1   **Title: Three-compartment body composition in academy**
2   **and senior rugby league players**
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39 **Abstract**
40 **Purpose:** This study compared the body size and three
41 compartment body composition between academy and senior
42 professional rugby league players using dual energy X-ray
43 absorptiometry (DXA).
44 **Methods:** Academy (age 18.1±1.1 years; n=34) and senior (age
45 26.2 ±4.6 years; n=63) rugby league players received one total-
46 body DXA scan. Height, body mass and body fat percentage
47 alongside total and regional fat mass, lean mass and bone
48 mineral content (BMC) were compared. Independent t-tests
49 with Cohen's d effect sizes and multivariate analysis of
50 covariance (MANCOVA), controlling for height and body
51 mass, with partial eta squared (η^2) effect sizes, were used to
52 compare total and regional body composition.
53 **Results:** Senior players were taller (183.2±5.8 vs. 179.2±5.7
54 cm; p=0.001; d=0.70) and heavier (96.5±9.3 vs. 86.5±9.0 kg;
55 p<0.001; d=1.09) with lower body fat percentage (16.3±3.7 vs.
56 18.0±3.7 %; p=0.032; d=0.46) than academy players.
57 MANCOVA identified significant overall main effects for total
58 and regional body composition between academy and senior
59 players. Senior players had lower total fat mass (p<0.001,
60 η^2=0.15), greater total lean mass (p<0.001, η^2=0.14) and greater
61 total BMC (p=0.001, η^2=0.12) than academy players. For
62 regional sites, academy players had significantly greater fat
63 mass at the legs (p<0.001; η^2=0.29) than senior players.
64 **Conclusions:** The lower age, height, body mass and BMC of
65 academy players suggest that these players are still developing
66 musculoskeletal characteristics. Gradual increases in lean mass
67 and BMC whilst controlling fat mass is an important
68 consideration for practitioners working with academy rugby
69 league players, especially within the lower body.
70
71 **Key Words:** anthropometry, dual energy x-ray absorptiometry
72 (DXA), fat mass, lean mass, bone mineral content
73
74

Introduction

Rugby league is an international collision sport involving frequent periods of high intensity activity separated by lower intensity activity.[1] Within rugby league, body composition is an important consideration for practitioners due to the requirements of players to have highly developed physiological capacities (e.g., speed, aerobic fitness)[2] alongside health implications (e.g., reducing injury). Past research has reported lower skinfolds and greater lean mass between elite and semi-elite players, alongside lower skinfolds being associated with greater playing minutes[3] and physiological capabilities.[4] Within the United Kingdom (UK), talented rugby league players are recruited to a professional club's academy programme between the ages of 16-19 years. One purpose of an academy programme is to develop the physical qualities of academy rugby league players to meet the increasing training and game demands at higher levels.[5,6] Therefore, understanding and evaluating the differences in anthropometric and body composition of academy and senior players is of value.

To date, the majority of research examining the body size and body composition (using skinfold assessments) profiles of rugby league players have evaluated the effect of playing level[3,7] and playing position[4,8] within junior and senior populations. An increase in height and body mass, and a decrease in the sum of skinfolds, is observed at higher playing levels. Reflecting the demands of the game, forwards tend to be taller and heavier with greater skinfold thickness within both junior[4,8,9] and senior[10] playing groups. Previous research has emphasized the importance of larger physical attributes in forward positions due to their game demands predominantly requiring a greater number of physical collisions (e.g., tackles, ball carries).[4,10]

Although research has reported differences in physical characteristics between junior and senior levels, no study has directly compared body size and three compartment body composition between academy and senior professional rugby league players as conducted in Australian Rules Football (AFL).[11] Given that junior players are still experiencing growth and maturation processes, this analysis is important for nurturing long-term health and performance development within junior rugby league players.

Recent studies in rugby league[12,13] and rugby union[14,15] have utilized dual energy x-ray absorptiometry (DXA) to analyse three-compartment body composition. Whilst the skinfold technique is useful for routine monitoring of body fat in athletes, DXA is a convenient and useful diagnostic tool for acquiring more comprehensive data on bone and body composition.[16] DXA provides both total and regional values of fat mass, lean mass and bone mineral content (BMC) which allows more accurate and reliable evaluations of body

125 composition in athletes.[17] The aim of this study was to
126 characterize and compare the body size and three-compartment
127 body composition of UK academy (Under 19s) and senior
128 professional rugby league players using DXA whilst also
129 considering playing position.
130
131   **Materials &Methods**
132 *Subjects*
133   Sixty-three senior professional players from two
134 European Super League clubs (backs: n=27, age 26.0±4.3
135 years; forwards: n=36, age 26.3±4.9 years), and 32 academy
136 players from one European Super League club (backs: n=15,
137 age 18.1±1.1 years; forwards: n=19, age 18.2±1.1 years),
138 participated in the study. All protocols received institutional
139 ethics approval and players provided written consent.
140 *Procedures*
141   A cross-sectional research design was used whereby
142 participants were tested during the last phase of the pre-season
143 period (January - February) in a euhydrated state (urine
144 osmolality <700mOsmol·kg^{-1}).[18] All scans were scheduled on
145 a rest day so activity levels did not affect the scans.
146 Participants wore minimal clothing, with shoes and jewellery
147 removed. Height was measured using a stadiometer (SECA
148 Alpha, Birmingham, UK) to the nearest 0.1cm and body mass
149 was measured using calibrated electronic scales (SECA Alpha
150 770, Birmingham, UK) to the nearest 0.1 kg. Each participant
151 received one total body DXA scan on a fan-beam GE Lunar
152 iDXA (Lunar iDXA, GE Medical Systems, UK) using
153 standard or thick mode depending on body size. Participants
154 lay in the supine position on the scanning table with the body
155 aligned with the central horizontal axis. Arms were positioned
156 parallel to the body, with legs fully extended and feet secured
157 with a canvas and Velcro support to avoid foot movement
158 during the scan acquisition.
159   One certified densitometrist led and analyzed all scans
160 following the manufacturer's guidelines for patient
161 positioning. The regions of interest (ROI) were manually
162 placed to enable the appropriate cuts according to the
163 manufacturer's instructions. Defined regions were for the
164 arms, legs and trunk. The appendicular ROI for the arms and
165 legs were defined by cut lines positioned proximally at the
166 coracoid process and superior iliac crest and lower ramus
167 respectively. The trunk region included the pelvis, abdomen
168 and chest. Scan analysis was performed using the Lunar
169 Encore software (Version 15.0). The machine's calibration
170 was checked and passed on a daily basis using the GE Lunar
171 calibration hydroxyapatite and epoxy resin phantom. There
172 was no significant drift in calibration for the study period.
173 Local precision values for our Centre (in healthy adult
174 subjects, aged 34.6 years) are 0.8% for total fat mass, 0.5%

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175   for total lean mass, and 0.6% for total BMC.[19] Precision of
176   estimation of values for regional fat mass, lean mass and
177   BMC have been previously reported.[20]
178
179   *Statistical analysis*
180   All statistical analyses were computed using SPSS
181   version 20 (IBM, Armonk, NY, USA). Before analysis,
182   normality and equality of variance of the variables were
183   assessed using a Kolmorgorov-Smirnov test. Independent T-
184   Tests compared body size and body composition parameters
185   between the academy and senior players and between players
186   grouped by playing position (backs *vs.* forwards). Cohen's
187   effect size statistics[21] were calculated with corresponding 90%
188   confidence intervals. Effect sizes were interpreted as <0.2
189   (trivial), 0.2-0.6 (small), 0.6-1.2 (moderate), 1.2-2.0 (large)
190   and>2.0 (very large). A multivariate analysis of covariance
191   (MANCOVA) compared body composition parameters
192   between academy and senior players, with height and body
193   mass applied as covariates to account for size differences
194   between levels. Following the MANCOVA, univariate analyses
195   were conducted. Effect sizes using partial eta squared (η^2) were
196   calculated and interpreted as 0.01 = small, 0.06 = medium and
197   0.14 = large according to Cohen.[22]
198
199   **Results**
200   Table 1 presents the mean and SD for height, body mass
201   and body fat percentage of the academy and senior players,
202   with sub-group comparisons by backs and forwards. Overall,
203   academy players were significantly shorter, lighter and with a
204   higher body fat percentage than senior players. Academy backs
205   were significantly lighter than senior backs but there were no
206   differences for height or body fat percentage. Academy
207   forwards were significantly shorter, lighter with higher body fat
208   percentage than senior forwards.
209   ****Insert Table 1 near here****
210   Table 2 presents the total and regional body
211   composition parameters for all players when controlling for
212   height and body mass. MANCOVA analyses between
213   academy and senior players revealed an overall significant
214   effect ($F_{12, 82}$ = 5.45, *p*<0.001, η^2=0.44). Univariate analysis
215   identified adjusted differences between academy and senior
216   players for each body composition parameter. Academy players
217   had greater total and regional fat mass, lower lean mass and
218   lower BMC. Specifically, large effect sizes (η^2=0.29) were
219   identified for leg fat mass with academy players having greater
220   leg fat mass than senior players.****Insert Table 2 near here****
221   Table 3 presents the total and regional body
222   composition parameters for backs and forwards when
223   controlling for height and body mass. MANCOVA analyses
224   between academy and senior forwards revealed an overall

225 significant effect ($F_{12, 40} = 4.61$, *p*<0.001, η^2=0.58) but no
226 overall effect was identified for the backs. In forwards,
227 univariate analysis identified significant differences between
228 academy and senior players, favoring the senior players, in all
229 adjusted body composition variables, except arm lean mass and
230 leg BMC. Specifically, large effect sizes were identified for
231 total fat mass, lean mass and BMC alongside arm BMC, leg fat
232 mass, trunk lean mass and trunk BMC where academy players
233 had greater fat mass and lower lean mass and BMC on all
234 occasions.
235   ****Insert Table 3 near here****
236
237   **Discussion**
238   Knowledge of body size and body composition profiles
239 as they relate to academy and senior professional rugby league
240 players is an important step towards optimizing the long-term
241 development of player performance. This is the first study to
242 evaluate and compare the three-compartment regional body
243 composition profiles of academy and senior rugby league
244 players using DXA. The findings showed that academy players,
245 especially academy forwards, are shorter, lighter with greater
246 body fat percentage than senior players. When height and body
247 mass were controlled, academy players possessed more fat
248 mass, and less lean mass and BMC than senior players.
249 Specifically, academy players have substantially greater fat
250 mass at the legs than senior players.
251   Height, body mass and body fat percentage
252 differentiated between academy and senior rugby league
253 players. Senior players were taller (ES = moderate) and heavier
254 (ES = moderate-large), likely reflecting that academy players
255 are still experiencing growth, maturation and developmental
256 processes, or a possible talent identification effect at the
257 professional level. These findings are consistent with
258 differences in body mass between junior and senior AFL
259 players.[11] Research elsewhere has demonstrated greater height
260 and body mass with age between 16 and 20 years[23] and
261 increases in body mass across a playing season[24] in academy
262 rugby league players. Given that the average age of the
263 academy players was 18.1 ± 1.1 years, it is likely that some
264 players are still developing and may not have attained adult
265 height due to the normal adaptations related to growth in
266 height, which continue to develop into early adulthood.[25] It is
267 also likely body mass will continue to develop into adulthood,
268 especially with the further inclusion of resistance training
269 (usually from 16 years of age in academy rugby players) and
270 nutrition interventions within an academy programme.[23]
271 Therefore, differences in height and body mass can be expected
272 between academy and senior players and it is recommended
273 that academy players are regularly monitored for height and
274 body mass into early adulthood.

6

275   For body fat percentage, a small difference was evident
276 between academy and senior players (18.0 ± 3.7 vs. 16.3 ± 3.7
277 %). Previous research between players aged 16 and 20 years[23]
278 has shown no difference in sum of four skinfolds by age
279 category, but studies directly assessing body fat percentage are
280 not available. A lower body fat percentage may be
281 advantageous for rugby league performance, as shown through
282 differences reported between Australian elite and semi-elite
283 players,[3] and relationships between lower sum of skinfolds and
284 playing minutes[3] and physical characteristics.[4] Although
285 momentum is an important characteristic for rugby league
286 performance,[2,24] the ability to accelerate may be compromised
287 by additional fat mass. Therefore, the increasing movement
288 demands of senior rugby league performance[6] may require
289 professional players to maintain sufficient levels of fat mass to
290 meet the demands of the game. Never-the-less, fat mass may
291 also have beneficial effects for players,[26] through secretion of
292 bone anabolic hormones from pancreatic beta cells, which may
293 bring faster and more complete recovery from bone micro
294 damage.[27] In addition, fat mass may provide direct protective
295 effects against fracture, as reported in non-sport populations.[28]
296 Thus, a certain amount of fat mass may be beneficial for
297 professional players, particularly younger players during peak
298 bone mass accrual, but to date, the exact requirements remain
299 unknown.
300   Findings between positional groups are consistent with
301 previous research in junior[14] and senior[1] players, with forwards
302 reported to be taller, heavier with a greater body fat percentage
303 than backs. For height, only small differences were identified
304 between academy and senior professional backs while
305 moderate differences were identified for forwards. This
306 suggests height may be a more important characteristic within
307 forward positions and more likely used within identification
308 processes for forwards. For body mass, senior professional
309 players were heavier (ES = moderate-large) for both backs and
310 forwards, suggesting that increased body mass is an important
311 consideration for the development of junior players into senior
312 professionals in all positions. For body fat percentage, senior
313 professional forwards were leaner (17.2 ± 3.7 vs.19.8 ± 3.1 %;
314 ES = moderate) than academy forwards with only trivial effects
315 observed between academy and senior professional backs.
316 Although forwards usually have a greater body fat percentage
317 than backs due to the contact demands of the position, this
318 finding suggests that it may be advisable for body fat to be
319 monitored in academy forwards for optimal player
320 development in terms of progressing to professional levels.
321 Longitudinal research would be valuable to determine the
322 extent and time course of body composition shifts, and in
323 relation to injury incidence, particularly in forwards
324 progressing from academy to senior professional level.

325   The lower fat mass, and greater lean mass and BMC of
326   senior professional players, when height and body mass were
327   controlled, is suggestive of attainment of musculoskeletal
328   maturity and increased training and match demands.[6] The
329   larger distances covered at high intensity running speeds,
330   increased repeated high intensity efforts together with the
331   contact and collision nature of the sport, would emphasise
332   increased lean mass and appropriate level of fat.[1,5] In terms of
333   growth and maturation, although height velocity plateaus in late
334   adolescence, lean mass and BMC continues to increase into the
335   early 20s.[29] As such, academy players are likely to be still
336   undergoing natural growth processes at completion of a UK
337   academy programme (i.e., 19 years of age) and into the early
338   years of competing at senior professional levels. This should be
339   considered by coaches and player development staff for player
340   recruitment and long-term player development.
341   This is the first study to evaluate both total and regional
342   three-compartment body composition profiles in rugby league
343   players, with previous research only available in rugby union
344   and Sevens players.[15] Quantifying regional distributions may
345   inform physical developmental priorities for junior and senior
346   players. Comparisons found differences between academy and
347   senior professional players between regions for fat mass, lean
348   mass and BMC that correspond with the overall findings that
349   senior professional players have greater lean mass and BMC
350   but reduced fat mass in each region. Interestingly a large
351   difference was observed in leg fat mass between academy and
352   senior professional players. This suggests that the development
353   processes at this age are characterized by greater fat mass in the
354   lower body during growth and maturation, or that advanced
355   training and playing interventions at senior level may reduce fat
356   mass within the lower body. Without a control group or
357   longitudinal investigation it is difficult to confirm this or
358   ascertain the mechanisms involved. However, due to the
359   importance of the legs for optimizing rugby specific actions
360   such as ball carrying, tackling and strength and power related
361   activity[2] this may be an important consideration for monitoring
362   and training purposes.
363   Although this study has developed upon previous body
364   composition research within rugby league, limitations do exist.
365   Participants were not fasted on testing, which increases the
366   error of measurement of body mass and lean mass within DXA
367   scans,[17] possibly questioning the differences between academy
368   and professional players. The cross-sectional nature of the
369   study means that body size and body composition can only be
370   determined acutely. Evaluating longitudinal changes in players'
371   body composition from academy to senior professional level
372   would be valuable to further inform on the role of fat mass,
373   lean mass and BMC for the optimal development in rugby
374   league. Finally, the inclusion of a control group would have

375 enabled greater insights into natural, age-related developments
376 in body size and composition.
377
378 **Practical Applications**
379 These findings demonstrate that body size and body
380 composition profiles differ between academy and senior
381 professional rugby league players and are therefore an
382 important consideration for junior player development.
383 Practitioners should be aware that academy players are
384 developing musculoskeletal characteristics and may still be
385 experiencing such processes when participating in a rugby
386 academy at 19 years of age. Greater differences also seem
387 apparent between academy and senior players within the
388 forwards position. Such processes may therefore affect player
389 recruitment and development strategies. Practitioners should
390 consider the gradual development of lean mass and BMC
391 whilst controlling fat mass in academy players on progress into
392 senior professional competition, especially within the forward
393 position. It is recommended that practitioners monitor body
394 size and body composition of players regularly into the early
395 twenties employing standardized protocols when using DXA.[30]
396 **Conclusions**
397 This is the first study to compare the body size and
398 body composition differences between academy and senior
399 professional rugby league players using DXA. Differences
400 were evident favoring the senior players suggesting academy
401 players may still be developing physically into early adulthood.
402 Given that greater lean mass and lower body fat are related to
403 physical ability and game performance in rugby league, the
404 development of these characteristics should be considered, but
405 alongside the impact upon health status (i.e. bone mass, injury
406 and injury prevention, illness). Further research evaluating
407 longitudinal changes in body composition profiles is required to
408 provide a greater understanding of this development process
409 and the individual effects of lean and fat mass on performance,
410 career longevity and health in this population.
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Table 1. Differences in height, body mass and body fat percentage between Academy (n=32) and Professional (n=63) rugby league players grouped by playing position (mean + SD)

	Academy	Professional	*P*	Cohen's d (90% CIs)
All Players				
Height (cm)	179.2 ± 5.7	183.2 ± 5.8	0.001	0.70 [0.32-1.05]
Body Mass (kg)	86.5 ± 9.0	96.5 ± 9.3	<0.001	1.09 [0.70-1.46]
Body Fat Percentage	18.0 ± 3.7	16.3 ± 3.7	0.032	0.46 [0.09-0.82]
Backs				
Height (cm)	178.5 ± 6.4	181.7 ± 5.9	0.11	0.52 [0.16-0.89]
Body Mass (kg)	82.1 ± 7.5	91.3 ± 8.6	0.001	1.14 [0.73-1.43]
Body Fat Percentage	15.8 ± 3.1	15.2 ± 3.4	0.60	0.18 [-0.18-0.54]
Forwards				
Height (cm)	179.7 ± 5.2	184.4 ± 5.6	0.004	0.87 [0.48-1.22]
Body Mass (kg)	89.9 ± 8.8	100.4 ± 7.8	<0.001	1.26 [0.89-1.67]
Body Fat Percentage	19.8 ± 3.1	17.2 ± 3.7	0.01	0.76 [0.37-1.10]

Table 2: Adjusted differences in total and regional body composition between academy and professional rugby league players presented as the mean (95% CIs), with covariates height and body mass.

	Academy	Professional	Difference	P	η^2
Total					
Fat Mass (kg)	17.1 (1.2)	14.1 (0.8)	3.0	<0.001	0.15
Lean mass (kg)	71.8 (1.0)	74.6 (0.8)	-2.8	<0.001	0.14
BMC (g)	4081 (101)	4313 (71)	-232	0.001	0.12
Regional					
Arms Fat Mass (kg)	1.78 (0.12)	1.54 (0.09)	0.24	0.003	0.09
Arms Lean mass (kg)	9.6 (0.3)	10.0 (0.2)	-0.4	0.017	0.06
Arms BMC (g)	575 (19)	631 (13)	-56	<0.001	0.19
Legs Fat Mass (kg)	6.2 (0.4)	4.6 (0.2)	1.6	<0.001	0.29
Legs Lean mass (kg)	24.6 (0.5)	25.3 (0.4)	-0.7	0.033	0.05
Legs BMC (g)	1537 (38)	1613 (27)	-76	0.004	0.09
Trunk Fat Mass (kg)	8.1 (0.7)	7.0 (0.5)	1.1	0.015	0.06
Trunk Lean mass (kg)	34.2 (0.7)	35.8 (0.5)	-1.6	0.001	0.12
Trunk BMC (g)	1380 (39)	1466 (28)	-86	0.001	0.11

Note: η^2 - 0.01 = small, 0.06 = medium and 0.14 = large; BMC = Bone Mineral Content

Table 3: Adjusted differences in total and regional body composition between Academy and professional rugby league players by playing position presented as the mean (95% CIs), with covariates height and body mass.

	Backs					Forwards				
	Academy	Professional	Diff	P	η^2	Academy	Professional	Diff	P	η^2
Total										
Fat Mass (kg)	13.7 (1.6)	12.6 (1.1)	1.1	0.307	0.03	19.3 (1.6)	15.4 (1.1)	3.9	<0.001	0.22
Lean mass (kg)	70.3 (1.6)	71.3 (1.1)	-1.0	0.346	0.02	73.3 (1.5)	76.9 (1.1)	-3.6	0.001	0.20
BMC (g)	4009 (139)	4135 (99)	-126	0.172	0.05	4157 (153)	4435 (105)	-278	0.007	0.14
Regional										
Arms Fat Mass (kg)	1.45 (0.16)	1.41 (0.12)	0.04	0.677	0.01	1.99 (0.18)	1.66 (0.12)	0.33	0.008	0.13
Arms Lean mass (kg)	9.3 (0.4)	9.5 (0.3)	-0.2	0.290	0.03	9.9 (0.4)	10.3 (0.2)	-0.4	0.086	0.06
Arms BMC (g)	562 (31)	602 (22)	-42	0.046	0.10	588 (26)	652 (18)	-64	<0.001	0.23
Legs Fat Mass (kg)	4.9 (0.6)	4.2 (0.4)	0.7	0.072	0.08	7.1 (0.6)	5.1 (0.4)	2.0	<0.001	0.41
Legs Lean mass (kg)	24.1 (0.9)	24.0 (0.6)	0.1	0.853	0.00	25.1 (0.6)	26.2 (0.4)	-1.2	0.01	0.12
Legs BMC (g)	1518 (58)	1566 (41)	-48	0.206	0.04	1569 (54)	1639 (37)	-70	0.054	0.07
Trunk Fat Mass (kg)	6.4 (1.0)	6.1 (0.7)	0.3	0.620	0.01	9.3 (1.1)	7.8 (0.8)	1.5	0.032	0.09
Trunk Lean mass (kg)	33.6 (1.0)	34.5 (0.8)	-0.9	0.232	0.04	34.7 (1.0)	36.8 (0.8)	-2.1	0.005	0.15
Trunk BMC (g)	1362 (51)	1391 (38)	-29	0.398	0.02	1400 (59)	1520 (40)	-120	0.003	0.16

Note: η^2 - 0.01 = small, 0.06 = medium and 0.14 = large; BMC = Bone Mineral Content