LOCOMOTOR CHARACTERISTICS OF THE WOMEN'S INAUGURAL SUPER LEAGUE COMPETITION AND THE RUGBY LEAGUE WORLD CUP

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Abstract

Understanding the locomotor characteristics of competition can help rugby league (RL) coaches optimise training prescription. To date, no research exists on the locomotor characteristics of women's RL. The aim was to compare the whole match and peak locomotor characteristics of women's RL competition at international (RL World Cup [WRLWC]) and domestic level (Super League [WSL]). Microtechnology data were collected from 58 players from 3-WSL clubs and 1-WRLWC team. Participants were classified into forwards (n = 30) and backs (n = 28). Partial least squares correlation analysis established which variables were important to discriminate between level of competition (international *vs.* domestic) and positional group (forwards *vs.* backs). Linear mixed effects models estimated the differences between standards of competition and positional group for those variables. International forwards were *most likely* exposed to greater peak 1-min average acceleration (standardised mean difference =1.23 [0.42 to 2.04]) and peak 3-min average acceleration (1.13 [0.41 to 1.85]) than domestic forwards. International backs *likely* completed greater peak 1-min average acceleration (0.83 [0.08 to 1.58]) than domestic backs and *possibly* completed greater high-speed-distances (0.45 [-0.17 to 1.07]). Findings highlight the need for positional specific training across levels to prepare representative players for the increased match characteristics of international competition.

Introduction

Rugby league (RL) is an intermittent, collision-based team sport played by both sexes across junior and senior age categories worldwide (Johnston, Gabbett and Jenkins, 2014). Recently, there has been an increase in both the professionalism and participation of women's rugby league in England and Australia. Both the Women's Super League (WSL) in England and the Women's National Rugby League competition in Australia were launched in 2018. The aims of these competitions are to concurrently increase the profile and participation of women's RL, while preparing their respective players for international competition; notably the quadrennial Women's Rugby League World Cup (WRLWC). Presently, there is a sparse evidence base in women's RL (Jones et al., 2016), and to the authors' knowledge, no research exists on the locomotor characteristics of match-play at any performance level in the women's game. This lack of understanding limits the ability of practitioners working with female players to optimally prepare their players for match-play.

Research within male RL has shown the match to consist of frequent bouts of high intensity activity (e.g. sprinting) and collisions (e.g. offensive ball carries and defensive tackles) separated by bouts of low intensity activity (e.g. walking; Weaving et al., 2018). The physical match characteristics of male RL have been extensively quantified at both senior (Waldron et al., 2011; Twist et al., 2014; Gabbett, 2015; Delaney et al., 2016; Weaving et al., 2018; Johnston et al., 2019) and youth (Waldron et al., 2014; Whitehead et al., 2018) levels. Across a whole match, senior male players have been reported to cover between 5,000 and 8,000 m (Johnston et

al., 2014; Twist et al., 2014) and undertake 30 to 65 collision events (Hulin et al., 2017) dependent on playing position (Gabbett et al., 2015).

While understanding the locomotor characteristics completed across the whole or each half of the match can provide practitioners with the external loads players are exposed to during match-play, such information is limited to assist in training prescription (Whitehead et al., 2018). Calculating the accumulation of the locomotor characteristics per units of time (e.g. average speed/acceleration over playing duration) can better allow practitioners to prescribe training drills, however this has its own methodological considerations. This is typically represented by averaging the speed completed across the whole match. However, given the intermittent nature of RL, averaging the locomotor characteristics over a match will inherently underrepresent the most demanding periods of match-play. As such, recent research in male RL has quantified the 'peak' locomotor characteristics by analysing the maximal average speeds or accelerations found during match-play over shorter durations (i.e. 1, 5, 10 min) (Hulin et al., 2015; Delaney et al., 2016; Weaving et al., 2018; Johnston et al., 2019). This method has also been reported to represent higher average speeds, in comparison to segmental analysis (e.g. 1 to 5, 5 to 10, 10 to 15 min; Whitehead et al., 2018). In male professional RL players, peak 1- and 5-min average speeds have been reported as ~154- 179 m.s^{-1} (Delaney et al., 2015, Delany et al., 2016) and ~92 to 126 m·min^{-1} (Hulin et al., 2015; Delaney et al., 2016) across positional groups. This is significantly higher than whole match average speeds (94-101m·min^{-1} (Gabbett et al., 2015) and highlights the benefit of analysing the peak demands to better understand the most intense periods of match play.

Understanding the locomotor characteristics of domestic competition in comparison to the international competition is important for two primary reasons. Firstly, understanding the characteristics of domestic competition is imperative to provide practitioners with information to then appropriately prepare players for the characteristics of match-play. Secondly, understanding the characteristics of the international competition, and identifying any difference between the standards of competition will allow practitioners to prescribe specific training drills to assist international player preparation. Given the absence of match characteristics in women's RL players, the aim of this study was therefore, for the first time to describe the whole match and peak duration-specific locomotor characteristics of women's RL match-play at both international (WRLWC) and domestic level during the inaugural WSL. A secondary aim was to determine which match characteristic variables are important to discriminate between playing position (i.e. forwards *vs.* backs) and competition standard (i.e. international *vs.* domestic) in this cohort.

Methods

Participants

An observational design was used to analyse the locomotor characteristics of women's rugby league at both international (WRLWC) and club (WSL) level. A total of 58 players from 3 domestic and 1 international team participated in the study with 7 participants included in both the WRLWC and WSL. Participants were classified into the 2 commonly used positional groups: forwards (n = 30) and backs (n = 28). Participants were excluded from the analysis if their match time was <10 min, due to the analytical techniques applied. Data was collected from 4 international fixtures and 5 domestic fixtures, with a total of 122 individual match observations recorded

(WRLWC = 51, WSL = 71). Individual observations ranged from 1 to 4 and 1 to 3 for WRLWC and WSL, respectively. Participants were familiarised with wearing microtechnology devices during training and warm up fixtures. Institutional ethics approval was granted from the University Research Ethics Committee. Participants provided informed consent prior to the commencement of the study.

Match Play Analysis

Each player wore a microtechnology technology unit (Optimeye S5, Catapult Innovations, Melbourne, Australia) as per manufacturer instructions. Each device contained a Global Positioning Systems (GPS) and Global Navigation Satellite System (GLONASS) sampling at 10 Hz and a tri- axial accelerometer, magnetometer and gyroscope, each sampling at 100 Hz. The test-retest reliability of the specific 10Hz GPS has been reported to be acceptable to measure instantaneous speed across a range of starting velocities (coefficient of variation: 2.0 to 5.3%) (Varley, Fairweather and Aughey, 2012; Scott, Scott and Kelly, 2016). The mean ± standard deviation (SD) number of satellites and horizontal dilution of precision (HDOP) during data collection were 11 ± 1 and 0.8 ± 0.1, respectively. Greater than 6 connected satellites and HDOP values less than 1 are considered ideal for GPS data collection (Malone et al., 2017).

To reduce the influence of inter-unit error, each participant was provided with the same device for the period of data collection. The units were placed within a pocket in a customised vest provided by the manufacturer with the unit situated between the scapulae. The coordinated universal time corresponding to the start and end of each players involvement in each half was clippedthrough the manufacturers software

(Catapult Openfield v1.16, Catapult Innovations, Melbourne, Australia). This was also completed for interchange players to ensure that only match time were included in the analysis and to ensure appropriate coding of their involvement. The raw 10 Hz data were downloaded using the manufacturer's software for analysis so only data from playing time were included.

Whole match locomotor characteristics

Locomotor variables analysed for whole-match characteristics were: total distance covered (m) and average speed (m·min⁻¹). These were further differentiated into the distance and average speed covered at high-speed (HSD m, HSD per min; > 5 m·s⁻¹) and sprinting (m and m·min⁻¹; > 7 m·s⁻¹). The speed thresholds used were consistent with those previously used during professional male RL competition (Weaving et al., 2018), to allow for comparisons between competitions.

Peak duration-specific average speeds (m·min⁻¹) and acceleration (m·s⁻²).

To establish the duration-specific average speed (m·min⁻¹), high-speed (m·min⁻¹) and average acceleration (m·s⁻²), a player's instantaneous speed (m·s⁻¹), derived from the Doppler shift method, was recorded every 0.1s (i.e. 10Hz). The raw 10Hz instantaneous speed data were then exported from the Catapult Openfield v1.16 software. The first speed sample represents the 'start' of the player's match involvement (i.e. half or interchange period), whilst the final speed sample represents the 'end' of their involvement. Players were excluded from analysis if their match time was <10 min per half, due to the analysis of moving averages being up to 10 min.

A custom-built algorithm in R (v R-3.1.3, R Foundation for Statistical Computing, Vienna, Austria) was developed to compute a moving average of each player's instantaneous speed and acceleration across different durations. Moving averages were calculated across different durations (1 min to 10 min) and was implemented through the *zoo* package. These durations were arbitrarily chosen to represent shorter and longer durations of activity due to their use in training prescription, which is consistent with previous literature (Delaney et al., 2015; Weaving et al., 2018; Johnston et al., 2019). For example, for a 10 min moving average of average speed, the algorithm computed a moving average for every 6000 instantaneous speed samples (i.e. 10 samples per second for 600 seconds [10 min]), with the maximal value taken for each match observation. This process was repeated for each of the respective 'durations' in the study. The maximum moving-average for each duration for each variable (average speed, acceleration and high-speed) was then calculated. For the peak locomotor characteristic variables, we adopted the same approach recently described by Delaney et al. (2017), whereby the power law slope and intercept were taken from the log-log relationship of the dependent variable for each of the time durations.

Statistical Analyses

Descriptive data are presented as the mean ± standard deviation (SD) for both standard of competition (international and domestic) and positional group (forwards and backs).

Partial least squares correlation analysis (PLSCA) was used to filter the locomotor characteristic variables able to discriminate between level of competition

(international *vs.* domestic) and positional group (forwards *vs.* backs) in the women's game (Abdi et al., 2013; Weaving et al., 2019; Barker and Rayens, 2003).

Prior to PLSCA, data were mean centred and standardised to unit variance. The baseline PLSCA model included a [36 x 122] matrix, *X,* containing the 36 variables that represent the locomotor characteristics for each player observation (n = 122) and a [4 x 122] matrix, *Y,* containing binary variables to represent the level of competition (international, domestic) and positional group (forward, back) for each player match observation (n = 122). The *X* and *Y* matrices were stored in a covariance matrix, *R* ($Y^{T}X$). Singular value decomposition of the matrix, *R,* yielded three orthogonal matrices: a left singular vector matrix, *U*, containing the saliences (weights) for matrix *Y,* a right singular vector matrix, *V,* containing the saliences (weights) for matrix *X* and a diagonal matrix, *S*, containing the singular values (Abdi et al., 2013; Weaving et al., 2019). The amount of shared information between the *X* (i.e. locomotor characteristics) and *Y* (i.e. binary variables for level of competition and position) matrices can be determined by quantifying the singular value *inertia* (i.e. the sum of the singular values) with greater inertia demonstrating greater relationships between the *X* and *Y* matrices (Weaving et al., 2019).

Firstly, we created a baseline PLSCA model with each of the 36 locomotor characteristic variables included in matrix, *X.* Once the inertia was calculated for the baseline model, we used a leave-one-variable-out (LOVO) approach as per previous methods (Weaving et al., 2019). This involved repeating the PLSCA with one predictor variable (locomotor characteristic variable) omitted from the analysis and the new *inertia* noted. This process was repeated with a different predictor variable

omitted each time (as described above) until the contribution of all the variables had been evaluated individually. The locomotor characteristic variables that created the largest decrease in singular value *inertia* compared to baseline PLSCA model were considered to possess the most relative importance to discriminate between the positional groups and playing standard. This was determined independently by 2 researchers through agreeing on a visual break (i.e. the 'elbow') within the decrease in singular value inertia plot.

The variables deemed to possess most relative variable importance were then included in a refined model, with only those variables included in matrix, *X*. The PLSCA process was repeated with the statistical significance of the calculated *inertia* value assessed using a permutation test in which the rows of *Y* were randomly permutated 10,000 times to produce the null distribution of all the possible inertia values that could occur just by chance (Abdi & Williams, 2013).

To visualise the discriminant capability of the variables included in the refined PLSCA model, scatterplots of the latent variables of the 1st and 2nd dimensions of the *X* matrix were produced. The latent variables are a composite 'score' of the locomotor characteristic variables that were deemed to possess most relative importance. These were constructed by projecting the mean centred and standardised player match observations onto the respective saliences for each dimension of the PLSCA model (Abdi et al., 2013). Therefore, a latent variable is a linear combination of the original variables and the weights of this linear combination are the saliences (Abdi et al., 2013; Weaving et al., 2019).

For the variables deemed important during the PLSCA, linear mixed effects models were then used to estimate the differences between standards of competition (international *vs.* domestic) and positional group (forwards *vs.* backs) using the *lme4* package (Bates et al., 2015) in R (version 3.3.1). Fixed effects of playing standard were estimated for both forwards and backs. Random effects were match identity and athlete identity. Standardised mean differences (SMD) with 95% confidence intervals were estimated from the ratio between the mean difference to the pooled SD and classified as *trivial* (< 0.2), *small* (0.2 to 0.59), *moderate* (0.60 to 1.19), *large* (1.2 to 1.99) and *very large* (2.0 to 4.0). The practical importance of the differences were established using magnitude based decisions (Batterham and Hopkins, 2006). The smallest worthwhile difference (SWD) was calculated as 0.2 x between-subject SD and assessed qualitatively as 25 to 75%, possibly; 75 to 95% likely, 95 to 99.5%, very likely and > 99.5%, most likely (Batterham and Hopkins, 2006). The magnitude was deemed unclear if the 90% CI overlapped positive and negative values of the SWD.

Results

Table 1 displays the mean ± SD for the whole match characteristics of women's RL match-play by positional group (forward and backs) and standard of competition (international *vs.* domestic).

Table 2 displays the mean ± SD for the peak average speeds (m·min^{-1}) peak high-speed-distance per min (m·min^{-1}) and peak average accelerations (m·s^{-2}) during

both the international and domestic competition for the forwards and backs positional groups.

Table 3 shows the power law slope and intercept values taken from the log-log relationship between the peak match characteristic variable (average speed, average acceleration and high-speed-distance) at each time duration (Table 2).

Table 4 and Figure 1 highlight the results of the PLSCA to discriminate between positional group and standard of competition. This includes the baseline model (Table 3; PLSCA Baseline Model) and the relative variable importance plot showing the decrease in singular value inertia when each variable was omitted from the baseline model (Figure 1). 1- and 3-min average acceleration, whole match high-speed-distance and peak 7-min high-speed-distance created the largest decreases in singular value inertia (Figure 1), and were subsequently included in a refined model (Table 2; PLSCA Model 1), which was significant following 10,000 permutations (p <0.0001).

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Table 1. Whole match characteristics (mean ±SD) for forwards and backs during international and domestic competition.

	Duration (min)	Total Distance (m)	High Speed Distance (m)	Sprint Distance (m)	Average Speed (m·min⁻¹)	High-Speed per min (m·min⁻¹)	Sprint per min (m·min⁻¹)
International Forwards	61 ± 22	4680 ± 1618	69 ± 66	2.4 ± 10.3	76.7 ± 8.8	1.1 ± 0.9	0 ± 0.1
International Backs	80 ± 11	6016 ± 1263	241 ± 146	17.7 ± 32.4	75.2 ± 6.1	4.1 ± 4.8	0.2 ± 0.3
Domestic Forwards	64 ± 14	4737 ± 1597	58 ± 53	0.8 ± 4.7	73.4 ± 10.0	1.2 ± 1.8	0 ± 0.0
Domestic Backs	82 ± 12	6099 ± 1883	190 ± 156	9.5 ± 23.9	74.3 ± 9.1	2.3 ± 1.7	0.1 ± 0.2

2 SD = Standard Deviation

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Table 2. Mean ± SD for the maximal duration-specific average speeds (m·min^{-1}), maximal average accelerations (m·min^{-2}) and maximal high-speed-distances for forwards and backs during international and domestic competition.

	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
Average speed (m·min^{-1})										
International Forward	144 ± 14	118 ± 12	110 ± 11	102 ± 12	96 ± 11	93 ± 11	90 ± 10	87 ± 9	85 ± 9	83 ± 10
Domestic Forward	140 ± 11	115 ± 11	105 ± 9	99 ± 8	94 ± 8	90 ± 9	88 ± 10	85 ± 10	84 ± 10	82 ± 10
International Back	144 ± 13	117 ± 14	106 ± 14	98 ± 14	93 ± 12	89 ± 12	86 ± 11	84 ± 9	81 ± 9	81 ± 10
Domestic Back	151 ± 17	121 ± 13	111 ± 12	104 ± 12	99 ± 11	95 ± 12	93 ± 12	91 ± 11	90 ± 11	88 ± 11
Average Acceleration (m·s^{-2})										
International Forward	0.79 ± 0.06	0.65 ± 0.06	0.60 ± 0.04	0.55 ± 0.05	0.52 ± 0.04	0.50 ± 0.04	0.49 ± 0.05	0.47 ± 0.05	0.46 ± 0.05	0.45 ± 0.05
Domestic Forward	0.70 ± 0.08	0.59 ± 0.07	0.54 ± 0.05	0.50 ± 0.05	0.48 ± 0.05	0.46 ± 0.05	0.45 ± 0.05	0.43 ± 0.06	0.43 ± 0.05	0.42 ± 0.05
International Back	0.78 ± 0.07	0.63 ± 0.05	0.58 ± 0.06	0.54 ± 0.04	0.52 ± 0.05	0.49 ± 0.04	0.48 ± 0.04	0.47 ± 0.04	0.46 ± 0.04	0.46 ± 0.04
Domestic Back	0.73 ± 0.05	0.61 ± 0.05	0.55 ± 0.05	0.52 ± 0.05	0.50 ± 0.05	0.48 ± 0.04	0.47 ± 0.04	0.46 ± 0.04	0.45 ± 0.04	0.44 ± 0.04
High Speed Distance (m·min^{-1})										
International Forward	25 ± 19	13 ± 13	9 ± 6	7 ± 5	6 ± 4	5 ± 4	5 ± 3	4 ± 3	4 ± 3	3 ± 3
Domestic Forward	18 ± 15	10 ± 10	7 ± 5	5 ± 4	4 ± 3	4 ± 3	3 ± 3	3 ± 2	3 ± 2	3 ± 2
International Back	40 ± 26	21 ± 21	15 ± 10	12 ± 8	10 ± 6	10 ± 6	9 ± 6	8 ± 5	7 ± 5	7 ± 4
Domestic Back	45 ± 19	24 ± 24	16 ± 7	13 ± 6	11 ± 5	10 ± 4	9 ± 4	8 ± 4	8 ± 3	7 ± 3

7 Figure 2 shows the scatterplots of the latent variables of the 1st and 2nd dimensions

8 of the refined *X* matrix (i.e. 1 and 3 min peak average acceleration, whole match

9 high-speed distance and peak 7 min high-speed distance) for each individual match

10 observation, classified by position (Figure 2A and Figure 2B) and competition

11 standard (Figure 2C and Figure 2D).

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Table 3. Intercept and slopes from power-law relationship for maximal duration-specific average speeds (m·min^{-1}), average accelerations (m·min^{-2}) and high speed distance (m) for each position competing in international and domestic competition.

Variable		WRLWC Forward	WSL Forward	WRLWC Back	WSL Back
Average Speed (m·min^{-1})	Intercept	371	348	395	368
	Slope	-0.24	-0.23	-0.25	-0.23
Average Acceleration (m·s^{-2})	Intercept	2.10	1.72	1.93	1.71
	Slope	-0.24	-0.22	-0.23	-0.21
High-Speed-Distance per minute (m·min^{-1})	Intercept	817	503	758	1045
	Slope	-0.86	-0.83	-0.74	-0.79

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Table 4. Results of the partial least squares correlation analysis including baseline model and refined model following leave one variable out process.

PLSCA model	Response variables (*Y* matrix)	Predictor Variables (*X* matrix)	Measured inertia	Odds from 10,000 permutation test (p value)
PLSCA Baseline	Dummy variables for International forward, International back Domestic forward, Domestic back	Acc_1, Acc_2, Acc_3, Acc_4, Acc_5, Acc_6, Acc_7, Acc_8, Acc_9, Acc_10, HSD_1, HSD_2, HSD_3, HSD_4, HSD_5, HSD_6, HSD_7, HSD_8, HSD_9, HSD_10, Whole game m·min, m·min_1, m·min_2, m·min_3, m·min_4, m·min_5, m·min_6, m·min_7, m·min_8, m·min_9, m·min_10, Sprint distance per min, Total Distance, Total Sprint distance, HSD, HSD per min	537.39	0.15
PLSCA Model 1	Dummy variables for International forward, International back Domestic forward, Domestic back	Acc_1, Acc_3, HSD, HSD_7	216.96	< 0.0001

Abbreviations: Acc = Acceleration; HSD = high-speed-distance. _1, _2 etc = represent peak duration period.

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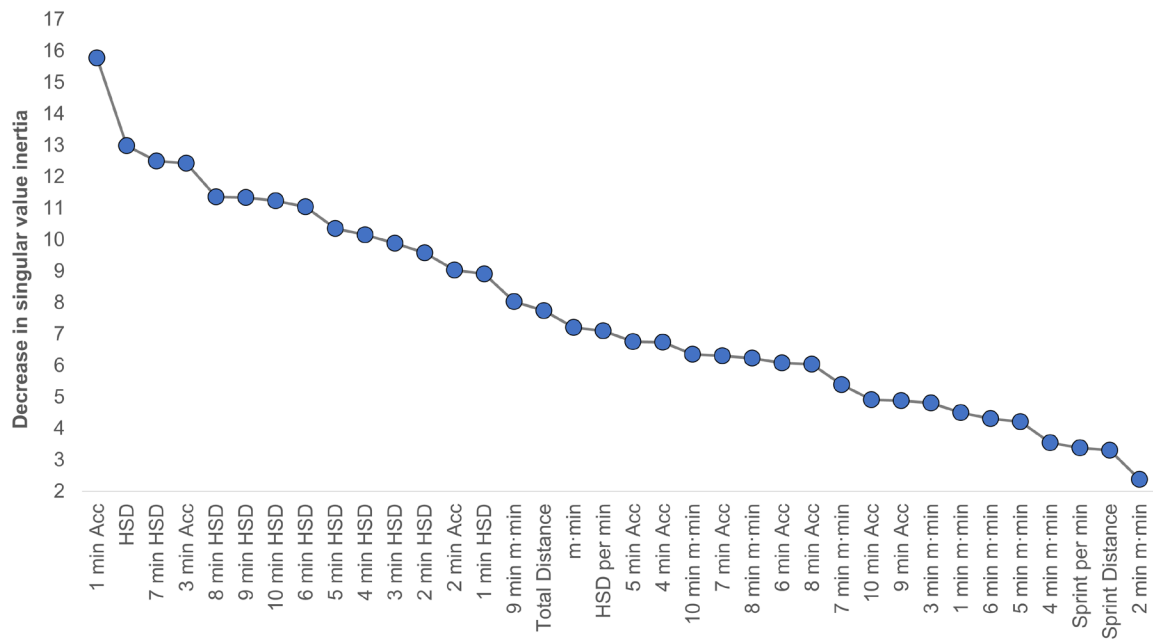
Figure 1. Plot of relative variable importance to discriminate between playing position and competition standard from leave one variable out partial least squares correlation analysis. 1 and 3 minute peak average acceleration, whole match high-speed distance and peak 7 minute high-speed distance per min created the largest decrease in singular value inertia compared to the baseline model (Table 2). Abbreviations: Acc = acceleration; HSD = high-speed-distance.
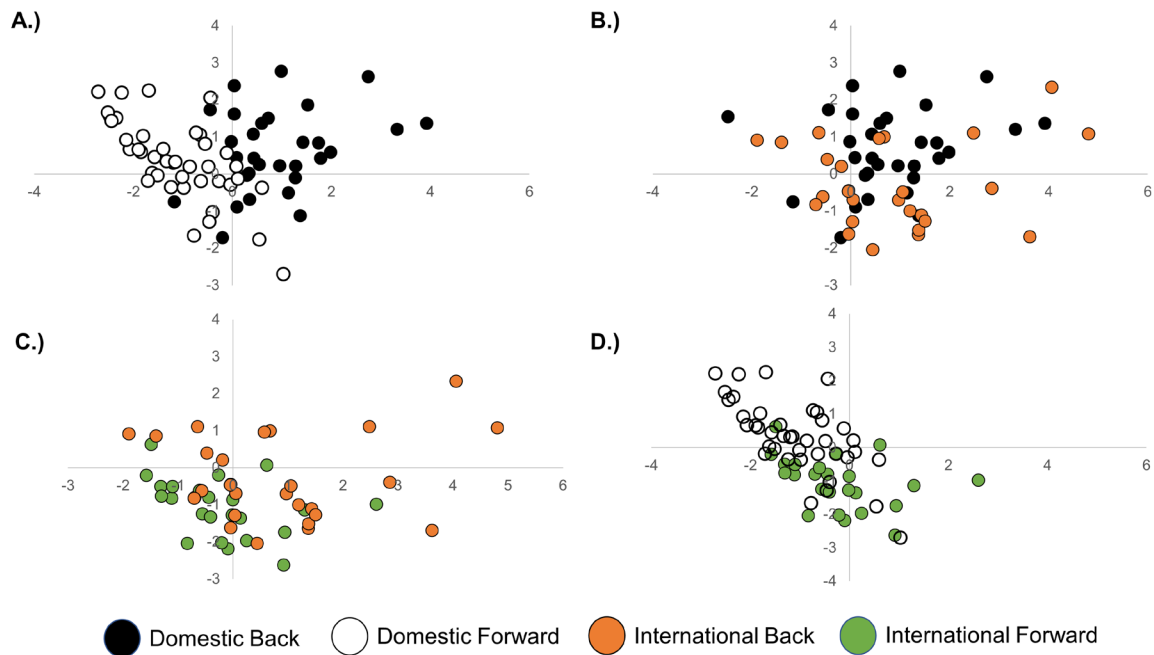
Figure 2: Latent variable plots of individual match observations for the 1st and 2nd dimensions of the *X* matrix. *X* matrix included peak 1 min and 3 min average acceleration, whole match high-speed distance and peak 7 minute high-speed distance per min. These observations were classed to discriminate between forwards and backs within the domestic (Figure 2A) and international competition (Figure 2B) and between standards of competition for the positional groups (Figures 2C, 2D).

Differences between playing standard

Forwards

International forwards were *most likely* exposed to greater peak 1 min average acceleration (standardised mean difference = 1.23 [90% confidence interval = 0.42 to 2.04]; descriptor: *large*) and peak 3 min average acceleration (1.13 [0.41 to 1.85]; *large*) than domestic forwards. There were *unclear* differences in high-speed-distance covered across the whole match (-0.07 [-0.65 to 0.51] and peak 7 min high-speed-distance (-0.27 [-0.48 to 1.02]).

52   *Backs*

53   International backs *likely* completed greater peak 1 min average acceleration (0.83

54   [0.08 to 1.58]; *moderate*) than domestic backs. There were *unclear* differences in

55   peak 3 min average acceleration (0.39 [-0.24 to 1.02]). International backs *possibly*

56   completed greater high-speed-distances (0.45 [-0.17 to 1.07]; *small*) across the

57   whole match than domestic backs. There were *unclear* differences in peak 7 min

58   high-speed-distance (0.09 [-0.66 to 0.84]).

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60   ***Differences between positions within a playing standard***

61   *Domestic*

62   Domesric backs were *likely* exposed to greater peak 1 min average acceleration

63   (0.41 [0.05 to 0.77]; *small*) and peak 3 min average acceleration (0.36 [0.00 to 0.72];

64   *small*) than domestic forwards. Domestic backs *most likely* completed greater high-

65   speed-distances across the whole match (1.62 [1.18 to 2.06]; *large*) than domestic

66   forwards. Domestic backs *most likely* completed greater peak 7 min high-speed

67   distances (1.40 [1.07 to 1.73]; *large*) than domestic forwards.

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69   *International*

70   There were *unclear* differences between international forwards and backs for peak 1

71   min average acceleration (0.01 [-0.69 to 0.71]). Forwards *possibly* completed greater

72   peak 3 min average accelerations (0.38 [-0.06 to 0.82]; *small*). Backs *most likely*

73   completed greater high-speed-distances (1.09 [0.43 to 1.75]; *moderate;* $p < 0.0001$)

74   and peak 7 min high-speed-distances (1.03 [0.57 to 1.49]; *moderate*; $p < 0.0001$)

75   than international forwards.

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Discussion

This is the first study to describe the whole and peak match characteristics of women's rugby league and compare between domestic and international standards of competition. PLSCA identified that the high-speed distance covered across the whole match, the peak high-speed distance covered across a 7-min duration, and peak 1- and 3-min average accelerations possessed the most relative importance to discriminate between standard of competition and position (Figure 1). From the comparisons of these variables we generally (11/16; 69%) observed differences between standard of competition and positional groups whilst the rest required more data for firm inference (*unclear*: 5/16; 31%). This generally highlights the requirement for positional specific training across all levels and for preparing representative players for the increased demands of international competition.

When comparing domestic and international standards of competition, international forwards were exposed to substantially greater average accelerations across the highest 1- and 3-min periods of competition than domestic forwards. This would suggest that forwards selected for international competition likely require exposure to these higher rates of acceleration activities during training. International backs were exposed to greater average accelerations during the highest 1 min period of competition and greater high-speed-distances across the whole match. This would suggest that backs selected for international competition likely require the development of abilities to maintain higher speeds for prolonged periods of time. These findings are in agreement with those reported in female rugby sevens players, whereby international players were reported to cover greater distances and at higher speeds than national level competition (Portillo et al., 2014) which was likely

102   explained by the better-developed physiological characteristics of international

103   players (Portillo et al., 2014).

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105   In agreement with the reported match characteristics of male RL at both an

106   international (Dempsey et al., 2018) and domestic level (Delaney et al., 2016),

107   positional differences in women's RL were observed within each standard of

108   competition. In the current study, domestic backs completed substantially greater

109   average accelerations during the highest 1- and 3-min periods of competition,

110   greater high-speed distances during the highest 7-min of competition and greater

111   high-speed distances over the whole match compared to forwards. At the

112   international level, forwards complete greater average accelerations during the

113   highest 3 min period whilst backs complete greater high-speed distances during the

114   highest 7 min period of the match and greater high-speed distances across the

115   whole match. Differences in locomotor characteristics between positions are likely

116   explained by the different positional characteristics and physical qualities of forwards

117   and backs. For example, the position specific characteristics of backs such as a kick

118   chase are likely to elicit opportunities of increased total distance and high-speed

119   running in comparison to forwards who are often involved in a higher number of

120   collisions (Dempsey et al., 2018). This may also partly be explained by differences in

121   physical characteristics between forwards and backs as Jones et al. (2016) reported

122   that international female backs were both faster and more powerful than forwards.

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124   At both international and domestic level, the whole match locomotor characteristics

125   of women's RL were lower than that reported for senior international, senior

126   domestic and junior international male RL players (Johnston et al., 2014; Twist et al.,

127 2014; Dempsey et al., 2018). For example, comparing women and men international

128 backs, women cover lower; total distances (6016 ± 1263 *vs.* 7255 ± 1260 m)

129 (Dempsey et al. 2018) and average speeds (75 m·min^{-1} *vs.* 85 m·min^{-1}). This is

130 consistent with findings in other sports such as soccer where the whole match

131 locomotor characteristics have been shown to be lower for women in comparison to

132 males (Datson et al., 2017). This demonstrates again how findings from male

133 competitions are likely not applicable to their female counterparts, thus highlighting a

134 need for female specific research within RL.

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136 In the current study, given the low instances of high-speed events observed in both

137 domestic (58 to 241m) or international (69 to 190m) women's RL in comparison to

138 findings in men's RL, findings of this study question the applicability of male derived

139 speed thresholds to the women's game. This is supported by the known differences

140 in physical qualities between male and female players, such as speed (i.e. male 20m

141 sprint: 3.09 ± 0.12s [Dobbin et al., 2019] *vs.* female 3.36 ± 0.18s [Jones et al.,

142 2016]). As such the use of male derived speed thresholds to determine HSR in

143 female players are likely not appropriate which requires further consideration to

144 ensure that the true locomotor characteristics of women's RL are represented.

145

146 An additional area of investigation in the current study was the quantification of the

147 highest rates of locomotor activity per different units of time, which has been widely

148 suggested to provide useful information for practitioners to evaluate the locomotor

149 rates of training (Delaney et al., 2015; Weaving et al., 2018; Whitehead et al., 2018;

150 Johnston et al., 2019). For example, in the current study, when considering the

151 international backs positional group, there was a 125% increase (9 *vs.* 4 m·min^{-1}) in

152 high-speed-distance per min when measured during the highest 7 minute period of

153 the match (Table 2) than when averaged across the whole match (Table 1). This

154 agrees with findings in professional rugby union where similar increases were

155 observed (Whitehead et al., 2018). Such data can provide useful information for

156 practitioners working with both domestic and international female players to ensure

157 that they are prepared for the highest locomotor rates experienced during matches. In

158 comparison to male RL, and similar to the whole game locomotor characteristics, lower

159 peak locomotor characteristics were found in the female game. For example, women

160 international backs appear to complete lower peak 1 min average speeds (144 ± 13

161 $m \cdot min^{-1}$) compared to male National Rugby League (175 ± 22 $m \cdot min^{-1}$; Delaney et al.,

162 2017), male European Super League (170 ± 3.8 $m \cdot min^{-1}$; Weaving et al., 2018), male

163 Academy (167 ± 14 $m \cdot min^{-1}$; Whitehead et al., 2018), male youth internationals (157

164 ± 5.6 $m \cdot min^{-1}$; Whitehead et al., 2018) and male youth domestic levels (168 ± 14

165 $m \cdot min^{-1}$; Whitehead et al., 2018). Collectively, the findings of the current study suggest

166 that practitioners working with domestic and international female players should aim

167 to expose players to these highest rates of average speed, high-speed and average

168 acceleration activities to appropriately develop the physical qualities required to meet

169 these characteristics during competition.

170

171 To support practitioners to plan training targets for technical-tactical drills, the power

172 law relationship between the peak average speeds completed across a range of

173 durations during matches has been proposed (Delaney et al., 2017). By using the

174 slope (i.e. rate of decline of peak locomotor rate) and the intercept values determined

175 from the relationship between the change in a peak locomotor characteristic (e.g.

176 average speed) with the change in duration (Table 2), practitioners can estimate the

177   target for a given drill for each individual player. Our present study is the first to

178   replicate this using locomotor data collected during women's rugby league (Table 3).

179   Based on the findings of the current study, a 3.5 min technical-tactical drill for

180   international forwards that aims to equal the peak average speed during matches

181   would require a target speed of ~103 m·min^{-1} (3.5 min peak m·min^{-1} = 371 x 210s$^{-0.24}$;

182   Table 3). This could assist practitioners to plan the locomotor characteristics of

183   technical-tactical training.

184

185   A limitation of this study is the small sample size and the homogeneity of the cohort.

186   However, given the limited opportunity for international competition outside of the RL

187   World Cup which occurs every four years, it is not possible to collect a larger sample

188   of international observations at this stage. Therefore, it is recommended that in line

189   with the 2021 World Cup, researchers aim to collect data across all international

190   squads during the competition to allow a more comprehensive analysis of the match

191   characteristics of elite women's RL.

192

193   **Conclusion**

194   This is the first study to describe the locomotor characteristics of women's RL and to

195   compare the whole and peak locomotor characteristics of match-play between

196   international and domestic competition. Findings suggest that the locomotor

197   demands of match play differ between standards of competition and between

198   positions and should be considered when preparing players for international

199   competition.

200

201   **Practical Applications**

202 This study provides the first descriptive data on the whole match and peak locomotor

203 characteristics of both international and domestic women's RL which can be used

204 for training program design. Findings suggested that for forwards, acceleration ability

205 may be most important. In contrast HSR ability may be an important physical quality

206 to develop for backs. Strength and conditioning specialists can use this data to

207 inform training prescription design, which will provide more specific development of

208 locomotor capacities required for women's RL competition

209

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