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The Anthropometric, Physical, and Relative Age Characteristics of an English Premiership Rugby Union Academy

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ABSTRACT

Long-term athlete development is a primary focus for the England Rugby Football Union (RFU). The purpose of this study was to explore the anthropometric, physical, and relative age characteristics of rugby union academy players based on age group and playing position. Seventy-eight participants were measured for height, body mass, 10 and 20 m sprint, countermovement jump, peak and relative power, sprint momentum for 10 and 20 m, reactive strength index, aerobic capacity, isometric hip extension, dominant handgrip strength, and birth quartile (BQ) across three age categories (i.e., under-16, under-18, and under-21) and two positions (i.e., forwards and backs). ANOVA and Kruskall–Wallis analysis were used to examine differences across each age category and position. TukeyHSD and Dunn's test with Bonferroni correction was used for further post-hoc analysis. BQ distributions were compared against national norms using chi-square analysis. Results revealed that both older forwards (P=0.005) and backs (P=0.002) had significantly greater body mass, momentum, power, and maximal aerobic capacity compared to younger players. However, older forwards had slower 10 m sprint times compared to younger forwards. Moreover, relatively older players were significantly overrepresented across all age groups when compared to relatively younger players. Findings suggest that: (a) players should aim to develop greater parameters of body mass, momentum, power, and aerobic capacity; (b) forwards should aim to develop acceleration, strength, momentum, and power; (c) backs should aim to develop momentum, power, and quickness; and, (d) coaches should consider relative age when recruiting and developing young players.

Key words: Talent identification; Talent development; Expertise; Physical development; Physiological profile; Rugby football

INTRODUCTION

The central aims of the World Rugby Federation is to globally improve the participation and growth of young athletes on a long-term basis (56). In light of this, the Rugby Football Union's (RFU; governing body of rugby union [RU] in England) objective is to develop more talented English players to maintain a world-leading position (16, 52). In order to hold such hegemony, the RFU has adopted a sophisticated talent identification and development system. However, questions remain surrounding the most suitable process to facilitate long-term athlete development (LTAD) towards senior expertise (52), due to the possible developmental drawbacks of such systems (7). Developmental pathways are mapped by RU academies in England to prepare talented young players for the demands of professional competition in adulthood (49). Selection into a RU academy can be a defining moment for a young player since these contribute to their progression towards senior professional level. LTAD in RU generally follows a pathway considered a *late specialisation model* (10), since players are selected from the age of 15 to 21 years and are subsequently exposed to a diverse range of physical activities that can have a long-term impact on individual development and performance (10, 40).

Due to the physical requirements of RU, researchers aimed to advance research on the performance requirements of players, documenting that they need high levels of strength, power, agility, speed, momentum, and aerobic capacity (11-14). Given the importance of physical factors on player progression and game performance (48), there are some studies focused on the characterisation of these physical qualities in English RU environments (11, 12, 24, 39, 43, 52), although a larger amount of evidence is available within English rugby league (4, 5, 18-22, 36, 45, 50, 51). Since these two sports have different rules (55), physical demands (18), and positional requirements (57), there is a need for more specific athlete development research in RU. In the context of RU, researchers have found that strength (absolute and relative) and power differentiate playing levels (1), whilst body mass, acceleration, and momentum characteristics differ between age groups (11). Since these changes also follow the incremental trajectory of growth and physical development, suitable pathways (e.g., RU academies) that nurture anthropometric and physical performance are a critical component within a professional structure to ensure player progression. Although previous research has outlined characteristics according to positional differences (12), these are yet to be analysed together with relative age.

It is generally accepted that different positions require different anthropometric and physical characteristics at both academy (12, 38) and senior professional (55, 57) levels. Specifically, forwards possess the greatest body mass and isometric strength, and backs require superior speed, change of direction, and agility. Physical characteristics also differ considerably based on playing level (e.g., age-grade vs. academy), age group (e.g., U16 vs. U18), and position (e.g., forwards vs. backs) (14, 17, 52, 54). Thus, it is important to consider the inter-individual disparities in the rate and timing of physical development can result in biases during the athlete development processes (49).

Relative age effects (RAEs) have been highlighted as one of the most frequent biases during selection of RU players (27). This phenomenon explains that when individuals are banded according to (bi)annual-age groups, those who are born near the beginning of the selection year are often overrepresented compared to those who are born towards the end (37). Thus, those players born in birth quarter one (BQ1; September, October, and November in England) may have developed enhanced physiological and psychosocial qualities compared to their later born BQ4 peers (i.e., June, July, and August), which subsequently allows them to outperform their younger same-age peers (15). RAEs have been found in different RU environments regardless of nationality (14, 25), gender (26), and age group (14, 31, 34). Moreover, it has been found to impact selection at different levels (27) and playing positions (25) in RU. However, further enquiry is required to better understand differences by birth quartiles and the impact on the athlete development process based on age group and position since these factors are yet to be analysed together across the academy of an English professional RU club.

To the authors' knowledge, no studies have investigated the anthropometric, physical, and relative age characteristics of academy players in an English academy from a Premiership RU club based on chronological age group and playing position. Understanding the magnitude of anthropometric, physical, and relative age characteristics based on age group and position will assist key stakeholders (i.e., coaches, selectors, practitioners, and policy makers) to better understand the LTAD process. Moreover, the need for more replication studies in order to draw more valid conclusions and help inform possible meta-analysis from studies in RU academies is also required; mainly due to the limited sample sizes that are generally available within these single case studies. This may also help observe the evolutionary trends of the LTAD process across professional RU academies by providing an updated physical profile of RU academy cohorts. Thus, the purpose of this study was to evaluate the anthropometric, physical, and relative age characteristics of English Premiership RU academy players based on age group (i.e., U16 vs. U18 vs. U21) and position (i.e., forward vs. backs) to offer recommendations for LTAD in RU.

METHODS

Experimental approach to the problem

Three age groups (i.e., U16, U18, and U21) and two playing positions (i.e., forwards and backs) within an English Premiership RU academy were assessed on fourteen parameters from three overarching characteristics: (a) anthropometric (i.e., height and body mass), (b) physical (i.e., 10 and 20 m sprint, countermovement jump [CMJ], peak and relative power, sprint momentum for 10 and 20 m, reactive strength index [RSI], aerobic capacity via the 30-15 intermittent fitness test [30-15IFT], isometric hip extension [IHE], and dominant handgrip strength), and (c) relative age (i.e., BQ). The accumulation of measures were specifically used to examine rugby-related characteristics that have been previously highlighted as influential during the TD processes in RU (52).

Participants

Seventy-eight Premiership RU academy players participated in this study. Players were separated by age group and playing position (forwards: U16=12, U18=17, U21=4; backs: U16=16, U18=25, U21=4). Institutional ethical approval was granted by Birmingham City University via the Health, Education, and Life Sciences (HELS) Academic Ethics Committee.

Procedures

All testing parameters were collected across six sessions during the first 6-weeks of the pre-season period. Subjects were instructed to follow a standardised training and recovery procedure in the 48-hours before the testing (e.g., not training to exhaustion, avoiding maximal loads, and re-fuelling appropriately post exercises). A standardised RAMP warm-up was completed and each test was fully explained and demonstrated prior to assessment. Data was gathered in the following order: BQ, body mass, height, CMJ, RSI, 10 and 20 m sprint, handgrip strength, IHE, and 30-15IFT. Peak power, relative peak power, and sprint momentum over 10 m and 20 m were calculated using a combination of these tests.

Body mass and height

Body mass and height, wearing only shorts, were measured to the nearest 0.1 kg and 0.1 cm using calibrated Seca Alpha (model 220) scales and Seca Alpha stadiometer (Seca, Hamburg, Germany), respectively. The practitioner intraclass correlation coefficient (ICC) and coefficient of variation (CV) had previously been calculated as r = 0.99 and CV = 2.9%.

Countermovement jump, reactive strength index, peak and relative power

Subjects performed the CMJ with hands on their hips positioned between two parallel infrared beams (Microgate, OptoGait, Italy). Subjects were instructed to complete the CMJ starting from a standing position, flex at the ankle-knee-hip to a self-selected depth, and to jump as high as possible. Subjects were familiar with the CMJ as this was used frequently in training. Subjects then completed the RSI test whereby they performed ten consecutive jumps for height whilst spending as little time in contact with the ground between jumps as possible. RSI was calculated for each jump as the ratio between height (in metres) and contact time (in seconds). The best score of the three attempts on both tests was recorded. Peak power was calculated using Sayers equation (46):

$$\textit{Peak power (W)} = (60.7 \cdot H) + (45.3 \cdot W) - 2055$$

“H” refers to the CMJ height in cm; and, “W” refers to body mass in kg. Relative peak power (W/kg) was also calculated dividing peak power by the player’s body mass. The ICC and CV were r = 0.95 and CV = 5% for the CMJ and r = 0.99 and CV = 4.5% for the RSI.

10 and 20 m sprint and momentum

Sprint time over 10 and 20 m were recorded using timing gates (Brower Timing Systems, IR Emit. Draper, UT, USA). These distances were habitually used by the club to test their players and have been used previously (11). After the standardised warm-up, the participants completed three maximal sprints with a 3-minute passive rest between attempts, as previously reported in literature (12). Each sprint started 0.3 m behind the initial timing gate, with players instructed to set off in their own time and run maximally through the final 20 m timing gate. The best of the three attempts was taken for analysis with times measured to the nearest 0.01-second.

The body mass of the athlete was multiplied by 10 and 20 m sprint velocities ($kg \cdot m^{-1} \cdot s^{-1}$) to obtain sprint momentum on those distances. The ICC and CV were r = 0.93 and CV = 1.3% and r = 0.91 and CV = 1.8% for the 10 and 20 m sprint, respectively.

30-15 intermittent fitness test

The 30-15IFT consisted of a 30-second shuttle run over a 40 m distance, interspersed with a 15-second recovery. The test began at 8 $km \cdot h^{-1}$ and is increased by 0.5 $km \cdot h^{-1}$ at each successive running shuttle. All procedures were followed as reported in previous literature (6). The test was terminated when subjects were no longer able to maintain the imposed speed of the test or when they did not reach a 3 m tolerance zone on three consecutive occasions. Previous research has shown the ICC of the 30-15IFT r = 0.96 and CV=1.6% (6). The velocity from the last completed stage was noted and used to the estimate $\dot{V}O_2max$ ($mL \cdot kg^{-1} \cdot min^{-1}$) through the following formula (6):

$$\dot{V}O_2max\ (mL \cdot kg^{-1} \cdot min^{-1}) = 28.3 - (2.15 \cdot G) - (0.741 \cdot A) - (0.0357 \cdot W) + (0.0586 \cdot A \cdot V_{IFT}) + (1.03 \cdot V_{IFT})$$

"V_{IFT}" is the final running velocity; "G" refers to gender (male = 1; female = 2); "A" is age; and, "W" is subject's body mass (kg).

Isometric hip extension and dominant handgrip strength

Isometric hip extension strength was measured using a portable Takei Back and Leg Dynamometer (Takei Scientific Instruments Co., Ltd, Tokyo, Japan), whereby participants stood on a portable platform with knees fully extended, back in a neutral position, and hips flexed. Participants gripped a handle connected to the platform by an adjustable chain and were instructed to pull as hard and as fast as possible, after a 3-second countdown, for 5-seconds. This test followed the procedure explained in previous literature (9) and related to various aspects of sport performance (3, 30, 32). Dominant handgrip strength was measured using the Takei 5401 Handgrip Dynamometer (Takei Scientific Instruments Co., Ltd, Tokyo, Japan). Participants performed the test sitting and holding their dominant hand's elbow squared, following standard procedure (33). Participants were instructed to "squeeze" as hard as possible after a 3-second countdown for 5-seconds. The best results of three attempts with a 3-minute rest for each test was recorded. Strong verbal encouragement was provided during each repetition. Similar portable isometric strength tests have been performed previously in athlete development literature (11, 38, 41). The ICC and CV were r = 0.97 and CV = 4.5% and r = 0.98 and CV= 3.4% for IHE and dominant hand grip strength, respectively.

Birth quartile

Each subjects' BQ was calculated using their date of birth. The English annual selection year (i.e., September to August) was used to allocate subjects into four quartiles: (a) BQ1 (i.e., September to November), (b) BQ2 (i.e., December to February), BQ3 (i.e., March to May), and BQ4 (i.e., June to August) (32). Participants' birth distribution was then compared against birth national norms as previously used in literature (27, 31).

Statistical analyses

Data are presented as mean ± standard deviation (SD) values using parametric (one-way ANOVA) and non-parametric (Kruskall–Wallis) analysis for each age category and a t-test and Wilcox test to analyse differences based on position. A Shapiro–Wilk test was used to determine if data were parametric or non-parametric according to a normal distribution of characteristics. Post-hoc analysis was performed to examine the effect size and statistical significance between both groups and positions using TukeyHSD and Dunn's test with Bonferroni correction, respectively. Significance was set for α level of 0.05, with Cohen's f calculated with ranges of 0.10 (small), 0.25 (medium), 0.40 (large), whilst a Cohen's d effect size (d) calculated with threshold values of 0.2 (small), 0.5 (medium), 0.8 (large), and 1.2 (very large) (8). Subjects' age group, forwards, backs, and combined BQ distributions were analysed and compared against national norms using a chi-square (χ^2) goodness-of-fit, with odds ratios (OR) and 95% confidence intervals (CI) to estimate reliability. Since the χ^2 does not reveal the magnitude of difference between quartile distributions, a Cramer's V was also used to report the effect size (0.00 and under 0.10, negligible; 0.10 and under 0.20, weak; 0.20 and under 0.40, moderate; 0.40 and under 0.60, relatively strong; 0.60 and under 0.80, strong; and, 0.80 and under 1.00, very strong) (29). Statistical analysis was conducted using IBM SPSS Statistics version 24.

RESULTS

Age group differences

Forwards

Results showed U16 forwards were significantly lighter than U21s (P=0.004) with a very strong effect size. Very large effect sizes were also found for the U16 (*f*=-1.6) and U18 (*f*=-1.4) forwards compared with the U21s for dominant handgrip strength, with U21s significantly stronger than U16s and U18s (P=0.018). Moreover, a significant difference and very strong effect size was noted for RSI between older (U21) forwards and U16s (P=0.014; *V*=-2.3). In addition, a strong effect size was found between the U16 and U21 forwards for 10 m sprint (*V*=-1.9), with U16s significantly quicker than U21s (P=0.015). Moderate to large effect size was reported in peak power (*f*=0.4) and sprint momentum on 10 m (*f*=–0.9), with older players being significantly more powerful and impactful. Lastly, a very strong effect size was found for the U16 forwards compared with U18 (*V*=-1.8) and U21 (*V*=-4.5) forwards for $\dot{V}O_2$max, with U16s possessing significantly lower aerobic capacity than U18s (P=0.009) and U21s (P<0.001). Height, IHE, and CMJ reported non-statistical significance.

Backs

Significant differences and strong to very strong effect sizes were recorded for body mass characteristics between U16 and U21 (P=0.002; *V*=-3.0) and U18 and U21 (P=0.042; *V*=-1.4) backs. In addition, strong to very strong effect sizes were found in U21s compared to U16s for CMJ (P=0.004; *V*=-1.9), RSI (P=0.016; *V*=-1.5), and $\dot{V}O_2$max (P=0.003; *V*=-2.7). Small to moderate effect size was reported for peak power and sprint momentum on 10 and 20 m, with older players possessing greater values. There were no other significant differences between U18 and U21 forwards or backs. Table 1 presents the age group characteristics for forwards and backs.

Table 1. Anthropometric and physical characteristics by age group and position

	Under 16 (1) Mean±SD	**Under 18 (2) Mean±SD**	**Under 21 (3) Mean±SD**	**One-way ANOVA P**	**Kruskall-Wallis P**	**Post-hoc**	**U16 vs. U18 effect size**	**U16 vs. U21 effect size**	**U18 vs. U21 effect size**
Forwards									
Body mass (kg)	88.9±10	97.4±7.63	111.7±7.3		0.005	1 < 3	-0.9 (-1.7 to -0.2)	-2.3 (-3.7 to -0.9)	-1.9 (-3.1 to -0.6)
Height (cm)	183.9±6.9	183.7±4.8	186±8.9		0.945		0.04 (-0.7 to 0.8)	-0.3 (-1.4 to 0.9)	-0.4 (-1.5 to 0.7)
IHE (kg)	145.3±25	157.1±26.09	180.3±22.1		0.111		-0.46 (-1.2 to 0.3)	-1.4 (-2.7 to 0.2)	-0.9 (-2.0 to 0.2)
Handgrip (kg)	45.8±7.6	48.6±6	57.9±7.5	0.018		1, 2 < 3	-0.4 (-1.15 to 0.3)	-1.6 (-2.8 to -0.3)	-1.4 (-2.6 to -0.2)
CMJ (cm)	31.8±4.4	35.7±6.95	38.7±3.0		0.081		-0.6 (-1.4 to 0.13)	- 1.7 (2.9 to - 0.4)	-0.4 (-1.6 to 0.6)
Peak power (W)	3907.6±306.9	4522.0±569.6	5356.8±502.1	0.000*		1 < 2 < 3	-0.9 (-1.7 to -0.1)	-2.3 (-3.7 to -0.9)	-2.0 (-3.2 to -0.7)
Relative peak power (W/kg)	44.1±2.9	46.4±4.5	47.9±1.5	0.945			0.0 (-0.7 to 0.7)	-0.2 (-1.4 to 0.8)	-0.4 (-1.4 to 0.6
RSI (m/ms)	1.12±0.20	1.34±0.37	1.61±0.37		0.014	1 < 3	-0.7 (-1.4 to 0.0)	-2.3 (-3.7 to -0.8)	-0.6 (-1.8 to 0.5)
10 m sprint (s)	1.71±0.10	1.82±0.13	1.93±0.10		0.011	1 < 3	-0.8 (-1.6 to -0.0)	-1.9 (-3.3 to -0.6)	-0.9 (-1.9 to 0.3)
20 m sprint (s)	3.11±0.20	3.23±0.21	3.13±0.23	0.445			-0.4 (-1.2 to 0.3)	0.0 (-1.1 to 1.1)	0.4 (-0.7 to 1.5)
Sprint momentum 10 m ($kg \cdot m^{-1} \cdot s^{-1}$)	521.6±49.9	541.9±39.9	588.2±55.0	0.002		1 < 3	-0.4 (-1.2 to 0.2)	-1.3 (-2.5 to -0.0)	-1.0 (-2.2 to 0.0)
Sprint momentum 20 m ($kg \cdot m^{-1} \cdot s^{-1}$)	579.0±52.9	637.6±91.9	727.1±41.1	0.031		1 < 3	-0.7 (-1.5 to 0.0)	-2.9 (-4.4 to -1.3)	-1.0 (-2.1 to 0.1)
$\dot{V}O_2$max ($mL \cdot kg^{-1} \cdot min^{-1}$)	58.8±1.7	61.2±0.99	65.9±0.8		0.001	1 < 2, 3	- 1.8 (-2.6 to -0.9)	-4.5 (-6.4 to -2.4)	-4.9 (-6.7 to -2.9)

Backs									
Body mass (kg)	71.7±6.3	77±8.9	89.3±1.8		0.002	1 < 3, 2 < 3	-0.7 (-1.31 to -0.0)	-3.0 (-4.4 to -1.5)	-1.4 (-2.6 to -0.3)
Height (cm)	176.9±7.7	176.9±6.8	182±3.4		0.241		-0.0 (-0.6 to 0.6)	-0.7 (-1.8 to 0.4)	0.8 (-1.8 to 0.3)
IHE (kg)	127.5±17.3	142.1±25.5	135.8±14.3		0.112		-0.6 (-1.3 to 0.0)	-0.5 (-1.6 to 0.6)	0.3 (-0.8 to 1.3)
Handgrip (kg)	44.9±5.1	46.5±7.7	51.7±5.1	0.212			-0.2 (-0.8 to 0.4)	-1.3 (-2.5 to -0.1)	-0.7 (-1.7 to 0.4)
CMJ (cm)	35.8±5.1	39.7±4.6	44.8±2.5		0.003	1 < 3	-0.8 (-1.5 to -0.1)	-1.9 (-3.1 to -0.6)	-1.1 (-2.2 to -0.0)
Peak power (W)	3365.6±457.3	3822.1±600.7	4708.9±220.3	0.002		1 < 2 < 3	-0.5 (-1.1 to 0.1)	-2.4 (-3.8 to -1.1)	-1.3 (-2.4 to -0.22)
Relative peak power (W/kg)	46.9±4.3	49.6±4.6	52.7±1.6	0.783			0.0 (-0.5 to 0.6)	-0.6 (-1.8 to 0.4)	-0.7 (-1.8 to 0.3)
RSI (m/ms)	1.51±0.32	1.64±0.38	2.01±0.54		0.036	1 < 3	-0.6 (-1.2 to 0.0)	-1.5 (-2.7 to - 0.3)	-1.0 (-2.1 to 0.1)
10 m sprint (s)	1.61±0.11	1.71±0.12	1.73±0.07		0.333		-0.4 (1.1 to 0.2)	-0.4 (-1.5 to 0.7)	0.0 (-1.0 to 1.1)
20 m sprint (s)	2.93±0.14	2.93±0.14	3.00±0.11	0.609			-0.2 (-0.8 to 0.4)	-0.5 (-1.6 to 0.6)	-0.3 (-1.3 to 0.8)
Sprint momentum 10 m ($kg \cdot m^{-1} \cdot s^{-1}$)	445.8±50.2	464.9 ±58.5	538.6±31.3	0.001		1 < 2 < 3	-0.3 (-0.9 to 0.2)	-1.9 (-3.1 to -0,6)	-1.3 (-2.4 to -0.1)
Sprint momentum 20 m ($kg \cdot m^{-1} \cdot s^{-1}$)	494.7±48.0	535.1±79.6	601.0 ±23.1	0.030		1 < 3	-0.5 (-1.2 to 0.0)	-2.3 (-3.6 to -1.0)	-0.8 (-1.9 to 0.2)
$\dot{V}O_2max$ (mL·kg-1·min-1)	62±2.2	64.6±2.6	69±2.7		0.002	1 < 3	-0.7 (-1.4 to -0.1)	-2.7 (-4.0 to -1.3)	-1.7 (-3 to -0.5)

Note: The column headings indicate overall effects (significance set for P = 0.05), post hoc, and effect size odd ratio (OR) set at 95% of CI, between age categories and characterise positions. IHE = isometric hip extension; CMJ = counter movement jump; RSI = reactive strength index; $\dot{V}O_2max$ = maximal oxygen uptake; ANOVA = analysis of variance

Positional differences

U16 forwards vs. backs

Within the U16 age group, strong to very strong effect sizes were found in body mass and height. Specifically, forwards were heavier (P<0.001; *V*=2.1) and taller (P=0.031; *V*=0.9) than backs. In regard to strength, U16 forwards were stronger than backs in the IHE (145±25 vs. 128±17.3, *V*=0.9), however statistical significance was not reached (P=0.052). Large to very large effect size was also reported for peak power (P<0.001; *d*=2.1), relative power (P=0.026; *d*=0.9), and both sprint momentum on 10 (P<0.001; *d*=1.5) and 20 m (P<0.001; d=1.6), with forwards recording greater scores. Lastly, the difference between U16 backs compared to forwards was significantly different for RSI (P=0.001; *V*=-1.4), 10 m sprint (P=0.014; *V*=0.8), 20 m sprint (P=0.008; *d*=1.1), and $\dot{V}O_2max$ (P<0.001; *V*=-1.9) in favour of the backs.

U18 forwards vs. backs

Within the U18 age group, forwards were heavier (P<0.001; *V*=2.4) and taller (P=0.001; *V*= 1.1) than backs. Regarding peak power (P<0.001; *d*=2.3), relative power (P=0.001; *d*=1.0), and both sprint momentum on 10 m (P<0.001; *d*=1.4) and 20 m (P<0.001; *d*=1.2), forwards reported a statistically significant higher scores than backs. Moreover, significant differences and large effect sizes were found between U18 forwards and backs for CMJ (P=0.021; *V*=-0.7), RSI (P<0.001; *V*=-0.9), 10 m sprint (P=0.001; *V*=1.1), 20 m sprint (P<0.001; *d*=1.3), and $\dot{V}O_2max$ (P<0.001; *V*=-1.6) in favour of the backs.

U21 forwards vs. backs

Within the U21 age group, forwards were heavier (P=0.028; *V*=4.2) and stronger (IHE; P=0.029; *V*=2.3) than backs, recorded greater peak power (P=0.002; *d*=3.5) and sprint momentum on 20 m (P=0.002; *d*=3.7), were slower over 10 m sprint (P=0.029; *V*=2.6), and possessed lower $\dot{V}O_2$max (P=0.028; *V*=-1.5) scores than backs. Table 2 reports significant differences between U16, U18, and U21 forwards and backs.

Table 2. Anthropometric and physical characteristics based on age group and position.

	Forwards Mean±SD	Backs Mean±SD	t	df	Wilcox test W	P	Effect size
U16							
Body mass (kg)	88.9±10.4	71.7±6.3			181	0.000*	2.1 (1.1 to 3.0)
Height (cm)	183.9±6.9	176.9±7.7			144	0.031*	0.9 (0.1 to 1.7)
CMJ (cm)	31.8±4.4	35.8±5.1			55	0.066	-0.8 (-1.6 to -0.0)
Peak power (W)	3907.6±306.9	3365.6±457.3	5.5	26		0.000*	2.1 (1.1 to 3.0)
Relative peak power (W/kg)	44.1±2.9	46.9±4.3	2.3	26		0.026*	0.9 (0.1 to 1.6)
RSI (mm/ms)	1.12±0.20	1.51±0.32			25	0.001*	-1.4 (-2.2 to -0.5)
IHE (kg)	145.3±25	127.5±17.3			139.5	0.052	0.9 (0.1 to 1.6)
Handgrip (kg)	45.8±7.6	44.9±5.1	0.4	18.2		0.725	0.1 (-0.6 to 0.9)
10 m sprint (s)	1.71±0.10	1.61±0.11			149	0.014*	0.8 (0.1 to 1.6)
20 m sprint (s)	3.11±0.20	2.93±0.14	2.9	23.3		0.008*	1.1 (0.3 to 1.9)
Sprint momentum 10 m ($kg{\cdot}m^{-1}{\cdot}s^{-1}$)	521.6±49.9	445.8±50.2	3.9	26		0.000*	1.5 (0.6 to 2.3)
Sprint momentum 20 m ($kg{\cdot}m^{-1}{\cdot}s^{-1}$)	579.0±52.9	494.7±48.0	4.4	26		0.000*	1.6 (0.7 to 2.5)
$\dot{V}O_2$max ($mL{\cdot}kg^{-1}{\cdot}min^{-1}$)	58.8±1.7	62±2.2			13	0.000*	-1.9 (-2.8 to -1.0)
U18							
Body mass (kg)	97.4±7.6	77±8.9			412	0.000*	2.4 (1.6. to 3.2)
Height (cm)	183.7±4.8	176.9±6.8			335	0.000*	1.1 (0.4. to 1.8)
CMJ (cm)	35.7±6.9	39.7±4.6			122	0.021*	-0.7 (-1.3. to -0.1)
Peak power (W)	4522.0±569.6	3822.1±600.7	7.4	40		0.000*	2.3 (1.5 to 3.1)
Relative peak power (W/kg)	46.4±4.5	49.6±4.6	3.4	40		0.001*	1.0 (0.4 to 1.7)
RSI (mm/ms)	1.34±0.37	1.64±0.38			110.5	0.009*	-0.9 (-1.5. to -0.3)
IHE (kg)	157.1±26.0	142.1±25.5			278	0.095	0.6 (-0.0. to 1.2)
Handgrip (kg)	48.6±6	46.5±7.7	1	38.3		0.333	0.3 (-0.3. to 0.9)
10 m sprint (s)	1.82±0.13	1.71±0.12			334.5	0.001*	1.1 (0.4. to 1.7)
20 m sprint (s)	3.23±0.21	2.93±0.14	3.8	25.9		0.000*	1.3 (0.6. to 1.9)
Sprint momentum 10 m ($kg{\cdot}m^{-1}{\cdot}s^{-1}$)	541.9±39.9	464.9±58.5	4.7	40		0.000*	1.4 (0.7 to 2.1)
Sprint momentum 20 m ($kg{\cdot}m^{-1}{\cdot}s^{-1}$)	637.6±91.9	535.1±79.6	3.8	40		0.000*	1.2 (0.5 to 1.8)
$\dot{V}O_2$max ($mL{\cdot}kg^{-1}{\cdot}min^{-1}$)	61.2±0.9	64.6±2.6			37	0.000*	-1.6 (-2.3. to -0.9)
U21							
Body mass (kg)	111.7±7.3	89.3±1.8			16	0.028*	4.2 (1.4. to 6.8)
Height (cm)	186±8.9	182±3.4			10	0.666	0.6 (-0.8. to 2.0
CMJ (cm)	38.7±3.0	44.8±2.5			1	0.059	-2.2 (-3.9. to -0.3)
Peak power (W)	5356.8±502.1	4708.9±220.3	5.0	6		0.002*	3.5 (1.1 to 5.9)

Relative peak power (W/kg)	47.9±1.9	52.7±1.6	0.8	6		0.448	0.5 (-0.8 to 1.9)
RSI (mm/ms)	1.61±0.37	2.01±0.54			4.5	0.387	-0.9 (-2.3. to 0.6)
IHE (kg)	180.3±22.1	135.8±14.3			16	0.029*	2.3 (0.4. to 4.2)
Handgrip (kg)	57.9±7.5	51.7±5.1	1.4	5.3		0.222	0.9 (-0.5. to 2.4)
10 m sprint (s)	1.93±0.10	1.73±0.07			16	0.029*	2.6 (0.5. to 4.6)
20 m sprint (s)	3.13±0.23	3.00±0.11	1	5		0.376	0.6 (-0.7. to 2.1)
Sprint momentum 10 m (kg·m^{-1}·s^{-1})	588.2 ±55.0	538.6 ±31.3	1.5	6		0.168	1.1 (-0.4 to 2.5)
Sprint momentum 20 m (kg·m^{-1}·s^{-1})	727.1 ±41.1	601.0 ±23.1	5.3	6		0.002*	3.7 (1.2 to 6.2)
$\dot{V}O_2$max (mL·kg^{-1}·min^{-1})	65.9±0.8	69±2.7			0	0.028*	-1.5 (-3.1. to 0.1)

Note: Post-hoc tests: t-test for parametrics and Wilcox test for non-parametrics variables. Positions' differences for the same age group is reported for anthropometrical and physical parameters mean ± SD. Significance set for *P* = 0.05 and Cohen's *V* and Cohen's *d* effect size odd ratio (OR) set at 95% of CI between age categories. IHE = isometric hip extension; CMJ = counter movement jump; RSI = reactive strength index; $\dot{V}O_2$max = maximal oxygen uptake; t = t-distribution for t-test; df = degree of freedom for t-test.

Table 3. Descriptive statistics of the birth quartile distributions based on age group and position vs. national norms.

	BQ1 (*n*=) %	BQ2 (*n*=) %	BQ3 (*n*=) %	BQ4 (*n*=) %	Total players (*n*=)	X^2 (df = 3)	Cramer's *V*	P	Q1 vs. Q4 (OR = 95% CI)	Q2 vs. Q4 (OR = 95% CI)	Q3 vs. Q4 (OR = 95% CI)
Under 16	14 (50%)	9 (32.2%)	3 (10.7%)	2 (7.1%)	28	13.1	0.5	0.004*	6.9 (1.1; 42.6)	4.6 (0.7; 29.9)	1.5 (0.1; 12.2)
Under 18	17 (40.4%)	9 (21.5%)	13 (31%)	3 (7.1%)	42	10.7	0.3	0.017*	5.6 (1.2; 25.1)	3.1 (0.6; 14.8)	4.4 (0.9; 20.4)
Under 21	2 (25%)	3 (37.5%)	0	3 (37.5%)	8	2.9	0.4	0.393	0.6 (0.0; 9.3)	1.0 (0.0; 13.0)	-
All players	33 (42.3%)	1 (27%)	16 (20.5%)	8 (10.2%)	78	16.4	0.3	0.000*	4.1(1.5; 11.1)	2.7 (0.9; 7.6)	2.0 (0.7; 5.9)
Forwards	12 (36.4%)	10 (30.3%)	8 (24.2%)	3 (9.1%)	33	5.4	0.2	0.130	3.9 (0.8; 19.5)	3.4 (0.6; 17.3)	2.7 (0.5; 14.1)
Backs	21 (46.7%)	11 (24.4%)	8 (24.2%)	5 (11.1%)	45	12.4	0.3	0.004*	4.1 (1.1; 14.9)	2.2 (0.5; 8.7)	1.6 (0.4; 6.6)

Note: BQ1 = September to November; BQ2 = December to February; BQ3 = March to May; BQ4 = June to August; Cramer's *V* effect size odd ratio (OR) set at 95% of CI between categories; Significance set at P = 0.05.

Birth quartiles

Within the U16 age group, significant differences were reported among BQs distribution (P=0.004; *V*=0.5). Specifically, 50% of players were born in BQ1, 32.2% were born in BQ2, 10.7% were born in BQ3, and 7.1% were born in BQ4. For the U18 age group, significant differences were reported (P=0.017; *V*=0.3). To be specific, 40.4% of players were born in BQ1, 21.5% were born in BQ2, 31% were born in BQ3, and 7.1% were born in BQ4. Taken together, cumulative data for forwards and backs showed weak effect sizes but statistically significant differences, with 42.3% of players born in BQ1, 27% born in BQ2, 20.5% born in BQ3, and 10.2% born in BQ4 (P<0.001; *V*=0.3). Birth quartile distributions for age groups and positions compared to national norms are reported in Table 3.

DISCUSSION

There is currently limited research that has investigated the anthropometric, physical, and relative age characteristics based on age group and position in English RU academy players. Moreover, the need for replication studies to inform possible meta-analysis is underscored by the limited sample sizes available to these types of case studies, whilst providing a novel physical profile will also help inform evolutionary trends when compared to older studies (11, 12). Thus, the purpose of this investigation was to evaluate these characteristics in an English Premiership RU academy across multiple age categories (i.e., U16, U18, and U21) and playing positions (i.e., forwards and backs). Similar to previous literature (11, 59), key findings revealed how anthropometric (i.e., body mass and height) and physical (i.e., power, momentum and aerobic capacity) characteristics differed across the three age groups. Results based on positional differences showed forwards were generally heavier, taller, stronger, more powerful, and more disruptive when compared to backs. In contrast, backs were quicker, faster, and possessed superior aerobic capacity. These findings are also in agreement with previous studies analysing similar RU players (e.g. 14, 38). Moreover, an interesting result of this investigation, in accordance with previous findings (25, 27), was that there was an overrepresentation of relatively older players compared to relatively younger players in the U16 and U18 age groups. In addition, birth quartile analysis by position also showed that backs reported a significantly skewed BQ distribution favouring relatively older players, while a similar trend was also found when all players were combined.

Regarding the anthropometric measures, there was an increase in body mass and height across the three groups, with U21 recording the highest value for both characteristics. This is unsurprising, since changes in body mass and height are in accordance to the normal trajectory of growth and maturation, although they are generally more pronounced during adolescence (i.e., age 13 to 16 years) following peak height velocity (53). The anthropometric results of the current study are in agreement with previous age group findings from an English RU academy at a professional club (body mass: U16=79.4±12.8 kg, U18=88.3±11.9 kg, U21=98.3±10.4 kg; height: U16=178.8±7.1 cm, U18=183.5±7.2 cm, U21=186.7±6.61 cm) (11). Moreover, the anthropometric findings in the present study based on position are similar to those previously shown in English RU academy players (forwards body mass: U16=87.6±8.1 kg, U18=93.8±7.0 kg, U21=105.5±8.5 kg; backs body mass: U16=70.5±10.8, U18=78.7±6.9, U21=87.6±10.7; forwards height: U16=181.9±6.3 cm, U18=188.1±6.2 cm, U21=190.1±5.6 cm; backs height: U16=175.6±6.6 cm, U18=178.9±3.9 cm, U21=181.6± 4.4 cm) (12). Since these previous studies were conducted in 2015, these current findings suggest that there are little evolutionary differences in anthropometric characteristics over half a decade on. Moreover, it could be speculated that a certain consistency in the acute:chronic training and playing load has been maintained in the sport of RU through this time. In light of this cumulative data, a systematic review and meta-analysis may be warranted to help draw more valid conclusions since it would comprise a larger representative sample.

The U18 group in this study was slightly lighter and shorter compared to the same-age international Irish players of Wood and colleagues' (54) investigation (forwards: 98.9±9 kg, backs: 91.9±7 kg; forwards: 185±1 cm, backs: 179±0.0 cm). This possibly suggests that the higher the level of U18 rugby (i.e., international youth vs. academy), the more important anthropometric characteristics are during the recruitment process (41). From a position-specific perspective, forwards were significantly heavier and taller than backs, with the exception of the U21s, whereby there was no significant difference in height. Together, these findings provide further evidence that there are increases in body mass and height across the three age groups, as well as further suggesting that backs are generally shorter and lighter compared to forwards. Only forwards reported a significant difference ($P=0.015$) for sprint time between U16 and U21 (1.71±0.10 s vs. 1.93±0.10 s). Interestingly, U16s were in fact faster over the initial 10 m. This result may be explained by differences in power-weight ratio across age-groups that result from the timing of peak weight velocity, which tends to occur around age 16 (38). Indeed, this is particularly important for coaches and practitioners to recognise, since the perception of a slower sprint score with increasing age may be negatively reflected on a player. As such, height, body mass, and sprint time should be considered as part of a battery of tests when planning the LTAD pathway in a RU academy (13).

Similar to previous literature investigating characteristics in an English (11) and Argentinian (59) RU academy, results regarding sprint momentum reported statistically differences among age groups. In the present study, U21 forwards recorded a greater momentum than U16 forwards both on 10 and 20 m sprint. However, this was slightly dissimilar to that found in the English academy (11), since they reported statistical significance differences among all age groups (i.e., U16<U18<U21), whereas we

only found it in some (i.e., U16<U21). Similarly, Zabaloy and colleagues (59) showed how younger Argentinian forwards possessed inferior sprint momentum compared to their older counterparts (i.e., U14<U16<U18<Senior). Thus, from the results of the present study, it could be speculated that forwards should train accelerations and impacts on longer (i.e., 20 m) distances. Interestingly, in the current research, backs were statistically more impactful over 10 m as they became older (U16<U18<U21), suggesting that: (a) older players' sprint momentum was influenced by greater body mass and (possibly) better running mechanics, (b) the normal trajectory of growth affected each age-group on this performance variable, and (c) coaches should include accelerations over short distances (i.e., 10 m) in a LTAD program if they aim to optimise backs' progression through the academy. To the author's knowledge, there is a lack of studies that treat sprint momentum specifically over 20 m in RU academies, therefore present discussion on this parameter is limited. From a positional standpoint, forwards generally possessed greater momentum than backs both on 10 and 20 m sprint. However, in the U21 group, sprint momentum on 10 m was not significantly different (P=0.168) for the two positions. This can be explained by the fact that at an older age, both positions accumulated enough sprint training to mitigate acceleration discrepancies on short distances. These findings on positional differences are in line with previous works (38, 59) and indicate that if academy players attempt to be classified as a forward, they need to possess exceptional momentum characteristics over both 10 m and 20 m distances. Altogether, it is possible to say that academy RU players should possess an optimal combination of body mass and speed and that sprint momentum should be trained over 10 and 20 m regardless age and playing position.

The handgrip and IHE strength tests are generally considered as two strength tests that have low risk of injury and have an acceptable reliability (9, 33). In the present study, with the exception of handgrip strength in forwards (U16 and U18 < U21), there were no significant differences in strength scores across the age groups. Whereas, when comparing positions, U21 forwards had a significantly higher IHE score than compared with backs; although it was not statistically significant in U16 and U18 groups. The absence of significant differences for handgrip strength between U16 and U18 groups, as well as reported across all groups for IHE, may be explained by the high presence of early born players across U16s and U18s which could have enhanced the standard for the parameter of strength within the group. In particular, data regarding dominant handgrip strength revealed that it could discriminate forwards by age groups (U16s and U18s vs. U21s). In-line with position-specific requirements in RU (12), dominant handgrip strength could reflect the fact that generally this type of strength may be associated to the superior upper body strength required by forwards during match-play (i.e., scrums and line-out). Thus, normative data for handgrip strength is required for athletes to progress to the last-age group in a professional academy. The results regarding IHE strength parameters also indicate that a specific level of maximal isometric force is required to distinguish players by position at an older age (U21). This is due to the fact that, although strength is an important parameter for all RU players (14), forwards require specific benchmarks for this quality; as already displayed in a recent study (38).

Results from this research show that CMJ differentiated age groups, with U16 backs scoring significantly lower than U21 backs (35.8±5.1 cm vs. 44.8±2.5 cm). This could reflect that older players possess greater power qualities and may have a better jumping skill, suggesting that both power development and jump technique progression should be structured in the LTAD continuum. From a positional viewpoint, backs jumped higher than forwards across all age groups; although this difference was only statistically significant in U18s (forwards: 35.7±6.9 cm; backs: 39.7±4.6 cm). Importantly, this reflect the fact that body mass is associated with jump height and instantaneous power production, thus, different quantities of work are performed by players with different body mass to achieve that height. These findings are in agreement with those of adolescent international Irish players (54), whereby backs jumped higher than forwards. An explanation for positional difference emerged in this research could be explained by the fact that forwards are typically required to produce a greater amount of power from semi-static actions during game (e.g., ruck, mauls, and scrums) (42, 54) whereas backs only spend 25% of their activity generating power from isometric contractions (54). Moreover, their power qualities contribute to optimise linear sprints, change of directions, and to achieve higher speed from different starting positions during games (42, 58). Thus, present results shows that power qualities assessed by CMJ can be an important factor during backs' LTAD and progression across an academy, and that specific benchmark should be used to distinguish players by position in U18s.

Power qualities measured in this investigation reported that peak power but not relative peak power distinguished age groups among forwards, with older players scoring higher than younger players (U16<U18<U21). In backs, statistically significance differences were found only among some age groups (i.e., U16 and U18 < U21). Together, these results are in line with a study of Howards and colleagues (23), which analysed the physical characteristics of the academy (U14 to U17) of a Premiership RU club, where mean values for peak power demonstrated a trend towards increasing with age group. From a positional perspective, peak power was greater in all-age forwards compared to backs (U16: P<0.001; U18: P<0.001; U21: P=0.002), whereas relative peak power was significantly greater only for forwards in both U16 (P=0.026), and U18 (P=0.001) groups. Although forwards' peak power results reflect the same outcome of that reported in an investigation surrounding the incidence of injury in forwards and backs in RU (2), in regards to the relative peak power, there no previous study that has examined this attribute within a RU population. Thus, the present research showed that both U16 and U18 forwards expressed more power per kilogram than their back counterpart, forwards were more powerful than backs and that there is more diversity among younger players than U21s. Therefore, these findings, along with information relative to the CMJ, suggest that diverse aspects of power should be trained in a RU academy for an adequate LTAD, as well as adding new benchmarking guidelines for practitioners.

Reactive strength index is defined as the ratio between jump height and contact time (m/ms) (35) and reflects an athlete's lower limb stiffness and stretch-shortening (SSC) cycle capabilities (35). The RSI has been largely used both in RU clubs, and has been linked with jump, sprint, and change of direction abilities (35, 58). Results from this investigation demonstrated that the RSI discriminated both age groups and positions, whereby older players (P=0.014) and backs (U16: P=0.001; U18: P=0.009) demonstrated significantly greater values compared to their respective counterparts. This may be due to the sum of RU practice and plyometric-based training that older players have accumulated. Moreover, positional differences could reflect the greater SSC that players require in this role (54, 57). Differences among groups and positions emerged in the current study suggest that athletic qualities linked to RSI should be planned and integrated across age-grade players for a more accurate LTAD in RU. To the authors' knowledge, although this test has been used routinely in professional clubs, there is no comparative data for RU players. Therefore, RSI score from this study could help practitioners of professional clubs in identifying normative measures for RU academies.

Aerobic capacity was estimated from the 30-15IFT. The results of this study confirm those of a previous investigation regarding the aerobic characteristics of English senior professional RU players (47), where it was found that backs had greater aerobic qualities compared to forwards. Thus, irrespective of age group, backs appear to possess significantly greater parameters of $\dot{V}O_2max$ from entry (i.e., U16) to expertise (i.e., professional level). Indeed, backs are normally leaner and have less body fat percentage compared to forwards, which facilitates their superior aerobic profile when expressed relative to body mass (38). Moreover, forwards' lower aerobic capacity is associated with the specific demand of their role, which generally requires them to cover less distance compared to backs (38, 40). The present study aligns with findings from a recent review on applied sport science in age-grade RU players in England (52). Till and colleagues (52) reported that older age groups have greater $\dot{V}O_2max$ scores and indicate that in order to progress to the U21 squad, it is necessary for players to possess excellent oxidative capacities to sustain the intensity of the game that increases alongside age.

The current study found a selection bias towards relatively older players. Indeed, similar findings were reported in: (a) senior international RU players (BQ1= 36% vs. BQ4= 27%) (25), (b) Welsh academy RU players (BQ1=29% vs. BQ4=21%) (27), and (c) English regional youth players (BQ1=60% vs. BQ4=23.4%) (44). Relative age effect phenomena was also found in the present developmental academy, in agreement with what was found in other similar academy environments (14, 28). More specifically, descriptive statistics in this current study show that early born U16 and U18 players were overrepresented (U16: BQ1=50% vs. BQ4=7.1%; U18: BQ1=40.4% vs. BQ4=7.1%), Moreover, in accordance with Kearney's (25) findings, this current study reported that 71.1% of backs were born in the first half of the year (BQ1 and BQ2). This may be due to selectors recruiting backs based on physical advantages (e.g., anthropometric and physical characteristics) that relatively older players often possess when compared to same age but later born peers (57). Interestingly, however, this was not the same for U21 group (BQ1=25% vs. BQ4=37.5%). In fact, present findings align with the results McCarthy and Collins (34), whereby possible *reversal effects* of relative age were evident. This suggests that a relative age bias plateaus towards adulthood and perhaps other technical, tactical, psychosocial, and perceptual characteristics (combined with results discussed) become more important for selection and progression after maturity. However, further research is required to substantiate these suggestions.

LIMITATIONS

It is important to consider the limitations of this study when interpreting its findings. It was not possible for this current study to analyse the specific on-field positions of forwards (e.g., prop, hooker, and flanker) and backs (e.g., scrum-half, fly-half, and wing) due to sample size restrictions. The conclusions for this study are also based on the restricted population of a single English Premiership RU academy, thus it is not possible to suggest these findings are representative of other academies, limiting their external validity. Moreover, due to the RAEs that were present within the sample, it is plausible to suggest that an academy with a younger relative age (i.e., no RAEs) may have lower mean values of the anthropometric and physical parameters, thus these benchmarks are not necessarily representative of potential to achieve senior status at adulthood. Future research should use a similar approach including specific on-field positions, a higher number of participants, comprise other physical parameters (e.g., peak height velocity, relative strength), and offer a longitudinal examination of these trends.

CONCLUSION

This investigation provides an insight into the anthropometric, physical, and relative age characteristics of English Premiership rugby union academy players based on age group (i.e., U16 vs. U18 vs. U21) and position (i.e., forward vs. backs). Data can be used as benchmarks to identify potential players for U16, U18, and U21 academy teams, as well as informing LTAD processes. Results show, in line with other studies (38), that anthropometric and physical parameters increase with age at different rates following the growth maturational trend, as well as demonstrating the positional differences that exist. Specifically, key findings suggest that all players should aim to develop greater parameters of body mass, power, sprint momentum, and aerobic capacity in order to meet the key prerequisites imposed by RU. Moreover, individual characteristics should be consider among playing positions. However, coaches and practitioners should act with caution, since there could be variation around the positional mean data presented, depending on training experience and age group.

There appears to be RAEs within academy RU. In particular, backs born in the first half of the year seem to be considerably overrepresented; possibly because superior anthropometric and physical characteristics are advantageous when facing forwards of a similar age. However, signs of possible *reversal effects* of relative age are prevalent due to RAEs plateauing towards adulthood, and thus a greater proportion of relatively younger players may be benefitting by the system. As such, coaches and practitioners should consider relative age when recruiting young players in RU academies, since relatively older players may be selected due to the current performance rather than their potential to develop into a senior professional. Future research is required on a larger population analysing the same characteristics based on age group and position to understand the external validity of these current findings.

CONFLICTS OF INTEREST AND SOURCE OF FUNDING

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