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

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

1 **Abstract**

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

5 *Design:* Retrospective longitudinal design

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

11 *Results:* Future professional players were younger than academy players with a greater estimated
12 $\dot{V}O_{2\max}$ compared to amateur players. Between Under 13s and 15s, professional players (5.8 ± 2.5 cm)
13 increased sitting height more than amateur (4.4 ± 2.1 cm) and academy (4.1 ± 1.4 cm) players. Logistic
14 regression analyses demonstrated improvements in sitting height, 60m sprint, agility 505 and
15 estimated $\dot{V}O_{2\max}$ between amateur and professional players with a high degree of accuracy
16 (sensitivity = 86.7%, specificity = 91.7%).

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

24

25 **Key Words:** 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 tomorrow¹. Many organisations implement talent identification practices designed to recognise current participants who have the potential to excel in particular sport contexts². 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 union³, rugby league⁴, 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 used². 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 time⁸. Longitudinal designs involve data collection on the same individuals for two or more time periods⁹ to track and evaluate performance change. Longitudinal approaches have been utilized in rugby league¹⁰ and rugby union¹¹ 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 = -0.85s¹⁰). 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 timepoint¹². This methodology allows researchers and practitioners to identify characteristics, potentially within adolescent athletes, that may be important for future sporting success¹². 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

1 that future professional rugby league players had lower sum of skinfolds and advanced fitness
2 characteristics at 13-15 years of age compared to those who attained amateur status with no
3 differences in characteristics observed between future professional and academy level players.

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

14 **Methods**

15 Fifty-one male junior rugby league players (mean age 13.59±0.25 years at Under 13s) who
16 were selected to the Rugby Football League's former talent identification and development
17 programme, the Player Performance Pathway (PPP; see ¹⁶ for a detailed description), participated in
18 the study. Players were selected to the PPP by rugby coaches using subjective decisions based on
19 current performance and future potential ¹⁶. Players in the present study were selected to the PPP on
20 three consecutive annual occasions in 2005 (Under 13s), 2006 (Under 14s) and 2007 (Under 15s). All
21 players were then subsequently tracked in relation to their career attainment in July 2008 and August
22 2015. By 2008, participants were classified as either: (a) selected to join a professional rugby league
23 club's academy; (b) continued to play amateur rugby league; or (c) no longer participating in rugby
24 league. By 2015, players were potentially able to progress into playing senior professional rugby
25 league within the European Super League. Consistent with previous investigations ^{12,15}, for the
26 purposes of this study, players were classified into three career attainment outcomes, (1) not selected
27 to an academy squad and classed as 'amateur' (n=12); (2) selected to a professional 'academy' but did

1 not play Super League (n=24), and (3) played 'professional' rugby league by the 2015 Super League
2 season (n=15).

3 All participants were assessed on their physical qualities in July 2005, 2006 and 2007. All
4 protocols received institutional ethics approval with consent provided by both players and
5 parents/guardians. The physical assessment included standard anthropometry (height, sitting height,
6 body mass, sum of 4 skinfolds), maturation (age at peak height velocity; PHV) and fitness (lower and
7 upper body power, speed, change of direction speed, estimated $\dot{V}O_{2max}$) characteristics. Intraclass
8 correlation coefficients and typical error measurements for each measure have been presented
9 previously^{4,17} and all measurement reliability and objectivity conformed to published expectations¹⁸.

10 Height, sitting height, body mass and sum of four skinfolds were collected in the morning in a
11 fasted state with participants wearing only shorts. Height and sitting height were measured to the
12 nearest 0.1cm using a Seca Alpha stadiometer. Body mass was measured to the nearest 0.1kg using
13 calibrated Seca alpha (model 770) scales. The sum of four skinfold thickness was determined using
14 calibrated Harpenden skinfold callipers (British Indicators, UK) with procedures in accordance with
15 Hawes & Martin¹⁹. An age at PHV prediction equation was used to measure maturity status²⁰. Years
16 from PHV (YPHV) were calculated by subtracting age at PHV from chronological age.

17 A standardised warm-up was conducted prior to fitness testing with tests performed in the
18 following order. Running speed was assessed over 10m, 20m, 30m and 60m using timing gates
19 (Brower Timing Systems, IR Emit, USA) recorded to the nearest 0.01s from three trials, separated by
20 3 minutes rest. Change of direction speed was assessed using the agility 505 test²¹. Three attempts
21 were performed on each foot with times recorded to the nearest 0.01s. A vertical jump test was used to
22 assess lower body power using a Takei vertical jump metre (Takei Scientific Instruments Co. Ltd,
23 Japan). A counter-movement jump was performed with hands positioned on hips, with jump height
24 measured to the nearest cm from three trials separated by 30 seconds rest²². Upper body power was
25 assessed using the 2kg medicine ball (Max Grip, China) chest throw²³. Participants were seated with
26 their backs against a wall and were instructed to throw the ball horizontally as far as possible.
27 Distance was measured to the nearest 0.1cm from the wall to where the ball landed with the furthest

1 of three trials used as the score. Maximal oxygen uptake ($\dot{V}O_{2\max}$) was estimated using the multistage
2 fitness test²⁴. Players were required to run 20m shuttles keeping in time with a series of beeps.
3 Player's running speed increased progressively until they reached volitional exhaustion. Regression
4 equations were used to estimate $\dot{V}O_{2\max}$ from the level reached during the multistage fitness test.

5 Mean and standard deviation (SD) scores were calculated for all dependent variables
6 according to age category and career attainment outcome. A repeated measures multivariate analysis
7 of variance test (MANOVA) was initially conducted to identify significant main effects for time
8 between age category, for group according to career attainment outcome, and whether an age category
9 x career attainment outcome interaction existed. Bonferroni pairwise comparisons were then
10 conducted to examine univariate effects between each dependent variable. Partial eta squared (η^2)
11 effect sizes were also calculated and interpreted as 0.01 = small, 0.06 = medium and 0.14 = large²⁵.
12 All analyses were conducted with SPSS version 21.0 with significance levels set at $p < 0.05$.

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

24

25

Results

26

27

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

1 comparison results according to age category, career attainment outcome and the age category x
2 career attainment outcome interactions.

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

4 ***Insert Table 2 near here***

5 Repeated measures MANOVA analyses identified significant main effects for age category
6 ($F=6120.7$, $p<0.001$, $\eta^2=1.00$) and all dependent variables. Pairwise comparisons showed all variables
7 significantly improved across the three annual-age categories except sum of four skinfolds and agility
8 505 left and right.

9 For career attainment outcome, analyses identified significant main effects ($F=2.12$, $p=0.005$,
10 $\eta^2=0.48$) with significant differences found for chronological age and estimated $\dot{V}O_{2max}$. Pairwise
11 comparisons found professional players were younger than academy players, and professional and
12 academy players had a greater estimated $\dot{V}O_{2max}$ than amateur players across the three age categories.

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

19 Logistic regression analysis revealed that physical changes between Under 13s and 14s in
20 YPHV ($\beta=-34.320$, $p=0.029$), sitting height ($\beta=4.564$, $p=0.025$) and body mass ($\beta=1.309$, $p=0.031$)
21 contributed to a predictive model (LR model 1) with a cross-validation accuracy of 88.9%. Between
22 Under 14s and 15s, 10m sprint ($\beta=22.225$, $p=0.025$) contributed to a model (LR model 2) with 66.7%
23 cross-validation predictive accuracy. Between Under 13s and 15s, sitting height ($\beta=-0.896$, $p=0.024$),
24 60m sprint ($\beta=-6.199$, $p=0.032$), agility 505 left ($\beta=-8.060$, $p=0.045$) and estimated $\dot{V}O_{2max}$ ($\beta=-$
25 0.431 , $p=0.025$) contributed to a model (LR model 3) with 81.5% cross-validation predictive
26 accuracy. Table 3 shows the results of the ROC analysis for the respective logistic regression models.
27 The models were able to distinguish with a high degree of accuracy at the Under 13s to 14s

1 (sensitivity = 93.3%, specificity = 91.7%; $p < 0.001$) and Under 13 to 15s (sensitivity = 86.7%,
2 specificity = 91.7%; $p < 0.001$) between the future professional and amateur players.

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

4 5 **Discussion**

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

19 When physical qualities were compared between career attainment level across the Under
20 13s-15s age categories, significant differences were found for chronological age and estimated
21 $\dot{V}O_{2\max}$. Future professional players were found to be younger, both chronologically and relatively,
22 than the future academy players, supporting the findings of previous research in rugby league¹⁵,
23 rugby union²⁶ and ice hockey²⁷. Furthermore, this suggests that relatively younger athletes selected
24 to a talent identification and development programme during adolescence tend to achieve greater
25 success in future career attainment. As such, this suggests that perceived advantages (e.g., selection
26 opportunities associated with increased age within chronological annual-age groups) may not be
27 advantageous for longer-term future career attainment in a sport context.

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

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

25 Recent research in AFL ⁵ has used logistic regression analysis to determine the characteristics
26 important for talent identification. Findings from our application of logistic regression analysis
27 suggest that the development of anthropometric and maturational characteristics is highly influential

1 in future career attainment in rugby league. Using a combination of logistic regression and ROC
2 analysis, we were able to use changes in YPHV, sitting height and body mass between Under 13s and
3 14s to correctly identify 93.3% of the future professionals and 91.1% of amateur players. Thus, the
4 development of body size in players selected into the talent identification programme seems important
5 for career attainment, particularly between 13 and 14 years of age which is the timing of maturation
6 ²⁸. 10 m speed improvement was identified as the only variable discriminating professional and
7 amateur players between Under 14 and 15 age categories with a sensitivity and specificity score
8 suggest that it may be an important variable. However, between Under 13s and 15s the development
9 of sitting height, 60m sprint, agility 505 and estimated $\dot{V}O_{2\max}$ all contributed to logistic regression
10 model and accurately distinguished between future professional and amateur players. This analysis
11 provides evidence that the improvement of a range of physical qualities contributes to successful
12 career attainment in rugby league as previously suggested ^{4,12,15} but may be limited by the collinearity
13 of some measures. On this basis, practitioners should aim to monitor maturation, alongside the
14 monitoring and development of anthropometric and physical qualities, within adolescent rugby league
15 players to support talent identification and development practices.

16

17 **Conclusions**

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

1 **Practical Implications**

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

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14

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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	62.6±7.6	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 $\dot{V}O_{2\max}$ (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

