Season-long changes in the body composition profiles of competitive female Rugby Union players assessed via Dual Energy X-ray Absorptiometry

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Running Head: Body Composition Changes in Female Rugby Union

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ABSTRACT:

Background: Reference data for the body composition values of female athletes are limited to very few sports, with female Rugby Union players having mostly been omitted from such analyses.

Methods: Using dual energy X-ray absorptiometry (DXA) scans, this study assessed the body composition profiles (body mass, bone mineral content; BMC, fat mass; FM, lean mass; LM, bone mineral density; BMD) of 15 competitive female Rugby Union players before and after the 2018/19 competitive season. Total competitive match-play minutes were also recorded for each player.

Results: Body mass (73.7±9.6 kg vs 74.9±10.2 kg, p≤0.05, *d*=0.13) and BMC (3.2±0.4 kg vs 3.3±0.4 kg, p≤0.05, d=0.15) increased pre- to post-season for all players. Conversely, FM (21.0±8.8 kg), LM (50.7±3.9 kg), and BMD (1.31±0.06 $g\cdot cm^{-2}$) were similar between time-points (all p>0.05). Accounting for position, body mass ($r_{partial(12)}$ = 0.196), FM ($r_{partial(12)}$ = -0.013), LM ($r_{partial(12)}$ = 0.351), BMD ($r_{partial(12)}$ = 0.168) and BMC ($r_{partial(12)}$ = -0.204) showed no correlation (all p>0.05) against match-play minutes.

Conclusion: The demands of the competitive season influenced specific body composition indices (i.e., body mass, BMC) in female Rugby Union players; a finding which was unrelated to the number of minutes played in matches. While the causes of such differences remain unclear, practitioners should be cognisant of the body composition changes occurring throughout a female Rugby Union competitive season and, where necessary, consider modifying variables associated with adaptation and recovery accordingly.

Key Words: Dual Energy X-ray Absorptiometry, female athlete, team sport, bone mineral density

1. INTRODUCTION:

Rugby Union (RU) is a field-based contact team sport characterized by repeated brief bouts of high-intensity exercise (i.e., running, sprinting, tackling, scrummaging, rucking, and mauling) interspersed with periods of low to moderate intensity activities (i.e., standing, walking, and jogging) [1]. In recent years, the popularity of female rugby has increased significantly [2]; now being played in over 100 countries [1]. Both males and females (15-a-side) play for 80 min under the same rules and with the same equipment. However, in contrast to their male counterparts [3,4,5] data pertaining to the match-play demands of 15-a-side female RU is limited [1,6].

Body composition is often assessed to provide an indication of an athlete's fitness and health status [7]. Traditionally, body composition is estimated using two- (e.g., skinfolds; SF, bioelectrical impedance; BIA, air displacement plethysmography; ADP) and more recently, three- (e.g., BIA, dual-energy X-ray absorptiometry; DXA) compartment models to calculate fat-free mass (FFM), lean mass (LM), fat mass (FM), and in the case of DXA, bone mineral content (BMC) [7,8,9]. Anthropometric measurement techniques provide an accurate measure of body composition, and tracking changes in such indices can be useful for evaluating the effectiveness of dietary and/or conditioning interventions. Furthermore, increases in LM within RU have benefitted performance [10,11]. Notably, increased LM may positively influence the power-to-weight ratios of players during match-play and improve key success predictors such as; momentum, strength, power, and speed [11,12]. It is therefore beneficial to have accurate information concerning measures of body composition in athletes for both health and performance purposes.

When compared to other methodologies of measuring body composition, DXA is widely regarded as the gold standard non-invasive method of measuring FM, FFM and separating FFM in to LM and bone [13]. Likewise, the method has also shown greater accuracy when ascertaining body composition measures relative to ADP [14], BIA [15] and SF [16] analyses, with DXA being highly correlated with both magnetic resonance imaging and computed tomography when measuring muscle mass [17]. By accounting for the variability in bone density that often exists in this population, DXA may also be a superior methodology for use with athletic females [7]. However, current reference values for the body composition of females when assessed by DXA are limited to a small number of sports such as soccer [18], track and field [19, 20], basketball [21] and softball [22].

While physical and body composition data exists for elite female Rugby League (RL) players [23], with significant differences in body mass, LM, FM and body fat percentage existing between forwards and backs, body composition values assessed by DXA for the 15-a-side format of female RU are scarce. Santos *et al*., [24] collated body composition data from both SF and DXA scans in 21 different sports (including both males and females), but no information was presented for female RU players [24]. Notably, Harty *et al*. [25] published body composition data of female collegiate RU players via DXA and reported significant differences between forwards and backs in all measured variables; findings which disagree with those of elite Scottish female RU players when measured via ADP [26]. Such contrasts may be associated with ADP being a two-component model of body composition which demonstrates a higher error (up to 13%) compared to DXA [14]. Acknowledging such equivocal findings, the aim of this study was to assess seasonal changes in the body composition of female RU players. Furthermore, to provide novel insight, we sought to also investigate whether changes in such values occurred as a result of involvement in a competitive playing season.

2. METHODS:

2.1 Experimental Approach to the Problem:

Using an observational approach, body composition was measured via DXA scan within competitive female RU players in both the pre-season (i.e., August 2018) and immediately post-season (i.e., March 2019) periods of the 2018/19 competitive calendar. Body composition variables of body mass, FM, LM, bone mineral density (BMD) and BMC were collected via DXA scans during pre-season. Measurements were repeated at the end of the same competitive season. Notably, DXA technology offers high precision and reliability when compared to other body composition methods such as BIA and anthropometry [17,27], and all scans were performed by the same qualified technician on each occasion. Throughout the duration of the competitive season, dietary intake was administered as per the club nutritionist's direction. Players were recommended to adopt diets in a periodized manner adhering to 1.2 - 2.0 $g{\cdot}kg^{-1}{\cdot}BM{\cdot}d^{-1}$ protein, ~5 $g{\cdot}kg^{-1}{\cdot}BM{\cdot}d^{-1}$ carbohydrate and 20-35% of daily energy intake from fats.

2.2 Participants:

All participants (n=15, age: 27±5 years, height: 169±5 cm, weight: 73.7±9.6 kg) were recruited from a team competing in the highest tier of female RU in the United Kingdom (i.e., Women's Premiership League). Six of the participants were professional, international players (International caps: 26±23). The study obtained institutional ethical approval and informed consent was sought from participants prior to study involvement.

2.3 Dual-energy X-ray absorptiometry (DXA):

For each measurement, participants were asked to attend the laboratory in a rested state and having fasted overnight. This was to eliminate changes in lean and total mass that corresponded to a volume of food/drink consumed prior to scanning [28]. Before measurements were taken, participants were screened for any existing injuries and/or pregnancy that may have precluded them from the scan. Stature was measured via portable stadiometer (Seca, Hamburg, Germany) to the nearest 1 mm and body mass was measured via calibrated weighing scales (Seca, Hamburg, Germany) to the nearest 0.1 kg. These data were inputted into the DXA computer for initial participant characteristics. DXA scans (DPX-L Lunar Prodigy, GE Medical Systems, Lunar Madison, Wisconsin, USA) assessed FM, LM, BMD and BMC through tissue X-ray absorption from two X-ray energy peaks [17] (enCORE 2008, version 12.30.008 software). Within the DXA procedure, participants were exposed to low levels of ionizing radiation (0.4 µGy per 1 full-body scan); thus posing minimal risk to health with exposures being comparable to that of everyday activity over a 24 h period at sea level [19,28]. During the scans, participants were required to lay supine on the DXA bed, with their hands in a pronated position by their sides (as per manufacturer instructions) and to wear minimal clothing to improve the accuracy of scan results as per the methods of Nana *et al*. [27]. These processes were repeated for the follow-up measures during the post-season period taken within four days of final playing encounter.

2.4 Match-Play Analysis:

Total match-play minutes were recorded over the 2018/19 competitive season from official match reports. A total of twenty competitive regular season women's RU matches were recorded; an average of one match played per week between September 2018 – March 2019, plus two additional play-off fixtures played between March 2019 – April 2019 (a maximum total of 160 min match-play minutes).

2.5 Statistical Analysis:

All data are presented as mean ± standard deviation. In the case of whole group changes between pre and post-season values, data were analyzed via SPSS (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp). Normality was assessed via Shapiro-Wilks test. A multivariate analysis of variance (MANOVA) was conducted to identify interaction and main effects. Where significant main effects were identified, Tukey's post hoc analysis and within-player paired t-tests were performed. Delta values of differences between pre- and post-season measures of body mass, FM, LM, BMD and BMC were calculated, and controlling for position, a Pearson's partial correlation was used to determine total playing minutes against these variables. Effect sizes (ES) were calculated in accordance with Cohen's *d* ES principles ($0 < ES < 0.2$ = trivial, $0.2 < ES < 0.5$ = small, $0.5 < ES < 0.8$ = medium, > 0.8 = large) [29]. An alpha level of $p \leq 0.05$ denoted significance. For the purposes of benchmarking positional data, and in the absence of inferential statistics due to insufficient statistical power, descriptive statistics are presented for each variable according to playing position (i.e., forwards vs backs).

3. RESULTS:

Body composition data can be seen in Table 1. Interaction effects were non-significant for all variables (all $p>0.05$). Significant time effects were observed across variables ($F_{(4,10)}= 4.734$, $p\leq0.05$, partial $\eta^2 = 0.654$). Specifically, body mass (Body $mass_{Pre}$: 73.7±9.6 kg, Body $mass_{Post}$: 74.9±10.2 kg, $p\leq0.05$, d=0.13) and BMC (BMC_{Pre}: 3.23±0.35 kg, BMC_{Post}: 3.28±0.36 kg, $p\leq0.05$, d=0.15) increased from pre- to post-season. Mean FM (20.1±8.3 vs 21.0±8.8 kg, d=0.11), LM (50.2±3.6 vs 50.7±3.9 kg, d=0.14) and BMD (1.30±0.07 $g\cdot cm^{-2}$ vs 1.31±0.06 $g\cdot cm^{-2}$, d=0.16) showed no differences between pre- and post-season measures (all $p>0.05$).

Mean average match-play durations for all participants (n=15) across the competitive season was 902±330 min. No differences were observed between positions for total match-play durations (Forwards: 790±298 min, Backs: 1030±338 min, $p>0.05$, d=0.81) or total full-game equivalents (Forwards: 10±4, Backs: 13±4, $p>0.05$, d=0.81). The relationships between match-play minutes and all DXA variables were not significant (Body mass: $r_{partial(12)} = 0.196$, $p\geq0.05$, FM: $r_{partial(12)} = -0.013$, $p\geq0.05$, LM: $r_{partial(12)} = 0.351$, $p\geq0.05$, BMD: $r_{partial(12)} = 0.168$, $p\geq0.05$ and BMC: $r_{partial(12)} = -0.204$, $p\geq0.05$).

*******INSERT TABLE 1 NEAR HERE*******

4. DISCUSSION:

The primary objective of this study was to profile the body composition profiles of female RU players before and after a competitive season. Secondly, via correlational analyses, we sought to also investigate whether changes in body composition values were related to the number of match-play minutes played. Although significant changes in body mass and BMC occurred over the course of a competitive season, ES analyses deemed these trivial. To the author's knowledge, this is the first study to investigate DXA-derived body composition changes of competitive female RU players throughout the course of a domestic season. Therefore, insight is offered into the benchmarks of body composition data of female RU players; findings which may have application to practitioners working with this specific sporting population.

Body mass increased by ~1.2 kg post-season relative to pre-season values; findings which despite being statistically significant were trivial as per ES analyses. Notably, the significant changes in body mass seen here support those observed previously in female Rugby Sevens [30] and female 15-a-side RU players [25,31]. The congruent changes in BMC also reported at post-season are unlikely to explain such responses given the differences in magnitude (i.e., Δbody mass: ~1.2 kg, ES: 0.13; ΔBMC: ~0.05 kg, ES: 0.15). Although non-significant, contributions from LM and FM are therefore more likely. In support of this, despite a lack of statistical significance, increased FM and LM occurred between pre- and post-season (equivalent to trivial ES of 0.11 and 0.14, respectively). While it is unclear as to the practical significance of, and the exact reasoning underpinning such observations, reductions in training loads have previously been attributed to increases in FM towards the end of a season in male, elite RU players [32] and may offer insight to explain such changes in female RU players. Likewise, increased LM occurred in both male elite RU and Australian football which was attributed to exposure to resistance training throughout the pre- and competitive season respectively [11,32], and may help explain the LM findings in the present study. Speculatively, and acknowledging that correlations to match-play minutes were non-significant, differences in body mass over the season may be attributed to specific match-play characteristics that RU players undertake [30]. For example, as body mass is correlated with increased scrum force [33] and larger force magnitudes [34], it may be suggested that larger athletes are either talent-identified or self-select to play in forward positions during their development, or that specific interventions have led to larger body masses versus backs [30]. Nevertheless, irrespective of the origins of such differences, the findings in this present study highlight that practitioners may also need to consider the effects of a competitive season on specific indices of body composition.

Increased BMC was also observed throughout the domestic season**,** but it must be noted that ES analyses deemed these trivial changes. These observations, both in terms of magnitude and direction, are supported by findings from female basketball (Baseline: 3.25±0.04 kg, Follow-Up: 3.30±0.04 kg; [19]). Training that consists of weight-bearing exercise, high-impact exercises [34] and associated RU-specific training and match-play, have previously been found to stimulate bone accretion [12,35]. Notably, bone mineral accrual mechanisms have been attributable to excess loading above accustomed levels during weight-bearing exercises [36,37]. Similarly, several modes of resistance exercise have been investigated in relation to BMD, with training involving high-intensity actions increasing BMD [35]. Such training modalities are commonplace in RU [38], and reflect the activities undertaken by the players in the present study.

Our BMD findings were comparable with that of female basketball players [19] and higher than observed in female soccer [19]. However, while specific body composition indices may need consideration when seeking to optimize performance in female RU, differences between pre- and post-season measures did not correlate against total match-play minutes. Collectively, these findings indicate that total match-play minutes alone have limited relationship to body composition when assessed in competitive female RU players. That said, ascertaining the potential role of other factors (e.g., training volume, match-play characteristics, dietary intake etc.) on markers of body composition remains to be investigated and presents itself as a future research opportunity.

Whilst a lack of statistical power precluded an inferential statistical approach to position-specific data analyses, the dearth of literature presently available presents an opportunity to provide practitioners with descriptive statistics regarding position-specific body composition findings (Table 1). Using the method of ADP, Nyberg & Penpraze [26] observed no between-position differences in anthropometric data in elite Scottish female RU players. More recently, reporting of position-specific DXA-derived anthropometric data in female collegiate RU players observed greater body mass, FM, FFM, BMD and BMC in forwards compared to backs [25]. In the case of the latter, and despite comparable assessment methodologies to those reported in the present study (i.e., DXA), the length of the assessment period (i.e., one season in the present study versus a more prolonged 3-year period) and its influence on the realization of adaptive responses resulting from accumulated training volumes should be considered. That said, despite a lack of statistical analysis for between-position differences, meaningful benchmark data is presented from a high-level competitive cohort of female RU players. Future research opportunities therefore exist to substantiate such findings in comparable populations.

Despite DXA being widely deemed a gold standard method for body composition analyses due to its accuracy and repeatability [39,40], the method is not without its limitations. Firstly, our findings suggest the possible role that increased FM may have had over the course of the competitive season. Research indicates that with increasing fat mass comes increased risk of error via DXA [39,41]. Also, the potential effects of the menstrual cycle on indices of body composition were not considered within this study. Although the effects of such changes on the accuracy of body composition measures via DXA scan are not fully understood [28], the influence of menses on the reliability of body composition estimates appears minimal in a cohort of pre-menopausal females [42]; whether this is true for female RU players remains to be investigated. Within these limitations, is the fact that DXA manufacturers' body composition estimation algorithms are not developed from athletic populations – meaning that reference values are compared against 'general' cohorts [27]. Therefore, refining algorithms to better reflect the characteristics of athletic populations (both male and female) may increase the resolution and accuracy of future research.

In summary, although trivial from an ES perspective, changes in specific indices of body composition were observed in competitive female RU players and such responses occurred throughout a domestic season (i.e., increased body mass and BMC). No significant changes were observed across the season in FM, LM and BMD, findings which were supported with trivial ES analyses. Therefore, given the limited literature available, further research into the body composition changes (both regional and total), involving longitudinal studies with a larger sample size of intermittent female team sports players within applied settings, are warranted.

Additionally, these findings provide insight into position-specific benchmark data and thus also highlight future opportunities for research in this respect.

This novel study provides data from a sample of competitive female RU players competing in the highest playing standard in the United Kingdom. Both body mass and BMC differed across the course of a competitive season. Because of the position-specific demands of RU, body composition changes need to be considered by sports science practitioners and where appropriate, an appropriate intervention implemented. Such considerations can help practitioners maximize performance over the course of a competitive season. Practitioners should therefore consider strength and conditioning and nutritional strategies to optimize changes in body composition for the sake of enhanced performance.

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AUTHOR CONTRIBUTIONS:

The study was designed by CCu and MR; data was collected and analyzed by CCu; data interpretation and manuscript preparation were undertaken by CCu, MR, MKR, NA and CCo. All authors approved the final version of the paper.

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COMPETING INTERESTS:

The authors declare that they have no competing interests.

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LEGENDS:

Table 1: Comparisons between pre- and post-season Dual Energy X-ray Absorptiometry scan measures of body mass (BM), fat mass (FM), lean mass (LM) bone mineral content (BMC) (all kg) and bone mineral density (BMD) ($g{\cdot}cm^{-2}$) of competitive female rugby union players. * within-variable difference relative to the pre-season value at $p \leq 0.05$ level. Position-specific data is not subject to inferential statistical analyses but is presented for descriptive purposes.

Table 1: Comparisons between pre- and post-season Dual Energy X-ray Absorptiometry scan measures of body mass (BM), fat mass (FM), lean mass (LM) bone mineral content (BMC) (all kg) and bone mineral density (BMD) ($g \cdot cm^{-2}$) of competitive female rugby union players. * within-variable difference relative to the pre-season value at $p \leq 0.05$ level. Position-specific data is not subject to inferential statistical analyses but is presented for descriptive purposes.

Time	Group	DXA Variable				
		BM (kg)	**FM (kg)**	**LM (kg)**	**BMD ($g \cdot cm^{-2}$)**	**BMC (kg)**
Pre-season	All (n=15)	73.7±9.6	20.1±8.3	50.2±3.6	1.30±0.07	3.24±0.40
	Forwards (n=8)	77.2±12.1	23.1±10.1	50.5±4.7	1.32±0.04	3.40±0.30
	Backs (n=7)	69.9±3.0	16.6±3.9	49.7±2.0	1.28±0.08	3.04±0.30
Post-Season	All (n=15)	74.9±10.2*	21.0±8.8	50.7±3.9	1.31±0.06	3.28±0.36*
	Forwards (n=8)	78.9±12.8	24.0±10.8	51.5±4.9	1.33±0.04	3.50±0.40
	Backs (n=7)	70.4±2.9	17.6±4.32	49.7±2.34	1.28±0.08	3.10±0.30