



LEEDS
BECKETT
UNIVERSITY

Citation:

Till, K and Jones, B and O'Hara, J and Barlow, M and Brightmore, A and Lees, M and Hind, K (2016) Three-Compartment Body Composition in Academy and Senior Rugby League Players. *International journal of sports physiology and performance*, 11 (2). 191 - 196. ISSN 1555-0265 DOI: <https://doi.org/10.1123/ijsp.2015-0048>

Link to Leeds Beckett Repository record:

<https://eprints.leedsbeckett.ac.uk/id/eprint/1482/>

Document Version:

Article (Accepted Version)

The aim of the Leeds Beckett Repository is to provide open access to our research, as required by funder policies and permitted by publishers and copyright law.

The Leeds Beckett repository holds a wide range of publications, each of which has been checked for copyright and the relevant embargo period has been applied by the Research Services team.

We operate on a standard take-down policy. If you are the author or publisher of an output and you would like it removed from the repository, please [contact us](#) and we will investigate on a case-by-case basis.

Each thesis in the repository has been cleared where necessary by the author for third party copyright. If you would like a thesis to be removed from the repository or believe there is an issue with copyright, please contact us on openaccess@leedsbeckett.ac.uk and we will investigate on a case-by-case basis.

1 **Title: Three-compartment body composition in academy**
2 **and senior rugby league players**

3
4

5 **Submission Type:** Original Investigation

6
7

8 Kevin Till*, Ben Jones, John O’Hara, Matthew Barlow, Amy
9 Brightmore, Matthew Lees, & Karen Hind

10
11

12 Research Institute for Sport, Physical Activity and Leisure,
13 Leeds Beckett University,
14 Leeds, West Yorkshire, United Kingdom

15
16

17
18

18 *Corresponding Author:
19 Dr Kevin Till
20 Room 111, Fairfax Hall
21 Research Institute for Sport, Physical Activity and Leisure,
22 Headingley Campus, Leeds Beckett University
23 West Yorkshire, LS6 3QS
24 Phone: (044-11) 01132-832600 Ext: 25182
25 Email: k.till@leedsbeckett.ac.uk

26
27

28 **Preferred Running Head:** Body composition in rugby league
29 players

30
31

31 **Abstract Word Count:** 246

32
33

33 **Text Only Word Count:** 2,760

34
35

35 **Number of Tables:** 3

36
37

37 **Number of Figures:** 0

38

Abstract

Purpose: This study compared the body size and three compartment body composition between academy and senior professional rugby league players using dual energy X-ray absorptiometry (DXA).

Methods: Academy (age 18.1 ± 1.1 years; $n=34$) and senior (age 26.2 ± 4.6 years; $n=63$) rugby league players received one total-body DXA scan. Height, body mass and body fat percentage alongside total and regional fat mass, lean mass and bone mineral content (BMC) were compared. Independent t-tests with Cohen's d effect sizes and multivariate analysis of covariance (MANCOVA), controlling for height and body mass, with partial eta squared (η^2) effect sizes, were used to compare total and regional body composition.

Results: Senior players were taller (183.2 ± 5.8 vs. 179.2 ± 5.7 cm; $p=0.001$; $d=0.70$) and heavier (96.5 ± 9.3 vs. 86.5 ± 9.0 kg; $p<0.001$; $d=1.09$) with lower body fat percentage (16.3 ± 3.7 vs. 18.0 ± 3.7 %; $p=0.032$; $d=0.46$) than academy players.

MANCOVA identified significant overall main effects for total and regional body composition between academy and senior players. Senior players had lower total fat mass ($p<0.001$, $\eta^2=0.15$), greater total lean mass ($p<0.001$, $\eta^2=0.14$) and greater total BMC ($p=0.001$, $\eta^2=0.12$) than academy players. For regional sites, academy players had significantly greater fat mass at the legs ($p<0.001$; $\eta^2=0.29$) than senior players.

Conclusions: The lower age, height, body mass and BMC of academy players suggest that these players are still developing musculoskeletal characteristics. Gradual increases in lean mass and BMC whilst controlling fat mass is an important consideration for practitioners working with academy rugby league players, especially within the lower body.

Key Words: anthropometry, dual energy x-ray absorptiometry (DXA), fat mass, lean mass, bone mineral content

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 minutes³ 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^{5,7} 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 senior¹⁰ 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

Subjects

132

133

134

135

136

137

138

139

140

141

142

143

144

145

146

147

148

149

150

151

152

153

154

155

156

157

158

159

160

161

162

163

164

165

166

167

168

169

170

171

172

173

174

Sixty-three senior professional players from two European Super League clubs (backs: $n=27$, age 26.0 ± 4.3 years; forwards: $n=36$, age 26.3 ± 4.9 years), and 32 academy players from one European Super League club (backs: $n=15$, age 18.1 ± 1.1 years; forwards: $n=19$, age 18.2 ± 1.1 years), participated in the study. All protocols received institutional ethics approval and players provided written consent.

Procedures

A cross-sectional research design was used whereby participants were tested during the last phase of the pre-season period (January - February) in a euhydrated state (urine osmolality $<700\text{mOsmol}\cdot\text{kg}^{-1}$).¹⁸ All scans were scheduled on a rest day so activity levels did not affect the scans. Participants wore minimal clothing, with shoes and jewellery removed. Height was measured using a stadiometer (SECA Alpha, Birmingham, UK) to the nearest 0.1cm and body mass was measured using calibrated electronic scales (SECA Alpha 770, Birmingham, UK) to the nearest 0.1 kg. Each participant received one total body DXA scan on a fan-beam GE Lunar iDXA (Lunar iDXA, GE Medical Systems, UK) using standard or thick mode depending on body size. Participants lay in the supine position on the scanning table with the body aligned with the central horizontal axis. Arms were positioned parallel to the body, with legs fully extended and feet secured with a canvas and Velcro support to avoid foot movement during the scan acquisition.

One certified densitometrist led and analyzed all scans following the manufacturer's guidelines for patient positioning. The regions of interest (ROI) were manually placed to enable the appropriate cuts according to the manufacturer's instructions. Defined regions were for the arms, legs and trunk. The appendicular ROI for the arms and legs were defined by cut lines positioned proximally at the coracoid process and superior iliac crest and lower ramus respectively. The trunk region included the pelvis, abdomen and chest. Scan analysis was performed using the Lunar Encore software (Version 15.0). The machine's calibration was checked and passed on a daily basis using the GE Lunar calibration hydroxyapatite and epoxy resin phantom. There was no significant drift in calibration for the study period. Local precision values for our Centre (in healthy adult subjects, aged 34.6 years) are 0.8% for total fat mass, 0.5%

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 Kolmogorov-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 statistics²¹ 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 ($F_{12, 82} = 5.45, p < 0.001, \eta^2 = 0.44$). 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 ($\eta^2 = 0.29$) 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 ($F_{12, 40} = 4.61, p < 0.001, \eta^2 = 0.58$) 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

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 years²³ and
261 increases in body mass across a playing season²⁴ 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.

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 years²³
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 minutes³ 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 performance⁶ 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 junior¹⁴ and senior¹ 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 activity² 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

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.

411

412

413

414

415

416

417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466

References

1. Johnston RD, Gabbett TJ, Jenkins DJ. Applied sport science of rugby league. *Sports Med.* 2014; 44:1087-1100
2. Baker DG, Newton RU. Comparison of lower body strength, power, acceleration, speed, agility, and sprint momentum to describe and compare playing rank among professional rugby league players. *J Strength Cond Res.* 2008; 22:153–158.11.
3. Gabbett TJ, Jenkins DG, Abernethy B. Relationships between physiological, anthropometric, and skill qualities and playing performance in professional rugby league players. *J Sports Sci.* 2011;29:1655-1664.
4. Till K, Cobley S, O’Hara J, Cooke C, Chapman C. Anthropometric, physiological and selection characteristics in high performance UK junior rugby League players. *Talent Dev Excellence.* 2010;2:193–207.
5. Black GM, Gabbett TJ. Repeated High-Intensity Effort Activity in Elite and Semi-Elite Rugby League Match-Play. *Int J Sports Physiol Perform.* 2014 Jul 22. [Epub ahead of print]
6. Gabbett TJ. Influence of playing standard on the physical demands of professional rugby league. *J Sports Sci.* 2013;31:1125-1138.
7. Till K, Cobley S, O’Hara J, Brightmore A, Chapman C, Cooke C. Using, anthropometric and performance characteristics to predict selection in junior UK rugby league players. *J Sci Med Sport.* 2011;14:264–269.
8. Cheng HL, O’Connor H, Kay S, Cook R, Parker H, Orr R. Anthropometric characteristics of Australian junior representative rugby league players. *J Sci Med Sport.* 2014;17:546-551
9. Till K, Cobley S, O’Hara J, Chapman C, Cooke C. A longitudinal evaluation of anthropometric and fitness characteristics in junior rugby league players. *J Sci Med Sport.* 2013;16:438–443.
10. Morgan PJ, Callister R. Effects of a preseason intervention on anthropometric characteristics of semi professional rugby league players. *J Strength Cond Res.* 2011;25:432–40.
11. Veale JP, Pearce AJ, Buttifant D, Carlson JS. Anthropometric profiling of elite junior and senior Australian football players. *Int J Sports Physiol Perform.* 2010;5:509-20.
12. Georgeson EC, Weeks BK, McLellan C, Beck BR. Seasonal change in bone, muscle and fat in professional rugby league players and its relationship to injury: a cohort study. *BMJ Open* 2012;2: e001400. doi:10.1136/bmjopen-2012-001400

- 467 13. Harley JA, Hind K, O'Hara JP. Three-compartment
468 body composition changes in elite rugby league players
469 during a super league season, measured by dual-energy
470 X-ray absorptiometry. *J Strength Cond Res.*
471 2011;25:1024–9.
- 472 14. Delahunt E, Byrne RB, Doolin RK, McInerney RG,
473 Ruddock CT, Green BS. Anthropometric profile and
474 body composition of Irish adolescent rugby union
475 players aged 16-18. *J Strength Cond Res.*
476 2013;27:3252-3258.
- 477 15. Higham DG, Pyne DB, Anson JM, Dziedzic CE, Slater
478 GJ. Distribution of fat, non-osseous lean and bone
479 mineral mass in international rugby union and rugby
480 sevens players. *Int J Sports Med.* 2014;35:575-582.
- 481 16. Toombs RJ, Ducher G, Shepherd JA, De Souza MJ. The
482 impact of recent technological advances on the trueness
483 and precision of DXA to assess body composition.
484 *Obesity.* 2012;20:30-39.
- 485 17. Nana A, Slater GJ, Hopkins WG, Burke LM. Effects of
486 daily activities on dual-energy X-ray absorptiometry
487 measurements of body composition in active people.
488 *Med Sci Sports Exerc* 2012;44:180-189
- 489 18. Shirreffs SM, Maughan RJ. Urine osmolality and
490 conductivity as indices of hydration status in athletes in
491 the heat. *Med Sci Sports Exerc.* 1998;30:1598-602
- 492 19. Hind K, Oldroyd B, Truscott J. In-vivo short term
493 precision of the GE Lunar iDXA for the measurement
494 of three compartment total body composition in adults.
495 *Eur J Clin Nutr.* 2011; 65:140-142
- 496 20. Hind K, Oldroyd B. In-vivo precision of the GE Lunar
497 iDXA densitometer for the measurement of
498 appendicular and trunk lean and fat mass. *Eur J Clin*
499 *Nutr.* 2013; 67: 1331-1333
- 500 21. Batterham AM, Hopkins WG. Making inferences about
501 magnitudes. *Int J Sports Physiol Perform.* 2006; 1:50-
502 57
- 503 22. Cohen, J. *Statistical Power Analysis for the Behavioral*
504 *Sciences* (2nd ed.). New Jersey, NJ: Lawrence Erlbaum,
505 1988.
- 506 23. Till K, Tester E, Jones B, Emmonds S, Fahey J, Cooke
507 C. Anthropometric and Physical Characteristics of
508 English Academy Rugby League Players. *J Strength*
509 *Cond Res.* 2014; 28:319-327
- 510 24. Till K, Jones B, Emmonds S, Tester E, Fahey J, Cooke
511 C. Seasonal changes in anthropometric and physical
512 characteristics within English academy rugby league
513 players. *J Strength Cond Res.* 2014; 28: 2689-2696.
- 514 25. Malina RM, Bouchard C, Bar-Or O. *Growth,*
515 *Maturation, and Physical Activity* (2nd ed.).
516 Champaign, IL: Human Kinetics, 2004.

- 517 26. Hind K, Gannon L, Brightmore A, Beck B. Insights into
518 relationships between body mass and bone: findings in
519 elite rugby players. *J Clin Densitom.* In press
520 27. Reid IM. Relationships between fat and bone.
521 *Osteoporos Int.* 2008;19:595-606
522 28. Reid IM. Fat and Bone. *Arch Biochem BioPhys*
523 2010;503:20-27
524 29. Molgaard C, Thomsen BL, Prentice A, Cole T,
525 Michaelsen KF. Whole body bone mineral content in
526 healthy children and adolescents. *Archives of Disease in*
527 *Childhood* 1997;76:9-15.
528 30. Nana A, Slater GJ, Hopkins WG, Halson SL, Martin
529 DT, West NP, et al. Importance of Standardized DXA
530 Protocol for Assessing Physique Changes in Athletes.
531 *Int J Sport Nutr Exerc Metab* 2014; Epub.
532 doi: 10.1123/ijsnem.2013-0111
533

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	<i>P</i>	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	<i>P</i>	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	<i>P</i>	η^2	Academy	Professional	Diff	<i>P</i>	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

