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Position-specific countermovement jump characteristics of elite Women's Rugby World Cup 2017 athletes

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Abstract – Rugby union (RU) is an intermittent team sport, with diverse playing positions, played internationally by both men and women. Considerable scientific attention has been devoted to men's RU, however despite the growth in the women's professional game, there is a significant lack of available physiological and normative data. The purpose of the present study was to investigate positional variation in countermovement jump characteristics from elite women's RU players. Qualitative data were collected from women's Rugby World Cup (2017) competitors ($n = 86$; age: 27 ± 5 years; body mass: 77.8 ± 10.6 kg; height: 1.69 ± 0.07 cm) and jump data (countermovement jumps) were collected using a 1200 Hz force platform ($n = 63$). Athletes were divided into positional unit (backs: $n = 39$ and forwards: $n = 47$) and by positional subgroups. Backs had greater jump height ($ES = 0.72$, $95\%CL \pm 0.50$), relative power output ($ES = 0.84$, $95\%CL \pm 0.50$), relative force production ($ES = 0.62$, $95\%CL \pm 0.51$) and reactive strength index (RSI; $ES = 0.62$, $95\%CL \pm 0.50$), compared to forwards (for all, $P < 0.02$). Backrows, halves and back-three players had greater relative force, relative power and jump height, compared to the front and second rows ($P < 0.03$; $ES > 0.70$). These data could aid in programming for long-term player development in women's RU and could have implications for “readiness” to compete at international level.

Key words: jump kinematics, elite female athletes, power output

Résumé – **Caractéristiques des sauts de contre-mouvement spécifiques à la position des athlètes d'élite de la Coupe du monde de rugby féminin 2017.** Le rugby à XV (RU) est un sport d'équipe intermittent, avec des positions de jeu diverses, joué au niveau international par des hommes et des femmes. Une attention scientifique considérable a été consacrée au RU masculin, mais malgré la croissance du jeu professionnel féminin, il existe un manque important de données physiologiques et normatives disponibles. Le but de la présente étude était d'étudier la variation de position des caractéristiques des sauts avec contre-mouvement chez les joueuses élités de RU. Des données qualitatives ont été collectées auprès des compétiteurs de la Coupe du monde de rugby féminin (2017) ($n = 86$; âge : 27 ± 5 ans ; masse corporelle : $77,8 \pm 10,6$ kg ; taille : $1,69 \pm 0,07$ cm) et les données de saut (sauts avec contre-mouvement) ont été collectées à l'aide d'une plateforme de force de 1200 Hz ($n = 63$). Les athlètes ont été divisés en unités de position (arrière : $n = 39$ et avant : $n = 47$) et en sous-groupes de position. Les arrières avaient des valeurs plus élevées de hauteur de saut ($ES = 0,72$, $95\%CL \pm 0,50$), de puissance de sortie relative ($ES = 0,84$, $95\%CL \pm 0,50$), de production de force relative ($ES = 0,62$, $95\%CL \pm 0,51$) et d'indice de résistance réactive (RSI ; $ES = 0,62$, $95\%CL \pm 0,50$), par rapports aux avant (pour tous, $P < 0,02$). Les joueurs d'arrière-plan, de moitié et d'arrière-trois avaient une force relative, une puissance relative et une hauteur de saut plus grandes que les joueurs de première ligne et de deuxième ligne ($P < 0,03$; $ES > 0,70$). Ces données pourraient aider à programmer le développement à long terme des joueurs dans le RU féminin et pourraient avoir des implications pour la préparation à la compétition au niveau international.

Mots clés : cinématique de saut, athlètes féminines d'élite, puissance de sortie

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1 Introduction

Rugby union (RU) in both the men's and women's game requires high levels of strength, power, speed, aerobic and anaerobic fitness (Cunningham *et al.*, 2018; Roberts, Trewartha, Higgitt, El-Abd, & Stokes, 2008; Sheppy *et al.*, 2019; Twist & Worsfold, 2015). Data from the elite men's game show that athletes are required to develop and maintain high force-velocity dominant characteristics (Cross *et al.*, 2014; Sedeaud *et al.*, 2012). These demands differ in magnitude and specificity depending on the diverse positional units of backs and forwards, and diverge further considering the individual requirements of specific positional sub-groups (15-a-side game; Quarrie, Hopkins, Anthony, & Gill, 2013; Smart, Hopkins, & Gill, 2013). While these game demands are starting to be understood in the women's game, and appear to be relatively similar to the men's game (covering similar total distances throughout 80 mins; ~ 6000 m match⁻¹) (Sheppy *et al.*, 2019), phenotypic differences are well documented in the men's game (Brazier *et al.*, 2018; Cahill, Lamb, Worsfold, Headey, & Murray, 2013; Deutsch, Kearney, & Rehrer, 2007; Quarrie *et al.*, 2013; Roberts *et al.*, 2008; Smart, Hopkins, Quarrie, & Gill, 2014); however, little is known of elite women's RU (Hene, Bassett, & Andrews, 2011; Hene & Bassett, 2013; Sheppy *et al.*, 2019). Thus limiting our understanding of the physiological requirements.

Since the introduction of women's RU (1994), participation has risen exponentially (World Rugby, 2018), amplified by the inclusion of the 7-a-side game (7's) to the modern Olympic games (IOC, 2017) and the recent, but not yet ubiquitous, introduction of professionalism (England Rugby, 2019). World Rugby estimates that there are currently 2.4 million female RU players world-wide (World Rugby, 2018), which represents a considerable proportion of overall participation ($> 25\%$ of ~ 9 million). Due to the inclusion of women's 7's in the Olympic games (2016), the physiological demands of International women's 7's players has been relatively well characterised (Agar-Newman, Goodale, & Klimstra, 2017; Clarke, Anson, & Pyne, 2017; Goodale, Gabbett, Stellingwerff, Tsai, & Sheppard, 2016; Malone, Earls, Shovlin, Eddy, & Winkelman, 2018). These data show that, similar to the men's 7's game (Clarke *et al.*, 2017), there are some, but few physiological differences between women's backs and forwards (higher mass relative quantities and sprint ability/capacity in the backs; Agar-Newman *et al.*, 2017; Misseldine, Blagrove, & Goodwin, 2018; Ohya *et al.*, 2015). Although women's RU athlete's regularly interchange between 7's and 15's codes (although data on this is currently lacking), the position specific physiological requirements and game demands differ vastly and cannot be directly compared. While there are some data on the physiological characteristics of elite and non-elite women's 15's, they are limited and often consist of low and underpowered samples (Hene *et al.*, 2011; Lockie *et al.*, 2016; Nyberg & Penpraze, 2016). Nonetheless, early attempts have been

made to quantify game demands using accepted methodologies (Suarez-Arrones *et al.*, 2014; Virr, Game, Bell, & Syrotuik, 2014).

Time-motion analysis and Global Positioning System (GPS) data of International and top club-level women's RU athletes show similar game demands, in that backs travel greater distances, spend more time at walking speeds (< 6 km $\cdot$ h⁻¹) and sprinting (> 14 km $\cdot$ h⁻¹), while forwards spend more time at moderate intensities (Sheppy *et al.*, 2019; Suarez-Arrones *et al.*, 2014; Virr *et al.*, 2014), similar to the relationship, but different in magnitude, to the men's game (walking speeds ~ 7 km $\cdot$ h⁻¹ and sprinting ~ 28 km $\cdot$ h⁻¹) (Quarrie *et al.*, 2013). There appears to be no differences in heart rate response at international level, but at armature club level (Canadian Premier Division), backs spent less time at > 80 maximum heart rate and had a work-to-rest ratio approximately twice that of forwards (data not available for International players; Virr *et al.*, 2014). These data present evidence of positional differences in game demands at both elite and non-elite level that could be reflected in anthropometric and physical characteristics. However, in non-elite Scottish players ($n = 19$), no difference in anthropometrics, 10–40 m sprint, agility or estimated $\dot{V}O_{2max}$ were identified between forwards and backs (although backs showed greater flexibility (Sit and Reach (cm), 16.3 ± 9.1 versus 28.9 ± 4.1 , respectively; Nyberg & Penpraze, 2016). In contrast, only one study has assessed phenotypic variation of elite players, in the South African 2010 World Cup pre-season training squad (forwards $n = 16$ and backs $n = 19$). In these candidate international players, forwards had greater body mass (~ 16 kg) and percentage fat mass ($\sim 4\%$), while backs had greater vertical jump height (7 cm), push-ups $\cdot$ min⁻¹ ($n \sim 8$), quicker 10 m (~ 0.2 s) and 40 m (~ 0.5 s) sprint times (Hene *et al.*, 2011). Interestingly, over a 32 week season in the same sample, sprint speed changed with high variability but vertical jump height remained consistent (Hene & Bassett, 2013). This might suggest that explosive leg power is both a good positional differentiator and a possible route to performance monitoring in women's RU athletes. The lack of evidence, particularly at the elite/international level, makes it difficult for practitioners to rely on or refer to these data. Thus, a greater understanding of women's RU physical and jump kinetics are warranted. Therefore, the aims of the present study was to compare kinetic jump data between positional groups to potential identify positional differentiator in a representative sample of International Women's Rugby World Cup (2017) competitors.

2 Methods

2.1 Experimental design

A cross-sectional research design was used to investigate participant characteristics, anthropometric measures (height, body mass) and kinetic jump data derived from the countermovement jumps performed on a force platform. All testing was carried out during the 2017

Women's Rugby World Cup in Dublin, Ireland and therefore athletes were intended to be trained to their most competitive performance level at the time of testing. All data were collected by an experienced senior Strength and Conditioning professional at the Institute for Sport and Health laboratories.

2.2 Participants

Sport science and medicine staffs from participating countries were approached to evaluate player and nation interest. Four nations agreed to participate and provided consent to recruit their athletes (knockout rankings between 5th and 10th place). Custom qualitative questionnaires were used to collect data on primary and secondary playing positions, international playing experience and highest competitive level ($n=86$). Of the consenting athletes, jump kinetic data were collected from athletes ($n=63$) during the two weeks prior to the first group game and forwarded for analysis. For the remaining athletes ($n=23$), the jump data were either not collected, due to prior injury/scheduling conflicts, or following initial data quality assurance it was deemed unacceptable for further analysis. Athletes were divided into their positional units of forwards ($n=34$; props, hookers, locks, flankers, number eights) and backs ($n=29$; scrum halves, fly halves, centres, wings, full backs) and subsequently divided into their positional sub-groups according to game demand data (Sheppy *et al.*, 2019). Anthropometric measures (height and body mass) were taken using standard methods. All participants provided individual written informed consent (provided in the athletes native language, if requested) and ethical approval was granted by University College Dublin Institutional Review Board. This study was conducted in accordance with the Declaration of Helsinki (2013).

2.3 Performance testing

From a standing position, with hands resting on the hips and feet extended throughout the flight to prevent knee tucking, two countermovement jumps (CMJs) were performed prior to resistance or field training. Two jumps were separated by ~ 90 s and the best performance (*i.e.* highest jump) was recorded and used for further analysis. A rapid countermovement was conducted by the participants descending until the knee angle reached approximately 90° , followed immediately by a vertical jump. Participants were instructed to jump “as high as possible”. Prior to testing, athletes were instructed to perform a prescribed warm up jump routine, which included, lower-limb mobility exercises and three sub-maximal CMJ efforts. Athletes were familiar (confirmed individually prior to jump) with the CMJ protocol, having performed it on a regular basis over preceding months.

All jumps were performed on a portable force platform at a sampling rate of 1200 Hz (HUR Labs, Tampere, Finland), variables were generated and initially analysed by custom software (Force Platform Software Suite,

Version 2.4.0, Tampere, Finland). The raw data were then exported to Microsoft Excel and analysed using a customised version of the template by (Chavda *et al.*, 2018). Specifically, the instantaneous acceleration ($\text{m}\cdot\text{s}^{-2}$) was obtained by dividing each force value according to the following equation:

$$A_i = (F_i/m) - g,$$

where F_i is the instantaneous force measured in Newtons, m is the body mass of the jumper in kilograms, and g the gravity acceleration. The velocity V_i ($\text{m}\cdot\text{s}^{-1}$) was calculated according to the following equation:

$$V_i = V_{i-1} + A_i \cdot t_i,$$

where V_{i-1} is the instantaneous velocity of the centre of mass at previous point in time and t_i is a $1/1200$ of a second. The threshold for take-off and landing was set at 5 SD above the force recorded during flight time. Jump height (cm) was calculated as:

$$JH = (V_{to}^2 / 2 \cdot g) 100,$$

where V_{to} is instantaneous velocity at take-off. Power was obtained by multiplying instantaneous force by instantaneous velocity and peak power (W) was identified as the maximum instantaneous power value. Peak power was divided by body mass of the jumper to obtain relative peak power ($\text{W} \cdot \text{kg}^{-1}$). Net peak force (N) was identified as the peak force value preceding take-off minus force corresponding to body weight. This was also expressed per kg of body mass, *i.e.* relative net peak force ($\text{N} \cdot \text{kg}^{-1}$). Reactive strength index ($\text{m} \cdot \text{s}^{-1}$) was calculated as JH (m) divided by contact time (s, from start of movement to take-off) (Chavda *et al.*, 2018).

2.4 Statistical analysis

Descriptive data are presented as means and standard deviations. Data were analysed using linear mixed models to perform pairwise comparisons by positional unit (Forwards *vs.* Backs) and sub-groups (Front Row *vs.* Second Row *vs.* Back Row *vs.* Halves *vs.* Centres *vs.* Back Three) allowing for unequal variances. The distributions of the jump data met the Shapiro–Wilk test criteria for normality ($P > 0.05$). Skewness and kurtosis values for the jump data were also examined and deemed to be within the acceptable range (Tabachnick, Fidell, & Ullman, 2014). No issues in uniformity of error were identified (Hopkins, Marshall, Batterham, & Hanin, 2009), so log transformation was avoided. The magnitudes of the differences between groups were assessed by means of standardisation (Cohen, 1988; Hopkins, 2002). These standardised effect sizes (ES) were subsequently evaluated according to the following scale: < 0.2 , trivial; 0.2 – 0.6 , small; 0.6 – 1.2 , moderate; 1.2 – 2.0 , large; > 2.0 , very large (Hopkins *et al.*, 2009). Bonferroni adjustments were applied to P-values for the multiple comparisons. For

Table 1. Means, standard deviations, effects, confidence limits, and null-hypothesis difference between means from anthropometric, countermovement jump performance indicators and qualitative data, between women's RU backs and forwards.

	Forwards Mean $\pm$ SD (n = 47)	Backs Mean $\pm$ SD (n = 39)	Difference (Forwards – Backs)	
			Effect ^a 95%CL	P-value
Age (years)	28 $\pm$ 5	26 $\pm$ 5	0.30 $\pm$ 0.42	0.16
Height (cm)	171 $\pm$ 6	166 $\pm$ 7	0.74 $\pm$ 0.43	0.001
Weight (kg)	83 $\pm$ 11	73 $\pm$ 8	1.10 $\pm$ 0.51	< 0.0001
Jump height (cm)	24.4 $\pm$ 4.2	28.7 $\pm$ 4.5	–0.72 $\pm$ 0.50	0.005
Reactive strength index (m $\cdot$ s ^{–1})	0.31 $\pm$ 0.08	0.36 $\pm$ 0.09	–0.62 $\pm$ 0.50	0.01
Peak force (N)	1015 $\pm$ 190	1003 $\pm$ 226	0.09 $\pm$ 0.51	0.74
Relative peak force (N $\cdot$ kg ^{–1})	12.3 $\pm$ 1.9	13.8 $\pm$ 2.7	–0.62 $\pm$ 0.51	0.02
Peak power (W)	3204 $\pm$ 373	3161 $\pm$ 437	0.12 $\pm$ 0.50	0.68
Relative peak power (W $\cdot$ kg ^{–1})	39.2 $\pm$ 4.8	43.8 $\pm$ 5.8	–0.84 $\pm$ 0.50	0.001
International RU experience, n (%)				
$\geq$ 5 years	28 (65)	23 (64)	–	–
6–10 years	8 (19)	9 (25)	–	–
> 10 years	7 (16)	4 (11)	–	–
Competed in 7's	14 (30)	30 (77)	–	–
Secondary position	30 (64)	29 (76)	–	–
Secondary position outside primary group	21 (45)	18 (47)	–	–

^a Effect sizes are that of the mean differences between positional groups.

null-hypothesis testing, alpha level was set at $P < 0.05$ and uncertainty expressed as 95% confidence limits. All analysis were performed in Statistical Analysis System (Version 9.4, SAS Inc., Cary, NC). *A priori* statistical power calculation revealed a sample of $n = 60$ was required to compare jump variables of six positional groups ($ES = 0.5$ and $1 - \beta = 0.80$; G* Power version 3.1.9.3).

3 Results

3.1 Participant characteristics

Forwards were 5 cm taller and had 10 kg greater body mass compared to backs, with no difference in age. Sixty-five percent of athletes had < 5 years of international RU experience and 51% competed internationally in both the 7's and 15's game. Over two-thirds (69%) reported a secondary playing position and 46% were "outside" of their primary positional group (Tab. 1).

3.2 Main analysis

There was a significant overall effect (by positional unit) for countermovement jump height ($P = 0.005$), relative peak force ($P = 0.02$), relative peak power ($P = 0.001$) and reactive strength index (RSI; $P = 0.01$; Tab. 1). Backs had a greater jump height ($ES = 0.72$, 95%CL ± 0.50), relative power output ($ES = 0.84$, 95%CL ± 0.50), relative force production ($ES = 0.62$, 95%CL ± 0.51) and RSI ($ES = 0.62$, 95%CL ± 0.50), compared to forwards. Differences between backs and forwards in respect of peak power output ($P = 0.68$; $ES = 0.10$, 95%CL ± 0.50) and net peak force production ($P = 0.85$;

$ES = 0.05$, 95%CL ± 0.51 ; Tab. 1). The violin plots, accompanying pairwise comparisons, reveal bimodal and multimodal phenotypic variation when considering only backs and forwards (Fig. 1). Each of these plots suggests that there is variability in jump performance that is not adequately captured in the overall comparison of backs *vs.* forwards and deeper positional analysis was required.

For positional sub-groups, *post-hoc* comparisons revealed that athletes in the backrow, halves and back three had greater relative force production, relative power output and jump height, compared to the front and second row athletes ($ES > 0.70$). Halves and back three athletes had greater RSI compared to front and second row athletes ($ES > 0.97$) and front row athletes had a greater net peak force than second row athletes ($ES = 0.91$, ± 0.68 ; Tab. 2). A series of dot plots illustrate the extent of the variability in jump characteristics across sub-groups (Fig. 2). Numerical descriptive data for each of these jump characteristics by sub-group are presented in supplementary Table S1 for practitioner reference (Supplementary Table S1).

4 Discussion

The present study provides the first position-specific normative jump kinetic data in the largest sample of international Women's Rugby World Cup competitors to date. In addition to positional distinctions, the violin plots presented herein show bimodal and multimodal variation in jump characteristics between unit groups (backs and forwards). This highlights the importance of advancing current literature that is limited to unit comparisons in

Fig. 1. Violin plots showing further positional variation embedded with the Backs and Forwards. “*” indicates null-hypothesis difference ($p < 0.05$) and “ES” is the effect size (difference in means divided by the between-subjects SD at 95%CL).

elite women’s RU (Hene *et al.*, 2011; Hene & Bassett, 2013; Suarez-Arrones *et al.*, 2014; Virr *et al.*, 2014) and the need to investigate more specific positional variation. To address this limitation, the current study revealed that the front five athletes (front and second row groups) had lower jump heights, and most relative force and power than backrows, halves and back three athletes. Furthermore, front rows had greater net peak force and peak power which represented large effects than all other athlete groups.

Alongside a number of high-intensity dynamic activities, all RU athletes are required to perform demanding low-velocity efforts, such as scrums, mauls, rucks and lineouts (Deutsch *et al.*, 2007; Smart *et al.*, 2014). Whilst the frequency of these activities will vary across positional groups, these match demands require RU athletes to develop and maintain the capacity to produce high external forces, and translate this into over-ground tasks requiring high velocity and power (Cross *et al.*, 2014). However, as with match demand metrics, these abilities are position specific and there is a considerable lack of

knowledge regarding elite women’s RU. The present data addresses some of these areas, demonstrating large differences in vertical jump parameters between positional groups, particular jump height and relative peak power/force data. This reflects a similar relationship in elite men where, backs have higher relative power (*i.e.* when body mass is factored) compared to forwards (Front 5, $49.4 \text{ W} \cdot \text{kg}^{-1}$ versus Back 3 and Centres, $59.8 \text{ W} \cdot \text{kg}^{-1}$), but is different from elite men in that forwards have higher absolute peak power (Heffernan *et al.*, 2017). A likely rationale for the difference in absolute peak power, between the men’s and women’s game (that becomes significant when scaling for body mass), is the aforementioned relatively recent introduction of professionalism in the elite women’s game (England Rugby, 2019) where the majority of current international players being semi-professional/amateur athletes. It is well documented in the men’s game that level-specific physiological characteristics can distinguish between semi-professional and professional players (Baker, 2001; Quarrie *et al.*, 1995; Smart *et al.*, 2013) and the present data reflects this mix

Table 2. Effects, confidence limits and null-hypothesis difference between means from countermovement jump performance indicators in selected playing position.

	Positional groups ^a		Difference	
			Effect ^b , 95%CL	P-value ^c
Jump height	Front row	Second row	0.01 ± 0.75	0.990
	“”	Backrow	-0.93 ± 0.73	0.029
	“”	Halves	-1.39 ± 0.82	0.006
	“”	Centres	-0.67 ± 0.99	0.190
	“”	Back three	-1.33 ± 0.88	0.013
	Second row	Backrow	-0.94 ± 0.74	0.028
	“”	Halves	-1.39 ± 0.83	0.006
	“”	Centres	-0.67 ± 1.00	0.186
	“”	Back three	-1.33 ± 0.88	0.013
	Backrow	Halves	-0.45 ± 0.82	0.263
	“”	Centres	0.27 ± 0.99	0.581
	“”	Back three	-0.40 ± 0.87	0.369
	Halves	“”	0.06 ± 0.94	0.902
	Centres	Halves	-0.72 ± 1.05	0.175
	“”	Back three	-0.66 ± 1.09	0.234
Reactive strength	Front row	Second row	0.08 ± 0.70	0.825
	“”	Backrow	-0.54 ± 0.75	0.173
	“”	Halves	-1.10 ± 0.99	0.035
	“”	Centres	0.29 ± 0.87	0.493
	“”	Back three	-0.97 ± 0.72	0.023
	Second row	Backrow	-0.62 ± 0.81	0.147
	“”	Halves	-1.18 ± 1.02	0.032
	“”	Centres	0.34 ± 1.05	0.414
	“”	Back three	-1.04 ± 0.77	0.022
	Backrow	Halves	-0.56 ± 1.05	0.270
	“”	Centres	0.25 ± 0.95	0.599
	“”	Back three	-0.43 ± 0.82	0.309
	Halves	“”	0.13 ± 1.03	0.782
	Centre	Halves	0.81 ± 1.12	0.152
	“”	Back three	-0.67 ± 0.93	0.162
Peak force	Front row	Second row	0.91 ± 0.68	0.025
	“”	Backrow	0.71 ± 0.92	0.150
	“”	Halves	1.13 ± 1.47	0.105
	“”	Centres	0.45 ± 1.04	0.389
	“”	Back three	0.51 ± 1.06	0.353
	Second row	Backrow	-0.20 ± 0.76	0.587
	“”	Halves	0.22 ± 1.47	0.697
	“”	Centres	-0.46 ± 0.92	0.301
	“”	Back three	-0.41 ± 0.93	0.377
	Backrow	Halves	0.43 ± 1.48	0.521
	“”	Centres	-0.26 ± 1.08	0.626
	“”	Back three	-0.21 ± 1.10	0.706
	Halves	“”	0.63 ± 1.53	0.382
	Centres	Halves	0.68 ± 1.52	0.337
	“”	Back three	-0.05 ± 1.19	0.928
Peak power	Front row	Second row	0.49 ± 0.67	0.160
	“”	Backrow	0.40 ± 0.80	0.320
	“”	Halves	0.78 ± 1.08	0.128
	“”	Centres	0.58 ± 0.67	0.111

Table 2. (continued).

Positional groups ^a			Difference	
			Effect ^b , 95%CL	P-value ^c
Relative peak force	Second row	Back three	0.21 ± 0.85	0.602
		Backrow	−0.09 ± 0.86	0.829
		Halves	0.29 ± 1.11	0.573
	Backrow	Centres	0.09 ± 0.76	0.815
		Back three	−0.28 ± 0.90	0.514
		Halves	0.38 ± 1.16	0.495
	Halves	Centres	0.18 ± 0.87	0.678
		Back three	−0.18 ± 0.99	0.710
		Centres	−0.56 ± 1.19	0.332
	Centres	Halves	−0.20 ± 1.11	0.697
		Back three	−0.36 ± 0.91	0.429
		Second row	0.50 ± 0.60	0.120
	Front row	Backrow	−0.23 ± 0.81	0.578
		Halves	−0.62 ± 1.25	0.283
		Centres	−0.56 ± 1.18	0.331
	Second row	Back three	−0.86 ± 1.02	0.114
		Backrow	−0.72 ± 0.70	0.057
		Halves	−1.12 ± 1.23	0.054
	Backrow	Centres	−1.06 ± 1.13	0.066
		Back three	−1.36 ± 0.94	0.014
		Halves	−0.40 ± 1.28	0.503
	Halves	Centres	−0.34 ± 1.22	0.570
		Back three	−0.63 ± 1.07	0.251
		Centres	−0.23 ± 1.38	0.722
Relative peak power	Front row	Halves	0.06 ± 1.48	0.930
		Back three	−0.30 ± 1.34	0.654
		Second row	−0.01 ± 0.67	0.980
	Second row	Backrow	−0.77 ± 0.72	0.056
		Halves	−1.38 ± 0.94	0.011
		Centres	−0.60 ± 0.84	0.17
	Backrow	Back three	−1.51 ± 0.89	0.007
		Backrow	−0.76 ± 0.74	0.062
		Halves	−1.37 ± 0.95	0.012
	Halves	Centres	−0.59 ± 0.86	0.182
		Back three	−1.45 ± 0.91	0.008
		Centres	0.17 ± 0.87	0.685
	Back three	Halves	−0.61 ± 0.96	0.196
		Back three	−0.74 ± 0.92	0.130
		Centres	−0.13 ± 1.07	0.801
	Back three	Centres	0.78 ± 1.04	0.137
		Back three	−0.91 ± 1.01	0.094

^a First positional group (left column) compared to the second (right column).^b Effect sizes are that of the mean differences between positional groups.^c The Bonferroni correction was applied to account for multiple comparisons.

“”Indicates repeat group of that above.

of professionalism in the current international women's game (*i.e.* full time players train more, adapt to training better and phenotypic differences would more easily present in non-relative scaled physiological measures). While limited physiological data exists on international women's RU athletes, the present

sample is representative of the wider international women's RU athletic population, in that the present anthropometric data (Tab. 1) aligns well with other women's Rugby World Cup 2006 and 2010 participants (Schick, Molloy, & Wiley, 2008; Taylor, Fuller, & Molloy, 2011).

Fig. 2. RU individual data positional variation. “a” indicates null-hypothesis difference from front row, “b” second row ($p < 0.05$). “~” indicates a null-hypothesis tendency at $p < 0.06$.

The present data in international women’s rugby show that, while forwards had greater body mass compared to backs (~ 10 kg), it did not translate into differences in lower-body net peak power (~ 40 W difference; Tab. 1). This differs from the positional differentiation of peak power in the men’s game, where forwards are substantially more powerful (~ 400 W difference; Brazier *et al.*, 2018; Heffernan *et al.*, 2017). However, after controlling for mass, international women’s backs had a greater relative power output and these data mirrored the men’s data (Tab. 1). To our knowledge, only two studies have investigated jump variables in women’s RU athletes, one with a collegiate sample using the “Just Jump” jump mat system ($n = 8$; Lockie *et al.*, 2016) and an elite South Africa Women’s Rugby World Cup 2010 training squad using the “Vertec Jump Tester” ($n = 32$; Hene *et al.*, 2011). Both studies reported higher jump heights than the present study (~ 41 cm) however, while there are a number of possible reasons for this (*e.g.* the sample), it is most likely that the significant variability in jump values compared to other technologies, including force platforms, explains these findings (such as that used in the present study: Buckthorpe, Morris, & Folland, 2012; Dobbin, Hunwicks, Highton, & Twist, 2017; McMahon, Jones, & Comfort, 2016; Menzel *et al.*, 2010; Muehlbauer, Pabst, Granacher,

& Busch, 2017). Therefore, these studies are not comparable to the present data, which utilised a validated Hur Labs force platform (Dobbin *et al.*, 2017). Therefore, the present study represents the best available jump kinetics data of elite women’s RU, nonetheless significantly more work is needed to increase awareness of physical and performance characteristics of elite female rugby 7s and 15s athletes.

Antithetically, male RU athletes are physiologically similar between international level and the most immediate lower athletic level (Smart *et al.*, 2013). However, international women’s RU athletes (the only available data is for 7s athletes, however a similar dynamic can be inferred for the 15s game) are physiologically superior (better maximal speed, $\sim 1 m \cdot s^{-1}$; neuromuscular recovery, ~ 230 U/L creatine kinase; Yo-Yo fitness, ~ 370 m) to the sub-elites immediately below (Clarke, Anson, & Pyne, 2015; Clarke *et al.*, 2017; Smart *et al.*, 2013; Vescovi & Goodale, 2015). This should be a consideration for coaches and NGOs when promoting female athletes to international level and the present data suggests possible jump kinetic characteristics for athletes accelerating through the competitive levels. From a practical perspective, if athletes and coaches are unaware of the differences in physiological demands, both positionally and when

accelerating from community rugby to representative RU, there is a potential injury risk. Less physically developed athletes are more likely to accrue musculoskeletal injury risk (e.g., dislocation, fracture, sprain/strain, stress fractures, tendonitis, bursitis, etc.) than those who are already physically prepared (Attwood, Roberts, Trewartha, England, & Stokes, 2019; de la Motte, Gribbin, Lisman, Murphy, & Deuster, 2017; de la Motte, Lisman, Gribbin, Murphy, & Deuster, 2019; Duke, Martin, & Gaul, 2017; Gabbett, Ullah, & Finch, 2012). In a series of systematic reviews of physical phenotypes and musculoskeletal injuries, moderate-to-strong evidence was identified for muscle strength, power, endurance and sprint ability to predict ankle sprains, Achilles tendon, hamstring and contact (defined by physiotherapist report) injury (de la Motte *et al.*, 2017, 2019). Therefore, developing an understanding of the physiological demands of international women's RU, and implementing appropriate practical changes, will inform athletes and coaches as to the required physiological capacity that may help prevent injury and may result in great match success (although this is yet to be empirically shown). Furthermore, recent data suggest that the relationship between training load and injury risk in RU follows an inverted U pattern (Cross, Williams, Trewartha, Kemp, & Stokes, 2016). Therefore knowing, in advance, the physiological requirements typical of international athletes and gradually achieving these practical implications with appropriate training strategies, could aid in the transition from community/club to international rugby (in women's RU this can often be a rapid acceleration) that could impact to lower injury risk – which has been shown in other team sports (Malone *et al.*, 2018).

Another consideration with women's RU, is that athletes frequently switch between playing position (70% of the present sample report a secondary position); therefore, knowledge of the variation in physiological demands from the primary to secondary position, could be an indicator for coaches as to the possible player success (or potentially the likelihood/odds of injury). The present data provides achievable targets for athletes and coaches when considering these demands and may provide adaptive training specific targets. In fact, a recent systematic review of pooled Women's Rugby World Cup (2006 and 2010; 2014 and 2017 data is currently unpublished) shows that props and centres were the most commonly injured athletes and in the present data these two groups (front rows hereafter) have similar values, with data on the back/forward unit split inconsistent through the literature (King *et al.*, 2019). The present study also collected data on secondary position statistics, however the sample was not powered (46%; $n = 38$) to investigate potential physiological differences between primary and secondary positions. The magnitude of the difference in physiological capacity between primary and secondary position could have a significant impact in potential injury susceptibility (given the data presented above; de la Motte *et al.*, 2017, 2019; Duke *et al.*, 2017; Gabbett *et al.*, 2012). Currently, there have been no attempts to quantify these differences or identify if injury rates differ depending on

weather a player is playing in their primary or secondary (outside of their primary positional group) position, but these data are highly warranted. Finally, these data are pre-competition values, assumed to be near to the athlete's physiological peak. Future research should investigate how these variables are subject to change (acutely and chronically) as a measure of fatigue or adaptation throughout an international season.

5 Conclusion

The present data provide important jump kinetic data of internationally competitive women's RU athletes, at unit and positional group level. Specifically, greater force and power variables were identified in the backrow, half back and back three positions, compared to front and second rows. These data can be used as a benchmark for nations and the development of athletes to international level, which could have important implications for injury risk. Future investigations should address this question in elite Women's RU and further consider the secondary position phenomena, as described above. Additionally, Women's RU athletes represent a unique population of female athletes, involved in a high velocity collision sport. Thus, important factors, such as menses and the effect of contraceptive medication should be included in future investigations, as both have significant impacts on muscle-tendon unit function and potentially injury susceptibility.

Supplementary Material

Table S1. Countermovement jump performance indicators by positional sub-group from women's Rugby World Cup (2017) competitors, presented as means $\pm$ standard deviations.

The Supplementary Material is available at <http://science-motricite.org/10.1051/sm/2021013/olm>.

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