Anthropometric and Physical Profiles of English Academy Rugby Union Players

Running Head: Anthropometric and Physical Profiles of English Academy Rugby Union Players

Joshua David Darrall-Jones, Benjamin Lee Jones and Kevin Till

Research Institute Sport, Physical Activity and Leisure, Leeds Metropolitan University, Leeds, West Yorkshire, United Kingdom

Corresponding Author:

Joshua Darrall-Jones

Room G03, Macaulay Hall

Research Institute for Sport, Physical Activity and Leisure

Centre for Sports Performance

Headingley Campus, Leeds Metropolitan University

W.Yorkshire, LS6 3QS

Phone: (0044) 7878598083

Email: J.Darrall-Jones@leedsbeckett.ac.uk

ABSTRACT

The purpose of the present study was to evaluate the anthropometric and physical characteristics of English regional academy rugby union academy players by age category (under 16, under 18 and under 21s). Data were collected on 67 academy players at the beginning of the pre-season period and comprised anthropometric (height, body mass and sum of 8 skinfolds) and physical (5 m, 10 m, 20 m & 40 m sprint, acceleration, velocity & momentum; agility 505; vertical jump; yo-yo intermittent recovery test level 1; 30-15 Intermittent Fitness Test; absolute and relative 3 repetition maximum (3RM) front squat, split squat, bench press, prone row and chin; and isometric mid-thigh pull). One way analysis of variance demonstrated significant increases across the three age categories ($p < 0.05$) for height (e.g., 16s = 178.8 ± 7.1; 18s = 183.5 ± 7.2; 21s = 186.7 ± 6.61 cm), body mass (e.g., 16s = 79.4 ± 12.8; 18s = 88.3 ± 11.9; 21s = 98.3 ± 10.4kg), countermovement jump height and peak power, sprint momentum, velocity and acceleration; absolute, relative and isometric (e.g., 16s = 2157.9 ± 309.9; 18s = 2561.3 ± 339.4; 21s = 3104.5 ± 354.0 N) strength. Momentum, maximal speed and the ability to maintain acceleration were all discriminating factors between age categories, suggesting that these variables may be more important to monitor rather than sprint times. These findings highlight that anthropometric and physical characteristics develop across age categories and provide comparative data for English academy Rugby Union players.

Key Words: Anthropometry, Player Profiling, Fitness Testing, Age Category

INTRODUCTION

Rugby union is a high intensity, intermittent contact sport characterised by high intensity efforts followed by incomplete recovery periods (17, 31, 35). Rugby union players typically cover between 5,000 and 7,000 m (15, 32, 34) during match play dependent upon playing position and level. The movement patterns reflect the high intensity nature of the sport and are characterised by accelerations, sprinting, ball carrying and tackling; interspersed with walking or jogging to reposition to further play the ball (17, 18, 20). The high level of contact experienced during competition through rucks, mauls and scrummaging require a high level of strength (1). Due to the demands of rugby union the development of aerobic capacity, speed, strength, power and optimal body composition are all required to enable the completion of training and competition across a game, season and career (19).

Given the importance of physical qualities for match performance and player progression (24, 25, 36), limited studies are available that consider the anthropometric and physical characteristics of rugby union players; especially in comparison to the well documented characteristics of rugby league players from the United Kingdom (UK) (39-41) and Australia (21-23). Current research in rugby union has demonstrated maximal strength and power differentiate between playing level (2), consistent with findings in rugby league (4-6), and sprint momentum differs between junior and senior levels with no differences found for sprint velocity (10). While these studies (2, 10) have described aspects of a rugby union player's physical profile, a complete testing battery to understand a players profile, especially within academy players (16-21 years) is not available. It is important for practitioners to understand the characteristics of players by age category, as selection and deselection occurs within a professional academy in order to identify potential first team players.

It has been demonstrated that height (23, 41), body mass and jump height (21, 23, 40, 41) increase across age categories in academy rugby league players; while speed and maximal aerobic power have both been shown to improve (21, 23) and remain stable (41). Sum of skinfolds have also demonstrated stability across age categories (23, 41). This suggests that changes in certain physical characteristics may be more trainable than others. Understanding when changes are likely to occur at certain age categories will assist practitioners to optimally train players.

Even within well-researched academy rugby league players, limitations exist within their testing batteries to provide a complete profile of player's physical qualities. For example some studies only address anthropometric and physiological characteristics (21-23), with predictions of peak power (43) from field-based jump tests. Portable force plates are now common in research studies (44), therefore the inclusion of such methods allows accurate measures of jump peak power due to the ability to measure vertical ground reaction force (38). In addition, some studies only use gym-based strength assessments (4-6); whereas tests such as the isometric mid-thigh pull (IMTP) using a portable force plate allows measures of maximal strength (peak force). Peak force measures, derived from the IMTP may further develop the understanding of the physical profiles of rugby union players by age category, as maximal strength has been demonstrated as a discriminating factor between playing levels (2, 4, 6) and between age categories (40, 41). Further, the IMTP has found significant correlations with dynamic performance in a number of sports, including Olympic weightlifting (27), sprint cycling (38) and more recently in rugby league players (44), with the latter suggesting that it may be a useful monitoring tool for both strength and power. With this in mind and considering that there is no reported IMTP data in rugby union players of any playing level, the test may be considered novel in the present study and give comparative data for future research studies in rugby union.

Finally, numerous studies have measured the aerobic qualities of academy rugby players, by estimating maximal oxygen uptake (21-23, 39) via the multistage fitness test (33), and high intensity running ability via the yo-yo intermittent recovery test level 1(Yo-Yo IRT-1) (40, 41). However, such assessments provide descriptive data for the respective cohorts, which is limited in use for training prescription. The development of new specific field tests can enable practitioners to measure velocity at maximal oxygen uptake ($v\dot{V}O_{2MAX}$) otherwise referred to as maximal aerobic speed (MAS; (12). As such, this cannot only be used to profile players, but also for the prescription of high intensity intermittent training (13, 14) to allow similar relative physiological loads for players of varying fitness levels. This, alongside an understanding of an individual's maximal velocity (maxV) also allows the calculation of the anaerobic speed reserve (ASR = maxV – MAS; (14). The anaerobic speed reserve has been suggested to be another important aspect of the locomotor profile of team sports players (14) with the suggestion that players with similar MAS, but an increased ASR can operate at a lower metabolic cost when running at the same supramaximal speeds. This may be a consideration for both the prescription of high intensity intermittent training and to understand the metabolic cost of match play. Despite this, no study has identified MAS, maxV or ASR in academy rugby players.

Such assessments within regional academy rugby union players can provide comparative data for the anthropometric and physical characteristics across age categories. Building a complete physical player profile would allow the practitioner to identify key characteristics that may need to be developed. Therefore, the purpose of the study was to evaluate the anthropometric and physical characteristics in English regional rugby union academy players across age categories (i.e., Under 16s, Under 18s and Under 21s) using a complete physical testing battery. It was hypothesised that height, body mass, jump height and maximal strength would increase across age categories, whilst measures of sum of skinfolds, and high intensity running ability would remain stable.

METHODS

Experimental Approach to the Problem

Junior rugby union players from a professional regional academy in the UK were assessed on a range of anthropometric (height, body mass and sum of 8 skinfolds) and physical (5 m, 10 m, 20 m & 40 m sprint, acceleration, velocity & momentum; agility 505; vertical jump; Yo-Yo IRT-1 ; 30-15 Intermittent Fitness Test (30-15IFT); 3 repetition maximum (3RM) front squat, split squat, bench press, prone row and chin; and isometric mid-thigh pull) characteristics across 3 age categories (Under 16s, Under 18s & Under 21s). This approach allowed comparison between regional academy rugby union players across age categories.

Subjects

A total of 67 junior rugby union players were assessed at the beginning of the pre-season in June 2014 (Under 16s, n = 29; Under 18s, n = 23; Under 21s, n = 15). Testing took place following a 6-week off-season training period whereby all players completed a 3-week preparation programme including full body resistance training, aerobic conditioning running and speed technique sessions. All experimental procedures were approved by the ethics committee with informed and parental consent (for players under 18 years) obtained.

Procedures

All testing was completed across 3 sessions during the first two weeks of the pre-season training period. Subjects were instructed to rest in the 48 hours prior to the initial testing session and to maintain normal eating and drinking habits throughout. The first session consisted of anthropometric (height, body mass, sum of 8 skinfolds), vertical jump, speed, agility 505 and the Yo-Yo IRT-1. Forty-eight hours later the second session consisted of 3RM strength (squat, bench press, prone row, split squat and chins) and an isometric mid-thigh pull. The third session consisted of the 30-15IFT and was completed seven days following the first session. Prior to all testing a standardized warm up was completed including jogging, dynamic movements and stretches; each test was fully explained and demonstrated prior to assessment. All testing was undertaken by the lead researcher who is accredited with the United Kingdom Strength & Conditioning Association (UKSCA), except sum of skinfolds.

Anthropometry: Body mass and height, wearing only shorts, were measured to the nearest 0.1 kg and 0.1 cm respectively using calibrated Seca alpha (model 220) scales and Seca Alpha stadiometer. Sum of eight site skinfolds (biceps, triceps, subscapular, suprailliac, abdominal, supraspinale, front thigh and medial calf) were determined using calibrated skinfold callipers (Harpenden, British Indicators, UK) by an International Society for the Advancement of kinanthropometry (ISAK) accredited practitioner. Practitioner intraclass correlation coefficient (ICC) and coefficient of variation (CV) had previously been calculated as $r = 0.99$ and CV = 2.9%

Vertical Jump: A countermovement jump (CMJ) was performed with the subjects hands placed on the hips, whilst stood on a portable forceplate (400 Series Force Plate – Fitness Technology, Adelaide, Australia) capable of recording vertical ground reaction forces (VGRF) at a sampling rate of 600Hz. The force plate was connected to a computer via USB and interfaced with computer software (Ballistic Measurement System (BMS)) allowing direct measurement of force-time characteristics and analysed using the BMS software. Jump height and peak power were recorded through the BMS software. Subjects were instructed to complete the CMJ starting from a standing position, moving to a self-selected depth and to jump as high as possible. Three maximal jumps were completed with 3 minutes rest between efforts. Subjects were familiar with the CMJ as this was used frequently in the previous seasons. Intraclass correlation coefficient and coefficient of variation for the CMJ were r = 0.95 and CV = 5%.

Sprint time, Velocity, Acceleration & Momentum: Sprints were assessed at 5 m, 10 m, 20 m & 40 m using timing gates (Brower Timing Systems, IR Emit, USA). These distances were chosen to enable assessment of initial and maximal sprint velocity and momentum as used by Barr et al. (10). Following the warm up, players completed three maximal sprints with 3 minutes rest between attempts. Each sprint was started 0.5m behind the initial timing gate, with players instructed to set off in their own time and run maximally through the final 40 m timing gate. The best of the three times was taken for analysis with times measured to the nearest 0.01 s. Velocity was calculated from the distance between splits divided by the change in time. Acceleration was calculated by the dividing the change in velocity by time between splits. Momentum was calculated by multiplying, between split velocity and body mass. Intraclass correlation coefficient and CVs for 5 m, 10 m, 20 m & 40 m sprint times were r = 0.85 and CV = 2.8%, r = 0.94 and CV = 1.4%, r = 0.90 and CV = 1.7% and r = 0.96 and CV = 1.2%.

Agility 505: The agility 505 was performed as previously described (39) whereby the subjects were positioned 15m from a turning point. Timing gates were placed at10m from the start point and 5m from the turn point. The subjects accelerated from the start, through the timing gates, turning 180° at the 15m mark and sprinted back through the timing gates. Alternate attempts were completed with the subjects turning off the left and right foot. The lead researcher only recorded attempts whereby the subject's foot crossed the 15 m mark. All times were recorded to the nearest 0.01s. The ICC and CV for the agility 505 were r = 0.83 and CV = 2.1% (left) and r = 0.86 and CV = 2.4% (right).

Yo-Yo Intermittent Recovery Test Level 1: The Yo-Yo IRT-1 was performed with the subjects completing 2 x 20m shuttle runs, interspersed with 10 seconds of active recovery.

The speed of the shuttles increased as the test progressed and is controlled by audio signals dictating the time in which the shuttles need to be completed within. The speed of the test increased progressively with the players stopping of their own volition or until they missed two consecutive beeps. (9). The distance ran was recorded for analysis. Previous research (29) has shown an ICC and CV for the Yo-Yo IRT-1 of r = 0.98 and CV = 4.6%.

30-15 Intermittent Fitness Test (30-15 IFT), Maximal Aerobic Speed (MAS) & Anaerobic Speed Reserve (ASR): The 30-15 IFT consisted of 30 second shuttle runs over a 40m distance, interspersed with 15 seconds of recovery. The test begins at $8 km\cdot hr^{-1}$ and is increased by $0.5 km\cdot hr^{-1}$ at each successive running shuttle. The speed of the test was controlled by a pre-recorded audio signal which beeped at appropriate intervals whereby players had to be within a 3m tolerance zones at each end or the middle of the 40m shuttle. At the end of each 30 second shuttle players were instructed to walk forwards to the nearest line, which were identified at each extremity and the middle of the shuttle at 20m. The test was terminated when players were no longer able to maintain the imposed speed of the test or when they did not reach a 3m tolerance zone on three consecutive occasions. The velocity from the last completed stage was noted as each players end speed for the test (13). The end speed of the test is reported to be ~ 120% v $\dot{V}O_{2MAX}$, thus allowing the calculation of speed at v $\dot{V}O_{2MAX}$ (MAS) to program running training interventions. The end speed was used to calculate the MAS of each player. Following this the ASR was then calculated by subtracting the MAS from the highest velocity calculated from the sprint split times. This was done as it has been suggested that the ASR may be a key variable to monitor to ensure optimal training intensity when prescribing supramaximal high intensity training (14). Previous research has shown the ICC of the 30-15IFT $r = 0.96$ and CV=1.6% (13).

Strength: 3-RM front squat, split squat, bench press, prone row and neutral grip chins were used to measure lower body bilateral and unilateral strength and upper body pushing and pulling strength for the under 18 & 21 players. These exercises were chosen as all were regularly used in the resistance training programs prescribed to the players. Participants performed a warm up protocol consisting of 8 repetitions with an empty barbell, followed by 2 sets of 5 and 3 repetitions at submaximal and near 3RM loads respectively. Following this all participants had 5 attempts to attain a 3RM effort. To achieve a 3RM front squat, players were required to move to a position with the top of the thigh at least parallel to the floor; this was determined by the lead researcher. Split squats were completed for both left and right legs. A 3RM effort was recorded when the top of the front leg was at least parallel with the floor with no excessive flexion at the lumbar spine. For the front and split squat, players were required to demonstrate adequate technique in both eccentric and concentric phases for the effort to be recorded. When completing the bench press the players chose a self-selected grip on the barbell. The barbell had to touch the chest and be returned to the start, locked out, position without assistance for a 3RM effort to be recorded. The prone row was completed with the players in a prone position on a bench which was fixed to a squat rack so that the bar was off the ground when at arm's length. The players were required to move the bar from the bottom position with the arms locked out, until both sides of the barbell touched the bench. The neutral grip chin was completed with an external weight attached to the player via a chinning belt. Players were required to start the chin from a dead hang with the elbows locked out and head in front of the arms. They were then instructed to pull themselves to a position where the chest was in contact with the bar. Following strength testing, all players' 3RM scores were divided by body mass to provide a score relative to body mass.

Isometric Strength Assessment: Isometric strength assessment was completed using the isometric mid-thigh pull, performed on a portable force plate with a specialist rack in which the barbell was immoveable (Fitness Technology, Adelaide, Australia). The specialist rack enabled the bar height to be altered by 3 cm increments, with further adjustments made with 1 cm thick wooden boards placed on the force plate allowing changes in bar height by 1 cm. This enabled each player to adopt a position similar to that of the 2nd pull during the power clean, with an upright trunk position and knee angle of ~ 120 - 130° (27, 38, 44). Once an optimal position was determined players were instructed to pull as hard and fast as possible following a 3 second countdown. This command is based on previous research suggesting that these instructions produce optimal results for both peak force (N) and peak rate of force development ($N \cdot s^{-1}$) (11). Following submaximal efforts, each player completed three maximal efforts with 3 minutes rest between efforts. Measures of peak and mean force were converted to a normalised measure (normalised force (Kg) = force (N) / force of gravity (9.81 $m \cdot s^{-1}$)) and relative to body mass (normalised force (Kg) / body mass (Kg)) in an attempt to make the interpretation of the measures easier for practitioners. Peak and mean force ICC and CV were r =0.97 and 3.5% and r =0.91 and 5.8%.

Statistical Analysis

Data are presented as means ± standard deviations for each age category (i.e., Under 16s, Under 18s and Under 21s). The ICC and CV were calculated for tests where multiple measurements were taken to convey the reliability of the measure. One way analysis of variance were conducted using SPSS version 21.0 to analyse differences between age groups with an alpha level of <0.05. Where significant differences were found, Bonferroni post hoc analyses were completed to detect differences between age categories. Cohen's effect size statistics (16) were calculated with threshold values of <0.2 (trivial), 0.2-0.6 (small), 0.6-1.2 (moderate), 1.2-2.0 (large) and >2.0 (very large), with corresponding 90% confidence intervals. Where the confidence intervals crossed both the positive and negative small effect (0.2) the ES was deemed unclear (28).

RESULTS

Table 1 shows the anthropometric, vertical jump and power, agility 505 and high intensity running ability characteristics of regional academy rugby union players by age category (Under 16s, Under 18s & Under 21s). The table presents overall effects, post hoc and effect sizes between-age category. Findings identified that age category had a significant effect on height (p=0.002), body mass ($p<0.001$), CMJ height and peak power ($p<0.001$), and agility 505 left (p=0.021) and right (p=0.005).

Anthropometric characteristics

Significant moderate differences were found for height between the Under 16s and Under 21s age categories (ES = -1.1). Moderate and small differences were found between Under 16s and Under 18s (-0.6); and Under 18s and Under 21s (-0.5). Body mass was significantly different from the Under 16s squad for both Under 18s (moderate, ES = -0.7) and Under 21s (large, ES = -1.5), while moderate differences were observed between the Under 18s and Under 21s (-0.8). No significant differences were found for sum of skinfolds between age categories. However, ES' suggest that the Under 21s age category had small to moderate increased skinfold thickness in comparison to the Under 16s (-0.4) and Under 18s groups (-0.7), respectively.

Vertical jump and agility characteristics

Countermovement jump height and peak power were significantly different between each age category. Differences between the Under 16s and Under 18s (-1.2), Under 16s and Under 21s (-3.1), and Under 18s and Under 21s (-1.5) jump height were all large; while differences for peak power were moderate (-0.9), large (-2.0) and moderate (-1.0) respectively. Agility 505 was significantly faster in the Under 21s than the Under 18s when turning off the left foot (large, ES = 1.4) and faster than both the Under 16s (large, ES = 1.2) and Under 18s (moderate, ES = 1.1) when turning off the right foot. No significant differences were identified for the Yo-Yo IRT-1, 30-15IFT or ASR between age groups with only trivial or small effects identified between age categories.

Insert Table 1 near here

Sprint characteristics

Table 2 shows the sprint time, momentum, velocity and acceleration of regional academy rugby union players by age category. Post hoc analysis identified that age category had a significant effect on 0-5 m (p=0.002), 0-10 m (p<0.001), 5-10 m ($p<0.001$), 10-20 m (p=0.001), 20-40 m (p<0.001) momentum, 5-10 m (p= 0.01) and 20-40 m (p=0.001) velocity, and 5-10 m (p=0.001), 10-20 m (p=0.007), 20-40 m (p<0.001) acceleration. No significant difference in sprint times for 5, 10, 20 and 40 m were found between age categories. However, sprint velocities calculated as an average velocity between timing gates (i.e., 0-5, 5-10 m) identified the Under 16s to have moderately decreased velocity between 5-10 m in comparison to the Under 21s (-1.1); and between 20-40 m in comparison to the Under 18s (moderate, ES = -0.9) and Under 21s (large, ES = -1.3) respectively. Sprint momentum was significantly lower in the Under 16s in comparison to both the Under 18s and Under 21s at all distances. The Under 18s had decreased sprint momentum at 5-10 (large, ES = -1.2)and 20-40 m (moderate ES = -1.1) in comparison to the Under 21s. Sprint acceleration was largely decreased between Under 16s and Under 21s at 5-10 m (-1.3), with measures at 10-20 m increased (moderately, ES = 1.1) for the Under 16s in comparison to the Under 21s age category. Acceleration for the Under 16s at 20-40 m found moderate and large reductions in comparison to the Under 18s (-1.1) and Under 21s (-1.7) age categories. The Under 21s demonstrated increased acceleration at 20-40m (moderate, ES = -1.1) in comparison to the Under 18s age category.

Insert Table 2 near here

Strength characteristics

Table 3 shows the strength characteristics of Under 18s and Under 21s regional academy rugby union players. Findings identified significant large to very large effects for 3RM front squat ($p<0.001$; ES = -2.1), split squat left ($p<0.001$; ES = -3.8), and right ($p<0.001$; ES = -3.6), bench press ($p<0.001$; ES = -2.1), prone row (p=0.001; ES = -1.2), chin (p<0.001; ES = -1.5), and chin + body mass (p<0.001; ES = -2.1). Similar findings were reported when measures were relative to body mass for front squat (p=0.001; ES = -1.4), split squat left (p<0.001; ES = -2.6) and right (p<0.001; ES = -2.5), bench press (p=0.001; ES = -1.2),, and chin + body mass (p=0.004; ES = -1.1).

Insert Table 3 near here

Table 4 shows the strength characteristics derived from the IMTP. Findings identified significant effects for peak force (N) (p<0.001), peak force (N·Kg) (p=0.002), mean force (N) (p<0.001). Peak force was decreased in Under 16s in comparison to Under 18s (moderate, ES = -1.2) and Under 21s (very large, ES = -2.9); while Under 18s demonstrated decreased peak force than Under 21s (large, ES = -1.5). When expressed relative to body mass peak force showed large differences between the Under 16s and Under 21s (-1.3). Mean force showed moderate and very large reductions in the Under 16s in comparison to Under 18s (-0.9) and

Under 21s (-2.3); while Under 18s demonstrated large reductions in comparison to the Under 21s (-1.4).

Insert Table 4 near here

DISCUSSION

Limited research is available that presents the anthropometric and physical characteristics of rugby union players. Therefore, the purpose of the study was to evaluate the anthropometric and physical characteristics in English regional rugby union academy players across age categories (i.e., Under 16s, Under 18s & Under 21s) using a complete physical testing battery. As hypothesised, anthropometric (height and body mass) and physical characteristics (CMJ height, peak power, sprint momentum, velocity and acceleration; agility 505; 3RM strength) developed across the three age categories. However, no differences were identified for sum of skinfolds, sprint times (5, 10, 20 & 40 m) and high intensity running ability (Yo-Yo IRT-1 & 30-15IFT) across the age categories.

Height and body mass developed across age categories, while there was a tendency for the Under 21 players to have an increased sum of skinfolds. This supports the hypothesis and is consistent with previous findings in academy rugby league players in the UK (41) and Australia (21, 23) whereby differences were identified between age categories for height and body mass but not sum of skinfolds. A lack of difference in sum of skinfolds has previously been suggested to be due to large inter-individual variation within squads of players (41), with a similar suggestion in the current dataset when considering the large *SD*s across age categories (i.e. Under 16s = 88.8 ± 41.9; Under 18s = 86.7 ± 21.3; Under 21s = 105.3 ± 35.4 mm). Changes in height and body mass are explained by the normal trajectory of growth and maturation that are expected into late adolescence following peak height velocity (42) and are likely influenced by large increases in testosterone following this process.

For physical characteristics the findings support the hypothesis that not all characteristics would improve across playing groups. CMJ height and peak power increased between each playing group which is consistent with previous work in rugby league in the UK (41) and Australia (21, 23) suggesting that lower body power increases with age. Whilst the latter mentioned studies used field-based methods, the current study provides comparative data derived from laboratory based measures, including an accurate assessment of peak power and is the first to report these measures in rugby union academy players. The changes in jump height and peak power can be explained due to the adaptation of growth and maturation processes, and the stimulus provided by strength and power training programs which have reported increased power output with increased levels of maximal strength (2, 4, 6). Such types of programmes are commonplace in regional rugby union academies, with the relationship between maximal strength and jump height well reported (30, 37).

As with previous literature (21, 23, 26, 41), no significant differences were reported for 5, 10, 20 and 40 m sprint time and high intensity running ability measured via the Yo-Yo IRT-1 between age categories, which was also the case for the 30-15IFT. The lack of increased running distance for both the Yo-Yo IRT-1 and the 30-15IFT may be due to the associated increases in body mass across age categories. These significant increases in body mass across all age categories do however suggest that the older players possess an increased capacity for high intensity running. There was a tendency for the ASR to be increased in the Under 18s and Under 21s in comparison to the Under 16s with no data currently available in academy rugby union or league players to make comparisons. Although comparisons cannot be made, it is suggested that players with a similar MAS but increased ASR are able to tolerate increased high intensity exercise with less metabolic cost (14) than their counterparts.

Thus indicating that the ASR may be an important aspect of an academy rugby union players physiological profile if they are to meet the demands of both training and match play of a game that is characterised by high intensity efforts (17, 18, 20).

While absolute speed times were not significantly different between age categories, when calculated as splits between distances (e.g., 0-5 m, 5-10 m), differences in momentum were identified at all distances. In rugby league and rugby union, momentum rather than speed has been identified as a discriminating factor between playing level (8, 10) and age category (40). Differences were also identified across the age categories for velocity and acceleration. This resulted in the identification of differences in 20-40 m velocity between age categories, highlighting that the Under 16s group had a lower velocity than at 10-20 m and were decelerating between 20-40 m. However, both the Under 18s and Under 21s still demonstrated signs of acceleration. This demonstrates that younger players (Under 16s) reach maxV faster and are unable to maintain this speed over distances of 20m, whereas the older age categories (Under 18s and Under 21s) were able to reach an increased maxV and maintain this speed for longer suggesting greater speed endurance. This suggests that practitioners should focus on maximal sprint training for Under 16s to enable improvements in maxV enabling them to make the transition between Under 16s and Under 18s rugby.

While some strength data is available in rugby union at senior level (1-3) only Argus et al. (2) have presented data of academy players aged between 16 and 21 years. The present results are the first to report strength characteristics for academy rugby union players in the Northern Hemisphere, and provide comparative data for Under 18s to Under 21s players. Findings support the hypothesis that absolute and relative strength differentiate between age categories as has been previously reported in academy rugby league (5, 6, 40, 41) and rugby union (2). They are also in contrast with the findings in Till et al. (41) in academy rugby league who reported relative strength to demonstrate less change due to the concomitant increases in body mass alongside increases in strength. In the present study the differences in relative strength between Under 18s & Under 21s demonstrated large ES with the exception of chin + body mass (moderate) and prone row (unclear). The latter is a similar finding to Till et al. (41) in that there was no significant difference in relative prone row between the Under 18s and Under 20s age categories in the rugby league academy players. Based on the current findings, absolute and relative strength can be expected to continue developing at an increased rate in regional academy rugby union players. To ensure this, an emphasis on maximal strength development with appropriate periodization should be employed. This should be a priority prior to senior rugby as it has been suggested that improvements in strength across a season (5) and over ten years (7) may be limited due to the requirement of intense concurrent training and a 'strength ceiling' when competing in senior competition.

Currently only one study exists reporting IMTP data for rugby (league) players (44) and the relation to dynamic sports performance. The authors (44) suggest that the IMTP may be a suitable alternative to monitoring strength and power progressions when strength and speed testing may be inappropriate in season; due to significant relationships with CMJ height and 10m sprint times. Despite this, there is no comparative data available for specific rugby union cohorts such as in the current study. An understanding of the likely changes from Under 16s to Under 21s in this cohort may allow practitioners to monitor the effectiveness of their training prescription. The current findings demonstrated that peak force distinguishes between age categories, with large to very large ES'. Not only does this reflect the findings for the strength measures in Under 18s and Under 21s, but demonstrates that maximal isometric force can differentiate between age categories. When expressed relatively differences are less pronounced with small to large ES between age categories. Mean force is similar to peak force in that differences are observed between each age category, however these vary from moderate (Under 16s vs. Under 18s) and very large (Under 16s vs. Under

21s). When mean force is expressed relatively differences are less pronounced with a tendency for a small difference between Under 16s and Under 18s and a moderate difference between Under 16s and Under 21s (ES of-0.6). Measures of peak force may offer an easy method of monitoring a players ‘global’ strength across a season, with measures recorded at the beginning of each mesocycle offering an insight to the effectiveness of strength training interventions.

In conclusion, the present study presents comparative data for anthropometric and physical characteristics for regional academy rugby union players from Under 16s to Under 21s age categories. The findings demonstrate that height; body mass, CMJ height and peak power, sprint momentum, maxV, acceleration, strength and isometric strength improve with age. Interestingly sprint times, Yo-Yo IRT-1, 30-15IFT and the ASR appear to remain stable across age categories. These findings suggest that anthropometric and physical characteristics develop at different rates in regional academy rugby union players possibly due to increases in body size during this period. However, present findings advance on previous research papers profiling the physical characteristics of academy rugby players through the use of a more thorough testing battery. The findings could be used to establish identification criteria and for assessing academy rugby players strengths and weaknesses. Further research is required to identify positional differences between and within age categories, and to describe the seasonal changes in anthropometric and physical characteristics of regional academy rugby union players.

PRACTICAL APPLICATIONS

Present findings provide comparative data for regional academy rugby union players at the beginning of pre season in the UK for the Under 16s, Under 18s and Under 21s age categories. The present data can be used to set targets for players returning at the beginning of pre season; however coaches need to understand that there will be variance around the mean data presented, between positions and depending on training age and injury history. Nevertheless, coaches and practitioners can use the current findings to ensure that an understanding of the development of anthropometric and physical characteristics is considered in the planning process for athletic development programs. Coaches should be aware of the characteristics that increase with age and those that do not, in understanding the physiological development of players. Further to this it may be more suitable to calculate velocities, momentum and accelerations from splits (0-5, 5-10 m) rather than an elapsed distance (0-10, 0-20 m). Assessments of high intensity running ability and sprinting should be considered in the context of the locomotor profile with consideration for the ASR, which may become more important as age increases to meet the demands of training and match play. Practitioners should prioritise maximal strength training, where appropriate, in a periodized manner to ensure consistent strength development due to the likely reduced improvements when competing at senior level. Where it is deemed inappropriate to strength test adolescent athletes, the completion of the IMTP may offer a quick and safer method to determine force production capabilities. In the current study both peak and mean force were converted to a normalised measure for easier understanding for coaches and practitioners as both kg (i.e. 1000N = 102 Kg) and X body mass (i.e. 102Kg/60Kg player = 1.7 X body mass). This may make comparisons between players easier and highlights a theoretical maximal strength capability at the time of testing.

ACKNOWLEDGEMENTS

The author would like to thank Debbie Smith in assisting with skinfold data collection, as well as all the players who were involved in the project. This research was part funded by Leeds Rugby as part of the Carnegie Adolescent Rugby Research (CARR) project.

REFERENCES

1. Appleby B, Newton RU, and Cormie P. Changes in strength over a 2-year period in professional rugby union players. *J Strength Cond Res* 26: 2538-2546, 2012.
2. Argus CK, Gill ND, and Keogh JW. Characterization of the differences in strength and power between different levels of competition in rugby union athletes. *J Strength Cond Res* 26: 2698-2704, 2012.
3. Argus CK, Gill ND, Keogh JW, Hopkins WG, and Beaven CM. Changes in strength, power, and steroid hormones during a professional rugby union competition. *J Strength Cond Res* 23: 1583-1592, 2009.
4. Baker D. Comparison of upper-body strength and power between professional and college-aged rugby league players. *J Strength Cond Res* 15: 30-35, 2001.
5. Baker D. The effects of an in-season of concurrent training on the maintenance of maximal strength and power in professional and college-aged rugby league football players. *J Strength Cond Res* 15: 172-177, 2001.
6. Baker D. Differences in strength and power among junior-high, senior-high, college-aged, and elite professional rugby league players. *J Strength Cond Res* 16: 581-585, 2002.
7. Baker DG. 10-year changes in upper body strength and power in elite professional rugby league players--the effect of training age, stage, and content. *J Strength Cond Res* 27: 285-292, 2013.
8. Baker DG and Newton RU. Comparison of lower body strength, power, acceleration, speed, agility, and sprint momentum to describe and compare playing rank among professional rugby league players. *J Strength Cond Res* 22: 153-158, 2008.
9. Bangsbo J, Iaia FM, and Krustrup P. The Yo-Yo intermittent recovery test : a useful tool for evaluation of physical performance in intermittent sports. *Sports Med* 38: 37-51, 2008.
10. Barr MJ, Sheppard JM, Gabbett TJ, and Newton RU. Long-term training-induced changes in sprinting speed and sprint momentum in elite rugby union players. *J Strength Cond Res* 28: 2724-2731, 2014.

11. Bemben MG, Clasey JL, and Massey BH. The effect of the rate of muscle contraction on the force-time curve parameters of male and female subjects. *Research quarterly for exercise and sport* 61: 96-99, 1990.

12. Billat V, Renoux J, Pinoteau J, Petit B, and Koralsztein J. Times to exhaustion at 90,100 and 105% of velocity at V̇O2 max (Maximal aerobic speed) and critical speed in elite longdistance runners. *Archives of physiology and biochemistry* 103: 129-135, 1995.

13. Buchheit M. The 30-15 intermittent fitness test: accuracy for individualizing interval training of young intermittent sport players. *J Strength Cond Res* 22: 365-374, 2008.

14. Buchheit M and Laursen PB. High-intensity interval training, solutions to the programming puzzle: Part I: cardiopulmonary emphasis. *Sports Med* 43: 313-338, 2013.

15. Cahill N, Lamb K, Worsfold P, Headey R, and Murray S. The movement characteristics of English Premiership rugby union players. *J Sports Sci* 31: 229-237, 2013.

16. Cohen J. *Statistical power analysis for the behavioral sciences.* (2nd ed.). New Jersey, NJ: Lawrence Erlbaum,1998.

17. Duthie G, Pyne D, and Hooper S. Applied physiology and game analysis of rugby union. *Sports Med* 33: 973-991, 2003.

18. Duthie G, Pyne D, and Hooper S. Time motion analysis of 2001 and 2002 super 12 rugby. J Sports Sci 23: 523-530, 2005.

19. Duthie GM. A framework for the physical development of elite rugby union players. *Int J Sports Physiol Perform* 1: 2-13, 2006.

20. Duthie GM, Pyne DB, Marsh DJ, and Hooper SL. Sprint patterns in rugby union players during competition. *J Strength Cond Res* 20: 208-214, 2006.

21. Gabbett TJ. Physiological characteristics of junior and senior rugby league players. *Br J Sports Med* 36: 334-339, 2002.

22. Gabbett TJ. A comparison of physiological and anthropometric characteristics among playing positions in junior rugby league players. *Br J Sports Med* 39: 675-680, 2005.

23. Gabbett TJ. Physiological and anthropometric characteristics of starters and non-starters in junior rugby league players, aged 13-17 years. *J Sports Med Phys Fitness* 49: 233-239, 2009.

24. Gabbett TJ, Jenkins DG, and Abernethy B. Relationships between physiological, anthropometric, and skill qualities and playing performance in professional rugby league players. *J Sports Sci* 29: 1655-1664, 2011.

25. Gabbett TJ, Jenkins DG, and Abernethy B. Relative importance of physiological, anthropometric, and skill qualities to team selection in professional rugby league. *J Sports Sci* 29: 1453-1461, 2011.

26. Gabbett TJ, Johns J, and Riemann M. Performance changes following training in junior rugby league players. *J Strength Cond Res* 22: 910-917, 2008.

27. Haff GG, Carlock JM, Hartman MJ, Kilgore JL, Kawamori N, Jackson JR, Morris RT, Sands WA, and Stone MH. Force-Time Curve Characteristics of Dynamic and Isometric Muscle Actions of Elite Women Olympic Weightlifters. *J Strength Cond Res* 19: 741-748, 2005.

28. Hopkins W, Marshall S, Batterham A, and Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc* 41: 3, 2009.

29. Krustrup P, Mohr M, Amstrup T, Rysgaard T, Johansen J, Steensberg A, Pedersen PK, and Bangsbo J. The yo-yo intermittent recovery test: physiological response, reliability, and validity. *Med Sci Sports Exerc* 35: 697-705, 2003.

30. Peterson MD, Alvar BA, and Rhea MR. The contribution of maximal force production to explosive movement among young collegiate athletes. *J Strength Cond Res* 20: 867-873, 2006.

31. Quarrie KL, Handcock P, Waller AE, Chalmers DJ, Toomey MJ, and Wilson BD. The New Zealand rugby injury and performance project. III. Anthropometric and physical performance characteristics of players. *Br J Sports Med* 29: 263-270, 1995.

32. Quarrie KL, Hopkins WG, Anthony MJ, and Gill ND. Positional demands of international rugby union: evaluation of player actions and movements. *J Sci Med Sport* 16: 353-359, 2013.

33. Ramsbottom R, Brewer J, and Williams C. A progressive shuttle run test to estimate maximal oxygen uptake. *Br J Sports Med* 22: 141-144, 1988.

34. Roberts SP, Trewartha G, Higgitt RJ, El-Abd J, and Stokes KA. The physical demands of elite English rugby union. *J Sports Sci* 26: 825-833, 2008.

35. Smart D. Physical Profiling of Rugby Union Players: Implications for Talent Development Auckland University of Technology., 2011.

36. Smart D, Hopkins WG, Quarrie KL, and Gill N. The relationship between physical fitness and game behaviours in rugby union players. *European journal of sport science* 14: S8-S17, 2014.

37. Stone MH, O'Bryant HS, McCoy L, Coglianese R, Lehmkuhl M, and Schilling B. Power and maximum strength relationships during performance of dynamic and static weighted jumps. *J Strength Cond Res* 17: 140-147, 2003.

38. Stone MH, Sands WA, Carlock J, Callan S, Dickie D, Daigle K, Cotton J, Smith SL, and Hartman M. The importance of isometric maximum strength and peak rate-of-force development in sprint cycling. *J Strength Cond Res* 18: 878-884, 2004.

39. Till K, Cobley S, O'Hara J, Chapman C, and Cooke C. A longitudinal evaluation of anthropometric and fitness characteristics in junior rugby league players considering playing position and selection level. *J Sci Med Sport* 16: 438-443, 2013.

40. Till K, Jones B, Emmonds S, Tester E, Fahey J, and Cooke C. Seasonal changes in anthropometric and physical characteristics within english academy rugby league players. *J Strength Cond Res* 28: 2689-2696, 2014.

41. Till K, Tester E, Jones B, Emmonds S, Fahey J, and Cooke C. Anthropometric and physical characteristics of english academy rugby league players. *J Strength Cond Res* 28: 319-327, 2014.

42. Vanttinen T, Blomqvist M, Nyman K, and Hakkinen K. Changes in body composition, hormonal status, and physical fitness in 11-, 13-, and 15-year-old Finnish regional youth soccer players during a two-year follow-up. *J Strength Cond Res* 25: 3342-3351, 2011.

43. Waldron M, Worsfold PR, Twist C, and Lamb K. The relationship between physical abilities, ball-carrying and tackling among elite youth rugby league players. *J Sports Sci* 32: 542-549, 2014.

44. West DJ, Owen NJ, Jones MR, Bracken RM, Cook CJ, Cunningham DJ, Shearer DA, Finn CV, Newton RU, and Crewther BT. Relationships between force–time characteristics of the isometric midthigh pull and dynamic performance in professional rugby league players. *J Strength Cond Res* 25: 3070-3075, 2011.

Table 1. Anthropometric, vertical jump, agility and high intensity running characteristics of Regional Academy Rugby Union players by age categories*.

	U16 (n=29) (1)	U18 (n=24) (2)	U21 (n=15) (3)	ANOVA	Post hocs	U16 vs. U18 Cohens d	U16 vs. U21 Cohens d	U18 vs. U21 Cohens d
Age (years)	15.5 ± 0.3	16.9 ± 0.5	19.0 ± 1.1	.000	3>2>1	-3.5 [-4.3, -2.8]	-5.3 [-6.4, -4.2]	-2.7 [-3.4, -1.9]
Height (cm)	178.8 ± 7.1	183.5 ± 7.2	186.7 ± 6.61	.002	1<3	- 0.6 [- 1.1, -0.2]	- 1.1 [- 1.7, -0.6]	- 0.5 [-1.0, 0.1]
Body Mass (kg)	79.4 ± 12.8	88.3 ± 11.9	98.3 ± 10.4	.000	1<2,3	- 0.7 [-1.2, -0.2]	- 1.5 [-2.1, -0.9]	- 0.8 [-1.4, -0.2]
Sum of 8 skinfolds (mm)	88.8 ± 41.9	86.7 ± 21.3	105.3 ± 35.4	.245		0.1 [-0.4, 0.6]	-0.4 [-1.0, 0.1]	-0.7 [-1.2, 0.1]
Countermovement Jump (cm)	33.5 ± 4.8	39.5 ± 6.1	47.1 ± 3.6	.000	1<2,3 2<3	-1.2 [-1.7, -0.6]	-3.1 [-4.0, -2.2]	-1.5 [-2.1, -0.8]
Countermovement Jump Peak Power (W)	3965 ± 650	4561 ± 641	5219 ± 606	.000	1<2,3 2<3	-0.9 [-1.5, -0.3]	-2.0 [-2.7, -1.2]	-1.0 [-1.7, -0.4]
Agility 505 (s) (left)	2.51 ± 0.17	2.57 ± 0.12	2.41 ± 0.10	.021	2>3	- 0.4 [- 0.9, 0.2]	0.7 [0.1, 1.3]	1.4 [0.6, 2.1]
Agility 505 (s) (right)	2.54 ± 0.14	2.52 ± 0.13	2.37 ± 0.15	.005	1,2>3	0.1 [- 0.4, 0.6]	1.2 [0.5, 1.8]	1.1 [0.4, 1.8]
Yo-Yo IRTL1 (m)	1144.6 ± 337.2	1225 ± 373.8	1243 ± 326.1	.641		- 0.2 [-0.8, 0.3]	- 0.3 [-0.9, 0.3]	-0.1 [-0.7, 0.6]
30-15 IFT ($km \cdot hr^{-1}$)	18.4 ± 1.3	18.6 ± 1.1	19.0 ± 1.1	.397		- 0.1 [-0.7, 0.4]	- 0.5 [-1.1, 0.1]	- 0.4 [-1.0, 0.3]
Anaerobic Speed Reserve ($km \cdot hr^{-1}$)	3.84 ± 0.52	4.04 ± 0.39	4.06 ± 0.26	.290		- 0.4 [-1.0, 0.1]	- 0.5 [-1.1, 0.2]	0.0 [-0.7, 0.6]

Data presented as mean ± SD & Cohen’s d effect size [90% confidence intervals]. *The number in parenthesis (i.e. [1]) in the column headings relate to the number used for illustrating significant ($p<0.05$) difference in the post hoc analysis between age categories.

Table 2. Sprint, momentum, velocity and acceleration of Regional Academy Rugby Union players by age categories*

	U16 (n=29) (1)	U18 (n=24) (2)	U21 (n=15) (3)	ANOVA	Post hocs	U16 vs. U18 Cohens d	U16 vs. U21 Cohens d	U18 vs. U21 Cohens d
5 m (s)	1.05 ± 0.09	1.06 ± 0.04	1.07 ± 0.07	.677		- 0.2 [-0.7, 0.3]	- 0.3 [-0.9, 0.3]	- 0.2 [-0.8, 0.5]
10 m (s)	1.82 ± 0.12	1.81 ± 0.06	1.79 ± 0.10	.688		0.1[-0.5, 0.6]	0.3 [-0.3, 0.9]	0.3 [-0.3, 1.0]
20 m (s)	3.10 ± 0.19	3.09 ± 0.12	3.07 ± 0.13	.895		0.1[-0.4, 0.6]	0.2 [-0.4, 0.7]	0.1 [-0.5, 0.8]
40 m (s)	5.66 ± 0.37	5.51 ± 0.24	5.43 ± 0.21	.085		0.5 [-0.1, 1.0]	0.7 [0.1, 1.3]	0.3 [-0.3, 1.0]
0 – 5 m Mom ($kg.s^{-1}$)	371 ± 61	413 ± 48	448 ± 65	.002	1<3	-0.7 [-1.2, -0.2]	-1.2 [-1.8, -0.6]	-0.6 [-1.2, 0.0]
0 – 10 m Mom ($kg.s^{-1}$)	426 ± 67	482 ± 54	535 ± 70	.000	1<2,3	-0.9 [-1.4, -0.4]	-1.6 [-2.2, -1.0]	-0.9 [-1.4, -0.3]
5 – 10 m Mom ($kg.s^{-1}$)	502 ± 81	580 ± 67	665 ± 78	.000	1<2,3 2<3	-1.0 [-1.6, -0.5]	-2.0 [-2.7, -1.4]	-1.2 [-1.8, -0.6]
10- 20 m Mom ($kg.s^{-1}$)	614 ± 98	686 ± 76	744 ± 95	.001	1<2,3	-0.8 [-1.3, -0.3]	-1.3 [-1.9, -0.7]	-0.7 [-1.3, -0.1]
20 - 40 m Mom ($kg.s^{-1}$)	605 ± 99	723 ± 71	810 ± 93	.000	1<2,3 2<3	-1.4 [-1.9, -0.8]	-2.1 [-2.8, -1.4]	-1.1 [-1.7, -0.5]
0 – 5 m V ($m \cdot s^{-1}$)	4.81 ± 0.40	4.72 ± 0.2	4.69 ± 0.33	.550		0.3 [-0.2, 0.8]	0.3 [-0.2, 0.8]	0.1 [-0.4, 0.7]
5 – 10 m V ($m \cdot s^{-1}$)	6.49 ± 0.47	6.64 ± 0.32	6.98 ± 0.47	.010	1<3	-0.4 [-0.9, 0.1]	-1.1 [-1.6, -0.5]	-0.9 [-1.5, -0.3]
10 – 20 m V ($m \cdot s^{-1}$)	7.94 ± 0.58	7.86 ± 0.39	7.80 ± 0.34	.705		0.1 [-0.4, 0.6]	0.3 [-0.3, 0.8]	0.2 [-0.4, 0.7]
20 – 40 m V ($m \cdot s^{-1}$)	7.82 ± 0.61	8.29 ± 0.48	8.50 ± 0.33	.001	1<2,3	-0.9 [-1.4, -0.3]	-1.3 [-1.9, -0.7]	-0.5 [-1.1, 0.1]
0 – 5 m Acc ($m \cdot s^{-2}$)	4.66 ± 0.75	4.47 ± 0.38	4.42 ± 0.63	.500		0.3 [-0.2, 0.8]	0.3 [-0.2, 0.9]	0.1 [-0.5, 0.7]
5 – 10 m Acc ($m \cdot s^{-2}$)	2.20 ± 0.79	2.56 ± 0.57	3.22 ± 0.75	.001	1<3	-0.5 [-1.0, 0.0]	-1.3 [-1.9, -0.7]	-1.0 [-1.6, -0.4]
10 – 20 m Acc ($m \cdot s^{-2}$)	1.17 ± 0.51	0.97 ± 0.34	0.64 ± 0.39	.007	1>3	0.5 [0.0, 0.9]	1.1 [0.5, 1.7]	0.9 [0.3, 1.5]
20 – 40 m Acc ($m \cdot s^{-2}$)	-0.04 ± 0.24	0.18 ± 0.11	0.30 ± 0.08	.000	1<2,3	-1.1 [-1.7, -0.6]	-1.7 [-2.3, -1.1]	-1.1 [-1.8, -0.6]

Data presented as mean ± SD & Cohen's d effect size [90% confidence intervals]. *The number in parenthesis (i.e. [1]) in the column headings relate to the number used for illustrating significant (p<0.05) difference in the post hoc analysis between age categories.

Table 3. Strength characteristics of Regional Academy Rugby Union players by age categories.

	U18 (n=24)	U21 (n=15)	ANOVA	U18 vs. U21 Cohens d
Front Squat (3RM) (kg)	88.6 ± 10.8	118.2 ± 17.8	.000	- 2.1 [- 2.9, - 1.3]
Split Squat (3RM) (kg) (right)	62.2 ± 13.1	112.8 ± 15.6	.000	- 3.6 [- 4.7, - 2.4]
Split Squat (3RM) (kg) (left)	62.2 ± 13.1	113.9 ± 14.1	.000	- 3.8 [- 5.0, - 2.6]
Bench Press (3RM) (kg)	82.6 ± 10.8	108.2 ± 14.1	.000	- 2.1 [- 2.8, - 1.4]
Prone Row (3RM) (kg)	84.6 ± 10.8	96.8 ± 8.2	.001	- 1.2 [- 1.8, - 0.6]
Chin (3RM) (kg)	12.3 ± 6.9	27.0 ± 12.5	.000	- 1.5 [- 2.1, - 0.8]
Chin + body mass (3RM) (kg)	101.0 ± 10.2	125.3 ± 13.2	.000	- 2.1 [- 2.8, - 1.3]
Relative Front Squat ($kg \cdot kg^{-1}$)	1.04 ± 0.17	1.24 ± 0.061	.001	- 1.4 [- 2.1, - 0.7]
Relative Split Squat (right) ($kg \cdot kg^{-1}$)	0.71 ± 0.2	1.20 ± 0.22	.000	- 2.5 [- 3.4, - 1.6]
Relative Split Squat (left) ($kg \cdot kg^{-1}$)	0.71 ± 0.2	1.21 ± 0.21	.000	- 2.6 [- 3.6, - 1.7]
Relative Bench Press ($kg \cdot kg^{-1}$)	0.95 ± 0.11	1.11 ± 0.15	.001	-1.2 [- 1.8, - 0.6]
Relative Prone Row ($kg \cdot kg^{-1}$)	0.97 ± 0.13	1.00 ± 0.13	.414	- 0.2 [- 0.8, 0.4]
Relative Chin + body mass ($kg \cdot kg^{-1}$)	1.15 ± 0.09	1.29 ± 0.15	.004	-1.1 [-1.7, -0.5]

Data presented as mean ± SD & Cohen's d effect size [90% confidence intervals].

Table 4. Isometric Mid-Thigh Pull characteristics of Regional Academy Rugby Union players by age categories*.

	U16 (n=29) (1)	U18 (n=24) (2)	U21 (n=15) (3)	ANOVA	Post hocs	U16 vs. U18 Cohens d	U16 vs. U21 Cohens d	U18 vs. U21 Cohens d
Peak Force (N)	2157.9 ± 309.9	2561.3 ± 339.4	3104.5 ± 354.0	.000	1<2,3 2<3	-1.2 [- 1.9, -0.6]	-2.9 [-3.6, -2.1]	-1.5 [-2.2, -0.8
Normalised Peak Force (Kg)	220.0 ± 31.6	261.1 ± 36.1	316.5 ± 36.1					
Peak Force (N·Kg^{-1})	28.1 ± 2.5	29.9 ± 2.9	31.4 ± 2.8	.002	1<3	-0.7 [-1.3, -0.1]	-1.3 [- 1.9, -0.7]	- 0.5 [- 1.2, 0.1]
Relative Peak Force (Kg·Kg^{-1})	2.86 ± 0.26	3.05 ± 0.29	3.21 ± 0.29					
Mean Force (N)	1924.0 ± 312.7	2209.1 ± 300.1	2604.0 ± 273.1	.000	1<2,3 2<3	-0.9 [- 1.5, -0.3]	-2.3 [- 3.0, -1.6]	-1.4 [-2.1, -0.7]
Normalised Mean Force (Kg)	196.1 ± 31.9	225.2 ± 30.6	265.4 ± 27.8					
Mean Force (N·Kg^{-1})	25.0 ± 2.2	25.8 ± 2.4	26.4 ± 2.5	.166		-0.4 [- 1.0, 0.2]	-0.6 [- 1.2, -0.1]	- 0.3 [- 0.9, 0.4]
Relative Mean Force (Kg·Kg^{-1})	2.54 ± 0.22	2.63 ± 0.24	2.69 ± 0.25					

Data presented as mean ± SD & Cohen's d effect size [90% confidence intervals]. *The number in parenthesis (i.e. [1]) in the column headings relate to the number used for illustrating significant (p<0.05) difference in the post hoc analysis between age categories.