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Variable and changing trajectories in youth athlete development:

Further verification in advocating a long-term inclusive tracking approach

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ABSTRACT

Based on hypotheses that athlete development can be variable and non-linear across a longitudinal period, and that 'relatively later maturing players' can reduce or negate developmental differences in later adolescence, this study examined a methodological issue concerning how best to assess anthropometric and fitness change relative to a broader population (i.e., 'across age categories' or 'per year'), and changes in case rugby league players (i.e., ages 13-15) across a 2 year period relative to an age and skill matched population (N = 1,172). Findings identified that a 'per year' method generated less deviated z scores across variables, suggesting less substantial change in case players relative to the population. When applied to additional players, z-score and radar graphs still showed developmental variability and longitudinal change, even within a relatively homogenous sample. The possibility of a 'later maturing player' rapidly reducing developmental differences within a two year period was identified. These findings affirm the potential for highly variable and changing trajectories between adolescent athletes, particular for those of differing maturation status. Practical implications point toward advocating a long-term inclusive tracking approach, the avoidance of (de)selection, and the reduction of a performance emphasis at adolescent stages of sport development systems.

Key Words: Talent Identification, Athlete Development, Maturation, Anthropometry, Physical Fitness, Coaching.

INTRODUCTION

Sporting national governing bodies and professional clubs across the world presently invest considerable economic and human resources in an attempt to identify and develop youthful prodigies that will hopefully become tomorrow's exceptional athletes. To achieve this goal, many organizations have historically deployed systems that identify and differentiate 'adolescent potential' from their counterparts. These systems often include using a combination of anthropometric and fitness testing procedures at one-off single time points (i.e., cross-sectional), alongside subjective coaching/scout assessments. However, the validity of such approaches has been questioned as they often fail to (a) consider differences in the biological development of youth athletes, (b) capture the multi-faceted nature of sport contexts (e.g., perceptual and cognitive skills), and (c) demonstrate a low general ability to predict adult expertise (4, 18, 27)

Related to (a), the maturational process (defined as the timing and tempo of progress toward the adult state) can vary substantially between individuals during adolescence. A wealth of evidence shows that variable and unstable anthropometric and physical development typically occurs at between 12-15 years in boys, and 11-14 years for girls (2, 10, 11, 22, 23). Greater chronological age (years) and relative age (months within a year) increase the likelihood of entering and progressing through maturation earlier, resulting in substantial variation between individuals in anthropometric and fitness variables (3, 15). Such development may be non-linear and unstable (1, 16), but are generally predictive of better physical capacities such as aerobic power, muscular strength, endurance and speed (19, 24, 28, 29), and therefore provide immediate physical performance advantages for most sport contexts (e.g., 12, 13). Coincidently or ironically, these events occur at a time when many sport organizations more intensively deploy their identification and differentiation procedures.

As all youth will eventually progress through maturation, it follows that later maturing (also likely to be relatively younger) individuals could 'catch-up' on anthropometric and fitness variables in later adolescence (e.g., see 9). To illustrate inter-individual variation, changes in developmental trajectories, and the ‘later maturing’ as being potentially able to ‘catch-up’ with their ‘earlier maturing’ counterparts in the later stages of adolescence (i.e., 14-15 years of age), Till, K, Cobley, S, O’Hara, J and Cooke, C (25) recently presented case studies of the longitudinal development of anthropometric and fitness characteristics within three Rugby League players selected to a talent development programme. Using standardised z scores, cases demonstrated differing initial profiles (i.e., at the Under 13 stage), but then changing trajectories across a two year period relative to mean values of 1,172 players. For instance, a later maturing (& relatively younger) player improved their anthropometric (e.g., height = +9.2%) and fitness (e.g., 60m sprint = -14.9 %) characteristics more than the earlier maturing (relatively older) player who made less (or detrimental) progress on the majority of characteristics assessed (e.g., height = +2.0 %, 60m sprint = -0.7 %) over the same time period.

In their analysis, Till, K, Cobley, S, O’Hara, J and Cooke, C (25) compared case values for a given measurement (e.g., height, body mass, 30m sprint) against a reference mean value taken from collapsing across the broader cross-sectional cohort (i.e., Under 13 - 15). However, a question as to whether this is the most accurate approach to sensitively detect change has been raised. Thus, part one of the current study examined the hypothesis that comparing cases against the mean values ‘across age categories’ may artificially inflate observed deviations in z scores. Due to a given case being potentially quantitatively different from the broader sample at a given time point, which includes players of different ages and stages of biological development, a 'per year' reference calculation was tested and compared (i.e., calculated separate for Under 13, 14 & 15).

In part two, the aim was to reassess and verify the claimed developmental changes in the anthropometric and physical characteristics as presented by Till et al., (25) applying the 'per year' reference calculation. Compared against the age and skill matched broader sample, changes in anthropometric and fitness characteristics of three youth rugby league players were examined. Akin to our original hypotheses, we predicted that our modified analysis would verify that even within a relatively homogenous sample, (a) developmental variability would be apparent, (b) developmental changes were still feasible within and across the longitudinal period, and (c) relative later maturing players would show a reduction or negation of such differences in later adolescent years. Confirmatory evidence here would help strengthen the broader argument that long-term monitoring of 'adolescent potential' beyond maturation is preferable to one-off 'pre-mature' assessments and (de)selection, if long-term athlete development is an overarching goal of sport systems.

METHODS

Experimental Approach to the Problem

This study (re)investigated the inter-individual variation in the development of anthropometric and fitness characteristics of (a) three original (see 25), and (b) three new youth rugby league players using an individual and longitudinal case study approach, with data referenced to a broader cohort of aged and skilled matched players. The UK Rugby league's national governing body the Rugby Football League (RFL) used a talent identification and development model, named the Player Performance Pathway, from 2001 to 2008 (see 26). Each year Regional representative selection occurred at the Under 13s, 14s and 15s annual-age categories with anthropometric and fitness testing undertaken on all players. Between 2005 and 2008, 1,172 anthropometric and fitness assessments were conducted in which 81 players were selected to the Player Performance Pathway on three consecutive occasions (i.e., Under 13s in 2005, Under 14s in 2006 and Under 15s in 2007). This data set contained both longitudinal and cross-sectional data, and respectively cases were drawn for comparison, and set against the broader player cohort to assess differing development trajectories.

Participants

Whether relating to secondary analysis of the original players, or analysis of the new cases, players were deliberately identified according to their maturational status, relative age and playing position. Maturation was classified by Years from Peak Height Velocity (YPHV) in accordance with procedures described by Mirwald, RL, Baxter-Jones, GAD, Bailey, DA and Beunen, GP (14). For relative age, player's birth-dates were categorised to reflect their birth quartile, with reference to 1st September as being applied to demarcate annual-age groups. That is, Quartile 1 (Q1) = birth-dates between September-November; Q2 = December-February; Q3 = March-May; and Q4 = June-August. Playing position was classified into four sub-groups (i.e., 'Outside-Backs', 'Pivots', 'Props' and 'Backrow'), as used in previous rugby league research (e.g., 21).

For part one of the study, anthropometric and physical data on the three players (Players 1, 2 & 3) reported in Till et al. were extracted and taken forward for secondary and modified data analyses (see section below). For part two of the study, three case players were identified. Player 4 was a relatively older 'Prop' (age = 13.87 years; Q1), ‘earlier maturer’ (YPHV = 0.67 years), who was taller (176.8 cm) and heavier (80.4 kg) relative to the broader sample of players at the same stage. Similarly, Player 5 was a Q2 (age = 13.64 years) 'Backrow', ‘average maturer’ (YPHV = 0.04 years) who was smaller (165.8 cm) and lighter (57.8 kg). While Player 6 was a relatively younger (13.11 years; Q4) 'Outside-Back', who was ‘late maturing’ (YPHV = -1.69 years); smaller (157.74 cm) and lighter (51.3 kg). These players, covering a range of maturation, relative age and playing positions, represent a deliberate bias in selection procedure for study purposes. While data in part one represents a secondary data analysis, all original procedures (described below) were approved by a University Ethics Committee. All players and parents provided written informed consent before participating in any testing.

Procedures

Anthropometric and fitness data assessments on all case players as well as the broader sample of players were conducted once per year at the same time of day (i.e., early evening) and year (i.e., July) on each occasion. Assessments were conducted on three consecutive years (i.e., Under 13s, 14s & 15s). Prior to testing all participants were instructed to refrain from strenuous activity 48 hours prior to testing and to consume their normal pre-training diet.

Anthropometry

Height and sitting height were measured to the nearest 0.1cm using a Seca Alpha stand. Body mass, wearing shorts only, was measured to the nearest 0.1kg using calibrated Seca alpha (model 770) scales. Sum of skinfold thickness was determined by measuring four skinfold sites (i.e., biceps, triceps, subscapular, suprailiac) using calibrated Harpenden skinfold callipers (British Indicators, UK). Skinfold procedures were in accordance with the recommendations by Hawes, MR and Martin, AD (7). Intraclass correlation coefficients (ICCs) and typical error measurements (TEM) for reliability of skinfold measurements were $r = 0.954$ ($p<0.001$) and 3.2% respectively, indicating acceptable reliability based on established criteria (i.e., > .80; 8).

Maturation (Age at PHV)

To ascertain maturational status, an age at peak height velocity (PHV) prediction equation was used (14). This prediction method used a gender specific multiple regression equation including height, sitting height, leg length, body mass, chronological age and their interactions. YPHV was calculated by subtracting age at PHV from chronological age.

Fitness Characteristics

Prior to fitness testing a standardised warm up was conducted and all players received full instructions of the tests. For each assessment the highest value of three trials was used. Lower body power was assessed using the vertical jump test (cm) and a Takei vertical jump metre (Takei Scientific Instruments Co. Ltd, Japan). A countermovement jump with hands positioned on the hips was used. The ICC and TEM for the vertical jump was $r = 0.903$ ($p<0.001$) and 2.9%, respectively. A 2kg medicine ball (Max Grip, China) chest throw measures upper body power (20). Players attempted to throw the ball horizontally as far as possible (measured to the nearest 0.1cm) while seated with their back against a wall. The ICC and TEM for the medicine ball chest throw was $r = 0.965$ ($p<0.001$) and 0.6%, respectively. Running speed was assessed over 10m, 20m, 30m and 60m using timing gates (Brower Timing Systems, IR Emit, USA). From a standing start 0.5m behind the initial timing gate, players started respective sprints in their own time. Times were recorded to the nearest 0.01s. The ICC and TEM for the 10m, 20m, 30m and 60m sprints were r = 0.788 ($p<0.001$), r = 0.852 ($p<0.001$), r = 0.899 ($p<0.001$) and r = 0.924 ($p<0.001$), and 8.4%, 4.5%, 3.3% and 2.3% respectively. Change of direction speed was assessed using the agility 505 test. Players were positioned 15m from a turning point with timing gates positioned 10m from the start point. Players accelerated from the starting point, through the gates, turned on the 15m line, and ran as quickly as possible back through the gates (5). Three alternate attempts on left and right turns were used, with times recorded to the nearest 0.01s. The ICC and TEM for the agility 505 left and right were r=0.823 and r=0.844 ($p<0.001$), and 3.5% and 3.1% respectively. Estimated maximal oxygen uptake (VO_{2max}) was assessed using the multistage fitness test (17). Players were required to run 20m shuttles keeping in time with a series of beeps in which running speed progressively increased until they reached volitional exhaustion. Regression equations were used to estimate VO_{2max} from the level reached during the test. The ICC and TEM for the multistage fitness test were 0.90 and 3.1% (6).

Data Analysis

For part one (i.e., original case players) and part two (i.e., three new case players) of the study, individual anthropometric and fitness profiles were firstly generated for each case player using z scores[1]. Z scores were calculated by the formula $(x - \mu / \sigma)$ where x is the raw score, μ is the mean of the population and σ is the standard deviation of the population. Z scores thus positioned a case individual (on any variable) against the broader sample averages and their distributions at each data collection time point, permitting a detection of change in anthropometric and

[1] Z scores are a basic standard score and convert raw scores to units of standard deviation in which the mean is zero and standard deviation is 1.0 (Thomas & Nelson, 2001).

fitness characteristics over time relative to the broader sample population. Z scores of -3, -2, -1, 0, 1 and 2 were calculated for each measurement at each annual age-group (i.e., Under 13s; Under 14s, & Under 15s) to represent mean and standard deviations of the broader sample for each respective year (See Table 4; *Note*: This is different to Till et al. who calculated reference values on the basis of an average across the year groups; i.e., Under 13-15 inclusive). For example, z scores for body mass at the Under 13s age category were -2 (41.7kg), -1 (52.2kg), 0 (62.7kg), 1 (73.2kg) and 2 (83.7kg); while at Under 14's they were -2 (49.2kg), -1 (59.7kg), 0 (70.2kg), 1 (80.7kg) and 2 (91.2kg) respectively. Estimates which occurred between these z scores were reflective of decimal place. With means of the broader sample acting as a reference point (i.e., 0 in terms of a z score), individual cases could then be positioned relatively for each year, and then be descriptively evaluated via table or radar graph presentation.

Specifically for part one of the study, z score values for the three case players - on the basis of 'across age category' calculation - were extrapolated from Till et al., and compared to z score values from the newly deployed 'per year group' calculation (as described above). A Degree of Change (DOC; 'across age category' – 'per year' z score) per variable was then calculated, along with an overall mean DOC across all variables (see Tables 1-3). To substantiate comparisons, paired t-tests on the mean DOC were also conducted to help determine whether the method of calculating z score values affected the overall assessment of longitudinal development and change in case player profiles.

Specifically for part two, longitudinal profiling on three additional new case players relative to the broader sample of players was conducted. Their raw anthropometric and fitness characteristics data (see Table 4) was converted to z scores applying the ‘per year’ reference method, and plotted onto radar graphs (see Figures 1-3), permitting descriptive comparison to the broader sample as well as case comparisons.

Insert Table 4 about here

RESULTS

Part One

Table 1 (Player 1), 2 (Player 2) and 3 (Player 3) illustrate the ‘across age category’ and ‘per year’ z score anthropometric and fitness profiles (annually and longitudinally) for the three original case players, as well as the DOC and mean DOC values.

Insert Table 1 about here

Insert Table 2 about here

Insert Table 3 about here

At the Under 13 age category, the ‘per year’ method of z score calculation, compared to the ‘across age-category’ (i.e., U13-15) method, appeared to *reduce* the general degree of deviation away from cohort mean values (across all measured variables) for all three players respectively (Mean DOC = 0.44; 0.41; 0.44; paired t-tests = $P<.0001$). This tendency was repeated at the Under 15 age category with z score values again restrained back toward broader player sample means (-0.40; -0.37; -.0.43 respectively). At Under 14’s there was less indication of impact on resulting z-scores, with anthropometric and fitness variables showing minimal change ($p> 0.05$); only Player 1’s Mean DOC was marginally affected ($t(11)= 3.52$; $p < 0.05$).

Part Two

Table 4 illustrates the mean (±SD) anthropometric and fitness characteristics of the player population at each time stage (i.e., Under 13s, 14s & 15s) as well as individual measurements for case players at respective time points. Figure 1 (Case Player 4), 2 (Case Player 5) and 3 (Case Player 6) illustrate the anthropometric and fitness z score profiles annually and longitudinally when plotted against the 'per year' values of the broader player population.

Insert Figure 1 about here

Insert Figure 2 about here

Insert Figure 3 about here

Cases Compared to Player Population

Player 4: In contrast to the broader sample at Under 13s, player 4 was early maturing, relatively taller and heavier. Between the Under 13s and 15s age categories, Y-PHV did not seemingly change, and minor z scores reductions in sitting height, height and body mass (e.g., 1.8 to 1.5) were apparent, suggesting that the broader sample were growing relatively more in the same time period. Sum of four skinfolds (-2.4) also did not change over this period, remaining very high throughout compared to the broader sample. Fitness characteristic z scores did vary though, and while MBT scores were above average, other characteristics were average or below at the Under 13s, and remained that way (e.g., vertical jump), or deteriorated across the two years (e.g., 10-60m sprint times; VO_{2max}) relative to the broader sample. See Figure 1.

Player 5: Across all variables a more ‘average’ and rounded profile is apparent relative to the population across Under 13-15s (see Figure 2). Y-PHV, body mass and sum of four skinfolds remained stable at 0, -0.3, and 0.5 respectively (i.e., developing in-line with the mean or better of the broader sample). From a slightly below average position at Under 13s, height (-0.5 to 0.2) and sitting height (-0.3 to

0.1) showed relative improvements across the two years. In terms of fitness, most measurements fluctuated generally around the 0 z score, or slightly below average (i.e., 0 to -0.5) at the Under 13 time point. However, there are then indications of relative but minor improvements in fitness performance which is most evident for the sprints (e.g., 30m -0.3 to 0.5), but also apparent for VO_{2max} (-0.5 to 0) across the two years. See Figure 2.

Player 6: Compared to the broader sample, player 6 can anthropometrically be described as a later maturing, smaller and lighter player (Y-PHV = -2.9, height = -1.4, sitting height = -2.7, body mass = -1.1) at the Under 13 time stage. These variables remain well below average from Under 13-15s, suggesting that he was a late maturer (as reflected by age at PHV). For fitness characteristics, player 6 likewise performed below average on all fitness variables (e.g., vertical jump = -1; agility 505 = -0) at the Under 13 stage. However, across the Under 14-15s age-groups, incremental fitness improvements - relative to the broader sample - were made. Scores improved from -1.0 to 0.3 on 10m, -0.9 to 0.6 on 30m, and -1.2 to 0.5 on 60m sprints; -1.0 to 0.1 on vertical jump; -0.5 to 0.0 on agility 505; and -0.4 to 0.1 on VO_{2max} . Overall, player 6 highlights an improving physical fitness trajectory from Under 13-15s when compared to the broader sample. See Figure 3.

Case Comparisons

Age and Maturation: Table 4 illustrates that player 6 was relatively younger and later maturing (see age at PHV and Y-PHV) when compared to player 5; whom was likewise chronologically and biologically younger than player 4. Although within the same annual age-group, maturational differences between player 6 and 4 during Under 13s can be estimated as being 2.36 years approximately.

Anthropometric Characteristics: For height, player 4 was over 10cm taller than player 5, and over 19cm taller than player 6. Variation was apparent for the degree of change in height and sitting height from Under 13-15, with player 6 increasing height the most in the period (i.e., player 4 = 3.3cm; player 5 = 13.2cm; player 6 = 15.7cm). To add, the percentage of predicted height indicated that while player 4 was taller across Under 13-15s, he had almost attained his final adult height (i.e., % of predicted height at Under 14s = 97.7%). In contrast, player 5 and 6 had lower percentage values (e.g., player 5 = 96%; player 6 = 90.2%) at the same annual-age stage; indicating more expected growth in the future. Figures from predicted height also suggest that player 6 would actually go on to be a slightly taller individual, and that all 3 players would possibly - at adult height - be within 3cm of each other (See Figure 4).

****Insert Figure 4 about here****

For body mass, while all case players showed increases over the annual-age groups, player 4 was over 22.6kg and 29.1kg heavier respectively than player 5 and 6 at the Under 13 stage. And, this was only partially reduced up to the Under 15s age-group (player 5 difference = 19.7kg; player 6 = 19.8kg). Similarly, player 4 exhibited consistently greater indications of body fat across the same period (i.e., sum of four skinfolds - Under 13 – 15's = 84.6, 77.5, & 76.5) compared to player 5 and 6 (e.g., player 5 Under 13-15s = 30.9, 34.7 & 31.1) who maintained or decreased their sum of skinfolds.

Fitness Characteristics: Vertical jump performance and its improvement was more consistent across the two years for all three players (i.e., player 4 & 6 = 9cm, 5 = 7cm). Similar jump heights were attained at Under 15s. For medicine ball chest throw, player 4 threw almost 1m further at the Under 13 stage with similar differences still apparent at the Under 15s age category. In terms of sprint times, player 5 was generally quicker across the 10-60m distances at Under 13s, Across the two years, improvement was evident in all players however greater improvement was made in Player 5 and 6 compared to player 4 (e.g., 30m sprint - Player 4 = -0.18s, Player 5 = -0.46s, Player 6 = -0.59s). From similar starting points at Under 13s (2.60-2.69s) in the Agility 505, player 5 and 6 (-0.22s) made better improvements while player 4's agility performance slightly deteriorated (i.e., 0.1s) in the same time period. Finally in terms of VO_{2max}, player 4 illustrated the lowest initial values and made the smallest incremental change from Under 13-15s (i.e., 41.1-42.1). While in the same period both player 5 and 6 improved by 5.6% (45.2-50.8).

DISCUSSION

This study re-examined and verified evidence demonstrating inter-individual longitudinal developmental changes in anthropometric and fitness characteristics of youth Rugby League players. Originality and strengths of this study lay in the application of a case profiling approach considered relative to a broader age and skill matched population on multiple anthropometric and fitness variables across two year longitudinal period of adolescence (i.e., Under 13s - 15s). This approach revealed developmentally variable and unique case player trajectories that would normally be hidden when athlete assessments are based on one-off coach observations, or when single time point measures on anthropometric and fitness variables are conducted and compared against central tendency values of a larger player sample.

Specific findings illustrate that the characteristics of the reference sample (i.e., including athletes 'across age categories' versus 'per year' matching) affected z-score values for the original case players reported in Till et al (25). An 'across age category' method may indeed inflate or deflate z score values, and suggests the possibility of greater anthropometric and fitness changes longitudinally than actually would be the case when applying an aged-matched comparison. The 'per year' method - at the Under 13 and 15 categories - reduced the degree of deviation away from extreme z score values (i.e., -3 to 2) and back toward broader cohort means (i.e., z score of 0). Plotted on radar graphs, this would generate less z-score dispersion from 0 for case players examined; and when considered longitudinally, the degree of likely (or potential) development change in anthropometric and fitness terms would appear less dramatic or severe. When practically interpreted (e.g., by a coach), this may affect perceptions of what appears to be different, variable or normal athlete development. Still, the potential for substantial developmental variability and trajectory change to occur across a two year period (akin to the period of data collection) should not be discounted. Part two verified this assertion.

Applying the 'per year' reference method, descriptive findings and radar plots verified hypotheses that even within a relatively homogenous larger sample (a) developmental variability occurred, (b) developmental changes were apparent within and across a two year period, and (c) that it is possible for a relatively later maturing player to more rapidly develop (compared to other cases and a broader cohort) beneficial anthropometric and fitness characteristics in a two year adolescent period. In alignment with Vaeyens et al., (27), this helps to highlight the present limitations in applied practice, notably early cross-sectional assessment (i.e., pre or during maturation) and early differentiation via (de)selection in athlete development programmes.

Supporting previous assertions (e.g., 1) that human development is dynamic and non-linear, inter-case and broader sample comparisons illustrated relative age, maturational, anthropometric and fitness variability at the Under 13 stage, as well as unique longitudinal change. For example, bar sum of skinfolds and estimated VO_{2max}, player 4 reflected a more mature and better performing (in fitness terms) individual at the Under 13 stage, suggesting 'good [talented] potential' for the future. Yet across the next two years, the trajectory of player 5 is more accelerated in preferred anthropometric (e.g., height) and fitness (e.g., sprint speed) terms, while player 4 maintains or regresses in terms of anthropometric and fitness measures. Player 6 also demonstrates better fitness development during the same period. At Under 15s, player 5 and 6 now arguably reflects better 'talent' or 'athlete potential' than player 4 even though they are less mature. Further, and based on their profiles, their onward trajectory would appear more positive. Such findings also suggest that a broader hypothetical pattern may be apparent; that adolescents who demonstrate advanced anthropometric and fitness characteristics at an earlier stage of adolescence may not (or to such an extent) improve upon these attributes throughout adolescence and into adulthood, and thus may not maintain their initial advantages (9, 25).

The fact that such variability and change is detectable (maybe partially related to playing position and task demands) even amongst what may be considered a relatively homogenous cohort (i.e., age matched 'representative regional level' Rugby League players) and within a relatively short period of time (i.e., 2 years) is important. If present here, then it suggests that patterns of anthropometric and fitness variation - highly correlated with maturational stage - exist. It also suggests that developmental variation may be wider still across different skill groups of Rugby league (and similar team sports) and the non-sporting population. The potential rapidity of developmental change may be fast in some cases, and generally slower in the broader population compared to the cases presented here. But if cases of 'early non-selected' athletes were tracked over time, and yet had exposure to appropriate training, then they too may also demonstrate 'good potential' a later time point (e.g., Under 16) for invested onward elite training and preparation.

In the present study, the case study approach and selection bias can be considered as limitations. Whilst recognised, the case study approach should also be seen as an appropriate research design to examine differing and variable athlete development trajectories. To help address such concerns, we have utilised a large age and skill matched reference sample to ascertain 'normative' baseline values and guide case evaluations. In terms of selection bias, for study purposes we deliberately identified variable cases. If athlete cases were examined randomly, then it is likely that a 'more average' (e.g., within one standard deviation, or z scores within +1 to -1) player development profile and trajectory would be illustrated. While a majority of players may be less diverse or changeable in their development when aged matched for comparison, this should not mean that variability and change does not occur. Indeed trajectory change may generally be more detectable over a longer time period (i.e., occurring at a slower pace). Although data was only available up until Under 15s for the present study, on-going research will need to assess the degree of potential variation in anthropometric and physical fitness characteristics at later stages of adolescence and beyond (i.e., 15-20 years of age). Determining whether and how developmental trajectories generally converge or widen (e.g., reduction in sum of skinfolds associated with improvements in fitness parameters), and how many athletes follow such paths will provide additional valuable information.

PRACTICAL APPLICATIONS

On the basis of present findings, specific implications for sport analysts, coaching practitioners. and development systems can be considered. In relation to part one of the study, monitoring and tracking athlete progress longitudinally using z scores and radar graph procedures may help to better demonstrate the complexity of athlete development, variability, and changes in trajectory relative to a broader sample of athletes. In doing so, it is valuable to consider the method of z score calculation. When evaluating individual youth athletes against a broader sample, 'age matching' as well as careful comparison of biological stages of development and skill level will be important to consider (e.g., Under 15 player compared to an Under 15 reference group). Unstable variability in adolescent ages and stages affects anthropometric and fitness characteristics as well as observed performance; thus challenging the capacity to accurately assess current potential relative to peers as well as predict future performance. For what may be deemed as 'exceptional' at one age and stage, may not remain the same (and thus the same individual) at a later time points (e.g., later maturing athletes may close the 'fitness and performance gap').

Athlete development systems which resemble the contexts of Rugby League will have to carefully factor in and control for growth, maturation and development to validate any form of (de)selection and differentiation in youth athletes. This recommends not only measuring and tracking underpinning parameters longitudinally to better ascertain developmental change, but also a 'mind set shift' in practitioners working within such systems. If the desired outcome of developing adult athletes remains, and if there is variability and instability during adolescence (i.e., difficult to assess and predict), then (de)selection of youth during this period needs to be avoided, or at least delayed. Such a recommendation would necessitate the replacement of a present emphasis on immediate performance success in youth, to one of promoting longer-term inclusion and involvement to permit development.

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Table 1: Z-score values & degree of change according to method of calculating reference cohort values for anthropometric and fitness characteristics for Player 1.

	Player 1								
	U-13			U-14			U-15		
	Across age categories	Per Year	DOC	Across age categories	Per Year	DOC	Across age categories	Per Year	DOC
Height (cm)	-2	-1.3	0.7	-0.8	-1	-0.2	0	-0.5	-0.5
Sitting Height (cm)	-2	-1.6	0.4	-0.7	-0.9	-0.2	0	-0.6	-0.6
Body Mass (kg)	-1.4	-0.9	0.5	-0.3	-0.4	-0.1	0.3	-0.2	-0.5
Sum of Four skinfolds (mm)	0.5	0.5	0	-0.5	-0.5	0	-0.6	-0.5	0.1
Vertical Jump (cm)	-0.6	-0.2	0.4	-0.2	-0.2	0	0.6	0.4	-0.2
Medicine Ball Chest Throw (m)	-1.4	-0.8	0.6	-0.5	-0.7	-0.2	0.9	0	-0.9
10m Sprint (secs)	-1.3	-1	0.3	0.4	0.3	0.1	0.3	-0.1	-0.4
20m Sprint (secs)	-1.5	-1	0.5	0.1	0.1	0	0.8	0.2	-0.6
30m Sprint (secs)	-1.4	-1	0.4	0	0	0	0.9	0.3	-0.6
60m Sprint (secs)	-1.4	-0.7	0.7	-0.3	-0.3	0	1.1	0.8	-0.3
Agility 505 (secs)	-0.5	-0.1	0.4	0.5	0.3	-0.2	1.1	0.9	-0.2
Estimated $\dot{V}O_{2max}$ (ml.kg^{-1}.min^{-1})	-0.4	0	0.4	-0.1	-0.2	-0.1	0.8	0.7	-0.1
MEAN	-1.12	-0.68	0.44**	-0.20	-0.29	-0.08*	0.52	0.12	-0.40**

Across 2 Years = Z-score in respect to average values across and including the whole U13-15 player sample.
Per Year = Z-score in respect to average values of the age-matched player sample (i.e., excluding those outside particular age-group).
DOC = Degree of Change (Across 2 Years – Per Year z-score).
**= P< 0.001; *= P< 0.05

Table 2: Z-score values & degree of change according to method of calculating reference cohort values for anthropometric and fitness characteristics for Player 2.

	Player 2								
	U-13			U-14			U-15		
	Across age categories	Per Year	DOC	Across age categories	Per Year	DOC	Across age categories	Per Year	DOC
Height (cm)	-1	-0.5	0.5	0.1	0.1	0	0.7	0.2	-0.5
Sitting Height (cm)	-1	-0.7	0.3	-0.2	-0.2	0	0.8	0.2	-0.6
Body Mass (kg)	-1	-0.5	0.5	-0.3	-0.3	0	0.4	0	-0.4
Sum of Four skinfolds (mm)	0.7	0.6	-0.1	0.7	0.5	-0.2	0.4	0.4	0
Vertical Jump (cm)	-0.4	-0.1	0.3	0.2	0.2	0	0.8	0.5	-0.3
Medicine Ball Chest Throw (m)	-0.1	0.8	0.9	0.1	0.2	0.1	1.4	0.8	-0.6
10m Sprint (secs)	0.4	0.7	0.3	0.7	0.8	0.1	0.6	0.4	-0.4
20m Sprint (secs)	-0.1	0.3	0.4	0.4	0.6	0.2	0.9	0.5	-0.4
30m Sprint (secs)	-0.2	0.2	0.4	0.6	0.7	0.1	1.3	0.9	-0.4
60m Sprint (secs)	-0.5	0.1	0.6	0.5	0.7	0.2	1.2	0.8	-0.4
Agility 505 (secs)	0.6	1	0.4	0.7	0.5	-0.2	1.1	0.9	-0.2
Estimated $\dot{V}O_{2max}$ (ml.kg^{-1}.min^{-1})	-0.4	0	0.4	0.7	0.6	-0.1	1	0.8	-0.2
MEAN	-0.25	0.16	0.41**	0.35	0.37	0.02 n.s.	0.88	0.53	-0.37**

Across 2 Years = Z-score in respect to average values across and including the whole U13-15 player sample.
Per Year = Z-score in respect to average values of the age-matched player sample (i.e., excluding those outside particular age-group).
DOC = Degree of Change (Across 2 Years – Per Year z-score).
**= P< 0.001; n.s. = non-significant DOC.

Table 3: Z-score values & degree of change according to method of calculating reference cohort values for anthropometric and fitness characteristics for Player 3.

	Player 3								
	U-13			U-14			U-15		
	Across age categories	Per Year	DOC	Across age categories	Per Year	DOC	Across age categories	Per Year	DOC
Height (cm)	-0.4	0.3	0.7	-0.1	-0.2	-0.1	0	-0.5	-0.5
Sitting Height (cm)	0	0.4	0.4	0.4	0.4	0	0.5	0	-0.5
Body Mass (kg)	0.3	1.2	0.9	1.4	1.8	0.4	1.7	1.7	0
Sum of Four skinfolds (mm)	-1	-1.1	-1	-2.1	-2.2	-0.1	-2.5	-2.5	0
Vertical Jump (cm)	-0.1	0.3	0.4	-0.3	-0.3	0	0.8	0.5	-0.3
Medicine Ball Chest Throw (m)	0	1.3	1.3	1.3	1.9	0.6	1.7	1.1	-0.6
10m Sprint (secs)	-0.4	-0.2	0.2	0.1	0	-0.1	-0.3	-0.7	-0.4
20m Sprint (secs)	-0.6	-0.1	0.5	-0.1	0	-0.1	-0.4	-0.8	-0.4
30m Sprint (secs)	-0.2	0.3	0.5	-0.4	0	-0.4	-0.2	-0.8	-0.6
60m Sprint (secs)	-0.4	0.3	0.7	0	0.1	0.1	-0.3	-1.2	-0.9
Agility 505 Left (secs)	-0.5	-0.1	0.4	-0.8	-1	-0.2	0.2	-0.2	-0.4
Estimated $\dot{V}O_{2max}$ (ml.kg^{-1}.min^{-1})	-0.8	-0.5	0.3	-1	-1	0	-0.8	-1.3	-0.5
MEAN	-0.34	0.18	0.44**	-0.13	-0.04	0.01 n.s.	0.03	-0.39	-0.43**

Across 2 Years = Z-score in respect to average values across and including the whole U13-15 player sample.
Per Year = Z-score in respect to average values of the age-matched player sample (i.e., excluding those outside particular age-group).
DOC = Degree of Change (Across 2 Years – Per Year z-score).
**= P< 0.001; n.s. = non-significant DOC.

Table 4: Anthropometric and fitness characteristics of all players and three case players selected to the Player Performance Pathway at Under 13's, 14's and 15's.

	Broader Sample			Player 4			Player 5			Player 6		
	U13s	U14s	U15s	U13s	U14s	U15s	U13s	U14s	U15s	U13s	U14s	U15s
Age (years)	13.60±0.27	14.58±0.27	15.57±0.27	13.87	14.87	15.87	13.64	14.64	15.64	13.11	14.11	15.11
Age at PHV (years)	13.54±0.62	13.58±0.54	13.74±0.55	13.2	13.2	13.4	13.6	13.6	13.8	14.8	14.5	14.6
Years from PHV (years)	0.06±0.59	1.00±0.58	1.83±0.54	0.67	1.67	2.47	0.04	1.04	1.84	-1.69	-0.39	0.51
Predicted Height (cm)	185.6±4.9	183.4±4.4	181.7±4.9	186.7	183.4	182.1	182.0	181.2	182.8	186.2	184.1	182.9
% of Predicted Height	91.5±2.9	95.4±2.1	97.6±1.4	94.7	97.7	98.9	91.1	96.0	97.9	84.7	90.2	94.8
Height (cm)	169.8±7.8	174.9±6.5	178.0±6.4	176.8	179.2	180.1	165.8	174.0	179.0	157.7	166.0	173.4
Sitting Height (cm)	86.6±4.4	88.7±3.7	90.7±3.5	89.2	91.6	92.2	85.2	89.8	91.0	73.3	81.5	86.0
Body Mass (kg)	62.7±10.5	70.2±10.5	76.4±10.4	80.4	84.5	92.5	57.8	66.4	72.8	51.3	62.2	72.7
Sum of Four skinfolds (mm)	37.5±15.1	39.1±16.3	40.9±15.0	84.6	77.5	76.5	30.9	34.7	31.1	46.5	40.1	35.4
Vertical Jump (cm)	38.8±5.1	40.8±5.2	42.8±5.2	31	37	40	35	37	42	34	37	43
Medicine Ball Chest Throw (m)	5.2±0.65	5.8±0.60	6.5±0.60	5.7	6.5	6.8	4.8	5.8	5.6	4.7	5.4	6.1
10m Sprint (seconds)	1.93±0.12	1.89±0.10	1.86±0.12	2.04	2.09	1.97	1.95	1.90	1.83	2.04	1.98	1.84
20m Sprint (seconds)	3.34±0.18	3.27±0.15	3.18±0.16	3.43	3.50	3.36	3.42	3.31	3.11	3.45	3.37	3.11
30m Sprint (seconds)	4.69±0.26	4.56±0.22	4.42±0.22	4.79	4.77	4.61	4.76	4.64	4.30	4.90	4.63	4.31
60m Sprint (seconds)	8.79±0.56	8.45±0.45	8.14±0.40	8.81	8.50	8.51	8.81	8.67	7.92	9.46	8.81	7.93
Agility 505 (seconds)	2.58±0.14	2.49±0.14	2.47±0.14	2.60	2.60	2.70	2.69	2.44	2.47	2.65	2.53	2.47
Estimated $\dot{V}O_{2max}$ (ml.kg^{-1}.min^{-1})	47.5±4.6	49.2±5.2	50.9±4.5	41.1	40.2	42.1	45.2	46.5	50.8	45.2	48.7	50.8

Figure 1: Anthropometric and fitness profile for Case Player 4.

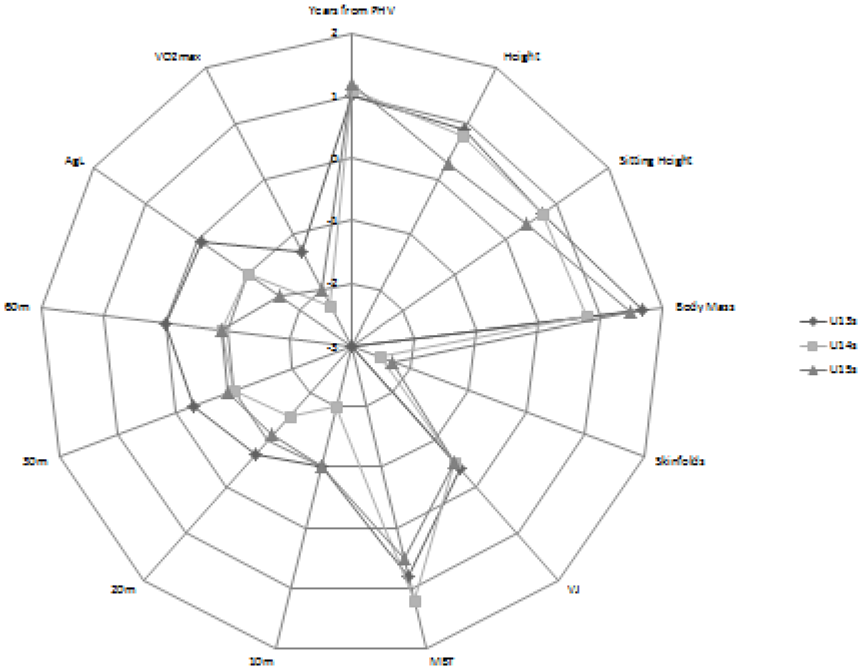


Figure 2: Anthropometric and fitness profile for Case Player 5.

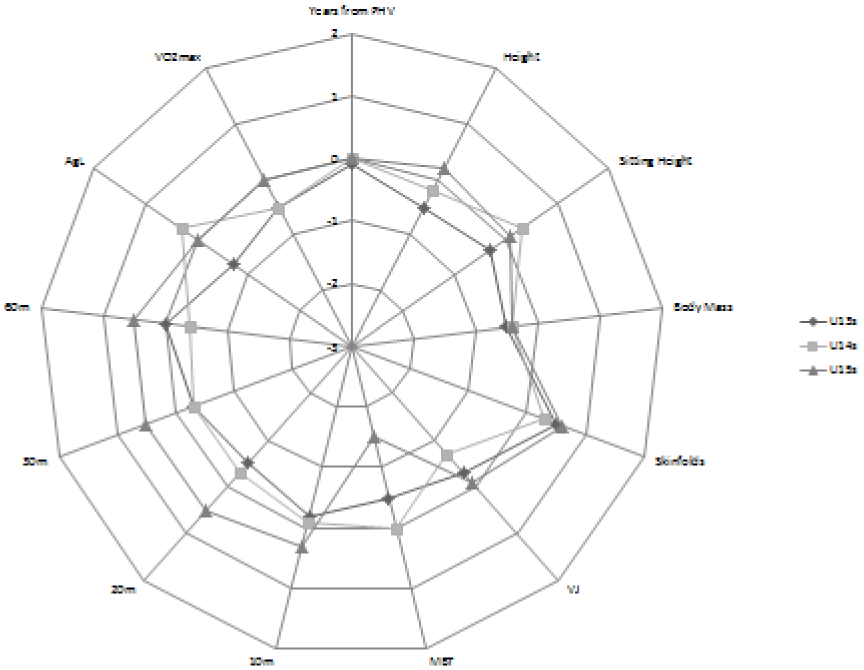


Figure 3: Anthropometric and fitness profile for Case Player 6.

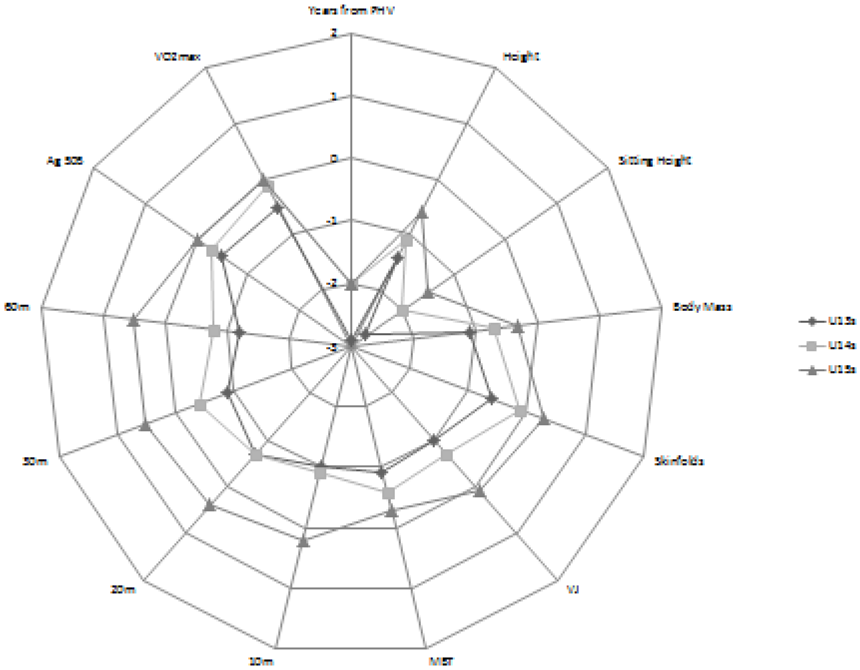
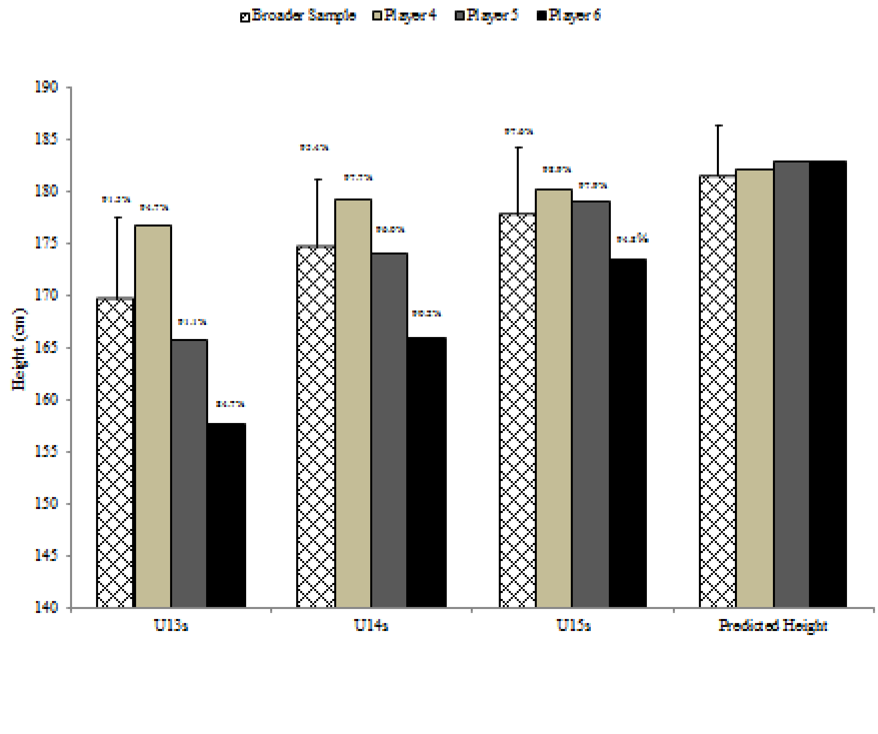


Figure 4: Height and percentage of predicted height of each player at Under 13's, 14's & 15's.



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