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2 **A longitudinal evaluation of anthropometric and fitness characteristics in junior rugby league**

3 **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 $\dot{V}O_{2\max}$ ($p < 0.05$). 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 performance³. 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 performance⁴. Therefore, when differentiating between an athlete's adolescent performance level and the potential for progression into adulthood, longitudinal studies are essential³.

Longitudinal studies in wider youth sport contexts have examined anthropometric and performance characteristics over time⁵, changes in characteristics over a playing season⁶ and the relationships between maturation and performance⁷. 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-selected⁸ and elite / sub-elite⁹ 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 power¹⁰. 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

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

11 Height and sitting height were measured to the nearest 0.1cm using a Seca Alpha stand. Body
12 mass, wearing only shorts, was measured to the nearest 0.1kg using calibrated Seca alpha (model 770)
13 scales. Sum of four skinfolds was determined by measuring four skinfold sites (biceps, triceps,
14 subscapular, suprailiac) using calibrated Harpenden skinfold callipers (British Indicators, UK) in
15 accordance with Hawes and Martin²⁰.

16 An age at PHV prediction equation was used to assess maturation²¹. This prediction method
17 used a gender-specific multiple regression equation including stature, sitting height, leg length, body
18 mass, chronological age and their interactions to estimate age at PHV²². Years from PHV was
19 calculated by subtracting age at PHV from chronological age.

20 Fitness tests were performed to determine lower and upper body power, speed, change of
21 direction speed and estimated $\dot{V}O_{2max}$. Prior to testing, a standardised warm up was conducted and all
22 players received full instructions and demonstrations of the assessments. Lower body power was
23 assessed using the vertical jump test (centimetres) measured using a Takei vertical jump metre (Takei
24 Scientific Instruments Co. Ltd, Japan). A countermovement jump with hands positioned on the hips
25 was used with jump height measured to the nearest cm from the highest of three attempts²³. A 2kg
26 medicine ball (Max Grip, China) chest throw (metres) was used to measure upper body power²⁴.
27 Participants were instructed to throw the ball horizontally as far as possible while seated with their

1 back against a wall and legs extended straight out in front of their body. Distance was measured to the
2 nearest 0.1m from the wall to where the ball landed with the highest of three trials used as the score.
3 Sprint speed (seconds) was assessed over 10m, 20m, 30m and 60m using timing gates (Brower Timing
4 Systems, IR Emit, USA). Participants were positioned from a standing start 0.5m behind the initial
5 timing gate and were instructed to start in their own time. Times were recorded to the nearest 0.01s
6 from the best of three attempts. Change of direction speed (seconds) was assessed using the agility 505
7 test ¹². Participants were positioned 15m from a turning point with timing gates positioned 10m from
8 the start point (5m from the turn point). Players accelerated from the starting point, through the timing
9 gates, turned on the 15m line and ran as quickly as possible back through the gates (i.e., 15m sprint,
10 turn, 5m sprint). Left and right foot turns were used, with three alternate attempts on each foot. Times
11 were recorded to the nearest 0.01s. Estimated $\dot{V}O_{2\max}$ (ml.kg⁻¹.min⁻¹) was predicted using the
12 multistage fitness test ²⁵. Players were required to shuttle run 20m, keeping to a series of beeps of
13 increasing speed until they reached volitional exhaustion. Regression equations were used to estimate
14 $\dot{V}O_{2\max}$ from the level reached during the multistage fitness test ²⁵.

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

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Results

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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

1 showing all variables significantly improved across the three age categories except for sum of four
2 skinfolds and agility 505 right.

3 ***Insert Table 1 near here****

4 MANCOVA analyses, controlling for age and maturation, found no significant main effect for
5 annual-age group ($F_{2, 80} = 0.818, p=0.713, \eta^2=0.310$) or any individual variable. MANCOVA analyses
6 identified significant overall main effects for the covariates of chronological age ($F_{14, 65} = 25.4,$
7 $p<0.001, \eta^2=0.85$), maturation ($F_{14, 65} = 77.1, p<0.001, \eta^2=0.94$) and maturation x time interaction ($F_{28,$
8 $s_1 = 2.8, p=0.001, \eta^2=0.61$). Table 1 shows the covariate relationships between chronological age,
9 maturation and maturation x time against each anthropometric and fitness characteristic. No
10 significant overall effect for chronological age x time or any individual variable was found.

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

24 ***Insert Table 2 and Figure 1 near here****

25 MANCOVA analyses identified a significant overall effect for playing position ($F_{42, 185} = 2.9,$
26 $p<0.001, \eta^2=0.40$) with significant differences found between positions for all variables except age at
27 PHV, height, sitting height and medicine ball throw. Pairwise comparisons found ‘Outside-Backs’ and

1 'Pivots' to be lighter than 'Backrow' who were lighter than 'Props' with similar findings shown for
2 skinfolds. 'Outside-Backs' outperformed 'Props' and 'Backrow' for the vertical jump, 20m, 30m and
3 60m sprint. 'Props' were again the worst performing position for agility 505 and estimated $\dot{V}O_{2max}$
4 tests. MANCOVA analyses showed no overall significant position x time interaction ($F_{84, 145} = 0.4$,
5 $p=0.47$, $\eta^2=0.37$) except for vertical jump ($F_{2, 80} = 2.3$, $p=0.040$, $\eta^2=0.08$).

6 For selection level (See Supplementary Table 1), MANOVA analyses identified a significant
7 overall main effect ($F_{45, 188} = 1.5$, $p=0.025$, $\eta^2=0.27$), however no significant differences were found for
8 any individual variable. No significant overall main effects were found for selection level x time ($F_{90,$
9 $145} = 1.0$, $p=0.441$, $\eta^2=0.38$), however interactions were evident for 20m ($F_{2, 80} = 2.4$, $p=0.034$, $\eta^2=0.08$)
10 and 30m ($F_{2, 80} = 3.0$, $p=0.008$, $\eta^2=0.11$) sprint. These results found sprint times changed between
11 selection levels during the two year period (e.g., 30m sprint - Regional-National players were the
12 slowest at Under 13s but the fastest at Under 15s). MANCOVA analyses identified a significant
13 overall main effect for selection level ($F_{42, 185} = 1.6$, $p=0.019$, $\eta^2=0.26$) but again no significant effects
14 were found for any particular variable. Significant interactions for selection level x time were apparent
15 for 20m ($F_{2, 80} = 2.6$, $p=0.019$, $\eta^2=0.10$), 30m ($F_{2, 80} = 3.5$, $p=0.003$, $\eta^2=0.12$) and 60m ($F_{2, 80} = 2.3$,
16 $p=0.03$, $\eta^2=0.09$) sprint.

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Discussion

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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 analyses¹³ 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

1 the adolescent period, which is limited within previous research in rugby league as well as other youth
2 sport contexts.

3 Since the 1970s maturation has been found to be a better predictor of performance than
4 chronological age²⁸. Although this relationship exists, many studies examining characteristics of
5 adolescent athletes have not explicitly considered maturation in their analyses until recently^{26,29}. Our
6 findings have demonstrated strong relationships between maturation with anthropometric
7 characteristics (e.g., height; $\eta^2 = 0.535$) and medicine ball throw ($\eta^2 = 0.401$). Furthermore, significant
8 time by maturation interactions were evident for anthropometric and fitness characteristics (e.g.,
9 medicine ball throw; sprint speed) highlighting the importance of considering maturation in the
10 evaluation of performance within adolescent populations.

11 Significant longitudinal differences were identified between playing positions across the two
12 years with the earlier maturing 'Props' being the worst performing position (e.g., agility, estimated
13 $\dot{V}O_{2max}$) in both MANOVA and MANCOVA analysis. These findings are consistent with previous
14 cross-sectional observations¹³ and prior research in junior^{10,11} and senior¹⁵ rugby league. This
15 provides further evidence, within a longitudinal sample, that although 'Props' are significantly taller
16 and heavier compared to other playing positions they actually underperform on a range of fitness
17 measures. This finding highlights that physical size is an important contributor towards selection
18 within junior representative levels. However, it seems coaches do not appear to consider the potential
19 detrimental effects that some aspects of size (e.g., body fat) may have upon the immediate and long-
20 term development of performance.

21 Findings identified no significant overall playing position by time interaction, demonstrating
22 anthropometric and fitness characteristics improved at a consistent rate between playing positions.
23 However, interactive effects were identified for height, vertical jump and estimated $\dot{V}O_{2max}$. Height
24 increased the most amongst the 'Pivots' (i.e., 'Pivots' = 9.97 cm; 'Outside-Backs' = 6.87 cm; 'Props'
25 = 6.15 cm; 'Backrow' = 6.54 cm) with data reflecting the 'Pivots' as typically later maturing players.
26 Although opportunities were available for selection for later maturing 'Pivots', these opportunities
27 may not have been available in other positions, with players potentially not selected based on their

1 maturation and size. This finding demonstrates the importance of measuring height longitudinally with
2 it important that coaches and/or scouts do not exclude players from selection and development
3 opportunities based on their height during adolescence. For vertical jump and estimated $\dot{V}O_{2\max}$,
4 ‘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
5 ‘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
6 years. Although the mechanisms behind these improvements are not known (e.g., training status),
7 these findings suggest that the ‘Props’ and ‘Backrow’ positions improved lower body power and
8 estimated $\dot{V}O_{2\max}$ the most during this adolescent period, with such improvement possibly necessary in
9 order to meet the demands of the game and be consistently selected to the pathway. These findings
10 open up several questions for coaches (e.g., how much did a player improve his vertical jump between
11 under 14s and 15? How does this compare with the team and/or national average?) for monitoring
12 players longitudinally on an individual basis during the adolescent period and beyond.

13 Identifying variables that distinguish between different selection levels within youth sport has
14 been common in prior research^{1,27,29} but is limited within longitudinal designs^{8,9}. The current findings
15 showed significant overall main effects for selection level but no significant differences were
16 identified for any individual variable. This highlights that a combination of anthropometric and fitness
17 characteristics may have contributed toward selection at each representative level across the two years.
18 These results differ from previous cross-sectional research¹⁴ whereby National player’s significantly
19 outperformed Regional players for sum of four skinfolds and fitness characteristics. This contradiction
20 may have occurred due to the smaller sample size used in the present study compared to previous
21 cross-sectional analyses (National = 302; Regional = 870¹⁷), and due to the creation of two additional
22 selection levels (i.e., National-Regional; Regional-National) but demonstrates that success at higher
23 levels is dependent on a wide range of well-developed physical qualities.

24 Time by selection level interactions found significant effects for 20m, 30m and 60m sprint
25 performance with differing improvements in sprint performance between the Under 13 and 15 age
26 categories demonstrated (e.g., 60m sprint - National = -0.37; Regional = -0.82; National-Regional = -
27 0.61; Regional-National = -0.80 s). These findings highlight that players who moved up in selection

1 (i.e., Regional-National) were the quickest in terms of sprint at the Under 15s (i.e., National = 8.17;
2 Regional = 8.13; National-Regional = 8.04; Regional-National = 7.96 s) and significantly improved
3 sprint speed during the two year period. This may have contributed to an increased likelihood of
4 selection to the National level. To add, these findings also demonstrate the variation and change in
5 performance that can occur between individuals during adolescence, again showing potential value in
6 monitoring individual changes longitudinally ³.

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

22 The current findings have implications for longitudinal monitoring of performance within
23 talent identification and development pathways in all youth sports. The large variability in the degree
24 of change in characteristics that occurred in the current junior rugby league players questions the use
25 of one-off physical assessments of junior athletes during adolescence ³⁰. Instead, regularly monitoring
26 the change in the development of characteristics may be more appropriate, with the current
27 longitudinal data providing average yearly changes in anthropometric and fitness characteristics. This

1 data could help track the development and progression of players' characteristics on a yearly basis
2 throughout adolescence. The interaction between playing position and time for height demonstrates
3 the variation in growth during adolescence. Coaches and scouts should understand the variation in
4 growth and maturation of junior players and not (de)select players. The present findings show earlier
5 maturing players (i.e., 'Props') are outperformed on fitness measures by later maturing players (i.e.,
6 'Outside-Backs', 'Pivots') demonstrating relationships between selection, size and performance during
7 adolescence. Current selection biases most likely occur as a result of the short term requirements (e.g.,
8 winning instead of longer term development) employed by coaches within youth sport. Therefore,
9 talented players identified at early ages may in fact be mistaken for early maturation and advanced
10 size, effectively discounting later maturing individuals who may 'catch-up' on particular fitness or
11 performance measures. National governing bodies and professional clubs should focus their attentions
12 on long term development, instead of early (de)selection of players that are predominantly used at the
13 moment. Potentially, delaying selection until late adolescence may reduce the impact of maturation
14 and physical qualities on selection within youth sports.

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Conclusion

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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 development³. 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

1 programmes should consider more regular long-term monitoring approaches, incorporating and
2 evaluating both age and maturation.

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Practical Implications

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- Coaches should understand the development of anthropometric and fitness characteristics amongst junior rugby league players aged 13-15 years.

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- Playing position and selection level should be considered in the evaluation of player characteristics over time.

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- 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.

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- Maturation is related to anthropometric, upper body strength and speed measures during adolescence and should therefore be considered in player evaluations.

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- Talent identification and development programmes should focus on an athlete's potential for future development instead of current adolescent performance.

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

	Under 13s (1)	Under 14s (2)	Under 15s (3)	F	MANOVA			MANCOVA Covariates		
					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

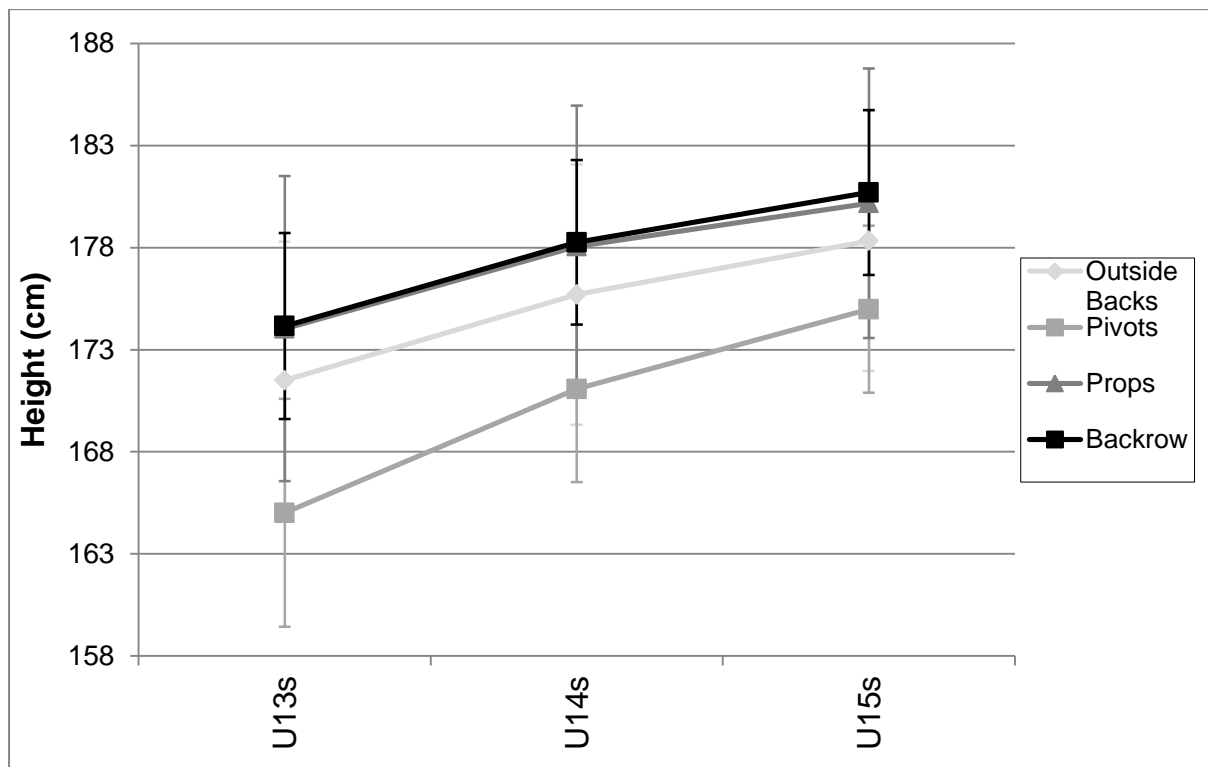
	Outside Backs (1)			Pivots (2)			Props (3)			Backrow (4)			MANOVA	MANCOVA
	U13s	U14s	U15s	U13s	U14s	U15s	U13s	U14s	U15s	U13s	U14s	U15s	Pairwise	Pairwise
Age (years)	13.66 ± 0.21	14.66 ± 0.21	15.66 ± 0.21	13.51 ± 0.31	14.51 ± 0.31	15.51 ± 0.31	13.64 ± 0.20	14.64 ± 0.20	15.64 ± 0.20	13.66 ± 0.20	14.66 ± 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 ± 0.11	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 (<i>n</i> =19)			Regional (<i>n</i> =34)			National-Regional (<i>n</i> =23)			Regional-National (<i>n</i> =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)

