the integration of more game-like, or representative, performance tests (i.e., small-sided games) to allow deeper insight into performance differences between female AF developmental levels.

5. Conclusion

This study provides preliminary insight into kicking and handballing accuracy in female AF players across a developmental pathway. Findings indicated elite seniors and high-level juniors had better kicking accuracy than all non-elite competition levels when performing the tests used in this study. Similarly, elite seniors had better dominant handballing accuracy than the other non-elite competition levels, however minimal differences were found for non-dominant handballing accuracy. Quartile reference data suggestive of competition level is applicable to athletes and coaches regarding skill development for junior to senior and non-elite to elite participation pathways. Thus, while these exploratory findings are specific to the parameters of the technical skill tests, the results from this study may assist coaches, sport practitioners, and sport scientists to better understand talent development in female AF players across the developmental pathway. Further research is needed to explore the relationship between technical skill and other areas defining sport expertise, such as physical fitness and perceptual capabilities, as well as their influence on game performance in female AF players. Additionally, future research should incorporate representative skill tests in the current population, such as small-sided games, while also examining the evolution of technical skill in the female AF over longitudinal timescales in response to the continued establishment of developmental pathways.

6. Declarations

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Disclosure of Interest

The authors report no conflict of interest.

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Ethics approval and consent to participate

All players were supplied a study explanatory statement, volunteered to participate, and provided informed consent prior to participation. For those players under 18 years of age, parent (or guardian) consent was also obtained. The study was approved by the Bond University Human Research Ethics Committee (16116).

Availability of data and material

Supporting data for individual participants is not available to be shared publicly, as at the time of gaining ethical approval for this study, participants were assured that their data would be published only as de-identified data included together with the collective results of the other participants.

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