A longitudinal evaluation of anthropometric and fitness characteristics in junior rugby league players considering playing position and selection level

Abstract

Objectives: The current study provided a longitudinal evaluation of the anthropometric and fitness characteristics in junior rugby league players across three annual-age categories (i.e., Under 13s, 14s & 15s) considering playing position and selection level.

Design: Longitudinal Design

Method: Eighty-one junior rugby league players selected to a talent development programme were tracked over a two year period. Anthropometric (height, sitting height, body mass and sum of four skinfolds) and fitness (lower and upper body power, speed, change of direction speed and maximal aerobic power) characteristics were measured on three occasions (i.e., Under 13s, 14s and 15s). Repeated measures MANOVA and MANCOVA (controlling chronological and maturational age) analysed changes across annual-age categories in relation to playing position and selection level.

Results: Findings identified significant improvements in anthropometric and fitness characteristics across annual-age categories ($p<0.001$). MANOVA and MANCOVA analysis identified significant overall effects for playing position ($p<0.001$) and selection level ($p<0.05$) throughout the two year period. Interactions between playing position and time were identified for height, vertical jump and estimated $\dot{V}O_{2max}$ ($p<0.05$). Selection level by time interactions were identified for 20m, 30m and 60m sprint ($p<0.05$).

Conclusions: This study demonstrates the improvement of anthropometric and fitness characteristics within junior representative rugby league players. Interactive effects for playing position and selection level by time highlight the variation in the development of characteristics that occur during adolescence. Tracking the progression of characteristics longitudinally during adolescence, instead of at one-off time points, may assist selection and/or performance assessments within rugby league and other youth sport contexts.

Keywords: Talent identification; maturation; development; athlete selection; expert performance.

Introduction

Talent identification and development are anecdotally perceived to be crucial in the pursuit of excellence, with many national governing bodies and professional clubs investing considerable resources to accelerate the development process of athletes at an early age [1,2]. Currently, research and practical applications of talent identification and development programmes predominantly utilise a cross-sectional approach to predict future adult performance [3]. The one-off nature of such assessments during adolescence fails to consider the impact of growth and maturation and only considers performance at specific time points. Instead, it is recommended that participants should be monitored over a number of years to improve the accuracy of the understanding of the factors that contribute to expert performance [4]. Therefore, when differentiating between an athlete's adolescent performance level and the potential for progression into adulthood, longitudinal studies are essential [3].

Longitudinal studies in wider youth sport contexts have examined anthropometric and performance characteristics over time [5], changes in characteristics over a playing season [6] and the relationships between maturation and performance [7]. However, studies using a longitudinal methodology within talent identification and development research are limited even though they have been recommended for the past decade [3,4]. Only two recent studies [8,9] have examined talent identified samples from a longitudinal perspective by tracking performance changes between selected / non-selected [8] and elite / sub-elite [9] juniors over a two year period. Both studies identified improvement in performance over time and between selection levels, however neither study considered maturational status in their analysis. This may have affected both selection and assessment scores, and highlighted potential interactions between time, growth, performance and selection during adolescence.

Rugby league is an intermittent, collision sport with players required to have high physiological capacities for strength, power, speed, agility and aerobic power [10]. Previous research has examined the effect of playing position and selection level on the anthropometric and fitness characteristics across junior and senior players (e.g., [10-14]) using cross-sectional analysis. Differences have been identified between playing positions at junior (e.g. [10,11,13]) and senior levels (e.g., [15]), demonstrating that 'Props' are usually taller, heavier with greater skinfold thickness than other positions but perform worse on a range of fitness tests (e.g., speed). Further, research has identified that anthropometric and fitness characteristics improve with playing level across junior levels (e.g., [14,16]). Although research exists examining anthropometric and fitness characteristics in rugby league, longitudinal data during adolescence is limited.

Between 2001 and 2008, UK rugby league's national governing body, the Rugby Football League (RFL), used a talent identification and development process, called the Player Performance Pathway (see [17,18] for details). Each year 100 players were selected to the Regional representative level at Under 13s, 14s and 15s annual-age categories. Between 2005 and 2008 anthropometric and fitness testing were conducted on all Regional players resulting in a total of 1,172 assessments. Within this sample, longitudinal data became available for players that were selected to the Pathway on three consecutive occasions (e.g., Under 13s in 2006, Under 14s in 2007 & Under 15s in 2008). On this basis, the primary purpose of the present study was to provide a longitudinal evaluation of the anthropometric and fitness characteristics of junior rugby league players selected to the Player Performance Pathway, whilst also controlling for chronological age and maturation. A secondary purpose was then to consider the differences in the development of characteristics between playing positions and selection level, which have previously been considered in cross-sectional studies, but not in longitudinal designs.

Methods

Eighty-one male junior rugby league players (mean age 13.6 ± 0.2 years at Under 13s) participated in the current study. In the two cohorts examined (i.e., Under 13s 2005 – Under 15s 2007; Under 13s 2006 - Under 15s 2008) the 81 players represented 41.3% (81 out of 196) of players who were retained in the Player Performance Pathway after initial selection at the Under 13s age category. All protocols received institutional ethics approval with parental and/or guardian consent provided.

Longitudinal data was evaluated by annual-age category (Under 13s, 14s & 15s), playing position and selection level. Playing position was classified into four sub-categories (i.e., 'Outside-Backs', *n*=25; 'Pivots', *n*=19; 'Props', *n*=16; 'Backrow', *n*=21) as used in previous rugby league research [19]. Selection level was grouped into four categories (i.e., Regional, National, National-Regional, Regional-National) dependent upon level of selection along the Player Performance

Pathway. Regional (*n*=34) and National (*n*=19) players were those players that were consistently selected to the Regional or National level of the pathway. National-Regional players were players selected at the National level at Under 13s but were only Regional players at the Under 15s age category (*n*=23) and therefore dropped down in selection level. Regional-National players were players who were selected at Regional level at Under 13s but were selected to National level by the Under 15s age category (*n*=5) and therefore moved up in selection level. Procedures for all anthropometric and fitness assessments undertaken on the players are detailed below. Assessments were undertaken at the same time of day (i.e., early evening) and year (i.e., July) on each occasion. Intraclass correlation coefficients for each measure have been presented in previous research [13,14] and all measurement reliability and objectivity confirmed to published expectations.

Height and sitting height were measured to the nearest 0.1cm using a Seca Alpha stand. Body mass, wearing only shorts, was measured to the nearest 0.1kg using calibrated Seca alpha (model 770) scales. Sum of four skinfolds was determined by measuring four skinfold sites (biceps, triceps, subscapular, suprailiac) using calibrated Harpenden skinfold callipers (British Indicators, UK) in accordance with Hawes and Martin [20].

An age at PHV prediction equation was used to assess maturation [21]. This prediction method used a gender-specific multiple regression equation including stature, sitting height, leg length, body mass, chronological age and their interactions to estimate age at PHV [22]. Years from PHV was calculated by subtracting age at PHV from chronological age.

Fitness tests were performed to determine lower and upper body power, speed, change of direction speed and estimated $\dot{V}O_{2max}$. Prior to testing, a standardised warm up was conducted and all players received full instructions and demonstrations of the assessments. Lower body power was assessed using the vertical jump test (centimetres) measured using a Takei vertical jump metre (Takei Scientific Instruments Co. Ltd, Japan). A countermovement jump with hands positioned on the hips was used with jump height measured to the nearest cm from the highest of three attempts [23]. A 2kg medicine ball (Max Grip, China) chest throw (metres) was used to measure upper body power [24]. Participants were instructed to throw the ball horizontally as far as possible while seated with their back against a wall and legs extended straight out in front of their body. Distance was measured to the nearest 0.1m from the wall to where the ball landed with the highest of three trials used as the score. Sprint speed (seconds) was assessed over 10m, 20m, 30m and 60m using timing gates (Brower Timing Systems, IR Emit, USA). Participants were positioned from a standing start 0.5m behind the initial timing gate and were instructed to start in their own time. Times were recorded to the nearest 0.01s from the best of three attempts. Change of direction speed (seconds) was assessed using the agility 505 test [12]. Participants were positioned 15m from a turning point with timing gates positioned 10m from the start point (5m from the turn point). Players accelerated from the starting point, through the timing gates, turned on the 15m line and ran as quickly as possible back through the gates (i.e., 15m sprint, turn, 5m sprint). Left and right foot turns were used, with three alternate attempts on each foot. Times were recorded to the nearest 0.01s. Estimated $\dot{V}O_{2max}$ ($ml.kg^{-1}.min^{-1}$) was predicted using the multistage fitness test [25]. Players were required to shuttle run 20m, keeping to a series of beeps of increasing speed until they reached volitional exhaustion. Regression equations were used to estimate $\dot{V}O_{2max}$ from the level reached during the multistage fitness test [25].

Mean and standard deviation (SD) scores were calculated for all dependant variables at each annual-age group according to all players, playing position and selection level. To examine significant differences and interactions between independent variables, repeated measures MANOVA analyses were initially conducted. This was followed by repeated measures MANCOVA, controlling for chronological and maturational age (years from PHV), to analyse the extent to which age and maturation contributed to the differences between the independent variables. Following multivariate analysis, Bonferroni pairwise comparisons were conducted to examine univariate effects. All analyses were conducted using SPSS 17.0 with effect sizes (η^2) calculated and significance levels set at $p<0.05$.

Results

Table 1 shows the anthropometric and fitness characteristics of all players selected to the Player Performance Pathway at each annual-age category. MANOVA analyses identified significant main effects for annual-age category ($F_{2, 80} = 4182.6$, $p<0.001$, $\eta^2=1.00$) with pairwise comparisons showing all variables significantly improved across the three age categories except for sum of four skinfolds and agility 505 right.

Insert Table 1 near here*

MANCOVA analyses, controlling for age and maturation, found no significant main effect for annual-age group ($F_{2, 80} = 0.818$, p=0.713, η^2=0.310) or any individual variable. MANCOVA analyses identified significant overall main effects for the covariates of chronological age ($F_{14, 65} = 25.4$, p<0.001, η^2=0.85), maturation ($F_{14, 65} = 77.1$, p<0.001, η^2=0.94) and maturation x time interaction ($F_{28, 51} = 2.8$, p=0.001, η^2=0.61). Table 1 shows the covariate relationships between chronological age, maturation and maturation x time against each anthropometric and fitness characteristic. No significant overall effect for chronological age x time or any individual variable was found.

Table 2 shows the anthropometric and fitness characteristics at each annual-age category according to playing position. MANOVA analyses identified significant overall main effects for playing position ($F_{45, 188} = 3.45$, p<0.001, η^2=0.50) with significant differences found for all variables except age. Pairwise comparisons found ‘Pivots’ were less mature and shorter than the ‘Props’ and ‘Backrow’, while ‘Props’ were the heaviest position with the greatest sum of four skinfolds. ‘Outside-Backs’ outperformed all positions on the vertical jump, 30m and 60m sprint tests, whilst also outperforming ‘Props’ on 10m and 20m sprint. For medicine ball throw, ‘Props’ and ‘Backrow’ significantly outperformed ‘Pivots’. For agility 505 and estimated $\dot{V}O_{2max}$ ‘Props’ were the worst performing position. No overall significant position x time interaction was found ($F_{90, 145} = 1.1$, p=0.46, η^2=0.39), however significant effects were identified for height ($F_{6, 80} = 3.9$, p=0.03, η^2=0.13) and estimated $\dot{V}O_{2max}$ ($F_{6, 80} = 2.41$, p=0.03, η^2=0.09). Figure 1 illustrates the relationship between playing position, height and estimated $\dot{V}O_{2max}$, demonstrating ‘Pivots’ increased height the most over the 2 years, with ‘Props’ and ‘Backrow’ improving estimated $\dot{V}O_{2max}$.

Insert Table 2 and Figure 1 near here*

MANCOVA analyses identified a significant overall effect for playing position ($F_{42, 185} = 2.9$, p<0.001, η^2=0.40) with significant differences found between positions for all variables except age at PHV, height, sitting height and medicine ball throw. Pairwise comparisons found ‘Outside-Backs’ and

'Pivots' to be lighter than 'Backrow' who were lighter than 'Props' with similar findings shown for skinfolds. 'Outside-Backs' outperformed 'Props' and 'Backrow' for the vertical jump, 20m, 30m and 60m sprint. 'Props' were again the worst performing position for agility 505 and estimated $\dot{V}O_{2max}$ tests. MANCOVA analyses showed no overall significant position x time interaction ($F_{84, 145} = 0.4$, p=0.47, η^2=0.37) except for vertical jump ($F_{2, 80} = 2.3$, p=0.040, η^2=0.08).

For selection level (See Supplementary Table 1), MANOVA analyses identified a significant overall main effect ($F_{45, 188} = 1.5$, p=0.025, η^2=0.27), however no significant differences were found for any individual variable. No significant overall main effects were found for selection level x time ($F_{90, 145} = 1.0$, p=0.441, η^2=0.38), however interactions were evident for 20m ($F_{2, 80} = 2.4$, p=0.034, η^2=0.08) and 30m ($F_{2, 80} = 3.0$, p=0.008, η^2=0.11) sprint. These results found sprint times changed between selection levels during the two year period (e.g., 30m sprint - Regional-National players were the slowest at Under 13s but the fastest at Under 15s). MANCOVA analyses identified a significant overall main effect for selection level ($F_{42, 185} = 1.6$, p=0.019, η^2=0.26) but again no significant effects were found for any particular variable. Significant interactions for selection level x time were apparent for 20m ($F_{2, 80} = 2.6$, p=0.019, η^2=0.10), 30m ($F_{2, 80} = 3.5$, p=0.003, η^2=0.12) and 60m ($F_{2, 80} = 2.3$, p=0.03, η^2=0.09) sprint.

Discussion

Considerate of the limited longitudinal research within talent identified samples, the purpose of the present study was to longitudinally evaluate the anthropometric and fitness characteristics of 81 junior rugby league players selected to a talent development programme. Findings highlight that anthropometric and fitness characteristics significantly improved across the three annual-age categories which support previous cross-sectional analyses [13] and research in other sports (e.g., soccer [26,27]). Furthermore, the present study provides average data for the changes in anthropometric (e.g., body mass, Under 13s–14s = 7.3 kg, Under 14s–15s = 6.5 kg) and fitness (e.g., vertical jump, Under 13s–14s = 2.4 cm, Under 14s–15s = 2.1 cm) characteristics within junior rugby league players during the adolescent period, which is limited within previous research in rugby league as well as other youth sport contexts.

Since the 1970s maturation has been found to be a better predictor of performance than chronological age [28]. Although this relationship exists, many studies examining characteristics of adolescent athletes have not explicitly considered maturation in their analyses until recently [26,29]. Our findings have demonstrated strong relationships between maturation with anthropometric characteristics (e.g., height; $\eta^2 = 0.535$) and medicine ball throw ($\eta^2 = 0.401$). Furthermore, significant time by maturation interactions were evident for anthropometric and fitness characteristics (e.g., medicine ball throw; sprint speed) highlighting the importance of considering maturation in the evaluation of performance within adolescent populations.

Significant longitudinal differences were identified between playing positions across the two years with the earlier maturing 'Props' being the worst performing position (e.g., agility, estimated $\dot{V}O_{2max}$) in both MANOVA and MANCOVA analysis. These findings are consistent with previous cross-sectional observations [13] and prior research in junior [10,11] and senior [15] rugby league. This provides further evidence, within a longitudinal sample, that although 'Props' are significantly taller and heavier compared to other playing positions they actually underperform on a range of fitness measures. This finding highlights that physical size is an important contributor towards selection within junior representative levels. However, it seems coaches do not appear to consider the potential detrimental effects that some aspects of size (e.g., body fat) may have upon the immediate and long-term development of performance.

Findings identified no significant overall playing position by time interaction, demonstrating anthropometric and fitness characteristics improved at a consistent rate between playing positions. However, interactive effects were identified for height, vertical jump and estimated $\dot{V}O_{2max}$. Height increased the most amongst the 'Pivots' (i.e., 'Pivots' = 9.97 cm; 'Outside-Backs' = 6.87 cm; 'Props' = 6.15 cm; 'Backrow' = 6.54 cm) with data reflecting the 'Pivots' as typically later maturing players. Although opportunities were available for selection for later maturing 'Pivots', these opportunities may not have been available in other positions, with players potentially not selected based on their maturation and size. This finding demonstrates the importance of measuring height longitudinally with it important that coaches and/or scouts do not exclude players from selection and development opportunities based on their height during adolescence. For vertical jump and estimated $\dot{V}O_{2max}$, ‘Props’ (4.4 cm; 5.6 ml.kg^{-1}.min^{-1}) and ‘Backrow’ (6.5 cm; 5.2 ml.kg^{-1}.min^{-1}) improved more than ‘Outside-Backs’ (3.7 cm; 1.0 ml.kg^{-1}.min^{-1}) and ‘Pivots’ (3.9 cm; 3.2 ml.kg^{-1}.min^{-1}) across the two years. Although the mechanisms behind these improvements are not known (e.g., training status), these findings suggest that the ‘Props’ and ‘Backrow’ positions improved lower body power and estimated $\dot{V}O_{2max}$ the most during this adolescent period, with such improvement possibly necessary in order to meet the demands of the game and be consistently selected to the pathway. These findings open up several questions for coaches (e.g., how much did a player improve his vertical jump between under 14s and 15? How does this compare with the team and/or national average?) for monitoring players longitudinally on an individual basis during the adolescent period and beyond.

Identifying variables that distinguish between different selection levels within youth sport has been common in prior research [1,27,29] but is limited within longitudinal designs [8,9]. The current findings showed significant overall main effects for selection level but no significant differences were identified for any individual variable. This highlights that a combination of anthropometric and fitness characteristics may have contributed toward selection at each representative level across the two years. These results differ from previous cross-sectional research [14] whereby National player’s significantly outperformed Regional players for sum of four skinfolds and fitness characteristics. This contradiction may have occurred due to the smaller sample size used in the present study compared to previous cross-sectional analyses (National = 302; Regional = 870 [17]), and due to the creation of two additional selection levels (i.e., National-Regional; Regional-National) but demonstrates that success at higher levels is dependent on a wide range of well-developed physical qualities.

Time by selection level interactions found significant effects for 20m, 30m and 60m sprint performance with differing improvements in sprint performance between the Under 13 and 15 age categories demonstrated (e.g., 60m sprint - National = -0.37; Regional = -0.82; National-Regional = -0.61; Regional-National = -0.80 s). These findings highlight that players who moved up in selection (i.e., Regional-National) were the quickest in terms of sprint at the Under 15s (i.e., National = 8.17; Regional = 8.13; National-Regional = 8.04; Regional-National = 7.96 s) and significantly improved sprint speed during the two year period. This may have contributed to an increased likelihood of selection to the National level. To add, these findings also demonstrate the variation and change in performance that can occur between individuals during adolescence, again showing potential value in monitoring individual changes longitudinally [3].

Although this study improved on previous cross-sectional [13,14] and longitudinal research [8,9], limitations exist. The use of the age at PHV prediction equation [21] as a measure of maturation has not been correlated with other maturity indicators (i.e., skeletal age, secondary sexual characteristics) within athletes. However, while accepting potential error, such an assessment of maturation remains beneficial, as it is a simple non-intrusive way of predicting maturation, as applied in other research [22]. Due to the field based nature of all tests applied the multistage fitness test was used to estimate $\dot{V}O_{2max}$, instead of a direct assessment. However, original research [25] identified a 0.92 correlation between the multistage fitness test and $\dot{V}O_{2max}$ suggesting the test is valid and reliable for estimating $\dot{V}O_{2max}$. Finally, the lack of available data beyond the Under 15s age category, due to the ceasing of the Player Performance Pathway at this age category, is another limitation. Data collected post adolescence and into early adulthood would be more informative to allow comparative measures through the later teenage years. Finally, the lack of multi-disciplinary assessments, including technical, tactical and psychological attributes, is a further limitation of the current study, which may have provided additional insight into the longitudinal development of junior rugby league players.

The current findings have implications for longitudinal monitoring of performance within talent identification and development pathways in all youth sports. The large variability in the degree of change in characteristics that occurred in the current junior rugby league players questions the use of one-off physical assessments of junior athletes during adolescence [30]. Instead, regularly monitoring the change in the development of characteristics may be more appropriate, with the current longitudinal data providing average yearly changes in anthropometric and fitness characteristics. This data could help track the development and progression of players' characteristics on a yearly basis throughout adolescence. The interaction between playing position and time for height demonstrates the variation in growth during adolescence. Coaches and scouts should understand the variation in growth and maturation of junior players and not (de)select players The present findings show earlier maturing players (i.e., 'Props') are outperformed on fitness measures by later maturing players (i.e., 'Outside-Backs', 'Pivots') demonstrating relationships between selection, size and performance during adolescence. Current selection biases most likely occur as a result of the short term requirements (e.g., winning instead of longer term development) employed by coaches within youth sport. Therefore, talented players identified at early ages may in fact be mistaken for early maturation and advanced size, effectively discounting later maturing individuals who may 'catch-up' on particular fitness or performance measures. National governing bodies and professional clubs should focus their attentions on long term development, instead of early (de)selection of players that are predominantly used at the moment. Potentially, delaying selection until late adolescence may reduce the impact of maturation and physical qualities on selection within youth sports.

Conclusion

Study findings highlight significant age related improvements in anthropometric and fitness characteristics, between playing positions and selection levels within the Player Performance Pathway. Further, when maturation was controlled as a covariate, analysis demonstrated strong effects with anthropometric and strength measures, and a time interaction with sprint speed. By tracking progression and change of characteristics longitudinally, key interactions between growth, maturation and performance can be considered to assist selection and/or performance within talented junior rugby league players. Given the priority for professional clubs and national governing bodies to identify talent for future adult competition, it is essential to be able to accurately differentiate between an adolescent's current performance and their potential for future development [3]. Changing current coaching philosophies from short-term performance requirements to longer term development are necessary. Future research and practical application within talent identification and development programmes should consider more regular long-term monitoring approaches, incorporating and evaluating both age and maturation.

Practical Implications

- Coaches should understand the development of anthropometric and fitness characteristics amongst junior rugby league players aged 13-15 years.
- Playing position and selection level should be considered in the evaluation of player characteristics over time.
- Evaluation of junior athletes should incorporate monitoring changes in performance characteristics (e.g., fitness) over time instead of comparing individuals using assessments at one-off time points.
- Maturation is related to anthropometric, upper body strength and speed measures during adolescence and should therefore be considered in player evaluations.
- Talent identification and development programmes should focus on an athlete’s potential for future development instead of current adolescent performance.

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References

1. Reilly T, Williams AM, Nevill A, et al. A multidisciplinary approach to talent identification in soccer. *J Sports Sci* 2000; 18(9): 695-702.
2. Abbott A, Collins D. Eliminating the dichotomy between theory and practice in talent identification and development: considering the role of psychology. *J Sports Sci* 2004; 22(5): 395-408.
3. Vaeyens R, Lenoir M, Williams AM, et al. Talent identification and development programmes in sport: Current models and future directions. *Sports Med* 2008; 38(9): 703-714.
4. Williams AM, Reilly T. Talent identification and development in soccer. *J Sports Sci* 2000; 18(9): 657-667.
5. Baxter-Jones ADG, Helms PJ, Muffulli N, et al. Growth and development of male gymnasts, swimmers, soccer and tennis players: A longitudinal study. *Ann Hum Biol* 1995; 22(5): 381-395.
6. Gabbett TJ. Performance changes following a field conditioning program in junior and senior rugby league players. *J Strength Cond Res* 2006; 20(1): 215-221.
7. Philippaerts RM, Vaeyens R, Janssens M, et al. The relationship between peak height velocity and physical performance in youth soccer players. *J Sports Sci* 2006: 24(3): 221-230.
8. Falk B, Lidor R, Lander Y, et al. Talent identification and early development of elite water polo players: a 2 year follow up. *J Sports Sci* 2004; 22(4): 347-355.
9. Elferink-Gemser MT, Visscher C, Lemmink KAPM, et al. Multidimensional performance characteristics and standard of performance in talented youth field hockey players: A longitudinal study. *J Sports Sci* 2007; 25(4): 481-489.
10. Gabbett TJ. A comparison of physiological and anthropometric characteristics among playing positions in junior rugby league players. *Br J Sports Med* 2005; 39(9): 675-680.
11. Gabbett TJ. Physiological characteristics of junior and senior rugby league players. *Br J Sports Med* 2002; 36(5): 334–339.
12. Gabbett TJ, Herzig PJ. Physiological characteristics of junior elite and sub-elite rugby league players. *Strength Cond Coach* 2004; 12(2): 19–24.

13. Till K, Cobley S, O'Hara J, et al. Anthropometric, physiological and selection characteristics in high performance UK junior Rugby League players. *Talent Development and Excellence* 2010; 2(2): 193-207.
14. Till K, Cobley S, O'Hara J, et al. Using Anthropometric and Performance Characteristics to Predict Selection in Junior UK Rugby League Players. *J Sci Med Sport* 2011: 14(3): 264-269.
15. Gabbett T, Kelly J, Pezet T. A comparison of fitness and skill among playing positions in sub-elite rugby league players. *J Sci Med Sport* 2008; 11(6): 585-92
16. Gabbett TJ, Kelly J, Ralph S, et al. Physiological and anthropometric characteristics of junior elite and sub-elite rugby league players, with special reference to starters and non-starters. *J Sci Med Sport* 2009; 12(1): 215-222.
17. Till K, Cobley S, Wattie N, et al. The prevalence, influential factors and mechanisms of relative age effects in UK Rugby League. *Scand J Med Sci Sports* 2010: 20(2): 320-329.
18. Till K, Cobley S, O'Hara J, et al. Talent Identification, Selection and Development in UK Junior Rugby League: An Evolving Process, chapter 9, in *Talent Identification and Development in Sport: International Perspectives*. Baker J, Cobley S, Schorer J editors, London, Routledge, 2011
19. Sykes D, Twist C, Hall S, et al. Semi-automated time-motion analysis of senior rugby league. *International Journal of Performance Analysis in Sport* 2009; 9(1): 47-59.
20. Hawes MR, Martin AD. Human Body Composition. In: Eston R. ed. and Reilly T. ed. Kinanthropometry and exercise physiology laboratory manual: Tests, procedures and data second edition. Volume 1: Anthropometry. London, Routledge. 2001: 7–43.
21. Mirwald RL, Baxter-Jones ADG, Bailey DA, et al. An assessment of maturity from anthropometric measurements. *Med Sci Sport Exerc* 2002; 34(4): 689-694.
22. Sherar LB, Baxter-Jones ADG, Faulkner RA, et al. Do physical maturity and birth date predict talent in male youth ice hockey players? *J Sports Sci* 2007; 25(8): 879-886.
23. Hunter JP, Marshall, RN. Effects of power and flexibility training on vertical jump technique. *Med Sci Sports Exerc* 2002; 34(3): 478-486.

24. Stockbrugger BA, Haennel RG. Contributing factors to performance of a medicine ball explosive power test: a comparison between jump and non jump athletes. *J Strength Cond Res* 2003; 17(4): 768-774.
25. Ramsbottom R, Brewer J, Williams C. A progressive shuttle run test to estimate maximal oxygen uptake. *Br J Sports Med* 1988; 22(4): 141–144.
26. Vaeyens R, Malina RM, Janssens M, et al. A multidisciplinary selection model for youth soccer: the Ghent Youth Soccer Project. *Br J Sports Med* 2006: 40(11): 928-934.
27. Gil S, Ruiz F, Irazusta A, et al. Selection of young soccer players in terms of anthropometric and physiological factors. *J Sports Med Phys Fitness* 2007; 47(1): 25-32.
28. Cumming GR, Garand T, Borysyk L. Correlation of performance in track and field events with bone age. *J Pediatr* 1972; 80(6): 970- 973.
29. Mohamed H, Vaeyens R, Matthys S, et al. Anthropometric and performance measures for the development of a talent detection and identification model in youth handball. *J Sports Sci* 2009; 27(3): 257-266.
30. Carling C, le Gall F, Reilly T, et al. Do anthropometric and fitness characteristics vary according to birth date distribution in elite youth academy soccer players. *Scand J Med Sci Sport* 2009; 19(1): 3-9.

Table 1: Characteristics of all players (*n*=81) selected to the Player Performance Pathway at the Under 13s, 14s & 15s age category

				MANOVA				MANCOVA Covariates		
	Under 13s (1)	**Under 14s (2)**	**Under 15s (3)**	**F**	**P**	η^2	**Pairwise**	**Age**	**PHV**	**PHV x Time**
Age (years)	13.62 ± 0.24	14.62 ± 0.24	15.62 ± 0.24	25256.19	***	0.997	1<2<3			
Age at PHV (years)	13.45 ± 0.54	13.53 ± 0.48	13.66 ± 0.45	31.239	***	0.281	1<2<3	***	***	***
Years from PHV	0.17 ± 0.59	1.09 ± 0.53	1.96 ± 0.51	2303.857	***	0.966	1<2<3		***	***
Height (cm)	171.2 ± 7.0	175.7 ± 6.2	178.6 ± 5.7	266.268	***	0.769	1<2<3		***	***
Sitting Height (cm)	86.4 ± 4.1	89.3 ± 3.4	91.1 ± 3.1	308.441	***	0.794	1<2<3	***	***	***
Body Mass (kg)	63.9 ± 9.8	71.1 ± 9.6	77.6 ± 9.8	467.187	***	0.854	1<2<3		***	
∑ Skinfolds (mm)	36.2 ± 15.0	39.3 ± 15.0	42.4 ± 16.0	15.893	***	0.166	1<3			
Vertical Jump (cm)	38.9 ± 5.0	41.3 ± 4.4	43.4 ± 5.1	57.415	***	0.418	1<2<3			*
MBT (m)	5.4 ± 0.6	5.9 ± 0.5	6.5 ± 0.6	209.969	***	0.724	1<2<3	**	***	*
10m Sprint (s)	1.96 ± 0.08	1.91 ± 0.08	1.87 ± 0.08	58.420	***	0.422	1>2>3			
20m Sprint (s)	3.36 ± 0.16	3.26 ± 0.14	3.18 ± 0.12	81.939	***	0.506	1>2>3			
30m Sprint (s)	4.70 ± 0.23	4.53 ± 0.20	4.41 ± 0.19	124.880	***	0.610	1>2>3			*
60m Sprint (s)	8.76 ± 0.54	8.39 ± 0.41	8.10 ± 0.41	121.072	***	0.602	1>2>3			*
Agility 505 Left (s)	2.56 ± 0.13	2.47 ± 0.10	2.44 ± 0.13	30.352	***	0.275	1>2>3			
Agility 505 Right (s)	2.57 ± 0.15	2.48 ± 0.11	2.47 ± 0.14	18.742	***	0.190	1>2,3			
Estimated $\dot{V}O_{2max}$ (ml.kg^{-1}.min^{-1})	47.9 ± 5.4	50.1 ± 4.7	51.3 ± 4.6	21.357	***	0.211	1<2<3			

*Note: MBT = Medicine Ball Chest Throw; * (p<0.05), ** (p<0.01), *** (p<0.001). The numbers in parentheses in column headings relate to the numbers used for illustrating significant (p<0.05) differences in the post-hoc analysis.*

Table 2: Characteristics of players selected to the Player Performance Pathway based on Playing Position at the Under 13s, 14s & 15s age categories

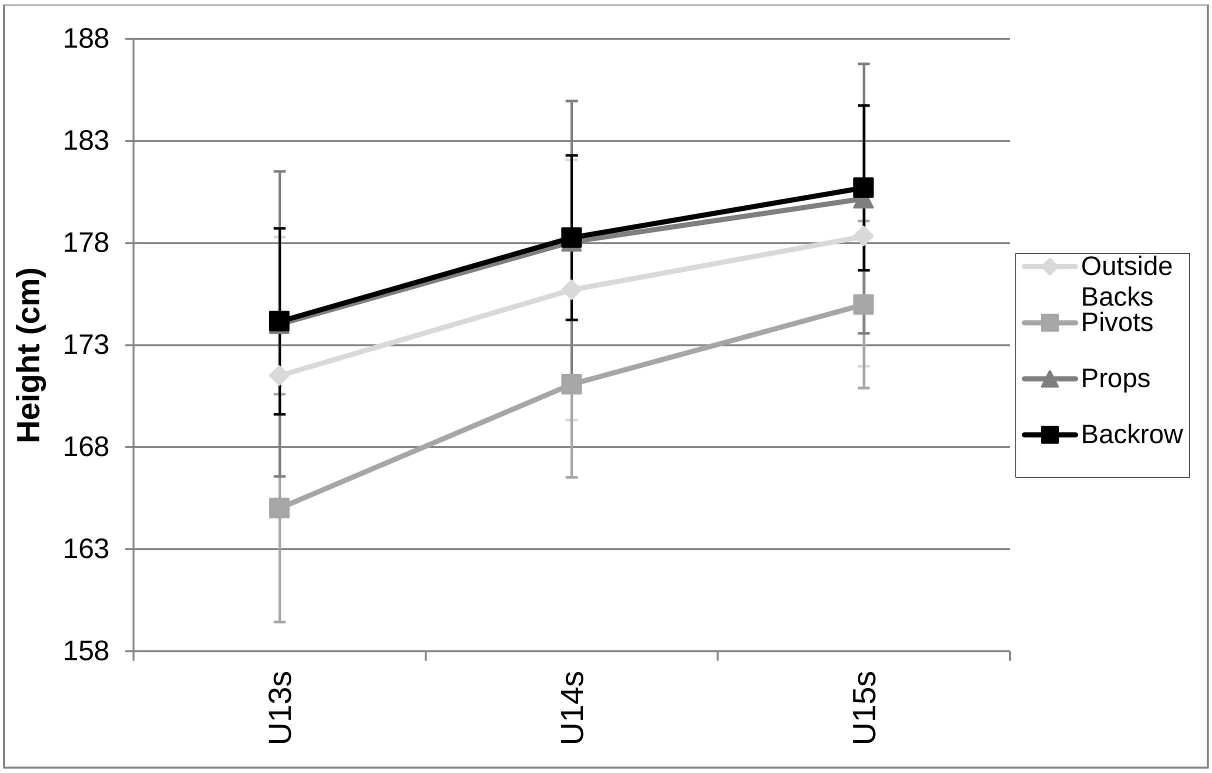
	Outside Backs (1)			**Pivots (2)**			**Props (3)**			**Backrow (4)**			**MANOVA**	**MANCOVA**
	U13s	**U14s**	**U15s**	**U13s**	**U14s**	**U15s**	**U13s**	**U14s**	**U15s**	**U13s**	**U14s**	**U15s**	**Pairwise**	**Pairwise**
Age (years)	13.66 ± 0.21	14.66 ± 0.21	15.66 ± 0.21	13.51 ± 0.31	14.51 ± 0.31	15.51 ± 0.31	13.64 ± 0.20	14.64 ± 0.20	15.64 ± 0.20	13.66 ± 0.20	14.66 ± 0.20	15.66 ± 0.20		
Age at PHV (years)	13.55 ± 0.51	13.64 ± 0.44	13.78 ± 0.46	13.79 ± 0.48	13.83 ± 0.47	13.93 ± 0.38	13.17 ± 0.53	13.28 ± 0.50	13.20 ± 0.53	13.22 ± 0.41	13.32 ± 0.35	13.47 ± 0.37	2<3,4	
Years from PHV	0.11 ± 0.53	1.02 ± 0.45	1.89 ± 0.46	-0.27 ± 0.63	0.69 ± 0.57	1.59 ± 0.45	0.47 ± 0.52	1.36 ± 0.48	2.19 ± 0.52	0.42 ± 0.43	1.33 ± 0.35	2.20 ± 0.38	2<3,4	
Height (cm)	171.5 ± 6.8	175.7 ± 6.4	178.3 ± 6.4	165.0 ± 5.6	171.1 ± 4.6	175.0 ± 4.1	174.0 ± 7.5	178.1 ± 6.9	180.2 ± 6.6	174.2 ± 4.6	178.3 ± 4.0	180.7 ± 4.0	2<3,4	
Sitting Height (cm)	86.2 ± 4.0	89.0 ± 3.3	90.8 ± 3.1	83.7 ± 4.3	87.4 ± 3.2	89.5 ± 2.9	87.8 ± 4.0	90.4 ± 3.5	91.8 ± 3.6	87.8 ± 3.1	90.7 ± 2.6	92.3 ± 2.3	2<4	
Body Mass (kg)	60.3 ± 6.1	67.9 ± 5.3	73.4 ± 6.3	55.5 ± 7.1	63.2 ± 7.9	70.0 ± 6.3	75.0 ± 8.8	81.5 ± 8.6	88.5 ± 9.3	67.2 ± 6.7	74.3 ± 7.4	80.7 ± 7.3	1,2<4<3	1,2<4<3
∑ Skinfolds (mm)	26.9 ± 5.8	32.2 ± 10.7	33.9 ± 8.9	31.9 ± 11.0	34.4 ± 13.9	35.6 ± 12.5	52.3 ± 18.6	53.2 ± 13.6	58.8 ± 16.5	39.0 ± 12.1	41.5 ± 14.3	45.3 ± 14.9	1<2,4<3	1<4<3; 2<3
Vertical Jump (cm)	42.4 ± 4.8	43.8 ± 3.7	46.1 ± 4.3	38.4 ± 4.5	40.0 ± 5.4	42.3 ± 5.7	35.9 ± 4.1	39.1 ± 4.0	40.3 ± 4.0	37.2 ± 4.0	41.1 ± 3.4	43.7 ± 4.8	1>2,3,4	1>3,4
MBT (m)	5.4 ± 0.5	5.9 ± 0.5	6.3 ± 0.6	5.0 ± 0.6	5.6 ± 0.6	6.2 ± 0.6	5.6 ± 0.8	6.1 ± 0.6	6.7 ± 0.7	5.6 ± 0.5	6.2 ± 0.4	6.8 ± 0.4	2<3,4	
10m Sprint (s)	1.92 ± 0.09	1.87 ± 0.07	1.83 ± 0.07	1.95 ± 0.09	1.92 ± 0.10	1.87 ± 0.07	2.01 ± 0.08	1.95 ± 0.07	1.91 ± 0.07	1.95 ± 0.06	1.90 ± 0.07	1.88 ± 0.08	1<3	1<3
20m Sprint (s)	3.28 ± 0.15	3.18 ± 0.11	3.10 ± 0.11	3.38 ± 0.16	3.28 ± 0.17	3.19 ± 0.10	3.47 ± 0.16	3.34 ± 0.11	3.25 ± 0.11	3.34 ± 0.12	3.26 ± 0.12	3.21 ± 0.11	1<3	1<3,4
30m Sprint (s)	4.57 ± 0.23	4.41 ± 0.15	4.28 ± 0.16	4.74 ± 0.24	4.56 ± 0.25	4.45 ± 0.17	4.85 ± 0.24	4.66 ± 0.17	4.48 ± 0.17	4.72 ± 0.15	4.54 ± 0.17	4.49 ± 0.17	1<2,3,4	1<3,4
60m Sprint (s)	8.44 ± 0.46	8.14 ± 0.30	7.80 ± 0.35	8.88 ± 0.56	8.49 ± 0.52	8.19 ± 0.35	9.10 ± 0.58	8.65 ± 0.35	8.30 ± 0.29	8.82 ± 0.39	8.39 ± 0.34	8.27 ± 0.39	1<2,3,4	1<2,3,4
Agility 505 L (s)	2.55 ± 0.12	2.43 ± 0.10	2.40 ± 0.11	2.57 ± 0.17	2.47 ± 0.07	2.45 ± 0.12	2.61 ± 0.12	2.59 ± 0.08	2.49 ± 0.17	2.55 ± 0.12	2.46 ± 0.10	2.42 ± 0.13	1,4<3	1,4<3
Agility 505 R(s)	2.55 ± 0.15	2.44 ± 011	2.41 ± 0.11	2.56 ± 0.16	2.47 ± 0.11	2.46 ± 0.14	2.62 ± 0.12	2.60 ± 0.08	2.55 ± 0.17	2.58 ± 0.13	2.47 ± 0.10	2.47 ± 0.14	1,2,4<3	1,2,4<3
Estimated $\dot{V}O_{2max}$ (ml.kg^{-1}.min^{-1})	50.8 ± 3.8	51.8 ± 5.1	51.8 ± 4.6	49.1 ± 3.7	50.1 ± 3.8	52.3 ± 3.4	42.4 ± 7.2	46.2 ± 4.3	48.0 ± 5.0	47.4 ± 3.4	50.8 ± 4.0	52.6 ± 4.1	1,2,4>3	1,2,4>3

Note: The numbers in parentheses in column headings relate to the numbers used for illustrating significant (p<0.05) differences in the pairwise analysis.

Supplementary Table 1: Characteristics of players selected to the Player Performance Pathway based on Selection Level at the Under 13s, 14s & 15s age categories

	National (*n*=19)			Regional (*n*=34)			National-Regional (*n*=23)			Regional-National (*n*=5)		
	U13s	**U14s**	**U15s**	**U13s**	**U14s**	**U15s**	**U13s**	**U14s**	**U15s**	**U13s**	**U14s**	**U15s**
Age (years)	13.61 ± 0.23	14.61 ± 0.23	15.61 ± 0.23	13.61 ± 0.27	14.61 ± 0.27	15.61 ± 0.27	13.66 ± 0.21	14.66 ± 0.21	15.66 ± 0.23	13.61 ± 0.23	14.61 ± 0.23	15.61 ± 0.23
Age at PHV (years)	13.40 ± 0.55	13.46 ± 0.45	13.62 ± 0.45	13.38 ± 0.50	13.44 ± 0.43	13.60 ± 0.47	13.60 ± 0.52	13.72 ± 0.45	13.81 ± 0.41	13.36 ± 0.79	13.62 ± 0.86	13.62 ± 0.77
Years from PHV	0.21 ± 0.68	1.15 ± 0.56	1.99 ± 0.55	0.22 ± 0.56	1.17 ± 0.48	2.01 ± 0.50	0.05 ± 0.56	0.93 ± 0.50	1.85 ± 0.44	0.25 ± 0.78	0.99 ± 0.82	1.99 ± 0.72
Height (cm)	171.7 ± 7.3	176.2 ± 6.6	178.6 ± 6.2	172.3 ± 6.7	177.2 ± 5.6	179.9 ± 5.4	168.9 ± 6.2	172.8 ± 5.3	176.2 ± 4.9	171.9 ± 11.4	176.9 ± 8.6	180.0 ± 7.6
Sitting Height (cm)	86.4 ± 4.3	89.5 ± 3.3	91.2 ± 3.2	86.8 ± 3.8	89.9 ± 3.2	91.5 ± 3.1	85.6 ± 4.0	88.3 ± 3.3	90.4 ± 2.7	86.9 ± 6.5	89.3 ± 5.2	91.2 ± 4.8
Body Mass (kg)	65.5 ± 9.4	73.3 ± 10.6	79.5 ± 9.5	65.0 ± 10.5	72.4 ± 9.5	78.7 ± 10.5	60.0 ± 8.5	66.4 ± 8.1	73.1 ± 7.9	67.6 ± 9.3	74.7 ± 5.9	83.3 ± 8.7
∑ Skinfolds (mm)	34.6 ± 9.6	38.8 ± 15.4	42.7 ± 15.4	38.8 ± 18.0	42.3 ± 16.4	44.6 ± 17.5	32.9 ± 13.9	33.7 ± 11.8	37.4 ± 12.9	40.6 ± 13.2	45.2 ± 11.7	48.3 ± 19.8
Vertical Jump (cm)	39.8 ± 4.7	40.6 ± 4.4	43.7 ± 5.2	38.0 ± 5.8	41.1 ± 4.4	42.2 ± 5.0	39.4 ± 4.5	42.4 ± 4.5	44.9 ± 5.1	39.4 ± 2.5	40.4 ± 5.0	43.4 ± 4.4
MBT (m)	5.5 ± 0.4	6.1 ± 0.5	6.5 ± 0.4	5.4 ± 0.7	5.9 ± 0.5	6.5 ± 0.7	5.3 ± 0.6	5.9 ± 0.5	6.6 ± 0.7	5.1 ± 0.8	6.0 ± 0.7	6.6 ± 0.5
10m Sprint (s)	1.93 ± 0.06	1.92 ± 0.07	1.87 ± 0.08	1.98 ± 0.09	1.92 ± 0.08	1.87 ± 0.07	1.92 ± 0.07	1.88 ± 0.10	1.87 ± 0.08	2.01 ± 0.11	1.91 ± 0.04	1.88 ± 0.10
20m Sprint (s)	3.29 ± 0.12	3.28 ± 0.14	3.17 ± 0.12	3.41 ± 0.16	3.28 ± 0.12	3.19 ± 0.12	3.31 ± 0.13	3.21 ± 0.16	3.17 ± 0.12	3.41 ± 0.21	3.24 ± 0.11	3.17 ± 0.16
30m Sprint (s)	4.61 ± 0.19	4.56 ± 0.22	4.43 ± 0.21	4.78 ± 0.23	4.56 ± 0.17	4.42 ± 0.18	4.63 ± 0.22	4.47 ± 0.23	4.39 ± 0.19	4.81 ± 0.32	4.50 ± 0.19	4.39 ± 0.19
60m Sprint (s)	8.54 ± 0.38	8.44 ± 0.45	8.17 ± 0.49	8.95 ± 0.55	8.44 ± 0.35	8.13 ± 0.36	8.65 ± 0.51	8.28 ± 0.45	8.04 ± 0.40	8.76 ± 0.81	8.30 ± 0.51	7.96 ± 0.39
Agility 505 L (s)	2.52 ± 0.11	2.44 ± 0.10	2.44 ± 0.11	2.59 ± 0.13	2.50 ± 0.12	2.43 ± 0.16	2.54 ± 0.14	2.46 ± 0.10	2.44 ± 0.11	2.64 ± 0.16	2.49 ± 0.04	2.50 ± 0.14
Agility 505 R(s)	2.57 ± 0.13	2.47 ± 0.12	2.50 ± 0.15	2.60 ± 0.16	2.50 ± 0.12	2.47 ± 0.16	2.52 ± 0.15	2.46 ± 0.10	2.43 ± 0.12	2.60 ± 0.19	2.50 ± 0.10	2.51 ± 0.14
Estimated $\dot{V}O_{2max}$ (ml.kg^{-1}.min^{-1})	47.8 ± 5.5	50.8 ± 4.4	52.2 ± 3.2	46.7 ± 6.3	49.2 ± 5.4	50.6 ± 5.6	50.0 ± 3.5	50.8 ± 4.4	51.7 ± 4.1	46.8 ± 2.3	49.4 ± 3.1	50.2 ± 3.5

Figure 1: Age Category against (a) Height and (b) Estimated for $\dot{V}O_{2max}$ for different Playing Positions



(b)