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

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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, η^2=0.15), greater total lean mass (p<0.001, η^2=0.14) and greater total BMC (p=0.001, η^2=0.12) than academy players. For regional sites, academy players had significantly greater fat mass at the legs (p<0.001; η^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 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 composition in athletes.[17] The aim of this study was to characterize and compare the body size and three-compartment body composition of UK academy (Under 19s) and senior professional rugby league players using DXA whilst also considering playing position.

Materials &Methods

Subjects

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 <700mOsmol·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 eproxy 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%

for total lean mass, and 0.6% for total BMC.[19] Precision of estimation of values for regional fat mass, lean mass and BMC have been previously reported.[20]

Statistical analysis

All statistical analyses were computed using SPSS version 20 (IBM, Armonk, NY, USA). Before analysis, normality and equality of variance of the variables were assessed using a Kolmorgorov-Smirnov test. Independent T-Tests compared body size and body composition parameters between the academy and senior players and between players grouped by playing position (backs *vs.* forwards). Cohen's effect size statistics[21] were calculated with corresponding 90% confidence intervals. Effect sizes were interpreted as <0.2 (trivial), 0.2-0.6 (small), 0.6-1.2 (moderate), 1.2-2.0 (large) and>2.0 (very large). A multivariate analysis of covariance (MANCOVA) compared body composition parameters between academy and senior players, with height and body mass applied as covariates to account for size differences between levels. Following the MANCOVA, univariate analyses were conducted. Effect sizes using partial eta squared (η^2) were calculated and interpreted as 0.01 = small, 0.06 = medium and 0.14 = large according to Cohen.[22]

Results

Table 1 presents the mean and SD for height, body mass and body fat percentage of the academy and senior players, with sub-group comparisons by backs and forwards. Overall, academy players were significantly shorter, lighter and with a higher body fat percentage than senior players. Academy backs were significantly lighter than senior backs but there were no differences for height or body fat percentage. Academy forwards were significantly shorter, lighter with higher body fat percentage than senior forwards.

****Insert Table 1 near here****

Table 2 presents the total and regional body composition parameters for all players when controlling for height and body mass. MANCOVA analyses between academy and senior players revealed an overall significant effect ($F_{12, 82} = 5.45$, $p<0.001$, $\eta^2=0.44$). Univariate analysis identified adjusted differences between academy and senior players for each body composition parameter. Academy players had greater total and regional fat mass, lower lean mass and lower BMC. Specifically, large effect sizes ($\eta^2=0.29$) were identified for leg fat mass with academy players having greater leg fat mass than senior players.****Insert Table 2 near here****

Table 3 presents the total and regional body composition parameters for backs and forwards when controlling for height and body mass. MANCOVA analyses between academy and senior forwards revealed an overall significant effect ($F_{12, 40} = 4.61$, $p<0.001$, $\eta^2=0.58$) but no overall effect was identified for the backs. In forwards, univariate analysis identified significant differences between academy and senior players, favoring the senior players, in all adjusted body composition variables, except arm lean mass and leg BMC. Specifically, large effect sizes were identified for total fat mass, lean mass and BMC alongside arm BMC, leg fat mass, trunk lean mass and trunk BMC where academy players had greater fat mass and lower lean mass and BMC on all occasions.

****Insert Table 3 near here****

Discussion

Knowledge of body size and body composition profiles as they relate to academy and senior professional rugby league players is an important step towards optimizing the long-term development of player performance. This is the first study to evaluate and compare the three-compartment regional body composition profiles of academy and senior rugby league players using DXA. The findings showed that academy players, especially academy forwards, are shorter, lighter with greater body fat percentage than senior players. When height and body mass were controlled, academy players possessed more fat mass, and less lean mass and BMC than senior players. Specifically, academy players have substantially greater fat mass at the legs than senior players.

Height, body mass and body fat percentage differentiated between academy and senior rugby league players. Senior players were taller (ES = moderate) and heavier (ES = moderate-large), likely reflecting that academy players are still experiencing growth, maturation and developmental processes, or a possible talent identification effect at the professional level. These findings are consistent with differences in body mass between junior and senior AFL players.[11] Research elsewhere has demonstrated greater height and body mass with age between 16 and 20 years[23] and increases in body mass across a playing season[24] in academy rugby league players. Given that the average age of the academy players was 18.1 ± 1.1 years, it is likely that some players are still developing and may not have attained adult height due to the normal adaptations related to growth in height, which continue to develop into early adulthood.[25] It is also likely body mass will continue to develop into adulthood, especially with the further inclusion of resistance training (usually from 16 years of age in academy rugby players) and nutrition interventions within an academy programme.[23] Therefore, differences in height and body mass can be expected between academy and senior players and it is recommended that academy players are regularly monitored for height and body mass into early adulthood.

For body fat percentage, a small difference was evident between academy and senior players (18.0 ± 3.7 vs. 16.3 ± 3.7 %). Previous research between players aged 16 and 20 years[23] has shown no difference in sum of four skinfolds by age category, but studies directly assessing body fat percentage are not available. A lower body fat percentage may be advantageous for rugby league performance, as shown through differences reported between Australian elite and semi-elite players, [3] and relationships between lower sum of skinfolds and playing minutes[3] and physical characteristics.[4] Although momentum is an important characteristic for rugby league performance, [2,24] the ability to accelerate may be compromised by additional fat mass. Therefore, the increasing movement demands of senior rugby league performance[6] may require professional players to maintain sufficient levels of fat mass to meet the demands of the game. Never-the-less, fat mass may also have beneficial effects for players,[26] through secretion of bone anabolic hormones from pancreatic beta cells, which may bring faster and more complete recovery from bone micro damage.[27] In addition, fat mass may provide direct protective effects against fracture, as reported in non-sport populations.[28] Thus, a certain amount of fat mass may be beneficial for professional players, particularly younger players during peak bone mass accrual, but to date, the exact requirements remain unknown.

Findings between positional groups are consistent with previous research in junior[14] and senior[1] players, with forwards reported to be taller, heavier with a greater body fat percentage than backs. For height, only small differences were identified between academy and senior professional backs while moderate differences were identified for forwards. This suggests height may be a more important characteristic within forward positions and more likely used within identification processes for forwards. For body mass, senior professional players were heavier (ES = moderate-large) for both backs and forwards, suggesting that increased body mass is an important consideration for the development of junior players into senior professionals in all positions. For body fat percentage, senior professional forwards were leaner (17.2 ± 3.7 vs.19.8 ± 3.1 %; ES = moderate) than academy forwards with only trivial effects observed between academy and senior professional backs. Although forwards usually have a greater body fat percentage than backs due to the contact demands of the position, this finding suggests that it may be advisable for body fat to be monitored in academy forwards for optimal player development in terms of progressing to professional levels. Longitudinal research would be valuable to determine the extent and time course of body composition shifts, and in relation to injury incidence, particularly in forwards progressing from academy to senior professional level.

The lower fat mass, and greater lean mass and BMC of senior professional players, when height and body mass were controlled, is suggestive of attainment of musculoskeletal maturity and increased training and match demands.[6] The larger distances covered at high intensity running speeds, increased repeated high intensity efforts together with the contact and collision nature of the sport, would emphasise increased lean mass and appropriate level of fat.[1,5] In terms of growth and maturation, although height velocity plateaus in late adolescence, lean mass and BMC continues to increase into the early 20s.[29] As such, academy players are likely to be still undergoing natural growth processes at completion of a UK academy programme (i.e., 19 years of age) and into the early years of competing at senior professional levels. This should be considered by coaches and player development staff for player recruitment and long-term player development.

This is the first study to evaluate both total and regional three-compartment body composition profiles in rugby league players, with previous research only available in rugby union and Sevens players.[15] Quantifying regional distributions may inform physical developmental priorities for junior and senior players. Comparisons found differences between academy and senior professional players between regions for fat mass, lean mass and BMC that correspond with the overall findings that senior professional players have greater lean mass and BMC but reduced fat mass in each region. Interestingly a large difference was observed in leg fat mass between academy and senior professional players. This suggests that the development processes at this age are characterized by greater fat mass in the lower body during growth and maturation, or that advanced training and playing interventions at senior level may reduce fat mass within the lower body. Without a control group or longitudinal investigation it is difficult to confirm this or ascertain the mechanisms involved. However, due to the importance of the legs for optimizing rugby specific actions such as ball carrying, tackling and strength and power related activity[2] this may be an important consideration for monitoring and training purposes.

Although this study has developed upon previous body composition research within rugby league, limitations do exist. Participants were not fasted on testing, which increases the error of measurement of body mass and lean mass within DXA scans,[17] possibly questioning the differences between academy and professional players. The cross-sectional nature of the study means that body size and body composition can only be determined acutely. Evaluating longitudinal changes in players' body composition from academy to senior professional level would be valuable to further inform on the role of fat mass, lean mass and BMC for the optimal development in rugby league. Finally, the inclusion of a control group would have enabled greater insights into natural, age-related developments in body size and composition.

Practical Applications

These findings demonstrate that body size and body composition profiles differ between academy and senior professional rugby league players and are therefore an important consideration for junior player development. Practitioners should be aware that academy players are developing musculoskeletal characteristics and may still be experiencing such processes when participating in a rugby academy at 19 years of age. Greater differences also seem apparent between academy and senior players within the forwards position. Such processes may therefore affect player recruitment and development strategies. Practitioners should consider the gradual development of lean mass and BMC whilst controlling fat mass in academy players on progress into senior professional competition, especially within the forward position. It is recommended that practitioners monitor body size and body composition of players regularly into the early twenties employing standardized protocols when using DXA.[30]

Conclusions

This is the first study to compare the body size and body composition differences between academy and senior professional rugby league players using DXA. Differences were evident favoring the senior players suggesting academy players may still be developing physically into early adulthood. Given that greater lean mass and lower body fat are related to physical ability and game performance in rugby league, the development of these characteristics should be considered, but alongside the impact upon health status (i.e. bone mass, injury and injury prevention, illness). Further research evaluating longitudinal changes in body composition profiles is required to provide a greater understanding of this development process and the individual effects of lean and fat mass on performance, 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