**Section:** Original Research

**Article Title:** 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:**

1  **Background:** Reference data for the body composition values of female athletes are

2  limited to very few sports, with female Rugby Union players having mostly been

3  omitted from such analyses.

4  **Methods:** Using dual energy X-ray absorptiometry (DXA) scans, this study assessed

5  the body composition profiles (body mass, bone mineral content; BMC, fat mass;

6  FM, lean mass; LM, bone mineral density; BMD) of 15 competitive female Rugby

7  Union players before and after the 2018/19 competitive season. Total competitive

8  match-play minutes were also recorded for each player.

9  **Results:** Body mass (73.7±9.6 kg vs 74.9±10.2 kg, p≤0.05, $d$=0.13) and BMC

10  (3.2±0.4 kg vs 3.3±0.4 kg, p≤0.05, d=0.15) increased pre- to post-season for all

11  players. Conversely, FM (21.0±8.8 kg), LM (50.7±3.9 kg), and BMD (1.31±0.06 g·cm$^{-}$

12  $^{2}$) were similar between time-points (all p>0.05). Accounting for position, body mass

13  ($r_{partial(12)}$ = 0.196), FM ($r_{partial(12)}$ = -0.013), LM ($r_{partial(12)}$ = 0.351), BMD ($r_{partial(12)}$ =

14  0.168) and BMC ($r_{partial(12)}$ = -0.204) showed no correlation (all p>0.05) against

15  match-play minutes.

16  **Conclusion:** The demands of the competitive season influenced specific body

17  composition indices (i.e., body mass, BMC) in female Rugby Union players; a finding

18  which was unrelated to the number of minutes played in matches. While the causes

19  of such differences remain unclear, practitioners should be cognisant of the body

20  composition changes occurring throughout a female Rugby Union competitive

21  season and, where necessary, consider modifying variables associated with

22  adaptation and recovery accordingly.

23

24  *Key Words:* Dual Energy X-ray Absorptiometry, female athlete, team sport, bone

25  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

58  limited to a small number of sports such as soccer [18], track and field [19, 20], basketball
59  [21] and softball [22].

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

76

## 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

107 measured via portable stadiometer (Seca, Hamburg, Germany) to the nearest 1 mm
108 and body mass was measured via calibrated weighing scales (Seca, Hamburg,
109 Germany) to the nearest 0.1 kg. These data were inputted into the DXA computer for
110 initial participant characteristics. DXA scans (DPX-L Lunar Prodigy, GE Medical
111 Systems, Lunar Madison, Wisconsin, USA) assessed FM, LM, BMD and BMC
112 through tissue X-ray absorption from two X-ray energy peaks [17] (enCORE 2008,
113 version 12.30.008 software). Within the DXA procedure, participants were exposed
114 to low levels of ionizing radiation (0.4 µGy per 1 full-body scan); thus posing minimal
115 risk to health with exposures being comparable to that of everyday activity over a 24
116 h period at sea level [19,28]. During the scans, participants were required to lay supine
117 on the DXA bed, with their hands in a pronated position by their sides (as per
118 manufacturer instructions) and to wear minimal clothing to improve the accuracy of
119 scan results as per the methods of Nana *et al.* [27]. These processes were repeated
120 for the follow-up measures during the post-season period taken within four days of
121 final playing encounter.

122

### 123 2.4 Match-Play Analysis:

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

129

### 130 2.5 Statistical Analysis:

131 All data are presented as mean ± standard deviation. In the case of whole group
132 changes between pre and post-season values, data were analyzed via SPSS (IBM
133 Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY:
134 IBM Corp). Normality was assessed via Shapiro-Wilks test. A multivariate analysis of
135 variance (MANOVA) was conducted to identify interaction and main effects. Where
136 significant main effects were identified, Tukey's post hoc analysis and within-player
137 paired t-tests were performed. Delta values of differences between pre- and post-

138  season measures of body mass, FM, LM, BMD and BMC were calculated, and

139  controlling for position, a Pearson's partial correlation was used to determine total

140  playing minutes against these variables. Effect sizes (ES) were calculated in

141  accordance with Cohen's *d* ES principles (0 < ES < 0.2 = trivial, 0.2 < ES < 0.5 =

142  small, 0.5 < ES < 0.8 = medium, > 0.8 = large) [29]. An alpha level of p≤0.05 denoted

143  significance. For the purposes of benchmarking positional data, and in the absence

144  of inferential statistics due to insufficient statistical power, descriptive statistics are

145  presented for each variable according to playing position (i.e., forwards vs backs).

146

147 **3. RESULTS:**

148 Body composition data can be seen in Table 1. Interaction effects were non-
149 significant for all variables (all p>0.05). Significant time effects were observed across
150 variables ($F_{(4,10)}$= 4.734, p≤0.05, partial $\eta^2$ = 0.654). Specifically, body mass (Body
151 mass$_{Pre}$: 73.7±9.6 kg, Body mass$_{Post}$: 74.9±10.2 kg, p≤0.05, $d$=0.13) and BMC
152 (BMC$_{Pre}$: 3.23±0.35 kg, BMC$_{Post}$: 3.28±0.36 kg, p≤0.05, $d$=0.15) increased from pre-
153 to post-season. Mean FM (20.1±8.3 vs 21.0±8.8 kg, $d$=0.11), LM (50.2±3.6 vs
154 50.7±3.9 kg, $d$=0.14) and BMD (1.30±0.07 g·cm$^{-2}$ vs 1.31±0.06 g·cm$^{-2}$, $d$=0.16)
155 showed no differences between pre- and post-season measures (all p>0.05).

156 Mean average match-play durations for all participants (n=15) across the competitive
157 season was 902±330 min. No differences were observed between positions for total
158 match-play durations (Forwards: 790±298 min, Backs: 1030±338 min, p>0.05,
159 $d$=0.81) or total full-game equivalents (Forwards: 10±4, Backs: 13±4, p>0.05,
160 $d$=0.81). The relationships between match-play minutes and all DXA variables were
161 not significant (Body mass: $r_{partial(12)}$ = 0.196, p≥0.05, FM: $r_{partial(12)}$ = -0.013, p≥0.05,
162 LM: $r_{partial(12)}$ = 0.351, p≥0.05, BMD: $r_{partial(12)}$ = 0.168, p≥0.05 and BMC: $r_{partial(12)}$ = -
163 0.204, p≥0.05).

164

165 **\*\*\*\*\*INSERT TABLE 1 NEAR HERE\*\*\*\*\***

166

167

168 **4. DISCUSSION:**

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

179 Body mass increased by ~1.2 kg post-season relative to pre-season values; findings
180 which despite being statistically significant were trivial as per ES analyses. Notably,
181 the significant changes in body mass seen here support those observed previously
182 in female Rugby Sevens [30] and female 15-a-side RU players [25,31]. The congruent
183 changes in BMC also reported at post-season are unlikely to explain such responses
184 given the differences in magnitude (i.e., Δbody mass: ~1.2 kg, ES: 0.13; ΔBMC:
185 ~0.05 kg, ES: 0.15). Although non-significant, contributions from LM and FM are
186 therefore more likely. In support of this, despite a lack of statistical significance,
187 increased FM and LM occurred between pre- and post-season (equivalent to trivial
188 ES of 0.11 and 0.14, respectively). While it is unclear as to the practical significance
189 of, and the exact reasoning underpinning such observations, reductions in training
190 loads have previously been attributed to increases in FM towards the end of a
191 season in male, elite RU players [32] and may offer insight to explain such changes in
192 female RU players. Likewise, increased LM occurred in both male elite RU and
193 Australian football which was attributed to exposure to resistance training throughout
194 the pre- and competitive season respectively [11,32], and may help explain the LM
195 findings in the present study. Speculatively, and acknowledging that correlations to
196 match-play minutes were non-significant, differences in body mass over the season
197 may be attributed to specific match-play characteristics that RU players undertake [30].
198 For example, as body mass is correlated with increased scrum force [33] and larger
199 force magnitudes [34], it may be suggested that larger athletes are either talent-
200 identified or self-select to play in forward positions during their development, or that

201 specific interventions have led to larger body masses versus backs [30]. Nevertheless,
202 irrespective of the origins of such differences, the findings in this present study
203 highlight that practitioners may also need to consider the effects of a competitive
204 season on specific indices of body composition.

205 Increased BMC was also observed throughout the domestic season, but it must be
206 noted that ES analyses deemed these trivial changes. These observations, both in
207 terms of magnitude and direction, are supported by findings from female basketball
208 (Baseline: 3.25±0.04 kg, Follow-Up: 3.30±0.04 kg; [19]).  Training that consists of
209 weight-bearing exercise, high-impact exercises [34] and associated RU-specific
210 training and match-play, have previously been found to stimulate bone accretion
211 [12,35]. Notably, bone mineral accrual mechanisms have been attributable to excess
212 loading above accustomed levels during weight-bearing exercises [36,37]. Similarly,
213 several modes of resistance exercise have been investigated in relation to BMD, with
214 training involving high-intensity actions increasing BMD [35]. Such training modalities
215 are commonplace in RU [38], and reflect the activities undertaken by the players in the
216 present study.

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

227 Whilst a lack of statistical power precluded an inferential statistical approach to
228 position-specific data analyses, the dearth of literature presently available presents
229 an opportunity to provide practitioners with descriptive statistics regarding position-
230 specific body composition findings (Table 1). Using the method of ADP, Nyberg &
231 Penpraze [26] observed no between-position differences in anthropometric data in elite
232 Scottish female RU players. More recently, reporting of position-specific DXA-

233   derived anthropometric data in female collegiate RU players observed greater body
234   mass, FM, FFM, BMD and BMC in forwards compared to backs [25]. In the case of the
235   latter, and despite comparable assessment methodologies to those reported in the
236   present study (i.e., DXA), the length of the assessment period (i.e., one season in
237   the present study versus a more prolonged 3-year period) and its influence on the
238   realization of adaptive responses resulting from accumulated training volumes
239   should be considered. That said, despite a lack of statistical analysis for between-
240   position differences, meaningful benchmark data is presented from a high-level
241   competitive cohort of female RU players. Future research opportunities therefore
242   exist to substantiate such findings in comparable populations.

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

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

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

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

277

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281

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286

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289

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292

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426 **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·cm$^{-2}$) of competitive female rugby union players. * within-variable difference relative to the pre-season value at p≤0.05 level. Position-specific data is not subject to inferential statistical analyses but is presented for descriptive purposes.

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| Time | Group | DXA Variable | | | | |
|------|-------|------|------|------|------|------|
| | | BM (kg) | FM (kg) | LM (kg) | BMD (g·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 |