Seasonal Changes in Anthropometric and Physical Characteristics within English Academy Rugby League Players

ABSTRACT

Professional rugby league clubs implement training programmes for the development of anthropometric and physical characteristics among academy aged players. However, research that examines seasonal changes in these characteristics is limited. The purpose of the study was to evaluate the seasonal changes in anthropometric and physical characteristics of academy rugby league players by age category (i.e., Under 14, 16, 18, 20). Data was collected on 75 players pre- and post-season over a 6 year period (resulting in a total of 195 assessments). Anthropometric (body mass, sum of 4 skinfolds) and physical (10 m and 20 m sprint, vertical jump, Yo-Yo intermittent recovery test and 1-RM squat, bench press and prone row) measures were collected. The Under 14s and 16s showed greater seasonal improvements in body mass (e.g., Under 14s = 7.4 ± 4.3 % vs. Under 20s = 1.2 ± 3.3 %) and vertical jump performance than Under 18s and Under 20s. In contrast, Under 18s and Under 20s players showed greater seasonal improvements in estimated $\dot{V}O_{2max}$ (e.g., Under 14s = -0.4 ± 10.5 % vs. Under 20s = 9.2 ± 7.6 %) and 10 m sprint in comparison to Under 14s and Under 16s. Seasonal strength improvements were greater for the Under 18s compared to Under 20s. Seasonal changes in anthropometric and physical characteristics occur within academy rugby league players. However, academy rugby league players experience differing seasonal improvements, specific to age and measure. Inter-player variability in the development of anthropometric and physical characteristics limits the extrapolation of our findings to individuals. Overall, this study provides comparative data for seasonal changes within academy rugby league players and supports the need to monitor player development.

Key words: anthropometry, strength, fitness, training, age category, junior

INTRODUCTION

P1 - Rugby league is a collision team sport played professionally worldwide (15). The game is most established in the UK, France, Australia and New Zealand (6, 29), with the European Super League and Australasian National Rugby League the two major professional leagues. The game demands of rugby league are intermittent, with frequent bouts of high-intensity activity (e.g., ball carrying, tackling) separated by low-intensity activity (e.g., jogging; 11, 15). Due to the high-intensity, collision and intermittent nature of the game, players require highly developed aerobic and anaerobic capacities alongside greater lean body mass in order to compete at the elite level (15, 29).

P2 - Research presenting the anthropometric and physical characteristics of academy-aged (13-20 years) rugby league players in Australia (1, 10, 12, 13, 14, 16, 18, 19, 20) and the UK (25, 31, 32, 34) is well documented demonstrating that characteristics increase with age and playing level. Although this research is well established, data examining the seasonal changes in such characteristics is limited to only one Australian study within Under 18 players (13). Gabbett (13) found significant improvements from pre- to post-season for sum of seven skinfolds sites (93.9 ± 22.5 to 84.4 ± 11.0 mm), 10 m sprint (1.85 ± 0.04 to 1.79 ± 0.03 s), vertical jump (54.8 ± 4.4 to 57.8 ± 2.2 cm) and estimated $\dot{V}O_{2max}$ (43.7 ± 3.8 to 52.1 ± 1.7 $ml \cdot kg^{-1} \cdot min^{-1}$). These results were compared with a control group of 9 non-training males, who demonstrated no change in any measure across the season, suggesting that improvements in anthropometric and physical characteristics occur due to rugby league specific training protocols across the season.

P3 - Within the UK, talented academy-aged rugby league players are recruited to train within professional clubs academy programmes between 13 and 20 years of age (see 31, 32 for the talent development pathway within the UK). A purpose of these programmes is to develop the anthropometric and physical qualities of academy rugby league players required to meet the increasing training and game demands at progressing levels (17). Although research exploring seasonal changes in Under 18 players is available (13), the expected absolute and percentage seasonal changes for anthropometric and physical characteristics for academy-aged (e.g., Under 14s to Under 20s) rugby league players is limited. Such information would be advantageous for rugby league practitioners to provide reference data for expected specific seasonal changes across academy-aged squads. Further, although a number of studies (25, 31) have analysed the relationships between anthropometric and physical characteristics, no study to date has presented the relationships between seasonal changes in these measures. Such analysis would provide evidence for strength and conditioning professionals to prioritize training programme design to optimize the development of anthropometric and physical characteristics.

P4 - Due to the limited research in this field the initial purpose of the study was to evaluate the seasonal changes in anthropometric and physical characteristics from pre- to post-season of English academy rugby league players at the Under 14, 16, 18 and 20 age categories. The second purpose was then to evaluate the relationships between seasonal changes in characteristics in an effort to determine whether interactions existed and, thus consider their implications for player training and development. It was hypothesized that seasonal improvements in anthropometric and physical characteristics would occur, which would differ between age categories. It was also hypothesized that relationships between changes in anthropometric and physical characteristics would also be evident.

METHODS

Experimental Approach to the Problem

P5 - Players from an English Super League club's academy were assessed for anthropometric (body mass and sum of four skinfolds) and physical (10 m and 20 m sprint, vertical jump, yo-yo intermittent recovery test level 1, 1-RM back squat, bench press and prone row) measures during pre- and post-season over a 6 year period. Players were categorized into four bi-annual age groups (Under 14s, 16s, 18s and 20s) as players at these age groups trained and competed together. This permitted comparisons of seasonal changes in anthropometric and physical characteristics in academy rugby league players between age categories.

Subjects

P6 - A total of 75 academy rugby league players were investigated between 2007 and 2012. This resulted in a total of 195 player assessments (Under 14s, n = 31; Under 16s, n = 75; Under 18s, n = 64; Under 20s, n = 25). All players trained at the professional Super League club. The Under 14 and 16 age categories performed one gym-based and one skill-based field session per week, whilst also training and competing with their local amateur club. The field session typically consisted of a 15 minute warm-up, incorporating some generic speed development work, followed by 60 minutes of skills, including technical drills and small-sided games. Gym-based training sessions focused on technique development, body weight competencies and general strength development. Under 18s and 20s players only trained and played at the professional club. This typically included three gym-based and two field-based sessions in the pre-season period (November – March) and two gym-based and three field-based sessions alongside one game per week during the season (March – September). Players not selected for matches would undertake an additional aerobic development training session. Typically, field-based training sessions were 60 minutes in duration and players were exposed to one speed session and one conditioning session per week. Gym-based programmes focused on strength and/or hypertrophy development during pre-season and either power development / strength maintenance or strength development / power maintenance in season. Each gym session lasted for approximately 50 minutes and included 3 key exercises (e.g., squat, ranging from 3-5 sets for 4 to 10 repetition), supplemented with an auxiliary superset exercise (focusing on movement deficits or injury prevention). Research has demonstrated that two, three or four sessions per week, with 3 to 6 sets, and repetitions ranging from 4-10, result in strength gains (28). All experimental procedures were approved by the Leeds Metropolitan University Ethics Committee with informed and parental consent provided along with permission from the rugby league club.

Procedures

P7 - All pre-season testing were completed across two evening sessions, separated by 48 hours, in November each year. This testing session occurred following a 6 week off-season programme whereby players had 3 weeks rest and a 3 week home programme. Post-season testing was completed across two testing sessions in a similar format towards the end of the playing season in August / September. All testing was undertaken by the lead researcher throughout the 6 year period. A standardised warm-up including jogging, dynamic movements and stretches was used prior to testing followed by full instruction and demonstration of the assessments. The first testing session incorporated field-based assessments of speed (10 m and 20 m sprint) and endurance (yo-yo intermittent recovery test level 1). The second testing session incorporated gym-based testing including anthropometric (body mass and sum of 4 skinfolds), lower body power (vertical jump) and one repetition maximum (1-RM) strength (back squat, bench press and prone row) measures.

P8 - *Anthropometry:* Body mass, wearing only shorts, was measured to the nearest 0.1 kg using calibrated Seca (Seca, Birmingham, United Kingdom) alpha (model 770) scales. Sum of four site skinfolds (biceps, triceps, subscapular, suprailliac) were determined using calibrated skinfold callipers (Harpenden, British Indicators, West Sussex, UK) in accordance to Hawes and Martin (22).

P9 - Lower body power: Countermovement jump, with hands positioned on the hips, was used to assess lower body power via a just jump mat (Probotics, Hunstville, AL, USA). Players were instructed to stand with feet shoulder width apart, flex their hips and knees and then jump as high as possible landing on the mat. Jump height was measured to the nearest 0.1 cm from the highest of three attempts (24) with 60 s rest allowed between each assessment. Intraclass correlation coefficient (ICC) and coefficient of variation (CV) for the vertical jump were r = 0.92 and CV = 2.6% indicating acceptable reliability based on established criteria (i.e., >.80; 23).

P10 - Speed: Sprint speed was assessed over 10 m and 20 m using timing gates (Brower Timing Systems, IR Emit, Draper, UT, USA). Players started 0.5 m behind the initial timing gate and were instructed to set off in their own time and run maximally past the 20 m timing gate. Times were recorded to the nearest 0.01 s with the quickest of the three times used for the sprint score. Intraclass correlation coefficient and CVs for 10 m and 20 m sprint speed were r = 0.85, CV = 4.5% and r = 0.91, CV = 3.0%, respectively. In addition to sprint speed, 10 m momentum ($kg.s^{-1}$) was also calculated by multiplying 10 m velocity ($m.s^{-1}$) by body mass (4).

P11 - Endurance: The Yo-Yo intermittent recovery test level 1 has recently been used to assess endurance performance in rugby league (21, 34). Players were required to run 20 m shuttles, keeping to a series of beeps, followed by a 10 s rest interval. Running speed increased progressively throughout until the players reached volitional exhaustion or until players missed two consecutive beeps resulted in the test being terminated. Total running distance was recorded and estimated $\dot{V}O_{2max}$ was predicted via the equation *distance run (in metres) × 0.0084 + 36.4*

(5). Previous research (26) has shown an ICC and CV for the yo-yo intermittent recovery test level 1 of r = 0.98 and CV = 4.6%.

P12 - Strength: 1-RM back squat, bench press and prone row were used as measures of lower body, upper body pushing and upper body pulling strength respectively for the Under 18 and 20 players. All players were accustomed to these exercises as they were regularly used in their gym training programme. Participants performed a warm up protocol of 8, 5 and 3 repetitions of individually selected loads followed by three attempts of their 1-RM with 3 minutes rest between attempts prescribed. The 1-RM back squat and bench press protocol was completed using a 2.13m (7ft) Olympic bar and free weights. All players had to back squat until the top of the thigh was parallel with the ground, which was visually determined by the lead researcher (4). Players then had to return to a standing position with adequate technique to record a 1-RM score. For the bench press, athletes lowered the barbell to touch the chest and then pushed the barbell until elbows were locked out. For the prone row, also known as a bench pull; a 1.52m (5ft) bar was used with players lay face down on a bench. The bench height was determined so player's arms were locked out at the bottom position and then had to pull the barbell towards the bench. 1-RM lifts were only included if both sides of the barbell touched the bench.

Data Analysis

P13 - Data are presented as mean ± standard deviations for pre- and post-season values alongside percentage change by age category. Kolmogorov-Smirnov tests were conducted to check data distribution with $p < 0.05$ indicating normality. Dependent samples t-tests were used to analyse differences between pre- and post-season testing scores at each respective age category. Univariate analysis of variance (ANOVA) were used to examine the differences in seasonal change between age categories, with a Tukey post-hoc test used and partial eta squared effect sizes (*η^2)* calculated. Pearsons correlations were performed to identify relationships between seasonal change in variables. R-values were interpreted as 0.1 - 0.3 = small, 0.3 - 0.5 = moderate, 0.5 - 0.7 = large and 0.7 - 0.9 = very large (8). SPSS (IBM, Armonk, New York, USA) version 19.0 was used to conduct analysis with all statistical significance set at $p < 0.05$.

RESULTS

P14 - Table 1 shows the anthropometric and physical characteristics of academy rugby league players at pre- and post-season by age category (i.e., Under 14s, 16s, 18s, 20s). Body mass significantly increased from pre- to post-season for the Under 14s ($p < 0.001$), 16s ($p < 0.001$) and 18s ($p < 0.001$) age categories with sum of four skinfolds significantly decreasing for the Under 14s ($p = 0.013$), 16s ($p = 0.02$), 18s ($p < 0.001$) and 20s ($p < 0.001$). Yo-Yo distance significantly increased for the Under 18s ($p = 0.003$) and 20s ($p < 0.001$) with a significant increase in estimated $\dot{V}O_{2max}$ also shown for the Under 18s ($p < 0.001$) and 20s ($p < 0.001$). 10 m and 20 m speed significantly increased for the Under 18s ($p = 0.011$ and $p = 0.046$) and 20s ($p < 0.001$ and $p = 0.012$) with 10 m momentum significantly increasing for the Under 14s ($p < 0.001$), 16s ($p <0.001$), 18s ($p = 0.008$) and 20s ($p <0.001$). Vertical jump significantly increased for the Under 14s ($p = 0.021$) and 16s ($p < 0.001$). 1-RM back squat and prone row significantly increased for the Under 18s (both $p < 0.001$) and 20s ($p = 0.001$ and $p < 0.001$) with only a significant increase for 1-RM bench press found for the Under 18s ($p < 0.001$).

Insert Table 1 near here

P15 - Table 2 shows the percentage seasonal change in anthropometric and physical characteristics between pre- and post-season by age category. Age category had an overall significant effect on percentage seasonal change for body mass ($p < 0.001$, $\eta^2 = 0.15$), Yo-Yo distance ($p < 0.001$, $\eta^2 = 0.13$), estimated $\dot{V}O_{2max}$ ($p < 0.001$, $\eta^2 = 0.13$), 10 m sprint ($p = 0.005$, $\eta^2 = 0.11$), vertical jump ($p < 0.001$, $\eta^2 = 0.12$), 1-RM back squat ($p = 0.02$, $\eta^2 = 0.13$) and 1-RM bench press ($p < 0.001$, $\eta^2 = 0.34$). There was no significant difference in percentage seasonal change between age categories for sum of four skinfolds, 20 m sprint, 10 m momentum and 1-RM prone row. Post-hoc analysis identified that percentage seasonal body mass change was significantly greater in the Under 16s compared to the Under 18s (p = 0.003) and 20s (p = 0.002). Yo-Yo distance percentage change was significantly less for the Under 14s than 18s (p = 0.06) and 20s (p < 0.001) and the Under 16s were significantly less than the Under 20s (p = 0.002). For estimated $\dot{V}O_{2max}$, Under 18s and 20s had a significantly greater percentage seasonal change than the Under 14s (p = 0.03) and 16s (p=0.002). For 10 m sprint, the percentage seasonal change for Under 20s was significantly greater than the Under 14s (p = 0.021) and 16s (p = 0.026). For vertical jump, percentage seasonal change was significantly greater in the Under 16s compared to 18s (p = 0.001) and 20s (p = 0.003). For strength measures, the Under 18s experienced significantly greater percentage seasonal change in 1-RM back squat (p = 0.02) and bench press (p < 0.001) than the Under 20s.

Insert Table 2 near here

P16 – Relationships between the seasonal changes in anthropometric and physical characteristics within all players revealed weak correlations between percentage seasonal change for body mass and estimated $\dot{V}O_{2max}$ (r = -0.208, 95% CI = -0.377 - -0.07, p = 0.009) and vertical jump (r = -0.238, 95% CI = -0.366 - -0.101, p = 0.002). Weak and moderate correlations were observed between percentage seasonal change in 10 m speed versus 20 m speed (r = 0.174, 95% CI = 0.035 - 0.307, p = 0.014) and 1-RM squat (r = 0.359, 95% CI = 0.231 – 0.475, p = 0.014).

When correlations between percentage seasonal changes in anthropometric and physical characteristics were explored by age category, the Under 14s showed strong significant correlations for; body mass versus sum of skinfolds (r = -0.573; 95% CI = -0. 77 - -0.28,p < 0.001) and vertical jump (r = 0.550, 95% CI = 0.24 – 0.76, p = 0.001); and moderate correlations between vertical jump versus sum of four skinfolds (r=0.342, 95% CI = -0.01 – 0.62, p = 0.042) and 10 m speed (r = -0.348, 95% CI = -0.63 – 0.01, p = 0.044). Under 16s only showed weak significant correlations for sum of four skinfolds versus 10 m speed (r = -0.271, 95% CI = -0.47 - -0.05, p = 0.022). Under 18s showed very strong and moderate significant correlations for 10 m speed versus 20 m speed (r = 0.857, 95% CI = 0.78 – 0.91, p < 0.001), vertical jump (r = -0.428, 95% CI = -0.61 - -0.20, p = 0.010) and 1-RM back squat (r = -0.480, 95% CI = -0.65 - -0.27, p = 0.010) alongside 20 m speed versus vertical jump (r = -0.506, 95% CI = -0.67 - -0.30,p = 0.002) and 1-RM back squat (r = -0.435, 95% CI = -0.62 - -0.21, p = 0.021). Under 20s showed significant correlations for; 10 m speed versus estimated $\dot{V}O_{2max}$ (r = -0.504, 95% CI = -0.75 - -0.14, p = 0.033) and 20 m speed versus estimated $\dot{V}O_{2max}$ (r = -0.787, 95% CI = -0.90 - -0.57, p < 0.001) and 1-RM prone row (r = -0.582, 95% CI = -0.79 - -0.24, p = 0.011).

Insert Table 3 near here

DISCUSSION

P17 - The purpose of the current study was to evaluate the seasonal changes in anthropometric and physical characteristics from pre- to post-season of English academy rugby league players by age category and evaluate the relationships between seasonal changes in these characteristics. As hypothesized, improvements in most anthropometric and physical measures occurred from pre- to post-season with differences observed between the percentage changes in characteristics between age categories. This suggests that anthropometric and physical characteristics improve from pre- to post-season but age category may impact upon the changes that occur. In addition, a range of significant relationships were found between changes in anthropometric and physical characteristics, which were influenced by age category.

P18 - There was a significant increase in body mass from pre- to post-season for the Under 14, 16 and 18 age categories demonstrating body mass increases across a season in academy rugby league players. When age categories were compared, the Under 14s and 16s significantly increased body mass compared to Under 18s and 20s (7.4 ± 4.3 and 5.2 ± 5.0 versus 2.5 ± 4.7 and 1.2 ± 3.3 %, respectively) demonstrating that younger age categories experience greater increases in body mass throughout a season. Although not measured within the study, it would be attributed that increased body mass changes would be more apparent during adolescence (i.e., Under 14s and 16) due to the normal adaptations related to growth and maturation (27) and that the development of body mass reduces as players mature and progress towards adulthood (9). Previous Australian research evaluating body mass change in Under 18 players has identified reductions across a season (-1.13%, 13) but an increase during a four month pre-season period (2.69%, 14). Although it is unclear the reasons behind this variance in body mass change it is suggested that body mass is monitored throughout a season, to aid in training programme interventions and longer term player development due to the requirement of lean body mass with increasing playing levels (15, 29, 32).

P19 - *S*ignificant seasonal reductions in sum of four skinfolds occurred for all age categories from pre- to post-season. This suggests that desirable changes in anthropometric characteristics occurred across a season with the increase in body mass, attributed to an increase in lean mass rather than fat mass. Despite the limited change in body mass for Under 20s, the greatest reduction in body fat occurred; suggesting players were able to increase lean mass from pre- to post-season. The seasonal change in sum of skinfolds for the current Under 18s (-8.2 ± 15.4%) is similar to those reported in previous Australian research across a playing season (-10.1%, 13) suggesting body fat percentage will reduce across a season. However, large standard deviations and confidence intervals for the change in sum of skinfolds suggest a large inter-individual change in body fat percentage occurs between players. Thus, strength and conditioning coaches should monitor body composition regularly and prescribe individual training programmes and nutritional interventions, specific to the athletes needs to achieve targets of below 30 mm for backs and 40 mm for forwards, recently proposed by Till et al. (34).

P20 - Only older players (Under 18s and 20s) significantly improved endurance performance via the Yo-Yo intermittent recovery test, with negligible seasonal changes apparent for younger players (Under 14s and 16s). The greatest increase in distance (46.1 ± 40.8 %) and estimated $\dot{V}O_{2max}$ (9.2 ± 7.6 %) was for the Under 20s age category, which may be attributed to the increase in training load and volume compared to the younger age groups. On the contrary, the training schedule for the Under 18s was similar to the Under 20s, suggesting varying training responses with age category. A potential reason for increased endurance change in the Under 20s age category, may be the smaller body mass increase compared to the younger age categories, which may impact upon endurance performance (31). Thus, strength and conditioning coaches should consider the impact of body mass on endurance performance and optimize increases in mass alongside endurance performance.

P21 - When compared with previous Australian research (13, 14), specifically for the Under 18s age category, the 4.9 ± 6.9% seasonal increase in estimated $\dot{V}O_{2max}$ was greater than seasonal changes (2.96 %, 13), but less than those reported for a 4 month pre-season period

(8.64 %, 13). This suggests that the specific time point of testing may determine the reported improvements (7), although comparative *net* seasonal improvements and changes in variables can be taken from this study. The estimated mean $\dot{V}O_{2max}$ for Under 18s at pre-season in this study (46.6 ± 2.8 $ml \cdot kg^{-1} \cdot min^{-1}$) was similar to and less than reported in Australian Under 18s rugby league players (training group, 50.6 $ml \cdot kg^{-1} \cdot min^{-1}$ and control group 47.0 $ml \cdot kg^{-1} \cdot min^{-1}$, 13; 46.3 $ml \cdot kg^{-1} \cdot min^{-1}$, 14), which may impact the response of estimated $\dot{V}O_{2max}$ during a season.

P22 - For 10 m and 20 m speed, younger players (Under 14s and 16s) demonstrated negligible improvements, no change or decreases in performance whereas older players (Under 18s and 20s) showed significant improvements in 10 m and 20 m speed. Previous research (31, 32) has identified increasing speed with age and although the current study only evaluate across a playing season, improvements would be expected highlighting the importance of longitudinal research designs to track player performance (34, 35). In addition, research (30) has suggested that the anaerobic system may differ in its development between younger and older players, which may warrant longitudinal studies, accounting for peak height and peak weight velocity and the effect on neuromuscular performance and coordination. When 10 m momentum was considered, significant increases in performance were identified for all age categories. This suggests that even though speed may have decreased at younger age categories (i.e., Under 14s and 16s), when speed was combined with body mass this showed an increase in momentum, which has been demonstrated as necessary for rugby league performance (4). Therefore, practitioners should be aware that absolute improvements in speed may not exist with age until changes in body mass stabilize, which should be considered in player identification and development. Instead, strength and conditioning coaches should understand the interaction between anthropometric and physical characteristics and assess measures such as momentum to monitor player development.

P23 - Vertical jump appeared to demonstrate an opposing trend to sprint speed, with younger players (Under 14s and 16s) experiencing significant improvements and older players (Under 18s and 20s) demonstrating a limited change in performance from pre- to post-season. As with relative and absolute aerobic power previously discussed, despite no improvement in vertical jump height, power output must have improved due to the increase in body mass. The reason for no further improvement in jump height for older players despite improvements in back squat strength and speed may be down to the specific training intervention and stimulus, or a *'jump ceiling'* in rugby players. Further improvements of strength and power *per se* may be observed and beneficial to sprint performance (3), but may not specifically relate to improved jump heights. Baker (2) reports a *'strength ceiling'* in rugby league players, thus a similar phenomenon may exist for specific tests such as the vertical jump.

P24 - Seasonal significant improvements in back squat and prone row were observed for Under 18s and 20s with seasonal improvements in bench press only evident for the Under 18s. This suggests that strength improvements occurred across a playing season in academy rugby league players with more significant gains observed in Under 18 players due to a lower training age. Findings demonstrate mean improvements in strength between 12 and 17% at the Under 18s age category, which decrease to between 4 and 7% in the bench press and squat exercises at the Under 20s. Such findings suggest 3 pre-season and 2 in season strength sessions a week elicit strength gains in academy-aged rugby league players.

P25 - The only relationships between seasonal changes in characteristics were observed for body mass and estimated $\dot{V}O_{2max}$, body mass and vertical jump, 10 m sprint and 20 m sprint, and 10 m sprint and 1-RM squat. Seasonal changes in vertical jump and back squat strength were related to sprint performance as previously reported (25), thus players should undertake well-structured and planned resistance training programmes in addition to field sessions to help develop the necessary physical characteristics required for rugby league performance. Based on the relationships observed strength and conditioning coaches should use a variety of tests to understand developments in athletic performance, as variables appear to develop at varying rates for each individual, despite similarities in training stimulus.

P26 - Although this study advances on existing research in that it evaluates seasonal changes in anthropometric and physical characteristics in UK players across age categories from Under 14 to Under 20 players, it is not without limitations. Firstly, the lack of control group in the study means it is difficult to ascertain whether seasonal changes are due to training adaptations or processes related to growth and maturation. Further, the lack of exact training volume and load details for the players and lack of control of training and activity away from the club could have potential impact on the expected changes to be expected. Future research should look to control training volume and load to establish seasonal changes against a set training prescription. Although these limitations exist, presenting research findings from an applied practical setting in relation to seasonal changes by age category should inform practitioners of the associated changes that may be observable within rugby league academy players.

P27 - In conclusion, findings demonstrated that younger players (Under 14s and 16s) increased body mass and improved sum of skinfolds and vertical jump between pre- and post-season, whereas older players (Under 18s and 20s) improved performance in all variables across the season except vertical jump. Due to the greater increases in body mass in younger players across the season, this may affect absolute changes in speed, which was demonstrated when 10 m momentum was considered. These findings suggest coaches should monitor changes in anthropometric and characteristics together (i.e., momentum) to understand seasonal changes in performance. The high standard deviations and ranges observed in the study suggest that there is large inter individual variation in seasonal changes in anthropometric and physical characteristics between individuals within chronological annual-age groups, which may be due to a number of factors such as training age, injuries, training volume and response to training. The findings could be used as comparative data for measuring seasonal change in performance with it recommended to monitor changes in performance at different stages of the season to fully understand the development of anthropometric and fitness characteristics within and across seasons.

PRACTICAL APPLICATIONS

P28 - Anthropometric and physiological characteristics are important for the development of elite rugby league players (11, 19) and this study demonstrates that anthropometric and physical characteristics change across a playing season specific to age category and measure. Strength and conditioning coaches and player development staff should use such data to monitor seasonal changes in player characteristics to assist in monitoring individual player progression and development whilst developing strength and conditioning training interventions. Coaches should aim to improve body composition (i.e., sum of skinfold reduction and lean mass gains) during a season but be aware of the influence that these anthropometric changes may have on absolute fitness performance (e.g., speed, endurance). This should be especially considered in younger age groups (Under 14s and 16s) where substantial gains in mass can occur throughout a season due to normal growth and maturation processes.

Finally, inter-player variability in the development of anthropometric and physical characteristics limits the extrapolation of our findings to individuals with player development considered on an individual and longitudinal basis (35).

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Table 1. Pre- and Post-Season Anthropometric and Physical Characteristics of Academy Rugby League Players by Age Category

	Under 14s		**Under 16s**		**Under 18s**		**Under 20s**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Body Mass (kg)	55.0 ± 12.3	58.8 ± 11.9***	70.9 ± 11.1	74.3 ± 10.8***	84.1 ± 10.8	86.0 ± 10.0***	90.3 ± 10.6	91.3 ± 10.4
∑ 4 Skinfolds (mm)	32.1 ± 8.6	29.3 ± 6.8*	38.2 ± 16.6	35.9 ± 13.6*	41.9 ± 17.6	37.6 ± 15.0***	41.7 ± 12.1	36.6 ± 12.4***
Yo-Yo Distance (m)	1027 ± 510	987 ± 465	1234 ± 408	1277 ± 470	1223 ± 328	1490 ± 413**	1161 ± 198	1662 ± 397***
Estimated $\dot{V}O_{2max}$ ($ml.kg^{-1}.min^{-1}$)	45.0 ± 4.3	44.7 ± 5.5	46.8 ± 3.4	47.1 ± 3.9	46.7 ± 2.8	48.9 ± 3.5***	46.2 ± 1.7	50.4 ± 3.3***
10 m Sprint (s)	1.94 ± 0.10	1.97 ± 0.10	1.83 ± 0.07	1.84 ± 0.08	1.82 ± 0.06	1.79 ± 0.07*	1.83 ± 0.09	1.79 ± 0.11**
20 m Sprint (s)	3.37 ± 0.17	3.37 ± 0.20	3.16 ± 0.12	3.15 ± 0.13	3.14 ± 0.10	3.09 ± 0.11*	3.15 ± 0.21	3.09 ± 0.20*
10 m Momentum ($kg.s^{-1}$)	287 ± 61	304 ± 32***	383 ± 55	399 ± 46***	458 ± 39	473 ± 33**	477 ± 64	494 ± 69***
Vertical Jump (cm)	38.9 ± 6.4	41.5 ± 5.2*	44.2 ± 5.7	48.1 ± 6.5***	48.1 ± 5.6	48.9 ± 6.6	50.7 ± 7.1	50.8 ± 7.4
1-RM Squat (kg)					118.4 ± 23.8	134.8 ± 19.5***	119.4 ± 18.4	127.8 ± 25.1**
1-RM Bench Press (kg)					92.6 ± 17.3	107.7 ± 19.4***	109.0 ± 19.3	112.8 ± 18.1
1-RM Prone Row (kg)					82.0 ± 11.4	91.6 ± 13.3***	86.8 ± 12.9	95.3 ± 12.7***

Significant differences between Pre- and Post-Season; *p<0.05; **p<0.01; ***p<0.001.

Table 2. Percentage Change in Anthropometric and Physical Characteristics in Academy Rugby League Players between Pre- and Post-Season by Age Category

	Under 14s (1)	Under 16s (2)	Under 18s (3)	Under 20s (4)	Post-hoc
Body Mass	7.4 ± 4.3 (0.8 – 15.3)	5.2 ± 5.0 (-7.9 – 18.5)	2.5 ± 4.7 (-7.5 – 17.5)	1.2 ± 3.3 (-3.8 – 8.8)	2 > 3, 4
∑ 4 Skinfolds	-7.8 ± 11.6 (-24.2 – 13.7)	-4.1 ± 15.1 (-32.0 – 43.4)	-8.2 ± 15.4 (-43.6 – 51.0)	-11.8 ± 12.5(-36.3 – 8.0)	
Yo-Yo Distance	0.0 ± 55.2 (-91.0 – 110.0)	9.6 ± 28.4 (-49.0 – 68.0)	23.7 ± 31.8 (-66.0 – 77.0)	46.1 ± 40.8 (0.0 – 98.0)	1 < 3, 4; 2<4
Estimated $\dot{V}O_{2max}$	-0.4 ± 10.5 (-18.7 – 18.2)	0.9 ± 7.2 (-32.4 – 15.5)	4.9 ± 6.9 (-15.0 – 17.9)	9.2 ± 7.6 (0.0 – 17.8)	1, 2 < 3, 4
10 m Sprint	1.3 ± 3.9 (-5.1 – 10.2)	0.5 ± 3.7 (-10.3 – 9.3)	-1.6 ± 2.5 (-4.7 – 3.8)	-1.9 ± 1.2 (-3.5 – -0.5)	4 > 1, 2
20 m Sprint	-0.1 ± 3.5 (-7.5 – 9.2)	-0.1 ± 2.7 (-6.2 – 5.5)	-1.3 ± 2.8 (-4.1 – 5.1)	-1.8 ± 2.3 (-4.4 – 0.9)	
10 m Momentum	6.3 ± 5.9 (-0.5 – 10.0)	4.6 ± 6.3 (-4.0 – 11.1)	3.5 ± 5.1 (-2.5 – 10.2)	3.5 ± 3.4 (-4.5 – 9.2)	
Vertical Jump	7.9 ± 12.7 (-14.3 – 32.0)	9.2 ± 10.7 (-12.5 – 46.0)	1.6 ± 7.4 (-11.6 – 21.2)	0.5 ± 7.5 (-13.5 – 10.5)	2 > 3, 4
1-RM Squat			15.8 ± 13.8 (-18.8 – 40.0)	6.5 ± 10.7 (-10.0 – 20.0)	3 > 4
1-RM Bench Press			16.9 ± 8.3 (5.9 - 33.3)	4.1 ± 6.8 (-9.1 – 14.3)	3 > 4
1-RM Prone Row			11.9 ± 8.7 (-10.0 – 27.6)	10.2 ± 6.4 (-5.1 – 19.4)	

Note: Data are presented as Mean ± SD (range). The numbers in parentheses in the column headings relate to the numbers used for illustrating significant ($p<0.05$) differences in the post-hoc analysis between age categories