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Lower limb musculoskeletal screening in elite female Australian football players

Benjamin F. Mentiplay [a, b, *], Andrea B. Mosler [a], Kay M. Crossley [a], David L. Carey [a, b], Kathleen Sakadjian [c], Riley Bodger [d], Benjamin Shipperd [e], Andrea M. Bruder [a, b]

[a] La Trobe Sport and Exercise Medicine Research Centre, La Trobe University, Australia
[b] School of Allied Health, Human Services and Sport, La Trobe University, Australia
[c] Melbourne Football Club AFLW, Australia
[d] Carlton Football Club AFLW, Australia
[e] Collingwood Football Club AFLW, Australia

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ABSTRACT

Objective: To report physical characteristics of lower-limb strength, endurance, range of motion, balance, and pain during adductor squeeze in elite female Australian Football (AF) players, and to examine the effect of limb dominance, previous AF experience, age, and previous level of sports participation on these characteristics.
Design: Cross-sectional study.
Setting: Three elite AF clubs.
Participants: Eighty-five female players. All were aged ≥18, contracted for the 2018 season, and participated in pre-season training.
Main outcome measures: The physical characteristic assessments included; pain on adductor squeeze, weight-bearing lunge, side bridge, isometric hip abduction and adduction strength, and the modified star excursion balance test.
Results: The adductor squeeze had low pain scores, with 93% of players scoring ≤2 on the numerical rating scale. Other assessment results were (mean ± SD): 10.8 ± 2.7 cm for weight-bearing lunge, 95 ± 39s for side bridge, 1.85 ± 0.23 and 1.85 ± 0.36Nm/kg for hip abduction and adduction strength respectively, and 92 ± 8% for the modified star excursion balance test. There was no clinically relevant effect of limb dominance, previous AF experience, age, or previous level of sports on physical characteristics.
Conclusions: Physical characteristics for five assessments are reported. These data can be used for comparison purposes in the screening and clinical management of elite female AF players.

1. Introduction

The inception of the Australian Football League Women's (AFLW) competition in 2017 resulted in women competing at the elite level of Australian Football (AF) for the first time. While this new league provided significant public interest and increased female participation in AF across all levels, limited information is currently known on the injuries faced by elite female AF players. Recent work in non-elite female AF players has suggested that the majority of injuries are to the lower-limb, with the most common being knee and ankle injuries (Fortington, Donaldson, & Finch, 2016; Fortington & Finch, 2016). Previous research in female soccer has shown differences in epidemiology between male and female soccer players across a range of injuries (Hägglund, Waldén, & Ekstrand, 2009; Larruskain, Lekue, Diaz, Odriozola, & Gil, 2018; Mufty et al., 2015). For example, female soccer players have a 2.2 times increased risk of anterior cruciate ligament (ACL) injury compared to males (Montalvo et al., 2018). Australian Football is a physically demanding, multi-directional contact sport (Gray & Jenkins, 2010), involving overhead marking with high impact landing, and tackling from any angle. The difference in injury risk for females compared to males, combined with the lack of exposure

* Corresponding author. La Trobe Sport and Exercise Medicine Research Centre, La Trobe University, Kingsbury Drive, Bundoora, Victoria, 3086, Australia.
E-mail address: b.mentiplay@latrobe.edu.au (B.F. Mentiplay).

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to AF specific demands and loading, has created a 'perfect storm' resulting in high injury rates in the first two seasons of AFLW. The 2018 AFLW Injury Report (Australian Football League, 2018) reported differences in injury incidence between elite male and female AF players, including the alarming statistic that females have a 9.2 times increased risk of ACL injuries compared to males (6.47 ACL injuries per 1000 player hours in the 2018 AFLW compared with 0.70 per 1000 player hours in the 2017 AFL men's competition).

Understanding the physical characteristics (such as: strength, range of motion, balance) of AFLW players could assist in the development of targeted primary and secondary injury risk reduction strategies (Wollin, Thorborg, Welvaert, & Pizzari, 2018). Establishing normative reference values within a particular cohort allows for comparison of individual results to the relevant sporting population (Cools et al., 2016; Mosler et al., 2017). However, data is needed that are sport, sex and participation level specific (e.g. elite versus recreational). Whilst research is emerging with a focus on female AF players (Black et al., 2018a, 2018b, 2019; Clarke et al., 2018, 2019), data on various physical characteristics have yet to be established in elite female AF players. Furthermore, demographic data such as previous sporting experience and AF history in this population is unknown. The physical characteristics specific to elite female AF players could also be used as a benchmark for players returning to the sport post-injury or to identify players who may benefit from targeted training. There is conflicting evidence on whether musculoskeletal screening tests of various physical characteristics can predict future injury in athletic populations (Bahr, 2016; Bakken et al., 2018; Mosler et al., 2018; Steffen et al., 2017; van Dyk et al., 2017). Nonetheless, these assessments provide important information for use by clinicians in injury management, including detection and prevention, as well as player development, rehabilitation, and return to sport.

Therefore, the primary aim of this study was to report the physical characteristics of elite female AF players. As the majority of injuries in female AF occur to the lower-limb (Australian Football League, 2018; Fortington et al., 2016), five commonly used assessments that have shown relationships with lower-limb injury (Gabbe, Finch, Wajswelner, & Bennell, 2004; Leetun, Ireland, Willson, Ballantyne, & Davis, 2004; Plisky, Rauh, Kaminski, & Underwood, 2006; Smith, Chimera, & Warren, 2015; Thorborg et al., 2014, 2017; Wollin, Pizzari, Spagnolo, Welvaert, & Thorborg, 2018) were chosen that pertain to lower-limb range of motion, endurance, strength, balance, and pain during adductor squeeze. The secondary aim was to examine the effect of leg dominance, AF experience, age, and highest level of previous sports participation on the results.

2. Methods

A convenience sample of elite female AF players participated in this cross-sectional study, recruited from three of four Melbourne-based AFLW clubs (eight clubs were involved nationally in the first two seasons of the AFLW). The players were tested in the pre-season of the 2018 AFLW season (November 2017 to January 2018). All players were 18 years of age or older, contracted for the 2018 AFLW season, healthy, and fully participating in pre-season training at the time of testing. The study was approved by the La Trobe University Human Ethics Committee (approval number S17-217), and all players provided written informed consent.

Players were assessed during a single session at their respective AFLW club. Demographic information was collected from each player including; age, height, weight, and leg dominance (the foot they preferred to kick a ball). Players were also asked two questions to determine their level of AF experience, and the highest level for any other sport they previously participated in regularly:

(1) How many years have you played AF (at any level)?
(2) What was the highest level attained for any other regular sports you have participated in (categorised as: no previous sport, recreational level, regional representative, state representative and national representative)?

Multiple players attended the testing concurrently, with a random order for the participants completing each assessment (circuit-based testing). A standardised warm-up was provided to the players prior to testing, which consisted of running on the spot, star jumps and squats. At least 1 min of rest was provided between each test. The five tests that players completed (Fig. 1) were chosen based on previous literature in musculoskeletal screening (Bennell, Talbot, Wajswelner, Techovanich, & Kelly, 1998; Evans, Refshauge, & Adams, 2007; Freke et al., 2018; Thorborg et al., 2011, 2017) and included: pain on adductor squeeze; weight-bearing lunge; side bridge; isometric strength of hip abduction and adduction; and the modified star excursion balance test (SEBT). Two physiotherapists, who were experienced and trained with the protocol, assessed isometric strength. For the remaining four assessments, various assessors (physiotherapists and exercise scientists) were used at each of the three clubs (the same assessors were used within each club). A standardised protocol was used to enhance consistency between assessors and each assessor attended a 30-min training session prior to testing.

Two adductor squeeze tests, one at 0° and one at 45° of hip flexion, were used to determine the presence of adductor-related groin pain (Fig. 1A and B) (Mosler et al., 2018). Pain on adductor squeeze tests (Mosler et al., 2018; Wollin, Pizzari et al., 2018) are valid indicators of groin pain in male soccer players with intra-rater reliability (concordance correlation coefficient = 0.90) previously established (Thorborg et al., 2017). The two tests were performed in supine, with the hips at 0° or 45° of flexion, with instructions to squeeze as hard as possible for 5 s. For the test at 0°, the assessor placed their forearm between the medial malleoli (Thorborg et al., 2017), while for the test at 45°, the assessor placed their hand between the medial femoral condyles. Players were asked to rate any pain experienced in the hip and groin region using a 0–10 Numerical Rating Scale, with 0 being 'no pain' and 10 being 'the worst possible pain' (Thorborg et al., 2017). One trial was performed for both tests, consistent with standard protocol (Thorborg et al., 2017).

Participants performed a weight-bearing lunge test to examine ankle dorsiflexion range of motion (Fig. 1C) (Bennell et al., 1998). The intra- (intraclass correlation coefficient (ICC) = 0.65 to 0.99) and inter-rater (ICC = 0.80 to 0.99) reliability for this test has previously been established (Powden, Hoch, & Hoch, 2015). As previously described (Konor, Morton, Eckerson, & Grindstaff, 2012), participants placed their foot along the line of the tape measure (barefoot without shoes or socks); with the opposite foot comfortably on the floor behind them ready to perform a lunge. Participants were instructed to lunge forward until their knee made contact with the wall, whilst ensuring their heel remained on the floor. The foot was then moved back in 1 cm increments until the participant was unable to touch their knee to the wall without lifting their heel. This procedure was repeated twice on both feet, with the highest recorded distance without lifting their heel (greater range of motion) used for analysis.

The side bridge (or side plank) test was used to examine trunk muscle endurance (Fig. 1D) (Evans et al., 2007). The intra- (ICC = 0.81 to 0.85) and inter-rater (ICC = 0.82 to 0.91) reliability has previously been established for this test (Evans et al., 2007). The participant was positioned in side-lying with only the foot (in their usual footwear) and forearm touching the ground and the opposite

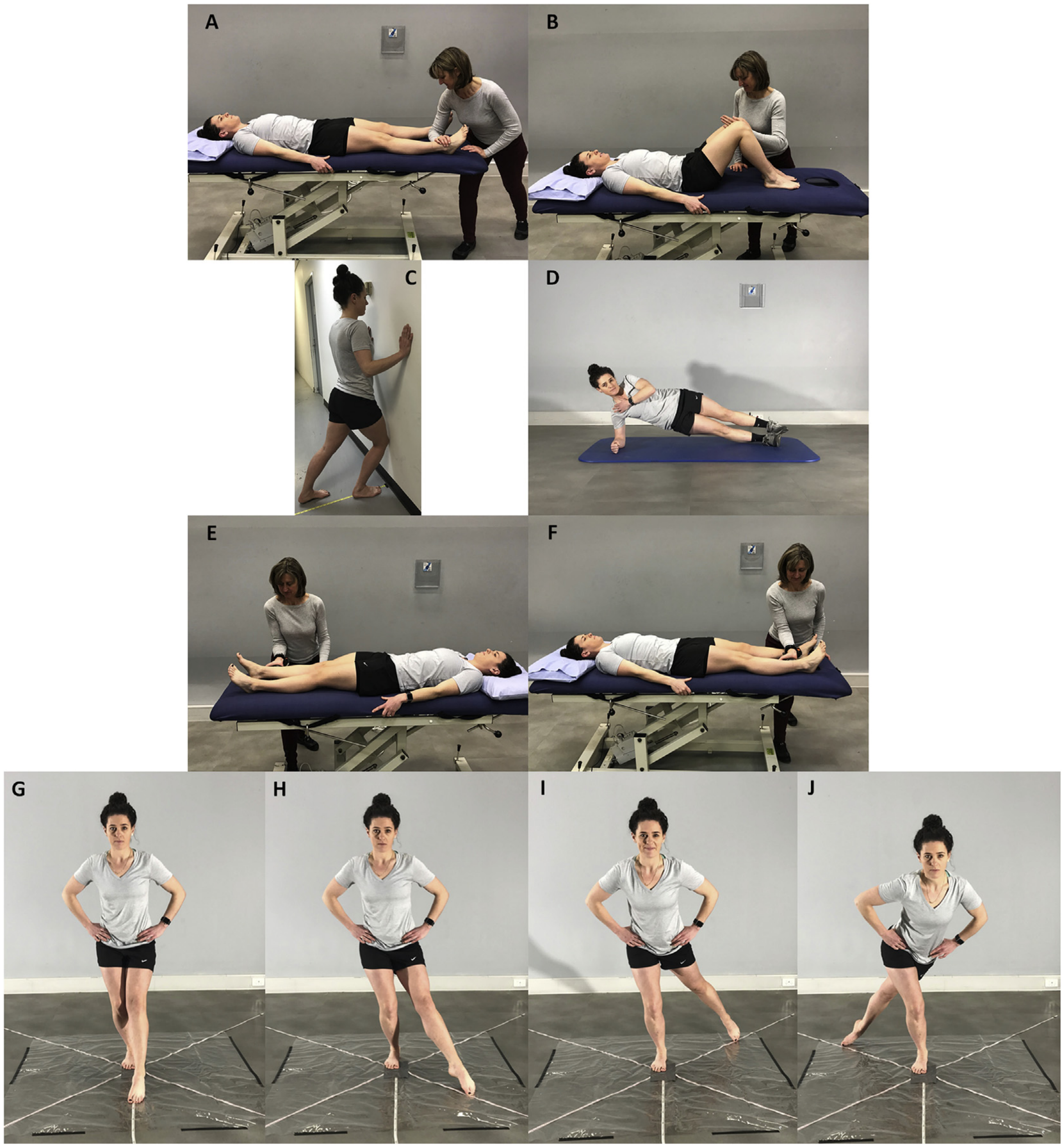

Fig. 1. The five assessments of various physical characteristics.
A) pain on adductor squeeze test at 0°; B) pain on adductor squeeze test at 45°; C) weight-bearing lunge test; D) side bridge; E) isometric hip abduction strength; F) isometric hip adduction strength; G) star excursion balance test - anterior; H) star excursion balance test - anteromedial; I) star excursion balance test - posteromedial; J) star excursion balance test - posterolateral.

arm placed across the chest. Participants were instructed to hold this position for as long as possible on each side, with a 60 s break between sides. Time (in seconds) was recorded until the participant could no longer hold the position and the hip touched the ground. One trial was performed on each side.

Isometric strength of hip abduction and adduction was measured in supine using a Commander PowerTrack II hand-held dynamometer (JTECH Medical Industries, Inc., UT USA; Fig. 1E and F) (Thorborg, Petersen, Magnusson, & Hölmich, 2010). The intra- (ICC = 0.87 to 0.98) and inter-rater (ICC = 0.92 to 0.98) reliability of the following testing procedure has previously been established (Mentiplay et al., 2015; Thorborg et al., 2010). Participants lay in supine, with their hips and knees extended and stabilised themselves by holding the side of the plinth. A line was marked for dynamometer placement around the leg (to cover both lateral and medial aspects) at 8 cm proximal to the most prominent part of the lateral malleolus. Participants were instructed to push as hard as they could against the dynamometer while the assessor maintained a static position (isometric 'make' test). One sub-maximal practice trial was provided prior to three recorded trials, and both limbs were assessed. As the testing was performed in a clinical setting, and due to varying time restrictions from each club, 52% of players had three recorded trials, 34% had two and 14% had one trial. The peak force value in Newtons was converted to torque (force multiplied by lever arm – distance in metres between the dynamometer line and the greater trochanter (Hanna, Fulcher, Elley, & Moyes, 2010)) and normalised to body mass (torque divided by body mass in kilograms). The highest value recorded across the trials for both limbs for hip abduction and adduction was used for analysis (reported in both N and Nm/kg as well as an adduction:abduction ratio). Hip adduction strength was excluded from the dataset if a participant scored greater than 2 on the Numerical Rating Scale for the pain on adductor squeeze tests to ensure the strength data reflected a pain-free population. Pain greater than 2 on the adductor squeeze test was chosen as previous work has suggested that scores of 0–2 indicate no or very minor hip and groin sporting-function restrictions (Thorborg et al., 2017).

The modified SEBT was used to assess dynamic balance (Fig. 1G to J) (Hertel, Miller, & Denegar, 2000). The intra- (ICC = 0.85 to 0.96) and inter-rater (ICC = 0.58 to 0.93) reliability of the SEBT has previously been established (Hertel et al., 2000). The SEBT involves standing on one leg (barefoot without shoes or socks) and reaching in set directions with the other leg. A practice trial was provided on both legs to ensure the participant understood the requirements of the test. As all eight directions of the SEBT are significantly correlated leading to redundancy ($r = 0.43$ to 0.92; $p < 0.05$) (Hertel, Braham, Hale, & Olmsted-Kramer, 2006), reach was measured in four directions (based on previous research (Freke et al., 2018) and to include the three directions of the Y-balance test) in the following order: anterior, anteromedial, posteromedial, and posterolateral. Participants were instructed to reach as far as possible with their hands on their hips along a tape measure running in each direction and lightly tap their toe on the tape measure, then return to an upright standing position. Reaching was repeated in a particular direction if the participant lost balance, moved the stance foot, removed their hands from their hips, or did not lightly touch the tape measure (e.g. missed the tape measure or put excessive weight through the reaching foot) as per previous protocols (Freke et al., 2018). Participants performed two trials of all directions on each leg, with the highest recorded distance used for analysis. The distances reached in each of the four directions were reported, along with a composite SEBT score, which was calculated as the sum of three directions (anterior, posteromedial, and posterolateral) (Plisky et al., 2006). These three directions are commonly used as the Y-balance test (Coughlan, Fullam, Delahunt, Gissane, & Caulfield, 2012; Smith et al., 2015), and were used in this study to provide a comparison to previous work. Also reported was the normalised distances as a percentage of leg length (reach distance divided by leg length multiplied by 100).

All data were analysed using *R* statistical software (R Core Team, 2018). Descriptive statistics were used to determine the mean, standard deviation, range, median and quartiles for each test, including graphic presentation using histograms and box plots. Data were stratified by dominant and non-dominant sides for all tests except the pain on adductor squeeze tests as they measure pain bilaterally. The raw and normalised values for the measures of hip strength and the modified SEBT were analysed. The effect of leg dominance, AF experience, age, and highest level of previous sports participation were examined for each of the tests (except for the adductor squeeze test) using linear mixed effect models (Bates, Mächler, Bolker, & Walker, 2015), with a random intercept fitted for each participant.

3. Results

A total of 85 participants were involved in the study with their characteristics provided in Table 1 and presented visually in Appendix A.1. Data regarding the number of years playing AF and previous sporting history were collected from 84/85 and 84/85 players respectively (two separate participants). There was a wide range of AF playing experience and previous sporting history (Table 1 and Appendix A.2).

All players (n = 85) completed the weight-bearing lunge test, isometric hip abduction strength and the modified SEBT. One player did not complete the pain on adductor squeeze tests, or hip adduction strength testing due to a recent groin injury. Another player did not complete adduction strength testing on their non-dominant side as they experienced discomfort during testing on that side. The results of a further 11 players were removed from hip adduction testing for both sides due to having pain greater than 2 on the adductor squeeze tests. Two players did not complete the side bridge tests, with one player having a shoulder injury (dominant side not tested) and one other player did not have their time recorded during testing for both sides.

Table 1
Participant data.

	Elite female AFLW players (n = 85)
Age *years*	25 ± 5 (18–38)
Height *m*	1.71 ± 0.07 (1.58–1.94)
Weight *kg*	67 ± 7 (45–88)
BMI *kg/m²*	22.9 ± 2.0 (17.9–28.4)
Leg dominance *right (%)/left (%)*	74 (87%)/11 (13%)
AF experience (n=84)* *years*	7.5 ± 5.4 (0–20)
Highest previous sporting level (n=84)* *n (%)*	
No other sporting history	4 (4.76%)
Recreational level	3 (3.57%)
Regional representative	21 (25.00%)
State representative	36 (42.86%)
National representative	20 (23.81%)

Note: data presented as mean ± standard deviation (range), or frequency (percentage) for leg dominance and highest previous sporting level. * = data from 1/85 and 1/85 players were not collected for Australian Football (AF) experience and previous sporting level respectively (two separate participants).

The results for each test are shown in Table 2. Graphic representation of the results for each test are included in Appendix A.3-A.6. Briefly, for the dominant limb the results (mean ± SD) were: 10.8 ± 2.5 cm for the weight-bearing lunge, 95.6 ± 41s for the side bridge, 1.88 ± 0.22 and 1.86 ± 0.38Nm/kg for hip abduction and adduction strength respectively, and 92.2 ± 8.2% for the modified SEBT composite score. The adductor squeeze had relatively low pain scores, with the majority (93%) of players scoring ≤2 on the Numerical Rating Scale.

Only participants with data for all variables (limb dominance, AF experience, age, and highest previous sporting level) were included in the linear mixed model analysis (n = 83). The results showed no clinically meaningful effect of leg dominance, AF experience, age, or highest previous sporting level on the physical characteristics (results presented in Appendix A.7). Limb dominance had a small, non-zero effect on hip abduction strength with the non-dominant limb weaker than the dominant limb (−4.77N [95%CI -7.45 to −2.09N]; −0.06Nm/kg [95%CI -0.09 to −0.03Nm/kg]).

4. Discussion

Our study is the first to report the results of standardised musculoskeletal screening assessment in elite female AF players. Despite the wide range in previous experience playing AF and the highest level of previous sport, we found no effect on the physical characteristics for previous AF experience or highest previous sporting level. Additionally, lower-limb dominance and age did not have a meaningful effect on test results. This emerging data may now be used in the assessment and management of elite female AF players, and to help understand the profiles of this relatively new and emerging sporting population.

The physical characteristic data described in our study of elite female AF players can be compared to other cohorts. For the pain on adductor squeeze tests, our results showed no player reported a score greater than 5 (a level which indicates that a player should stop current football activity and seek attention; Thorborg et al., 2017). Interestingly, our data showed 32% of participants reported pain (a score >0) at either testing position of the adductor squeeze, suggesting that this test is provocative in a healthy female AF population, even in the pre-season period. However, we cannot compare our results to other research in females as none is

Table 2
Physical characteristics of elite female Australian Football players.

Test	Unit	Mean ± SD	Minimum	Q1	Median	Q3	Maximum
Pain on adductor squeeze							
Performed at 0° (n = 84)	***NRS***	0.5 ± 1.0	0.0	0.0	0.0	0.0	4.0
Performed at 45° (n = 84)		0.5 ± 1.0	0.0	0.0	0.0	0.0	5.0
Weight bearing lunge							
Dominant (n = 85)	***cm***	10.8 ± 2.5	4	9	11	13	15
Non-dominant (n = 85)		10.8 ± 2.9	4	9	11	13	18
Side bridge							
Dominant (n = 83)	***seconds***	95.6 ± 41.0	38	67.5	88	109	300
Non-dominant (n = 84)		93.8 ± 37.6	37	63.75	88	117.75	216
Isometric hip abduction							
Dominant (n = 85)	***N***	150.8 ± 18.7	105	136	149	165	204
Non-dominant (n = 85)		146.4 ± 21.4	79.2	134	149	158	206
Dominant (n = 85)	***Nm/kg***	1.88 ± 0.22	1.43	1.73	1.88	2.03	2.39
Non-dominant (n = 85)		1.82 ± 0.25	1.11	1.67	1.80	2.01	2.54
Isometric hip adduction							
Dominant (n = 73)	***N***	148.3 ± 29.5	79.2	132	149	171	217
Non-dominant (n = 72)		145.5 ± 28.4	79.2	126.5	145	167.5	203
Dominant (n = 73)	***Nm/kg***	1.86 ± 0.38	1.00	1.58	1.87	2.09	2.79
Non-dominant (n = 72)		1.83 ± 0.35	1.02	1.58	1.81	2.03	2.60
Isometric ADD:ABD ratio							
Dominant (n = 73)	***ADD:ABD***	1.00 ± 0.17	0.62	0.87	1.01	1.11	1.41
Non-dominant (n = 72)		1.01 ± 0.17	0.64	0.88	1.00	1.12	1.36
Star excursion balance test (cm)							
Anterior							
Dominant (n = 85)	***cm***	65.9 ± 7.0	45	61	65	70	95
Non-dominant (n = 85)		66.1 ± 7.3	50	62	65	70	100
Dominant (n = 85)	***%***	72.8 ± 6.8	51.1	68.5	72.3	76.1	93.1
Non-dominant (n = 85)		73.1 ± 7.3	56.8	68.2	72.8	77.3	98.0
Anteromedial							
Dominant (n = 85)	***cm***	72.1 ± 8.6	57	68	71	74	116
Non-dominant (n = 85)		71.7 ± 8.1	56	67	71	76	112
Dominant (n = 85)	***%***	79.6 ± 8.0	63.0	74.0	79.5	83.7	113.7
Non-dominant (n = 85)		79.3 ± 8.1	61.8	73.8	79.1	84.5	109.8
Posteromedial							
Dominant (n = 85)	***cm***	94.0 ± 9.5	72	89	95	99	120
Non-dominant (n = 85)		94.0 ± 8.8	75	88	95	99	117
Dominant (n = 85)	***%***	103.9 ± 9.7	81.8	96.9	103.3	110.6	128.0
Non-dominant (n = 85)		103.9 ± 9.8	78.4	97.7	104.2	110.5	125.0
Posterolateral							
Dominant (n = 85)	***cm***	90.5 ± 10.9	63	85	90	97	124
Non-dominant (n = 85)		90.5 ± 11.4	58	80	94	99	120
Dominant (n = 85)	***%***	99.9 ± 10.9	71.6	91.8	101.1	106.8	126.7
Non-dominant (n = 85)		100.0 ± 12.1	65.9	90.8	102.2	109.4	122.2
Composite*							
Dominant (n = 85)	***cm***	250.4 ± 25.0	183	237	249	263	332
Non-dominant (n = 85)		250.6 ± 25.0	183	229	252	267	337
Dominant (n = 85)	***%***	92.2 ± 8.2	69.3	87.0	92.0	97.8	108.5
Non-dominant (n = 85)		92.3 ± 8.7	69.3	86.5	92.3	98.9	110.1

Note: Refer to the text for reasons of missing data. Q1 and Q3 are the 25th and 75th percentile respectively. NRS = numerical rating scale with 0 being 'no pain' and 10 being 'the worst possible pain'. Hip strength reported as raw and normalised values (normalised results converted to torque and normalised to body mass). ADD:ABD ratio = adduction:abduction ratio with values greater than 1 indicating stronger adductors and values below 1 indicating stronger abductors. Modified star excursion balance test results also reported as raw and normalised values (normalised to leg length and reported as a percentage). * = the composite star excursion balance test value is the result of adding three directions together for the raw score or an average for the normalised score (anterior, posteromedial, and posterolateral).

available for this test in female athletes. Whilst variable responses to any pain provocation test are likely across a season, providing a baseline characteristic in pre-season in this unique population assists with the development of normative reference values for this test in female athletes. One previous study in elite youth male soccer players found higher pain levels compared to the current study, with 45% of participants reporting pain on the adductor squeeze test (Wollin, Pizzari et al., 2018). For the weight-bearing lunge test, our study reported an average of 10.8 cm. This average was slightly lower than results reported in males; with a recent study in professional male soccer players reporting 11.2 cm for uninjured limbs (van Dyk, Farooq, Bahr, & Witvrouw, 2018), and another study in elite male AF players reporting a preseason average of 11.4 cm (Esmaeili et al., 2018). This finding may indicate a need to normalise the weight bearing lunge to height or limb length to allow for direct comparison across cohorts. Limited data exists on normative values for the side bridge test, although one study reported (in 47 elite (state level) female athletes of various sports) a mean time of 91 s (Evans et al., 2007), similar to the averages in our study of 95.6 and 93.8 s on the dominant and non-dominant sides respectively.

For hip strength, a previous study of 86 elite male soccer players showed higher strength (dominant side abduction = 2.35 ± 0.33 and adduction = 2.45 ± 0.54Nm/kg; ratio dominant = 1.04 ± 0.18 and non-dominant = 1.06 ± 0.17) (Thorborg et al., 2011) compared to the elite female AF players in the current study. However, another study in 16 uninjured elite and sub-elite male soccer reported almost identical results to our study (dominant side abduction = 1.89 ± 0.25 and adduction = 1.87 ± 0.43Nm/kg; ratio dominant = 0.99 ± 0.18) (Thorborg et al., 2014). Despite these differences when comparing to previous literature in elite and sub-elite males, the normative reference values may change if elite female AF becomes more professional with full-time players. A study in a comparable population of female high school soccer players examined eccentric hip strength ('break' test) and reported strength values of 1.98 ± 0.44 and 1.54 ± 0.29Nm/kg for hip abduction and adduction strength respectively (McHugh, Tyler, Tetro, Mullaney, & Nicholas, 2006). The lower adduction strength results compared to previous work could be due to a number of methodological differences between our study such as; different testing methods (e.g. use of the greater trochanter or anterior superior iliac spine for measuring lever arm length), smaller sample size, or the different sport of the participants. These findings emphasise the need to compare hip strength test results to normative reference data established in an equivalent cohort with regards to sex, age, sport, and testing methods. In our study, the average normalised composite value for three directions of the modified SEBT was 92 ± 8%. The value from our study is lower than those reported in: 28 female College soccer players (102% on the Y balance test) (Chimera, Smith, & Warren, 2015), 44 professional male soccer players (101.8% on the Y balance test) (Butler, Southers, Gorman, Kiesel, & Plisky, 2012), and 105 female High School basketball players (98.4% on the SEBT) (Plisky et al., 2006). These findings suggest that the modified SEBT may be a valuable test to screen in female AF populations. The differences in screening results of our cohort with previous studies highlights the need for population specific normative reference data.

No clinically meaningful effect of limb dominance was found on our results. Hip abduction strength on the non-dominant limb showed a small effect to be 4.77N weaker than the dominant limb, however the clinical importance of this effect is questionable, as previous research has reported a standard error of measurement for hip abduction strength using the same protocol of up to 4.2N and a minimal detectable change of up to 11.6N (Thorborg et al., 2010). Previous AF experience, age, and highest level of previous sport participation had no effect on the screening test results. It would be reasonable to hypothesise that female AF players who have been involved in other elite sporting environments or players that have no experience with AF may perform differently on certain tests. However, the results of our study suggest that all players performed at a similar level, irrespective of previous AF experience, age, or highest previous sporting level. These unexpected findings may be due to either the heterogeneity or sample size of our cohort. In future years, with improved development pathways for female AF players, and more exposure for females to AF across all levels of participation, the physical characteristics could potentially reveal differences for elite female AF players.

The aim of our study was to establish preliminary data on the physical characteristics determined from musculoskeletal screening of elite female AF players from a new and evolving sporting competition. Clinicians working with female AF players will now be able to compare the results from their players to our data in the screening, prevention and management of injuries. These data may be used to identify impairments, track progress through rehabilitation, determine the efficacy of performance-based training programmes, and establish individualised return-to-sport guidelines.

Our study does have some limitations. Only five commonly used tests were examined, and further research is needed to understand the profiles of elite female AF players in other important clinical assessments (e.g. quadriceps/hamstring strength or upper limb assessments). The hip abduction and adduction strength assessments involved differing amounts of trials for each participant. Our analysis used the best of available trials for each participant, with previous research showing strong reliability for this method for both two (Mentiplay et al., 2015) and four (Thorborg et al., 2010) trials. We also removed the hip adduction strength data from participants who reported pain during the adductor squeeze tests. Whilst this reduced the number of participants for hip adduction strength, this ensured our normative strength data was obtained from players who were free of groin pain. Additionally, the two questions used to determine previous AF experience and highest previous level of sport may be subject to recall bias, with further research needed to examine the long-term impact of previous sporting experience. There could also be heterogeneity within the groups when categorising previous sporting level into five pre-determined groups (e.g. a national level would involve different training loads depending on the sport and age of participation at that level). The sample size of 85 players is relatively low to represent normative data. However, when considering the 2018 AFLW season contained only 8 clubs with approximately 30 players at each club, the 85 included participants represents approximately 35% of the total population of AFLW players. Another limitation of our study is the evolving nature of the AFLW, which may result in changes to the physical profile of the players over the coming seasons. With the AFLW planned to expand to 14 clubs by the 2020 season, the sizeable addition of future players to the current group may impact on the physical profiles we have presented.

5. Conclusion

This study reports the physical characteristics for five musculoskeletal screening assessments of elite female AF players participating in the 2018 AFLW season. There was no clinically relevant effect of limb dominance, previous experience with AF, age, or highest previous level of sports participation on the results. These data can be used to help understand the profile of elite female AF players and used by clinicians for injury management, detection and prevention. Further research is required to build on the current study to examine other assessments, as well as to determine how these physical characteristics change within and between seasons as the AFLW competition evolves over time.

Ethical approval

Ethical approval was obtained for this study from the La Trobe University Human Ethics Committee (approval number S17-217).

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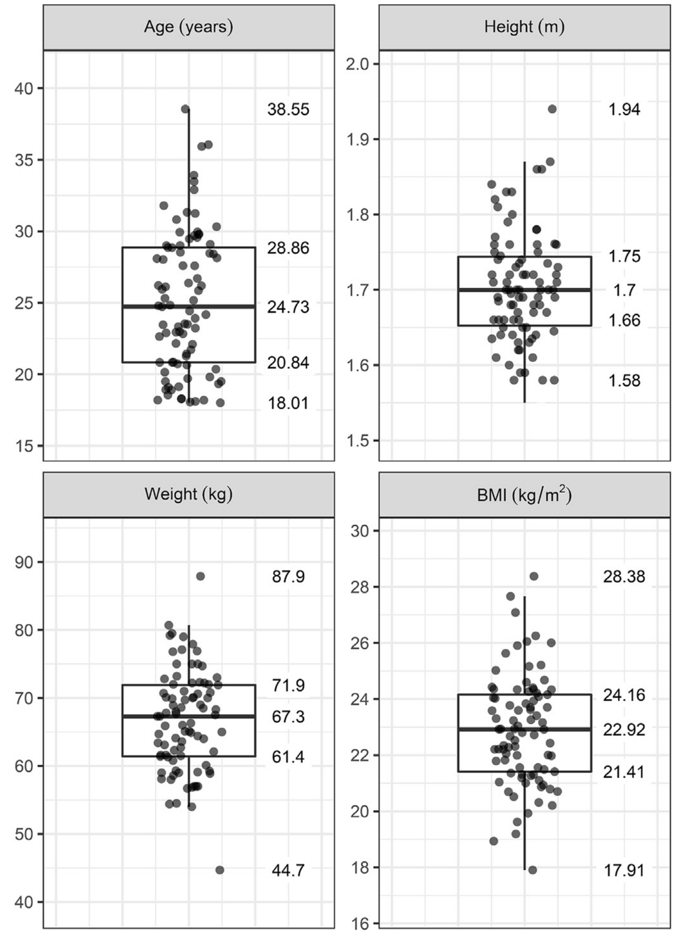
Conflicts of interest

None declared.

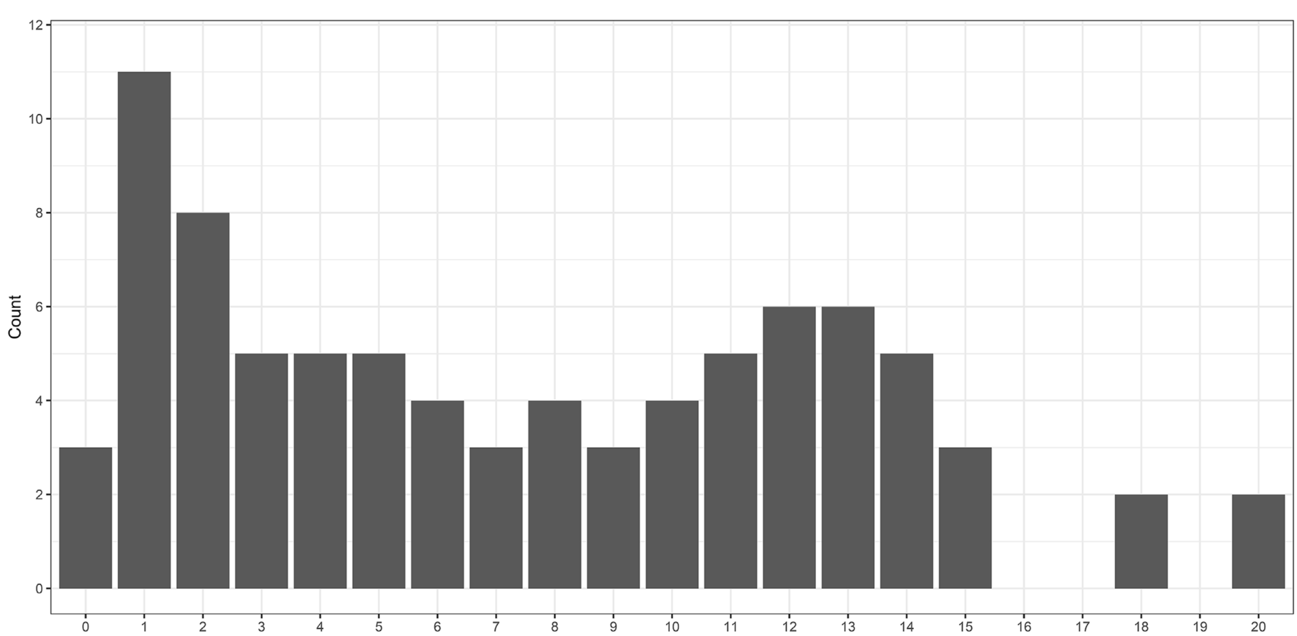
Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ptsp.2019.08.005.

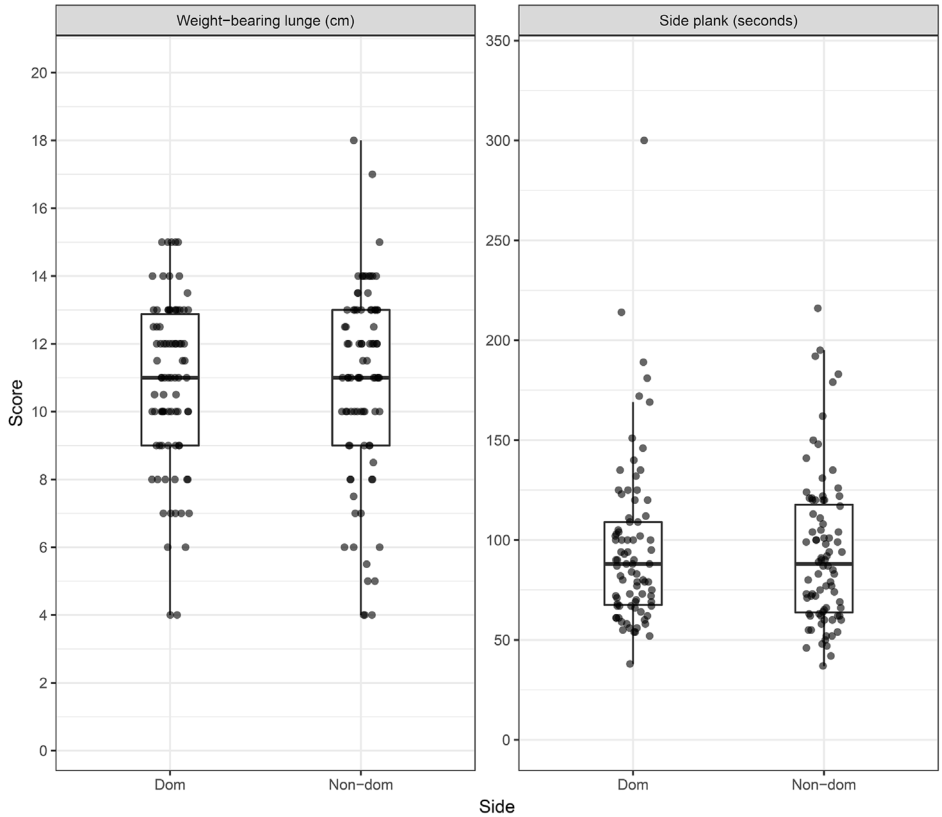
Appendix



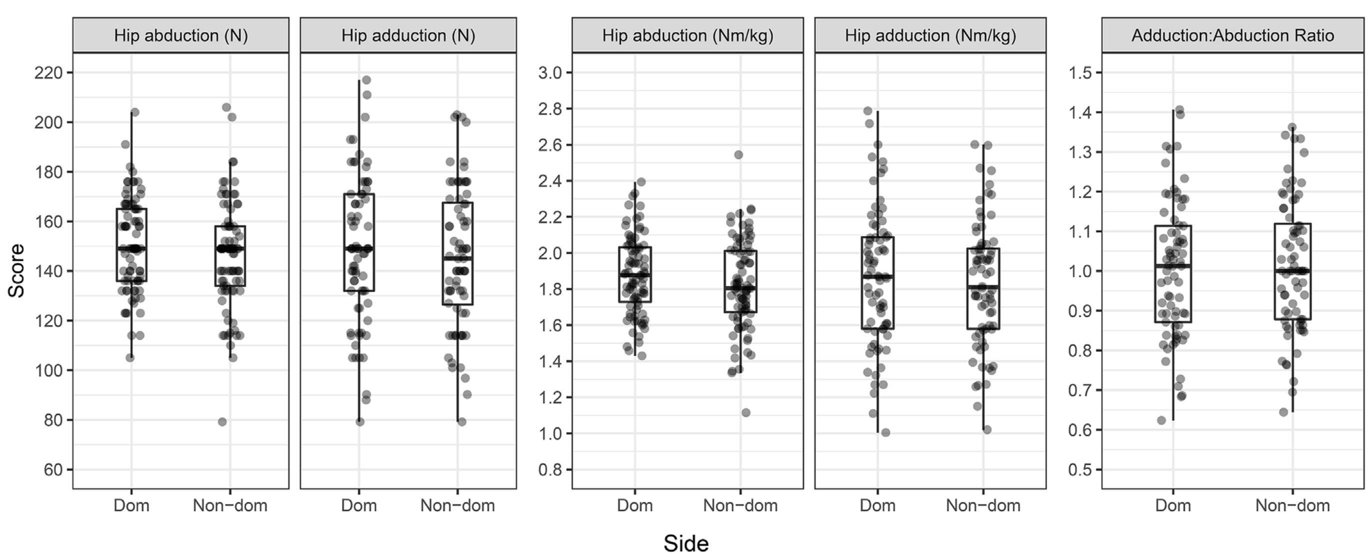
Appendix Fig. A.1. Participant characteristics presented with box-plots (n = 85). Each dot represents one participant, with the descriptive statistics presented on the right-hand side of each plot (from top to bottom: maximum value, 75th quartile, median, 25th quartile, minimum value).



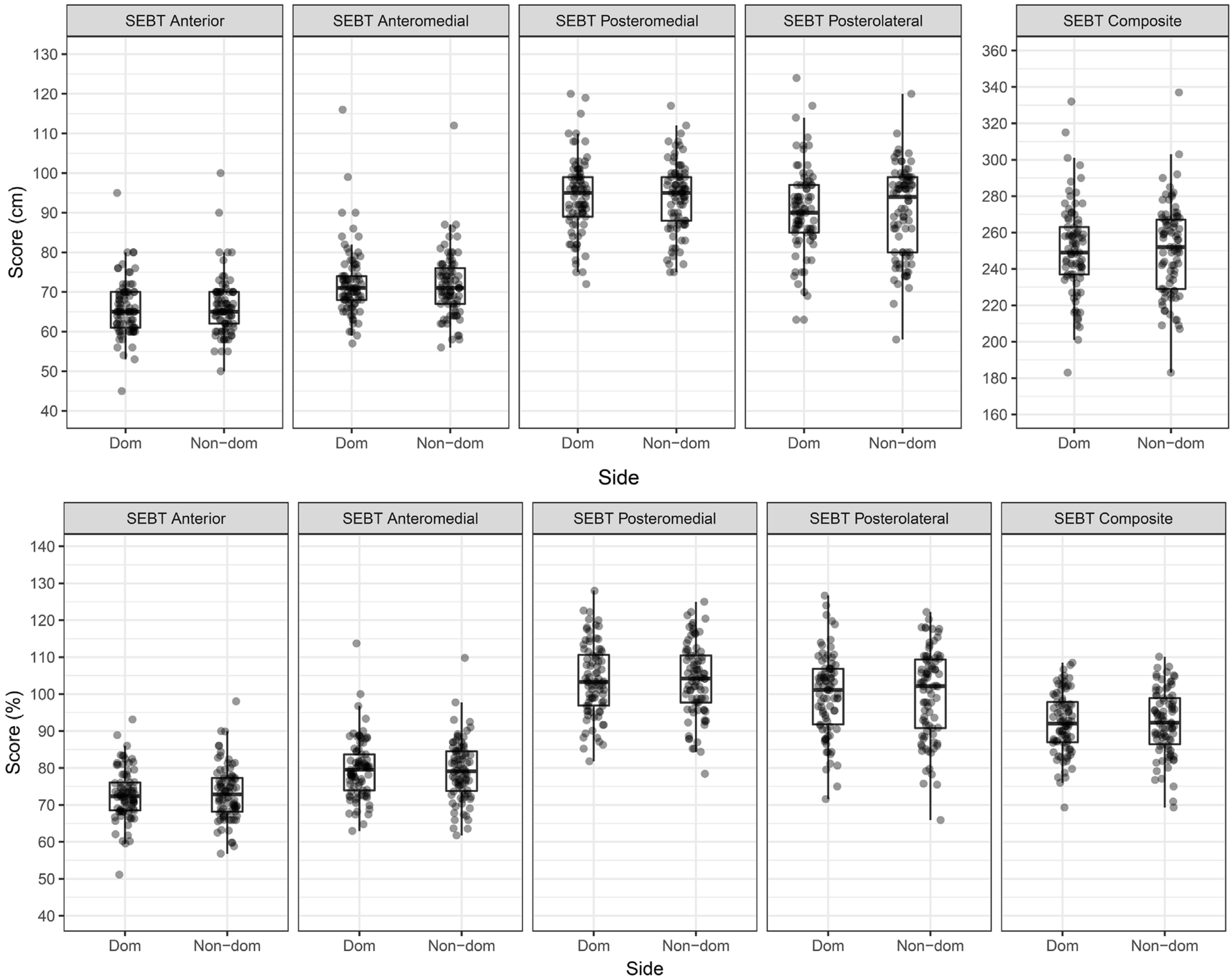
Appendix Fig. A.2. Histogram of the number of years playing Australian Football (n = 84).



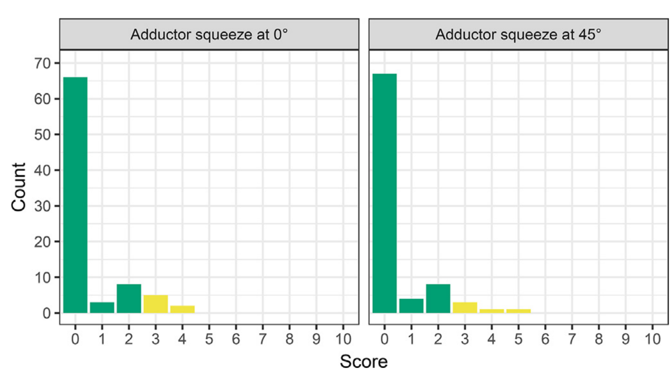
Appendix Fig. A.3. Box-plots for the dominant (Dom) and non-dominant (Non-dom) sides of the weight-bearing lunge test (n = 85) and the side bridge/plank (n = 83 dominant and 84 non-dominant). The descriptive statistics for each plot are presented in Table 2 in the manuscript.



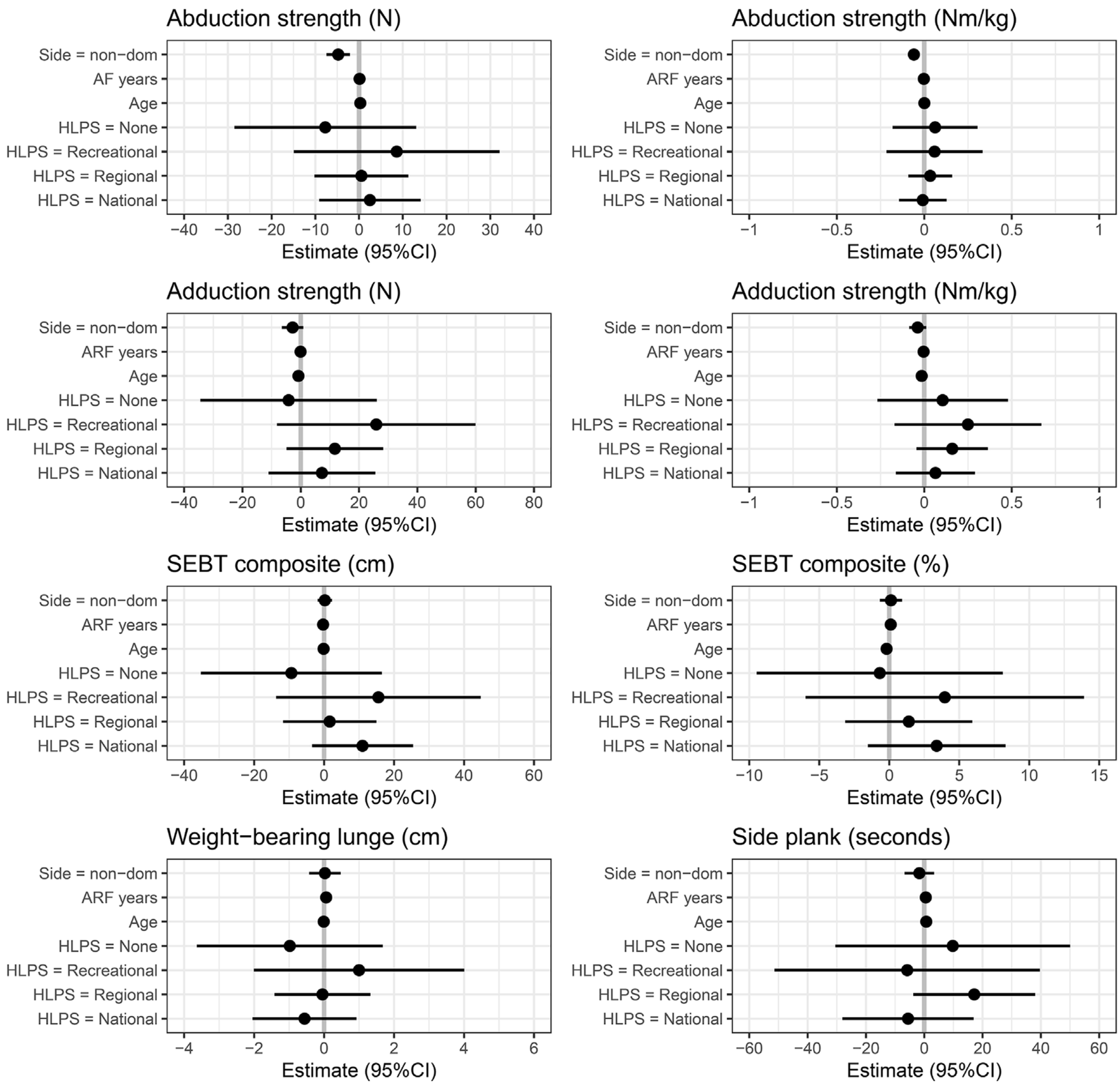
Appendix Fig. A.4. Box-plots for the dominant (Dom) and non-dominant (Non-dom) sides of the raw and normalised isometric hip abduction (n = 85) and adduction (n = 73 dominant and 72 non-dominant) strength testing. The descriptive statistics for each plot are presented in Table 2 in the manuscript.



Appendix Fig. A.5. Box-plots for the dominant (Dom) and non-dominant (Non-dom) sides of the raw (cm) and normalised (% of leg length) modified star excursion balance test (n = 85). The descriptive statistics for each plot are presented in Table 2 in the manuscript.



Appendix Fig. A.6. Histograms of the pain on adductor squeeze test at 0° and 45° of hip and knee flexion (n = 84).



Appendix Fig. A.7. Results of the linear mixed effect models showing the estimated fixed effects of limb dominance (side = non-dom), Australian Football experience (ARF years), age (Age), and highest level of previous sport (HLPS). The effect of limb dominance is expressed relative to the dominant side, and effect of previous sporting level (HLPS) is expressed relative to the group of participants with state level experience (as this was the group with the largest sample). The estimate with 95% confidence internal (95%CI) shows the effect that each covariate has on the test listed in the title of each sub-figure.
Hip abduction strength (expressed as both N or Nm/kg) shows a small, non-zero effect for the non-dominant side to be weaker than the dominant side by −4.77N or −0.06Nm/kg. As the confidence interval crosses 0 for all other estimates in all other figures, there is no effect on the results.
Participant numbers for each model: hip abduction (n = 83 with 166 limbs), hip adduction (n = 71 with 141 limbs), modified star excursion balance test (n = 83 with 166 limbs), weight-bearing lunge (n = 83 with 166 limbs), and side plank (n = 82 with 163 sides).

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