Till, K., Morley, D., O'Hara, J. et al. (2017) A retrospective longitudinal analysis of anthropometric and physical qualities that associate with adult career attainment in junior rugby league players. *Journal of Science and Medicine in Sport,* DOI: 10.1016/j.jsams.2017.03.018

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PII:	S1440-2440(17)30359-6
DOI:	http://dx.doi.org/doi:10.1016/j.jsams.2017.03.018
Reference:	JSAMS 1495
To appear in:	*Journal of Science and Medicine in Sport*
Received date:	29-10-2016
Revised date:	9-2-2017
Accepted date:	23-3-2017

Please cite this article as: Till Kevin, Morley David, O'Hara John, Jones Ben L, Chapman Chris, Beggs Clive B, Cooke Carlton, Cobley Stephen.A retrospective longitudinal analysis of anthropometric and physical qualities that associate with adult career attainment in junior rugby league players.*Journal of Science and Medicine in Sport* http://dx.doi.org/10.1016/j.jsams.2017.03.018

A retrospective longitudinal analysis of anthropometric and physical qualities that associate with adult career attainment in junior rugby league players

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Abstract word count: 253

Word count: 2,886

No. of Tables: 3

No. of Figures: 0

Abstract

Objectives: To retrospectively compare the longitudinal physical development of junior rugby league players between the Under 13 and 15 age categories in relation to their adult career attainment outcome.

Design: Retrospective longitudinal design

Methods: Fifty-one former junior rugby league players were retrospectively grouped according to their career attainment outcome as adults (i.e., amateur, academy or professional). As juniors, players undertook a physical testing battery on three consecutive annual occasions (Under 13s, 14s, 15s) including height, body mass, sum of four skinfolds, maturation, vertical jump, medicine ball chest throw, 10-60 m sprint, agility 505 and estimated $\dot{V}O_{2\max}$.

Results: Future professional players were younger than academy players with a greater estimated $\dot{V}O_{2\max}$ compared to amateur players. Between Under 13s and 15s, professional players (5.8±2.5 cm) increased sitting height more than amateur (4.4±2.1 cm) and academy (4.1±1.4 cm) players. Logistic regression analyses demonstrated improvements in sitting height, 60m sprint, agility 505 and estimated $\dot{V}O_{2\max}$ between amateur and professional players with a high degree of accuracy (sensitivity = 86.7%, specificity = 91.7%).

Discussion: Findings demonstrate that the development of anthropometric, maturational and physical qualities in junior rugby league players aged between 13 and 15 years contributed to adulthood career attainment outcomes. Results suggest that age, maturity and size advantages, commonly observed in adolescent focused talent identification research and practice, may not be sensitive to changes in later stages of development in order to correctly identify career attainment. Practitioners should identify, monitor and develop physical qualities of adolescent rugby league players with long-term athlete development in mind.

KeyWords: Talent identification, talent development, maturation, adolescence

Introduction

Sport national governing bodies and professional clubs invest considerable resources (e.g., time, finances, staff) to identify and develop young talented athletes in the hope that they may become the professionals of tomorrow [1]. Many organisations implement talent identification practices designed to recognise current participants who have the potential to excel in particular sport contexts [2]. This has led to an increased research interest in the process of talent identification over the last decade, with research in this field having been undertaken in a wide variety of sports (e.g., rugby union[3], rugby league [4], Australian Rules Football [AFL] [5]). Although talent identification research and practice is now common, it is often limited by the cross-sectional nature of the methodologies used [2]. While these methodologies have merit, they tend to assume that current adolescent performance can be used to predict outcomes in adulthood, an approach which fails to consider the dynamic nature of athlete development, which is impacted upon by factors such as growth and maturation [2,6,7].

Longitudinal and retrospective research methodologies are two approaches that can address the limitations of cross-sectional methods and detect athlete change over time [8]. Longitudinal designs involve data collection on the same individuals for two or more time periods [9] to track and evaluate performance change. Longitudinal approaches have been utilized in rugby league [10] and rugby union [11] to account for the role developmental factors (e.g., growth and maturation) play in physical performance during adolescence. For instance, Till et al. [10], demonstrated large inter-individual differences and changes in physical performance characteristics of 13-15 year old athletes; with later maturing players demonstrating greater performance improvement than earlier maturing athletes (e.g., 60m sprint, Early = -0.46s; Later = -0.85s [10]). These findings highlight the value of longitudinal tracking in understanding physical development variability and dynamics in youth athletes.

Retrospective designs use an athlete's future career attainment and retrospectively analyse individuals cross-sectional data from an earlier timepoint [12]. This methodology allows researchers and practitioners to identify characteristics, potentially within adolescent athletes, that may be important for future sporting success [12]. Previously, in talent development research, such designs have helped determine the physical characteristics of adolescent athletes associated with adult career attainment (i.e., amateur or professional) in soccer [13,14] and rugby league [12,15]. For example, Till et al. [12] reported that future professional rugby league players had lower sum of skinfolds and advanced fitness characteristics at 13-15 years of age compared to those who attained amateur status with no differences in characteristics observed between future professional and academy level players.

In the emerging research field of talent identification and athlete development, any study, which combines longitudinal and retrospective methodological approaches, should in theory yield new insights that are important. Although prior studies have implemented longitudinal (e.g., [7,10]) and retrospective (e.g., [12,15]) research methodologies, no study to the authors knowledge has combined these two methods to evaluate the developmental changes in adolescent athletes that are associated with future career attainment outcomes. Therefore, the aim of this study was to retrospectively compare the longitudinal physical development of adolescent athletes (i.e., junior rugby league players) between the Under 13 and 15 age groups in relation to their long-term career attainment outcome.

Methods

Fifty-one male junior rugby league players (mean age 13.59±0.25 years at Under 13s) who were selected to the Rugby Football League's former talent identification and development programme, the Player Performance Pathway (PPP; see [16] for a detailed description), participated in the study. Players were selected to the PPP by rugby coaches using subjective decisions based on current performance and future potential [16]. Players in the present study were selected to the PPP on three consecutive annual occasions in 2005 (Under 13s), 2006 (Under 14s) and 2007 (Under 15s). All players were then subsequently tracked in relation to their career attainment in July 2008 and August 2015. By 2008, participants were classified as either: (a) selected to join a professional rugby league club's academy; (b) continued to play amateur rugby league; or (c) no longer participating in rugby league. By 2015, players were potentially able to progress into playing senior professional rugby league within the European Super League. Consistent with previous investigations [12,15], for the purposes of this study, players were classified into three career attainment outcomes, (1) not selected to an academy squad and classed as 'amateur' (n=12); (2) selected to a professional 'academy' but did not play Super League (n=24), and (3) played 'professional' rugby league by the 2015 Super League season (n=15).

All participants were assessed on their physical qualities in July 2005, 2006 and 2007. All protocols received institutional ethics approval with consent provided by both players and parents/guardians. The physical assessment included standard anthropometry (height, sitting height, body mass, sum of 4 skinfolds), maturation (age at peak height velocity; PHV) and fitness (lower and upper body power, speed, change of direction speed, estimated $\dot{V}O_{2\max}$) characteristics. Intraclass correlation coefficients and typical error measurements for each measure have been presented previously [4,17] and all measurement reliability and objectivity conformed to published expectations [18].

Height, sitting height, body mass and sum of four skinfolds were collected in the morning in a fasted state with participants wearing only shorts. Height and sitting height were measured to the nearest 0.1cm using a Seca Alpha stadiometer. Body mass was measured to the nearest 0.1kg using calibrated Seca alpha (model 770) scales. The sum of four skinfold thickness was determined using calibrated Harpenden skinfold callipers (British Indicators, UK) with procedures in accordance with Hawes & Martin [19]. An age at PHV prediction equation was used to measure maturity status [20]. Years from PHV (YPHV) were calculated by subtracting age at PHV from chronological age.

A standardised warm-up was conducted prior to fitness testing with tests performed in the following order. Running speed was assessed over 10m, 20m, 30m and 60m using timing gates (Brower Timing Systems, IR Emit, USA) recorded to the nearest 0.01s from three trials, separated by 3 minutes rest. Change of direction speed was assessed using the agility 505 test [21]. Three attempts were performed on each foot with times recorded to the nearest 0.01s. A vertical jump test was used to assess lower body power using a Takei vertical jump metre (Takei Scientific Instruments Co. Ltd, Japan). A counter-movement jump was performed with hands positioned on hips, with jump height measured to the nearest cm from three trials separated by 30 seconds rest [22]. Upper body power was assessed using the 2kg medicine ball (Max Grip, China) chest throw [23]. Participants were seated with their backs against a wall and were instructed to throw the ball horizontally as far as possible. Distance was measured to the nearest 0.1cm from the wall to where the ball landed with the furthest of three trials used as the score. Maximal oxygen uptake ($\dot{V}O_{2max}$) was estimated using the multistage fitness test [24]. Players were required to run 20m shuttles keeping in time with a series of beeps. Player's running speed increased progressively until they reached volitional exhaustion. Regression equations were used to estimate $\dot{V}O_{2max}$ from the level reached during the multistage fitness test.

Mean and standard deviation (SD) scores were calculated for all dependent variables according to age category and career attainment outcome. A repeated measures multivariate analysis of variance test (MANOVA) was initially conducted to identify significant main effects for time between age category, for group according to career attainment outcome, and whether an age category x career attainment outcome interaction existed. Bonferroni pairwise comparisons were then conducted to examine univariate effects between each dependent variable. Partial eta squared (η^2) effect sizes were also calculated and interpreted as 0.01 = small, 0.06 = medium and 0.14 = large [25]. All analyses were conducted with SPSS version 21.0 with significance levels set at $p<0.05$.

To assess the physical qualities that best predicted career attainment outcome, binomial logistic regression analysis was performed using the changes in physical qualities between the age categories, with career attainment outcome coded as a binary variable (1 = Professional, 0 = Amateur). These groups were selected because binomial logistic regression can only cope with two groups, and these groups represented opposite ends of the player spectrum. Analysis was performed using in-house algorithms written in 'R' (open source statistical software), with all study variables included in the initial model. Variable selection was undertaken using a step-wise approach, with variables excluded if non-significant. The general applicability of the predictive logistic regression models was tested using 10-fold cross-validation. To maximize sensitivity (true positive rate) and specificity (true negative rate), receiver operating characteristic (ROC) analysis was used to calculate optimum cut-off values.

Results

Table 1 shows the physical qualities at each age category according to career attainment outcome. Table 2 shows the repeated measures MANOVA univariate analyses and pairwise comparison results according to age category, career attainment outcome and the age category x career attainment outcome interactions.

Insert Table 1 near here

Insert Table 2 near here

Repeated measures MANOVA analyses identified significant main effects for age category (F=6120.7, $p<0.001$, $\eta^2=1.00$) and all dependent variables. Pairwise comparisons showed all variables significantly improved across the three annual-age categories except sum of four skinfolds and agility 505 left and right.

For career attainment outcome, analyses identified significant main effects (F=2.12, p=0.005, $\eta^2=0.48$) with significant differences found for chronological age and estimated $\dot{V}O_{2\max}$. Pairwise comparisons found professional players were younger than academy players, and professional and academy players had a greater estimated $\dot{V}O_{2\max}$ than amateur players across the three age categories.

For age category x career attainment outcome interactions, analyses identified significant main effects (F=1.66, p=0.049, $\eta^2=0.72$) with significant differences found for sitting height, 10m and 20m sprint. Greater improvements in sitting height were found for professional (5.8±2.5 cm) compared to amateur (4.4±2.1 cm) and academy (4.1±1.4 cm) between Under 13s and 15s. For 10m and 20m sprint, professional (-0.09±0.07; -0.16±0.10 s) and amateur (-0.08±0.06; -0.19±0.13 s) players demonstrated greater improvements than academy (-0.05±0.06; -0.09±0.11 s) players.

Logistic regression analysis revealed that physical changes between Under 13s and 14s in YPHV (β=-34.320, p=0.029), sitting height (β=4.564, p=0.025) and body mass (β=1.309, p=0.031) contributed to a predictive model (LR model 1) with a cross-validation accuracy of 88.9%. Between Under 14s and 15s, 10m sprint (β=22.225, p=0.025) contributed to a model (LR model 2) with 66.7% cross-validation predictive accuracy. Between Under 13s and 15s, sitting height (β=-0.896, p=0.024), 60m sprint (β=-6.199, p=0.032), agility 505 left (β=--8.060, p=0.045) and estimated $\dot{V}O_{2\max}$ (β=-0.431, p=0.025) contributed to a model (LR model 3) with 81.5% cross-validation predictive accuracy. Table 3 shows the results of the ROC analysis for the respective logistic regression models. The models were able to distinguish with a high degree of accuracy at the Under 13s to 14s (sensitivity = 93.3%, specificity = 91.7%; $p<0.001$) and Under 13 to 15s (sensitivity = 86.7%, specificity = 91.7%; $p<0.001$) between the future professional and amateur players.

Insert Table 3 near here

Discussion

Originality in the current study is highlighted by the longitudinal, retrospective research design that allowed for changes in physical qualities between Under 13s-15s to be evaluated against adult career attainment outcome. The longitudinal development of physical qualities in a sample of junior rugby league players selected to a talent development program on three consecutive occasions (i.e., Under 13s, 14s, 15s) was related to adult career attainment outcome (i.e., amateur, academy or professional). Findings demonstrated that future professional players were chronologically younger than academy players, and had a greater estimated $\dot{V}O_{2max}$ than amateur players. Future professional players increased sitting height more than academy and amateur players. Further, amateur and professional players improved 10m and 20m sprint performance more than academy players. Logistic regression analysis demonstrated that anthropometric and maturational characteristics differentiated between career attainment outcome between Under 13s and 14s age categories and 10m sprint between Under 14s and 15s. The development of sitting height, speed, change of direction speed and estimated $\dot{V}O_{2max}$ differentiated between career attainment outcome between Under 13s and 15s.

When physical qualities were compared between career attainment level across the Under 13s-15s age categories, significant differences were found for chronological age and estimated $\dot{V}O_{2max}$. Future professional players were found to be younger, both chronologically and relatively, than the future academy players, supporting the findings of previous research in rugby league [15], rugby union [26] and ice hockey [27]. Furthermore, this suggests that relatively younger athletes selected to a talent identification and development programme during adolescence tend to achieve greater success in future career attainment. As such, this suggests that perceived advantages (e.g., selection opportunities associated with increased age within chronological annual-age groups) may not be advantageous for longer-term future career attainment in a sport context.

Estimated $\dot{V}O_{2\max}$ was found to be greater in academy and professional players compared to amateur players across the Under13-15s age categories; a finding consistent with previous cross-sectional [4] and retrospective [12,15] research in rugby league. Such findings suggest that enhanced aerobic power during adolescence may contribute to an increased career attainment in rugby league. Interestingly, unlike previous cross-sectional [4], longitudinal [10] and retrospective [12,15] studies in rugby league, no other physical qualities (e.g., vertical jump, speed, agility 505) demonstrated a significant difference according to career attainment level. The reduced sample size, compared to previous investigations [12,15] and large inter-player variability may have led to no significant differences in these physical qualities.

Findings also demonstrated that sitting height improved to a greater extent in professional, compared to amateur and academy players. This suggests that future professional players were more likely to mature later due to the relationship between maturational status and development of sitting height [20,28]. This is further supported by the moderate effects (although not significant) found for changes in height and body mass, with greater gains in professional than amateur players (i.e., height, professional = 9.0, amateur = 6.7 cm; body mass, professional = 15.7, amateur = 12.0 kg). These findings are also consistent with prior rugby league [15] and soccer [14] studies, highlighting how earlier maturation in adolescence does not necessarily translate into advanced career attainment outcomes, irrespective of selection to a talent identification and development programme. Later maturers may in fact have a greater likelihood of career attainment success, possibly due to greater potential for improvement [7,10] and/or due to the required development of other technical, tactical or psychological factors in more challenging environments [29]. The assessment of anthropometric characteristics and maturation status within adolescent players could be considered to allow potential dispensation criteria to supplement age grade grouping to provide greater participation and selection opportunities for later maturing players as proposed in rugby union [30].

Recent research in AFL [5] has used logistic regression analysis to determine the characteristics important for talent identification. Findings from our application of logistic regression analysis suggest that the development of anthropometric and maturational characteristics is highly influential in future career attainment in rugby league. Using a combination of logistic regression and ROC analysis, we were able to use changes in YPHV, sitting height and body mass between Under 13s and 14s to correctly identify 93.3% of the future professionals and 91.1% of amateur players. Thus, the development of body size in players selected into the talent identification programme seems important for career attainment, particularly between 13 and 14 years of age which is the timing of maturation [28]. 10 m speed improvement was identified as the only variable discriminating professional and amateur players between Under 14 and 15 age categories with a sensitivity and specificity score suggest that it may be an important variable. However, between Under 13s and 15s the development of sitting height, 60m sprint, agility 505 and estimated VO_{2max} all contributed to logistic regression model and accurately distinguished between future professional and amateur players. This analysis provides evidence that the improvement of a range of physical qualities contributes to successful career attainment in rugby league as previously suggested [4,12,15] but may be limited by the collinearity of some measures. On this basis, practitioners should aim to monitor maturation, alongside the monitoring and development of anthropometric and physical qualities, within adolescent rugby league players to support talent identification and development practices.

Conclusions

In summary, findings showed that physical qualities and the rate of development in anthropometric, maturational and physical qualities of junior rugby league players aged between 13 and 15 years contributed to future career attainment (i.e., professional levels). Younger and later maturing individuals selected to the talent development programme between Under 13s and 15s age groups appeared to have greater likelihood of attaining professional levels. Likewise, players with advanced estimated $\dot{V}O_{2\max}$, may have a greater likelihood of higher career attainment outcome. The development of sitting height, speed, change of direction speed and estimated $\dot{V}O_{2\max}$ during adolescence appear to be important factors for future career attainment outcomes and practitioners should identify, monitor and develop such physical qualities of adolescent rugby league players with long-term athlete development in mind.

Practical Implications

- Practitioners should understand that advanced age and earlier maturation within chronological annual-age groups might not be an accurate indicator of longer-term future career attainment.
- Advanced physical qualities, particularly estimated $\dot{V}O_{2\max}$, of adolescent rugby league players may contribute to long-term career attainment, and could be more carefully considered in talent identification and development practices.
- The systematic training and development of physical qualities including speed, change of direction speed and estimated $\dot{V}O_{2\max}$, should be emphasised in adolescent player development to increase the likelihood of higher level career attainment.

Acknowledgements

This research was supported by the Rugby Football League (RFL) and the authors would like to thank the RFL for providing the data. There was no financial assistance associated with this research.

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Table 1: Anthropometric and physical qualities of players selected to the PPP at Under 13s, 14s and 15s age categories according to career attainment outcome

	Amateur (n=12)			**Academy (n=24)**			**Professional (n=15)**		
	U13s	**U14s**	**U15s**	**U13s**	**U14s**	**U15s**	**U13s**	**U14s**	**U15s**
Age (years)	13.59±0.24	14.59±0.24	15.59±0.24	13.71±0.12	14.71±0.12	15.71±0.12	13.42±0.31	14.42±0.31	15.42±0.31
Age at PHV (years)	13.34±0.59	13.53±0.66	13.60±0.58	13.51±0.48	13.57±0.40	13.71±0.44	13.38±0.62	13.44±0.50	13.55±0.37
Years PHV (years)	0.24±0.58	1.06±0.66	1.98±0.58	0.20±0.50	1.13±0.42	2.00±0.45	0.04±0.70	0.98±0.55	1.90±0.48
Height (cm)	171.4±6.7	175.0±6.1	178.1±5.0	170.5±4.6	174.7±4.7	177.3±5.0	170.6±7.9	176.6±5.8	179.6±4.2
Sitting Height (cm)	87.2±4.4	89.2±4.5	91.3±4.0	86.6±3.5	89.3±2.8	91.0±2.7	85.6±4.2	89.3±3.2	91.4±2.2
Body Mass (kg)	65.4±12.4	70.1±12.3	77.4±11.4	62.6v7.6	69.5±9.0	76.2±10.4	63.0±11.4	71.6±10.6	78.7±10.3
Skinfolds (mm)	41.4±20.3	44.5±17.4	46.2±19.0	35.8±14.8	35.4±16.2	42.3±18.2	33.4±13.7	37.4±14.3	36.8±13.3
Vertical Jump (cm)	37.5±4.5	39.3±3.3	41.3±3.9	38.6±4.7	42.2±4.2	43.5±4.9	38.7±4.3	41.3±3.9	43.9±5.4
MBT (m)	5.4±0.8	5.8±0.8	6.4±0.9	5.4±0.5	5.9±0.4	6.5±0.5	5.3±0.8	6.0±0.6	6.7±0.5
10m (s)	1.97±0.09	1.95±0.09	1.89±0.08	1.94±0.06	1.91±0.07	1.89±0.07	1.95±0.09	1.88±0.10	1.86±0.10
20m (s)	3.41±0.18	3.34±0.15	3.22±0.12	3.32±0.13	3.23±0.11	3.22±0.15	3.34±0.15	3.22±0.15	3.18±0.14
30m (s)	4.81±0.26	4.67±0.23	4.50±0.17	4.67±0.20	4.50±0.17	4.44±0.18	4.66±0.23	4.49±0.21	4.38±0.22
60m (s)	9.17±0.60	8.62±0.51	8.27±0.36	8.75±0.44	8.28±0.32	8.19±0.39	8.69±0.49	8.33±0.41	8.09±0.42
Agility 505 L (s)	2.60±0.13	2.52±0.13	2.48±0.23	2.50±0.15	2.48±0.12	2.46±0.12	2.56±0.12	2.47±0.10	2.41±0.11
Agility 505 R (s)	2.61±0.18	2.53±0.16	2.52±0.19	2.51±0.16	2.46±0.12	2.53±0.14	2.57±0.13	2.48±0.11	2.43±0.09
Estimated $\dot{V}O_{2max}$ (ml.kg^{-1}.min^{-1})	45.5±7.2	45.7±5.4	47.9±4.6	47.7±5.9	51.8±4.5	52.2±5.3	48.6±3.8	50.6±3.7	53.7±2.9

Table 2: Repeated Measures MANOVA results examining annual-age category, career attainment outcome (and interaction) on anthropometric and physical qualities.

	Annual-Age Category				**Career Attainment Outcome**			**Annual-Age Category x Career Attainment Outcome**	
	P	η^2	**Pairwise**		**P**	η^2	**Pairwise**	**P**	η^2
Age (years)	<0.001	1.00	13s<14s<15s		0.002	0.24	Acad>Pro	0.50	0.03
Age at PHV (years)	<0.001	0.30	13s<14s<15s		0.648	0.02		0.54	0.03
Years PHV (years)	<0.001	0.97	13s<14s<15s		0.704	0.01		0.45	0.04
Height (cm)	<0.001	0.80	13s<14s<15s		0.720	0.01		0.10	0.09
Sitting Height (cm)	<0.001	0.81	13s<14s<15s		0.949	0.00		0.049	0.11
Body Mass (kg)	<0.001	0.87	13s<14s<15s		0.850	0.01		0.06	0.09
Skinfolds (mm)	<0.001	0.11	13s<15s		0.369	0.04		0.21	0.06
Vertical Jump (cm)	<0.001	0.40	13s<14s<15s		0.284	0.05		0.67	0.02
MBT (m)	<0.001	0.71	13s<14s<15s		0.805	0.01		0.32	0.05
10m (s)	<0.001	0.41	13s>14s>15s		0.368	0.04		0.023	0.11
20m (s)	<0.001	0.51	13s>14s>15s		0.226	0.06		0.026	0.12
30m (s)	<0.001	0.62	13s>14s>15s		0.098	0.09		0.26	0.05
60m (s)	<0.001	0.66	13s>14s>15s		0.070	0.11		0.075	0.09
Ag 505 L (s)	0.001	0.15	13s>14s		0.183	0.07		0.32	0.05

Ag 505 R (s)	0.014	0.10	13s>14s		0.210	0.06		0.075	0.09
Estimated $\dot{V}O_{2max}$ (ml.kg^{-1}.min^{-1})	<0.001	0.23	13s<14s<15s		0.006	0.19	Amat<Acad, Pro	0.19	0.06

Table 3. Results of the ROC analysis using the logistic regression model outcome predictions

	Logistic regression model	**Area under curve**	**Cut-off value**	**True positives**	**False negatives**	**True negatives**	**False positives**	**Sensitivity (%)**	**Specificity (%)**	**P value**
Age range: U13 – U14										
Professional vs amateur	LR model 1	0.956	0.372	14	1	11	1	93.3	91.7	<0.0001
Age range: U14 – U15										
Professional vs amateur	LR model 2	0.778	0.521	11	4	9	3	73.3	75.0	0.0010
Age range: U13 – U15										
Professional vs amateur	LR model 3	0.928	0.577	13	2	11	1	86.7	91.7	<0.0001