A multidimensional approach to identifying the physical qualities of male English regional academy rugby union players; considerations of position, chronological age, relative age and maturation

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Abstract

Interpreting the physical qualities of youth athletes is complex due to the effects of growth, maturation and development. This study aimed to evaluate the effect of position, chronological age, relative age and maturation on the physical qualities of elite male academy rugby union players. 1,424 participants (*n*=2,381 observations) from nine Rugby Football Union Regional Academies prospectively completed a physical testing battery at three time points, across three playing seasons. Anthropometrics, body composition, muscular power, muscular strength, speed, aerobic capacity and running momentum were assessed. Positional differences were identified for all physical qualities. The largest effect sizes were observed for the associations between chronological age (*d*=0.65 to 0.73) and maturation (*d*=-0.77 to -0.69) and body mass related variables (i.e. body mass and running momentum). Relative strength, maximum velocity and aerobic capacity were the only models to include two fixed effects with all other models including at least three fixed effects (i.e. position and a combination of chronological age, relative age and maturation). These findings suggest a multidimensional approach considering position, chronological age, relative age and maturation is required to effectively assess the physical qualities of male age grade rugby union players. Therefore practitioners should use regression equations rather than traditional descriptive statistic tables to provide individualised normative comparisons thus enhancing the application of testing results for talent identification and player development.

Keywords: talent identification, long-term athlete development, physical performance

Highlights

- Practitioners should record and incorporate position, chronological age, relative age and maturation into the physical evaluation of elite academy rugby union players.
- The regression equations provided within this study offer highly generalisable comparative values that are specific to a players chronological and biological development.
- Through the use of enhanced player evaluation practitioners will be able to make more informed decisions surrounding talent identification and athlete development.

Introduction

Talent identification and development systems place a large emphasis on developing the physical qualities of youth athletes to promote health, reduce injury risk and increase performance in preparation for elite competition (Bergeron et al., 2015). As such, the quantification of physical qualities is essential for talent identification, player and programme evaluation, informing training prescription and guiding goal setting (Barker & Armstrong, 2010). Additionally the assessment of physical qualities is important, as they can differentiate future career success in both Olympic (Bullock et al., 2009) and team (Fontana et al., 2017; Gonaus & Müller, 2012; Till, et al., 2016) sports. However, the interpretation of physical qualities in youth athletes is complex due to growth, maturation and development (Bergeron et al., 2015; Till & Baker, 2020). Therefore, to effectively compare the results of physical testing in practice, it is important to gain an understanding of the factors influencing the physical qualities of youth athletes.

Due to the high intensity, collision-based nature of rugby union match play, well-developed physical qualities are favourable to increase performance and reduce injury risk (Hislop et al., 2017; Owen et al., 2020; Read et al., 2018). Cross-sectional research within rugby union pathways has previously identified athletes within older age grades to be taller, heavier, stronger, more powerful and possess greater sprint momentum and relative aerobic fitness (Darrall-Jones et al., 2016; Darrall-Jones et al., 2015; Darrall-Jones et al., 2016; Durandt et al., 2006). Positional differences are also apparent with forwards observed to be taller, heavier and stronger than backs who possess greater speed qualities and aerobic capacities (Darrall-Jones et al., 2016; Durandt et al., 2006). While there is an abundance of literature assessing age grade and positional differences in the physical qualities of rugby union players (Owen et al., 2020), this provides a unidimensional approach to player evaluation and fails to address factors which could affect the interpretation of results (e.g. chronological age, maturation or relative age) (Till & Baker, 2020; Till et al., 2018). In comparison to research in rugby league (Till et al., 2014; Till & Jones, 2015) and soccer (Carling et al., 2009; Towlson et al., 2018), a limited assessment of the effects of maturation (Howard et al., 2016) and relative age (Grobler et al., 2017) on physical qualities in rugby union is currently available. Furthermore, the current rugby union literature is limited by single squad studies, small sample sizes and a large variation in testing methods restricting the generalisability of findings, reducing the statistical power and preventing the comparison of findings between studies (Owen et al., 2020). Additionally, the categorisation of chronological age into age groups limits the analysis to between group comparisons, leading to a loss of information regarding the relationship between dependent and independent variables (Altman & Royston, 2006).

Therefore, using a multi-club design the purpose of this study was to determine and evaluate the relationships between the physical qualities of male English Regional Academy rugby union players (aged U15-U18 years) and playing position, chronological age, relative age and maturation with a multidimensional approach. Such analyses will provide comparative data accounting for the effects of possible confounding factors on the physical qualities of academy rugby union players and enhance the ability of practitioners to identify and evaluate players, set goals and prescribe appropriate training to improve performance and reduce injury.

Methods

A total of 2,381 observations were recorded from 1,424 male participants (age 16.2 ± 1.0 years) from nine English Regional Academies over a three-year period (2017 to 2020). All participants were selected to a regional Rugby Football Union (RFU) academy in England. Written consent was provided by all participants and, where the participant was under the age of 16 years, a parent or guardian. All testing procedures were clearly explained prior to testing. Ethics for the experimental procedures were granted by the University of Bath prior to data collection.

The testing battery was designed in collaboration with the RFU and representatives from professional rugby union clubs in 2016 to ensure that all players within a squad (e.g. n=25-50) could be tested within a single session (typically 2 hours). All testing was completed by the research team, visiting each academy to ensure standardisation. Data was collected at three timepoints (i.e. June-October; November-February; March-May) across a season, with a maximum of 8 testing periods in total with one lost due to COVID-19. Not all participants were measured at each timepoint (mean=2, range=1-7). As a result of facility availability and the option for clubs to opt out of tests, variation in the observations in each test were also observed (total observations for each test reported in Table 1-2). Participants completed a standardised warm up, anthropometric measurements, countermovement jump (CMJ), isometric mid-thigh pull (IMTP) and 40m sprint prior to a 30-15 intermittent fitness test (30-15IFT). Two trials were recorded for the CMJ, IMTP and 40m sprint. The within session reliability (coefficient of variation [CV] and interclass correlation coefficient [ICC]) from the repeated trials of these tests are reported below.

Anthropometrics and body composition

Standing and sitting height were measured to the nearest 0.1 cm using a portable stadiometer (Seca 213, Hamburg, Germany). Body mass was collected, wearing minimal clothing (e.g., shorts and t-shirt) using calibrated analogue scales (Seca, Hamburg, Germany) to the nearest 0.1 kg. Bioelectrical impedance analysis (Tanita BF-350, Tokyo, Japan) was used to quantify body fat percentage.

Relative Age and Maturation

The relative age of participants was calculated by grouping participants in birth quartiles (Q1 = September-November (*n*=564), Q2 = December-February (*n*=374), Q3 = March-May (*n*=284), Q4 = June-August (*n*=202)) based on month of birth from the age grade cut off for rugby union in England (1st September-31st August). The Mirwald prediction equation (Mirwald et al., 2002) was used to assess age at peak height velocity (APHV). Subjects leg length was determined by subtracting sitting height from standing height. The standard estimated error of the boys equation is ± 6 months (Mirwald et al., 2002).

Physical tests

The CMJ was performed with hands on hips and each foot placed on an individual force plate (PS-2141, Pasco, Roseville, California, USA) (Lake et al., 2018). No attempt was made to control the depth or speed of the countermovement with subjects only instructed to *'jump as high as possible'* (Darrall-Jones et al., 2015). A customised R script (R4.0.0, R Foundation for Statistical Computing) was used to calculate jump height via flight time and peak power from the raw force file**.** The highest jump was used for analysis. The ICC and CV for CMJ height and peak power were 0.85 and 3.8% and 0.95 and 2.0%, respectively.

The IMTP was performed using a dynamometer (T.K.K.5402, Takei Scientific Instruments Co. Ltd, Niigata, Japan) attached to a wooden platform to provide a safe and valid assessment of maximal force production (Owen et al., 2020). This method has been validated against fixed force plates (Dobbin et al., 2018; Till et al., 2018). The participants were instructed to follow the protocol outlined by Till et al. (Till et al., 2018). The highest score was used for analysis and peak force was calculated using a correction equation (Till et al., 2018). Relative strength was measured by dividing peak force by body mass. The ICC and CV were 0.90 and 3.3%.

Speed was evaluated over 10, 20, 30 and 40 m using photocell timing gates (Brower Timing Systems, Salt Lake City, UT). Participants started in their own time, 0.5 m behind the first gate in a 2 point stance (Darrall-Jones et al., 2016). The fastest 10 m time was used for analysis with times measured to the nearest 0.01 s. Maximum velocity was calculated by identifying the fastest 10m split and dividing the time by the distance between splits (10 m). Only trials recorded on an all-weather pitch were used for analysis. The ICC and CVs for the 10, 20, 30 and 40 m sprint times were 0.79 and 1.3%, 0.86 and 0.9%, 0.92 and 0.8% and 0.93 and 0.8%, respectively. The 30-15IFT was completed according to protocols previously outlined (Buchheit, 2008). The ICC and CV for the 30-15IFT have previously been reported as 0.96 and 1.6% (Buchheit, 2008). To assess running performance relative to body mass, 10m, maximum and 30-15IFT momentum were calculated by multiplying the recorded velocities ($m.s^{-1}$) by body mass (kg) (Darrall-Jones et al., 2016; Scott et al., 2017).

Statistical analysis

Hierarchical mixed models were used to evaluate the effect of position, chronological age, relative age and maturation on physical qualities. To address error arising from non-uniform residuals, the dependent variables were log transformed prior to analysis and back transformed post analysis. Participants were nested within academies and included as random effects to account for the non-independence of repeated measures and identify within-player and between-team and -player variability (expressed as standard deviation [SD]). Playing position (i.e. prop (*n*=322), hooker (*n*=155), second row (*n*=233), back row (*n*=528), scrum half (*n*=221), fly half (*n*=222), centre (*n*=337) and back three (*n*=363)), chronological age, relative age quartile (Q1, Q2, Q3 and Q4) and APHV were included as fixed effects. Positional groups were included within the model as a categorical variable. Chronological age and APHV were retained as continuous variables and centred on the sample mean with a 1-unit change equalling a 1-year difference. Nonlinear quadratic terms for chronological age and APHV were also assessed within the models. Relative age quartile was dummy coded and treated as ordinal data, with coefficients centred on Q1 and a 1-unit change representing a one quartile change (e.g. Q1 to Q2; Suppl. 1). The number of observations used in each model are reported in parentheses in Tables 1 and 2.

A stepwise deletion strategy was selected whereby all the fixed effects were included in the initial model and were removed if they failed to demonstrate statistical significance ($p<0.05$) until the minimal adequate model was obtained. The normality of residuals were checked through the visual inspection of Q-Q plots. Collinearity of fixed effects was assessed using a variance inflation factor, with ≥5 indicating substantial multi-collinearity. The estimated effects (95% confidence interval [CI]) were reported and should be interpreted as the positional mean and effect of a one-unit change for chronological age, relative age and maturation. Subsequent regression equations were built using the estimated positional means as the intercept and fixed effects as coefficients. Tukey pairwise comparisons were performed to identify significant differences ($p<0.05$) between positional means as the differences could not be tested statistically within the initial model. Effect sizes (ES) based on Cohen’s *d* were also reported, with thresholds set as: <0.2 trivial; 0.2 small; 0.6 moderate; 1.2 large and 2.0 very large (Hopkins et al., 2009). All data analysis was conducted in R using the lme4 (Bates et al., 2015), lmerTest (Kuznetsova et al., 2017) and emmeans packages.

Results

The mean and standard deviation for APHV was 13.9 ± 0.6 years. Positional means, estimated effects for chronological age, relative age and maturation, and the standard deviations for random effects from the final models are presented in Tables 1-2. The resultant regression equations for each model are provided in Figure 1. Significant positional differences were identified for all qualities assessed, with significant differences and the associated ES shown in Figure 2.

Insert Tables 1 – 2 near here

Insert Figure 1 near here

Insert Figure 2 near here

Linear positive relationships were identified between chronological age and body composition (*d*=0.18), CMJ height (*d*=0.22), CMJ peak power (*d*=0.62), IMTP (*d*=0.53) and maximum velocity (*d*=0.17) suggesting older players observed higher values. Positive nonlinear relationships were observed for height (*d*=0.35), body mass (*d*=0.65), 10m momentum (*d*=0.73), maximum momentum (*d*=0.73) and 30-15IFT momentum (*d*=0.67) with negative quadratic effects revealing older players are taller, heavier and have greater momentum although differences diminish with increases in age. A negative relationship, and therefore faster 10m sprint times (*d*=-0.10) were identified with increases in chronological age. Chronological age was identified as non-significant for relative IMTP and 30-15IFT. Therefore no differences were present and chronological age was removed from the model.

Relative age was observed to have trivial positive relationships with height (*d*=0.04), body mass (*d*=0.07), body composition (*d*=0.04), CMJ height (*d*=0.04), CMJ peak power (*d*=0.12), IMTP (*d*=0.07), 10m momentum (*d*=0.10), maximum momentum (*d*=0.07) and 30-15IFT momentum (*d*=0.06) indicating players in later birth quartiles score higher in these qualities. A trivial negative effect was also observed with 10m sprint (*d*=0.05), suggesting later birth quartiles are faster. No significant relationship for relative IMTP, maximum velocity or 30-15IFT and relative age were identified.

Late maturation was associated with lower body mass (*d*=-0.76), body fat (*d*=-0.21), CMJ peak power (*d*=-0.44), 10m momentum (*d*=-0.77), maximum momentum (*d*=-0.73) and 30-15IFT momentum (*d*=-0.69). Negative nonlinear relationships were observed for height (*d*=-0.64), isometric mid-thigh pull (*d*=-0.43) and 10m sprint (*d*=0.01). Negative quadratic terms for height and IMTP indicate diminishing benefits for early maturing players, whilst positive terms for 10m speed suggest diminishing benefits for late maturers. A trivial positive linear relationship was identified for 30-15IFT (*d*=0.12). Late maturation was also associated with greater relative isometric midthigh pull (*d*=0.19), although this was nonlinear. No significant relationships were identified between maturation and CMJ height and maximum velocity.

Random Effects

The within-player and between-team and -player variability (SD; ±90%CI) from the fully adjusted models can be observed in Table 1 and 2. The greatest variation was observed between players, followed by within player. The between team random effects provided the least variation in the models.

Discussion

This is the largest and most comprehensive assessment of physical qualities of male academy rugby union players to date. Furthermore, it is the first study to model the effect of playing position, chronological age, relative age and maturation on physical qualities within any sport. Positional differences were identified for all physical qualities, while chronological age, relative age and maturation had the greatest effect on body mass related variables. Chronological age, relative age and maturation were not retained within all models, but the inclusion of at least two fixed effects for each model suggests that the evaluation of physical qualities is multidimensional. These findings suggest that traditional descriptive statistics previously reported for the physical qualities of male rugby union players by age grade (e.g. Darrall-Jones et al., 2015 and Durandt et al., 2006) should be used with caution due to their unidimensional and categorical approach to interpreting such data. Practitioners should therefore calculate individualised comparative data from regression equations (Figure 1), to provide a comprehensive and effective evaluation of a player's physical qualities.

Positional differences were identified for all physical qualities. The post-hoc analysis suggests that categorising players into forwards and backs, as per previous research (Darrall-Jones et al., 2016), is a generalisation of positional differences with some positions possessing unique physical qualities within these sub groups. For example, props have the greatest body mass, body fat percentage and momentum compared to all forwards, while the back three have greater speed qualities compared to all backs. These findings identify the set of physical qualities for each position and highlight the current selection practices surrounding this. Therefore, practitioners should be aware of both position specific qualities and the biases/perceptions associated with success at each position to inform decisions surrounding evaluation and prescription using a multidimensional approach.

This was the first study within the rugby codes to report the effect of chronological age as a continuous variable on physical qualities as opposed to annual-age grouping (e.g. Under 16s). The differences observed for a 1 year difference in chronological age were comparable to those previously identified between age grades, with older players possessing enhanced anthropometric, muscular power, muscular strength, speed and momentum qualities (Darrall-Jones et al., 2016; Darrall-Jones et al., 2015; Durandt et al., 2006). These findings are likely to be a result of the growth and maturation process in combination with increased training exposure (Weakley et al., 2019) and reinforce the importance of concurrently developing physical qualities throughout the pathway. Due to the range of birth dates observed throughout the year the use of chronological age provides a more accurate estimation of the physical qualities compared to when players are pooled into age grades by a single cut-off date, which can be confounded by other factors such as relative age (Till et al., 2018). In addition, the use of chronological age allows for effective comparisons to be made throughout the season whereas previous cross-sectional findings are only suitable for comparisons during the time of data collection within the study (e.g. pre-season (Darrall-Jones et al., 2015)). Chronological age should therefore be used in the regression equations presented (Fig. 1) to provide more accurate testing standards and player evaluations.

In contrast to the previous literature which suggests there are limited relationships between relative age and the physical qualities of age grade athletes (Carling et al., 2009; Grobler et al., 2017; Till et al., 2014), the current study suggests relatively younger rugby union players have greater anthropometrics, body fat, absolute strength, muscular power, momentum qualities and faster 10m times. Although only trivial effect sizes were identified, it should be noted that a one quartile change was identified within the model and therefore the difference between the most diverse quartiles (i.e. Q1 to Q4) should be considered as more practically meaningful. These findings do not refute the previous suggestion that players selected in talent development systems are homogenous (Carling et al., 2009; Till et al., 2014), but rather propose that when matched by position, chronological age and maturation, players in later quartiles that remain in the development pathway display enhanced physical qualities. As later quartiles require more time to 'catch up' to their peers, relative age has limited implications on the physical preparation, training and development of players. However, given the previously identified relative age effect within rugby union pathways and the importance placed on physical size in rugby union (Kelly et al., 2021; McCarthy et al., 2016), relative age should be considered when comparing players during the selection and de-selection process where later quartile players may appear to be physically inferior but require further time to develop.

Advanced maturation was associated with greater anthropometrics, body fat, strength, CMJ peak power, 30-15IFT performance, momentum qualities and superior 10 m sprint performance, which is similar to previous research in rugby codes (Howard et al., 2016; Till et al., 2016). The greater absolute strength but lower relative strength is indicative of the relationship between maturation, the resultant increases in body mass and physical qualities. Increases in fat free mass as a result of early maturation are likely to result in enhanced muscular strength and power (Malina et al., 2004), while greater total body mass contribute to increased momentum (Howard et al., 2016). However, the trivial positive and negative effects observed for 10 m and 30-15IFT performance, respectively and removal of maturation from the maximum velocity model are consistent with previous suggestions that both sprinting (Barr et al., 2014) and 30-15IFT performance (Darrall-Jones et al., 2016) are attenuated by greater body mass in rugby union players. Maturation status should therefore be considered as part of the long-term training process whereby the timing of maturation dictates training optimisation and standardises talent identification. The running qualities (e.g. running mechanics) and relative strength of early maturing players should be challenged to deal with their greater body mass, while developing the lean mass of later maturing athletes should be considered when prescribing training. Furthermore, although advanced maturation appears to result in desirable increases in size and strength with limited negative effects on running ability, practitioners should be wary of the short-term benefits of advanced maturation during the talent identification process (Till et al., 2016; Till et al., 2014). Further research is required to identify the longitudinal relationship between maturation, body mass and physical qualities.

Limitations

This study used the largest sample to date to assess the physical qualities of male age grade rugby union players and the findings are highly generalisable across elite academies due to the participation of nine out of fourteen RFU regional academies in the study. However, participant recruitment was limited to talent identified individuals selected to RFU regional academies. Due to selection biases within development pathways (e.g., relative age effect (Kelly et al., 2021; McCarthy et al., 2016)) and the enhanced physical qualities observed in academy players compared to their non-talent identified counterparts (Dimundo et al., 2021; Jones et al., 2018), the generalisability of results at lower levels of the participation pathway may be limited. Further research across the pathway with consideration of playing level would not only increase the generalisability of the current study but also highlight the qualities and confounding factors that are important for selection. It is also acknowledged that there are limitations to the use of indirect methods used to measure maturation (Malina et al., 2012). The aim of the testing battery was to provide a comprehensive physical assessment of a squad within a single session and therefore the assessment was required to be time efficient in addition to being valid and reliable. Due to the variability between assessment methods (Malina et al., 2012) it is therefore suggested that practitioners maintain consistency between the methods used within the study when applying the findings in practice. Whilst the importance of physical qualities for performance is well documented (Owen et al., 2020), rugby union performance is complex encompassing technical and tactical components. Therefore, it is acknowledged that this study fails to consider other factors of rugby union performance and player development (i.e. technical and tactical) but does build upon previous research evaluating physical qualities across sports (Darrall-Jones et al., 2015; Durandt et al., 2006; Grobler et al., 2017; Howard et al., 2016).

Conclusion

This study evaluated the effects of position, chronological age, relative age and maturation on the physical qualities of elite male academy rugby union players. Positional differences were identified for all physical qualities, while the effects of chronological age, relative age and maturation were more prevalent for body mass related variables (e.g. momentum). The novel analysis methods considering multiple confounding factors highlighted the need to evaluate physical qualities using a multidimensional approach on an individual basis. It is therefore recommended that practitioners consider position, chronological age, relative age and maturation where relevant and use the regression equations provided (Figure 1) to calculate individualised comparative data when evaluating the physical qualities of male academy rugby union players. The enhanced interpretation of testing results and understanding of these factors presented can be used to assist the selection process, goal setting and training prescription of male academy rugby union players and applies to athletes across sports.

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Table 1. Positional means, estimated effects of chronological age, relative age and maturation and the within-player, between-player and team variation for height, body mass, body composition, muscular power and muscular strength in academy rugby union players.

	Height (cm) (n=2381)	Body mass (kg) (n=2381)	Body fat (%) (n=2331)	Countermovement jump height (cm) (n=2157)	Countermovement jump peak power (W) (n=1203)	Isometric mid-thigh pull (N) (n=1704)	Relative isometric mid-thigh pull ($N \cdot kg^{-1}$) (n=1704)
Position	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**
Prop	179.4 (178.7 to 179.3)	92.6 (91.1 to 94.4)	23.7 (22.8 to 24.7)	29.6 (28.7 to 30.4)	4264 (4149 to 4384)	2460 (2394 to 2528)	26.4 (25.7 to 27.1)
Hooker	178.0 (176.7 to 179.3)	85.6 (83.0 to 88.3)	20.8 (20.0 to 21.7)	31.2 (30.2 to 32.3)	4082 (3957 to 4220)	2440 (2308 to 2579)	28.5 (27.1 to 30.3)
Second Row	181.9 (180.6 to 183.3)	85.1 (82.7 to 87.7)	17.9 (17.4 to 18.5)	32.1 (31.2 to 33.1)	4080 (3962 to 4211)	2419 (2296 to 2550)	29.2 (27.7 to 30.8)
Back Row	180.5 (179.2 to 181.8)	82.9 (80.6 to 85.3)	18.0 (17.6 to 18.5)	33.3 (32.4 to 34.3)	4096 (3991 to 4211)	2411 (2102 to 2531)	29.7 (28.3 to 31.1)
Scrum Half	176.0 (174.5 to 177.5)	72.0 (69.7 to 74.5)	14.7 (14.4 to 15.2)	34.9 (33.6 to 36.2)	3545 (3439 to 3664)	2227 (2102 to 2359)	31.2 (29.5 to 33.1)
Fly Half	178.0 (176.5 to 179.4)	75.3 (72.9 to 77.8)	15.5 (15.1 to 16.0)	33.7 (32.6 to 34.9)	3741 (3631 to 3863)	2263 (2141 to 2393)	30.4 (28.8 to 32.1)
Centre	179.1 (177.7 to 180.4)	78.5 (76.2 to 80.9)	16.6 (16.2 to 17.0)	35.2 (34.1 to 36.3)	4055 (3945 to 4176)	2390 (2271 to 2516)	30.9 (29.3 to 32.5)
Back Three	178.8 (177.0 to 179.8)	75.8 (73.5 to 78.2)	15.5 (15.2 to 15.9)	37.6 (36.4 to 38.9)	4108 (3991 to 4237)	2369 (2249 to 2496)	31.6 (30.0 to 33.3)
Covariate	**Estimated effect (95% CI)**	**Estimated effect (95% CI)**	**Estimated effect (95% CI)**	**Estimated effect (95% CI)**	**Estimated effect (95% CI)**	**Estimated effect (95% CI)**	**Estimated effect (95% CI)**
Age	2.5 (2.3 to 2.7)	8.6 (8.1 to 9.1)	1.7 (1.4 to 2.1)	1.6 (1.4 to 1.9)	526 (471 to 585)	258 (232 to 285)	
Age^2	-0.2 (-0.3 to -0.1)	-0.5 (-0.7 to -0.2)					
Relative Age	0.3 (0.0 to 0.5)	0.9 (0.5 to 1.3)	0.4 (0.1 to 0.7)	0.3 (0.1 to 0.6)	104 (67 to 144)	36 (20 to 54)	
APHV	-3.9 (-4.2 to -3.6)	-9.4 (-9.8 to -9.0)	-2.0 (-2.3 to -1.6)		-377 (-420 to -327)	-177 (-200 to -152)	1.5 (1.1 to 1.9)
APHV^2	-0.3 (-0.5 to -0.1)					-34 (-57 to -8)	-0.4 (-0.7 to -0.1)
Random Effects	**SD (95% CI)**	**SD (95% CI)**	**SD (95% CI)**	**SD (95% CI)**	**SD (95% CI)**	**SD (95% CI)**	**SD (95% CI)**
Residual (within-player)	1.0 (1.0 to 1.1)	2.9 (2.8 to 3.1)	2.7 (2.5 to 3.0)	2.4 (2.2 to 2.6)	243 (219 to 270)	180 (167 to 197)	2.0 (1.8 to 2.2)
Between-player	4.8 (4.6 to 5.1)	7.9 (7.5 to 8.4)	5.9 (5.4 to 6.4)	4.2 (3.9 to 4.5)	527 (479 to 573)	238 (216 to 261)	2.9 (2.6 to 3.1)
Between-team	0.8 (0.4 to 1.4)	1.6 (0.8 to 2.8)	0.8 (0.4 to 1.6)	0.8 (0.4 to 1.5)	82 (17 to 171)	67 (36 to 124)	0.6 (0.3 to 1.1)

APHV, age at peak height velocity, *30-15IFT*, 30-15 intermittent fitness test

Table 2. Positional means, estimated effects of chronological age, relative age and maturation and the within-player, between-player and team variation for speed, aerobic capacity and momentum qualities in academy rugby union players

	10m sprint (s) (n=1379)	Maximum velocity ($m \cdot s^{-1}$) (n=1379)	30-15IFT final velocity ($km \cdot h^{-1}$) (n=1146)	10m momentum ($kg \cdot m \cdot s^{-1}$) (n=1379)	Maximum momentum ($kg \cdot m \cdot s^{-1}$) (n=1379)	30-15IFT momentum ($kg \cdot m \cdot s^{-1}$) (n=1146)
Position	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**
Prop	1.89 (1.87 to 1.92)	7.77 (7.65 to 7.90)	16.9 (16.6 to 17.2)	494 (483 to 505)	729 (711 to 747)	447 (437 to 459)
Hooker	1.86 (1.82 to 1.91)	7.97 (7.85 to 8.09)	17.7 (17.4 to 18.1)	459 (439 to 480)	682 (648 to 717)	428 (408 to 449)
Second Row	1.83 (1.79 to 1.87)	8.09 (7.98 to 8.20)	18.3 (18.0 to 18.6)	463 (444 to 483)	686 (654 to 719)	432 (412 to 452)
Back Row	1.81 (1.77 to 1.85)	8.24 (8.14 to 8.34)	18.5 (18.2 to 18.8)	453 (435 to 471)	673 (644 to 704)	426 (408 to 445)
Scrum Half	1.80 (1.75 to 1.84)	8.37 (8.25 to 8.50)	18.9 (18.6 to 19.4)	401 (383 to 420)	606 (575 to 638)	383 (364 to 403)
Fly Half	1.81 (1.77 to 1.86)	8.32 (8.20 to 8.45)	19.1 (18.7 to 19.5)	411 (393 to 430)	622 (592 to 654)	400 (381 to 420)
Centre	1.78 (1.74 to 1.81)	8.58 (8.47 to 8.70)	18.8 (18.5 to 19.2)	440 (422 to 458)	671 (641 to 703)	417 (399 to 437)
Back Three	1.75 (1.71 to 1.79)	8.82 (8.69 to 8.94)	18.9 (18.6 to 19.2)	433 (415 to 451)	667 (636 to 699)	399 (381 to 418)
Covariate	**Estimated effect (95% CI)**	**Estimated effect (95% CI)**	**Estimated effect (95% CI)**	**Estimated effect (95% CI)**	**Estimated effect (95% CI)**	**Estimated effect (95% CI)**
Age	-0.01 (-0.02 to -0.01)	0.13 (0.10 to 0.16)		55 (50 to 59)	89 (82 to 97)	48 (43 to 52)
Age^2				-2 (-4 to 0)	-3 (-6 to 0)	-5 (-7 to -3)
Relative Age	-0.01 (-0.01 to 0.00)			7 (4 to 10)	8 (4 to 13)	4 (1 to 7)
APHV	-0.01 (-0.02 to 0.00)		0.2 (0.1 to 0.4)	-55 (-58 to -52)	-86 (-91 to -81)	-44 (-48 to -41)
APHV^2	0.01 (0.00 to 0.02)					
Random Effects	**SD (95% CI)**	**SD (95% CI)**	**SD (95% CI)**	**SD (95% CI)**	**SD (95% CI)**	**SD (95% CI)**
Residual (within-player)	0.05 (0.05 to 0.06)	0.28 (0.26 to 0.31)	0.6 (0.6 to 0.7)	20 (18 to 21)	35 (32 to 38)	18 (17 to 20)
Between-player	0.06 (0.06 to 0.07)	0.34 (0.31 to 0.37)	0.9 (0.8 to 0.9)	42 (38 to 45)	66 (60 to 71)	35 (32 to 38)
Between-team	0.03 (0.01 to 0.05)	0.14 (0.07 to 0.25)	0.4 (0.2 to 0.7)	10 (5 to 19)	17 (8 to 33)	11 (6 to 21)

APHV, age at peak height velocity; *30-15IFT*, 30-15 intermittent fitness test

Figure 1. Regression equations to estimate the physical qualities of male age grade rugby union players by position, chronological age, relative age and maturation.

Figure 2. Pairwise comparisons by position for A; height (cm), B; body mass (kg), C; body fat (%), D; countermovement jump height (cm), E; countermovement jump peak power (W), F; isometric mid-thigh pull peak force (N), G; relative isometric mid-thigh pull peak force ($N \cdot kg^{-1}$), H; 10m time (s), I; maximum velocity ($m \cdot s^{-1}$), J; 30-15 intermittent fitness test final velocity ($km \cdot h^{-1}$), K; 10m momentum ($kg \cdot m \cdot s^{-1}$), L; maximum momentum ($kg \cdot m \cdot s^{-1}$), M; 30-15 intermittent fitness test momentum ($kg \cdot m \cdot s^{-1}$). Mean values for each position are reported. The connecting lines indicate a significant difference ($p<0.05$) with the colour corresponding to the effect size.