An individualized longitudinal approach to monitoring the dynamics of growth and fitness development in adolescent athletes

Running Head: Monitoring the dynamics of growth and fitness

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ABSTRACT

This study evaluated the development of anthropometric and fitness characteristics of three individual adolescent junior rugby league players, and compared their characteristics with a cross-sectional population matched by age and skill level. Cross-sectional anthropometric and fitness assessments were conducted on 1,172 players selected to the Rugby Football League's (RFL's) talent development programme (i.e., the Player Performance Pathway) between 2005 and 2008. Three players of differing relative age, maturational status and playing position were measured and tracked once per year on three occasions (Under 13s, 14s, 15s age categories) and compared against the cross-sectional population. Results demonstrated that the later maturing players increased height (Player 1 = 9.2 %; Player 2 = 7.8 %) and a number of fitness characteristics (e.g., 60m speed – Player 1 = -14.9 %; Player 2 = -9.9 %) more than the earlier maturing player (Player 3 – Height = 2.0 %, 60m sprint = -0.7 %) over the two year period. The variation in the development of anthropometric and fitness characteristics between the three players highlights the importance of longitudinally monitoring individual characteristics during adolescence to assess dynamic changes in growth, maturation and fitness. Findings showcase the limitations of short-term performance assessments at one-off time points within annual-age categories; instead advocating individual development and progression tracking without de-selection. Coaches should consider using an individual approach, comparing data with population averages, to assist in the prescription of appropriate training and lifestyle interventions to aid the development of junior athletes.

Keywords: Anthropometry, Coaching, Maturation, Rugby League, Talent Identification.

INTRODUCTION

To identify potential talent for developmental programs in sport, many current systems often use cross-sectional analyses of annual-age cohorts during early or mid-adolescence. Adjusted to suit the specific demands of respective sports (e.g., soccer; 11, 20), these analyses are also often comprised of anthropometric and fitness based assessments (21). But on these premises, a number of key assumptions and limitations can be highlighted (6) including the lack of due consideration to the potential impact of key growth and maturation processes that occur during adolescence (36).

Maturation is defined as the timing and tempo of progress towards the mature adult state (17), and during adolescence maturation can vary considerably between individuals (18). Advanced chronological age and maturation within similar chronological annual-age groups can create size and fitness (e.g., strength and endurance) advantages. These are hypothesized to confound the relationship between anthropometric and fitness characteristics with sporting performance (24). In the context of male youth sport, this has led to the over representative selection of relatively older (5) and earlier maturing (27) boys. Thus, individuals may be (dis)advantaged on performance measures when compared within chronological annual-age groups (3) using cross-sectional assessments.

Set against the above tendencies, it is also evident that physical advantages presented by advanced maturation during adolescence are also largely transient and can reduce as individual's progress into young adulthood (14, 35). For instance, physically dominant junior athletes may not maintain their initial advantages and attributes throughout maturation and into young adulthood; and in fact many late maturing individuals may appear to 'catch-up'. This therefore potentially questions the validity of talent identification practices, at the adolescent stage (2); and likewise emphasises how inter-individual differences may generate unstable non-linear development of fitness and performance (25). If such growth and development is dynamic, then the ability to identify and predict ‘future talent’ using one-off anthropometric and fitness assessments also rests on uneasy foundations. Instead it would appear more logical to longitudinally monitor and track individual progression, providing more valid information to better identify and develop youth athletes (36).

To date, longitudinal data within talent identification and development research is limited (7, 8, 35). Few studies take into account inter-individual variation that may occur during adolescence, and no study yet emphasizes an individualized approach to illustrate the argument and problem of non-linear development. Therefore, using longitudinal data, the purpose of the current study was to evaluate the variation in the development of anthropometric and fitness characteristics of three individual junior rugby league players selected within a talent development programme and compare their characteristics against a traditional cross-sectional population, matched by age and skill level. A secondary purpose was then to illustrate the different developmental trajectories that occurred during adolescence, with intent to highlight the practical implications of individual long-term monitoring and assessment within junior athletes. It was hypothesized that the individual development of the three players would be dynamic, with each player demonstrating a different developmental trajectory that could influence subsequent performance and selection within junior rugby league.

METHODS

Experimental Approach to the Problem

This study investigated the inter-individual variation in the development of anthropometric and fitness characteristics of three junior rugby league players using an individual and longitudinal case study approach. 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 34 for more details). 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). Therefore, longitudinal data became available for these players, in which this data set was used for the case study subjects and cross-sectional population to evaluate and compare the differing development trajectories of the case study players.

Subjects

Case study players were identified according to their maturational status, relative age and playing position as previously used in research by the authors (31). Maturation was classified by Years from Peak Height Velocity (YPHV) in accordance with Mirwald et al. (22). For relative age, player's birth-dates were categorised to reflect their birth quartile (Q), with reference to the 1st September date used for creating annual-age groups. 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 (29).

Three individual players were used for the case study analysis. Player 1 was a Q4, ‘Outside-Back’ with an YPHV of -0.95 years (at the Under 13s age category). Player 2 was a Q2, ‘Pivot’ with an YPHV of -0.18 years (Under 13s). Player 3 was a Q1, ‘Prop’ with an YPHV of 0.52 years (Under 13s). A deliberate bias was introduced in the selection of these subjects for the case study analysis such that they covered a range of maturation, relative age and playing positions. This selection process was intentionally undertaken to allow illustration of the different developmental trajectories, with reference to variability in the changes in growth and fitness that occur during adolescence. All experimental procedures were approved by the Leeds Metropolitan University Ethics Committee and all subjects and parents provided written informed consent before participating in any of the testing.

Procedures

Anthropometric and fitness assessments 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 and 15s) for the case study players with the procedures for each measure detailed below. 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 only shorts, was measured to the nearest 0.1kg using calibrated Seca alpha (model 770) scales. The sum of skinfold thickness was determined by measuring four skinfold sites (biceps, triceps, subscapular, suprailiac) using calibrated Harpenden skinfold callipers (British Indicators, UK) in accordance with the recommendations by Hawes and Martin (12). 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; 13).

Maturation (Age at PHV)

To measure maturity status, an age at peak height velocity (PHV) prediction equation was used (22). This prediction method used a gender specific multiple regression equation including stature, 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 (centimetres) measured using a Takei vertical jump metre (Takei Scientific Instruments Co. Ltd, Japan). A countermovement jump with hands positioned on the hips was used, which measured jump height to the nearest cm. 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 was used to measure upper body power (28). Participants were instructed to throw the ball horizontally as far as possible while seated with their back against a wall with distance measured to the nearest 0.1cm. 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). Participants were positioned from a standing start 0.5m behind the initial timing gate and were instructed to start in their own time. Times were recorded to the nearest 0.01s. 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. Participants 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 (9). 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 $\dot{V}O_{2max}$ was assessed using the multistage fitness test (26). 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 $\dot{V}O_{2max}$ from the level reached during the test (26). The ICC and TEM for the multistage fitness test were 0.90 and 3.1% (10).

Data Analysis

Anthropometric and fitness characteristics of the population (1,172 players selected to the Player Performance Pathway) are shown in Table 1.

****Insert Table 1 here****

The three individual case-study players were firstly compared against the population. For this comparison, anthropometric and fitness profiles were created for each player using radar graphs and 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. This approach allowed the tracking of changes in anthropometric and fitness characteristics over time with relative comparisons to the

[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 (30).

population. Z-scores of -3, -2, -1, 0, 1 and 2 were used to represent the mean and standard deviations of the population. For example, values for Height were -3 (151.7cm), -2 (159.0cm), -1 (166.7cm), 0 (174.4cm), 1 (182.1cm) and 2 (189.8cm). Characteristics between these z-scores were classified by decimal place. Following comparisons with the population, characteristics of players in terms of z-scores and change in performance were then descriptively compared and analysed between each case study player.

RESULTS

Table 2 shows the anthropometric and fitness characteristics of the three individual players at the three annual-age groups (i.e., Under 13s, 14s and 15s). Table 3 presents the percentage change in characteristics between the annual-age categories (i.e., Under 13s-14s; Under 14s-15s; Under 13s-15s) for each player. Figure 1 (Player 1), 2 (Player 2) and 3 (Player 3) illustrate the anthropometric and fitness profiles of the three individual players compared against the z-scores for the population.

Insert Table 2 here

Insert Table 3 here

Insert Figures 1, 2 and 3 here

Cases Compared to Population

Player 1: Player 1 was later maturing, shorter and lighter than the whole sample at the Under 13s age category. Between the Under 13s and 15s annual-age categories, z-scores for height (-2.0 to 0), sitting height (-2.0 to 0) and body mass (-1.4 to 0.3) all improved, however, sum of four skinfold scores decreased (0.5 to -0.6). Fitness characteristics were slightly above (vertical jump, agility 505, estimated $\dot{V}O_{2max}$) or below (med ball chest throw, 10m – 60m sprint) the z-score of -1 at the

Under 13s age category. All fitness characteristics improved to z-scores of approximately 1 (Figure 1) by the Under 15s. These results represent Player 1 as a later maturing player with lower anthropometric characteristics than the population, but who performed at an average level on fitness tests relative to the population throughout the two year period.

Player 2: Player 2 was also later maturing, shorter and lighter than the population at the Under 13s age category. Between the Under 13s and 15s age categories z-scores for height (-1.0 to 0.7), sitting height (-1.0 to 0.8) and body mass (-1.0 to 0.4) improved, whilst sum of four skinfolds remained constant. Fitness characteristics were approximately 0 at the Under 13s age category with improvement evident to z-scores of approximately 1 (Figure 2) at Under 15s. These results represent Player 2 as an average maturer, with average anthropometric characteristics compared to the population, but who performed above average on fitness characteristics throughout the two year period.

Player 3: Player 3 was earlier maturing who scored approximately 0 for anthropometric characteristics at the Under 13s age category. Between the Under 13s and 15s age categories z-scores for height (-0.4 to 0) and sitting height (0 to 0.5) slightly improved while body mass (0.3 to 1.7) and sum of four skinfolds (-1 to -2.5) increased. Sum of four skinfolds at the Under 15s age category represented values significantly greater than the population. Fitness characteristics z-scores were between 0 and -1 at the Under 13s age category. Improvements in some fitness characteristics occurred between Under 13s and 15s (e.g., vertical jump -0.1 to 0.8), however, performance in speed, agility and estimated $\dot{V}O_{2max}$ did not change across the two year period (Figure 3). These results represent Player 3 as being above average for anthropometric and some fitness characteristics at the Under 13s age category with little change apparent across the two year period.

Case Comparisons

Age and Maturation: Table 2 shows Player 1 was a younger and later maturing player than Player 2 who was younger and later maturing than Player 3. The difference in maturation between Player 1 and 3 at the Under 13s annual-age category was 1.47 years as a result of differing birth dates (i.e., chronological ages) and maturation timing (i.e., age at PHV).

Anthropometric Characteristics: For height and sitting height at the Under 13s age category Player 3 was taller than Player 2 who was taller than Player 1. Variation was apparent in the change in height and sitting height between the three players with Player 1 (9.2%) and Player 2 (7.8%) growing significantly more than Player 3 (2.0%). Therefore, the advantages Player 3 would have experienced at the Under 13s age category were no longer applicable at Under 15s, as Player 3 was now the same height as Player 1. For body mass and sum of four skinfolds, Player 3 was heavier with a greater sum of four skinfolds than Player 2 who was heavier with a lower sum of four skinfolds to Player 1 across the age categories. Consistent increases in body mass were evident across all three players between the Under 13s and 15s age categories.

Fitness Characteristics: Vertical jump performance was consistent across the two years for the three players with similar improvements evident (Player 1 = 18.9%, Player 2 = 18.4% and Player 3 = 12.5%) resulting in all three players having a similar vertical jump at the Under 15s age category (Player 1 = 44cm, Player 2 & 3 = 45cm). For medicine ball chest throw, both Player 2 and 3 outperformed Player 1 at the Under 13s age category, and although Player 1 demonstrated the greatest improvement (38.3%), gains were also evident in Player 2 (21.1%) and 3 (20.0%). For speed, specifically 20m, 30m and 60m sprint, Player 2 was faster than Player 3 who was faster than Player 1 at the Under 13s age category. However, significant changes in sprint performance occurred across the two years with Player 1 improving sprint performance the most (20m = -10.8%, 30m = -11.0%, 60m = -14.9%) followed by Player 2 (20m = -5.2%, 30m = -8.4%, 60m = -9.9) with Player 3 showing very little change in sprint performance over the two year period (20m = -1.5%, 30m = -0.2%, 60m = -0.7%). This resulted in Player 2 being slightly faster than Player 1 with both demonstrating greater speed than Player 3 at Under 15s. Agility 505 results identified similar findings to speed, with a greater improvement in Player 1 (Left = 11.0%, Right = 8.9%). Player 1 and 2 outperformed Player 3 at the Under 15s age category. For estimated $\dot{V}O_{2max}$ Player 1 and 2 had similar values at Under 13s and 15s age categories with Player 1 (11.3%) and 2 (15.3%) improving performance across the two years. However, Player 3 had a lower estimated $\dot{V}O_{2max}$ than both Player 1 and 2 with no change in performance found across the three measurement occasions.

DISCUSSION

Using longitudinal data collected from the RFL's Player Performance Pathway, the purpose of this study was to (i) evaluate the individual development of anthropometric and fitness characteristics of three case study players compared to a cross-sectional population, matched by age and skill level; and (ii) illustrate and compare the different development trajectories that occur during adolescence to highlight the practical implications of individual long-term monitoring and assessment within junior athletes. This is the first study to emphasize an individual and longitudinal case study approach within talent identification and development research. As hypothesized, the results demonstrate the highly dynamic development of anthropometric and fitness characteristics and illustrate the differing developmental trajectories within adolescent athletes. Importantly, the variability in both anthropometric and fitness performance and change in characteristics over time, highlight the potential flaws in cross-sectional assessment and early differentiation of players.

Individual case study players were compared against an age and skill matched population using radar graphs (Figure 1, 2 and 3) to uniquely present and give clear understanding of the development of anthropometric and fitness characteristics for the respective players. This method of comparing cases longitudinally against a population supports limitations of previous cross-sectional designs common in talent identification and development research (36). Adolescents who demonstrate advanced anthropometric and fitness characteristics (i.e., Player 3 at Under 13s) may not necessarily improve these attributes throughout adolescence (i.e., limited change in characteristics of Player 3 between Under 13-15) and therefore may not maintain initial advantages experienced (2). A number of factors such as maturation, developmental variation or training effects may impact upon this process (1). Therefore, assessing characteristics longitudinally, allows changes in an individual's characteristics to be assessed over time, instead of at one-off time points within annual-age categories as is commonly used within current cross-sectional methodologies.

A further limitation of cross-sectional designs, until recently (23, 33), is that they fail to consider maturational status (or relative age) of the respective samples. However, the current anthropometric and fitness profiles not only compare individual characteristics with a population, but also consider relative age and maturational status of the individual players. For example, Player 1 was a relatively younger and later maturing player who had lower anthropometric characteristics than the population but performed on average for fitness throughout the two year period. In a context (i.e., talent development programme) where relatively younger and later maturing players have previously been demonstrated to lack selection opportunities (19, 27, 32) this supports previous research (31) suggesting that later maturing players can perform on a par with earlier maturing players within a high performance sample.

The added element of comparing individual cases – relative to the population - over a number of years is another unique aspect of the current research design. The current data identifies significant changes in anthropometric and fitness characteristics across the two year period for Players 1 and 2 with little change apparent for Player 3, illustrating the variability in the changes of anthropometric and fitness characteristics during the adolescent period. Findings at the Under 13s age category support previous research (14, 25) that fitness performance is related to biological maturation with a gradient of performance in adolescent males for early > average > later maturers. However, changes between the Under 13s and 15s supports previous research (14, 15, 35) that later maturers (i.e., Players 1 and 2) can catch up in anthropometric (e.g., height) and fitness (e.g., speed) performance during adolescence as earlier maturers (i.e., Player 3) have less potential for growth and fitness improvement and therefore have a reduced margin for progression.

Monitoring longitudinal change in growth and fitness performance (in comparison to a population and between individual cases) during adolescence can therefore inform the potential for future development and progression relative to normative or specific sample comparisons (e.g., talented junior rugby league players). Based on the current data, it seems appropriate to consider that Players 1 and 2 have greater potential to be successful at a later age (and maybe skill level) due to their recent improvement in anthropometric and fitness characteristics during adolescence. While Player 3 may have been considered talented at the Under 13s age category based on characteristics assessed at that time, and the notable correlations of these characteristics with sporting performance, it is worthwhile to note that this individual did not change in terms of fitness characteristics over the two year period into the Under 15s age category. Thus, as an underperforming player compared to the population, even though earlier maturing, without appropriate training, conditioning and lifestyle intervention (e.g., nutrition) it would be questionable whether this player would continue to improve beyond adolescence to meet the demands of rugby league at more advanced levels (e.g., academy).

Although this research has used a unique individualized and longitudinal case study design limitations still exist. Firstly, the sample size of three players is an obvious limitation but is required to explore this individualized approach. Second, the bias in selection of the three case study participants to provide data across differing relative age, maturation and playing position is a potential limitation. However, this selection process was used to illustrate the different developmental trajectories and variability in changes in growth and fitness during the adolescent period. If three different players would have been used differing results would have been evident, however this only strengthens the argument for an individualized longitudinal approach, especially during adolescence. The ceasing of data collection at the Under 15s age category is another limitation. Data collected beyond adolescence and into young adulthood would be more relevant and informative to follow and compare measures through the later development years (16), as many physical qualities that distinguish between players may not be apparent until late adolescence or beyond (37). Unfortunately, the Player Performance Pathway ceased at the Under 15s age category and therefore data was unavailable. Finally, the lack of multi-disciplinary assessments (i.e., technical, tactical and psychological) is a further limitation, which may have provided additional insight into the longitudinal development of junior rugby league players.

In conclusion, the present study evidences the dynamic changes in anthropometric and fitness characteristics between three junior rugby league players during adolescence compared to an age and skilled match population. The data supports recent recommendations (36) that longitudinal assessments, specifically on an individual basis, should be conducted within the research and practical application of talent identification and development within youth sport. These findings should better encourage individual player assessment and development, and reduce early (de)selection policies that are currently common within youth sport contexts. That said, the lack of data beyond the Under 15s age category is a limitation of the current study, and continued monitoring of characteristics into young adulthood is required to fully understand the dynamics of growth and development and its impact upon performance. To address these concerns, individual, multidisciplinary, longitudinal approaches that monitor player development from junior age categories into senior and elite levels of performance should be the focus of both empirical research and applied practice.

PRACTICAL APPLICATIONS

The dynamic changes in characteristics over a two year period highlighted in the current investigation demonstrate the variability in development of anthropometric and fitness characteristics during adolescence. Coaches should understand that cross-sectional approaches during this key developmental period only provide a snapshot of current performance, failing to consider factors such as age, maturation, development and training. Instead, coaches should monitor the change and progression of anthropometric and fitness characteristics (alongside other multidisciplinary characteristics) using an individualized and longitudinal approach. As players progress through adolescence, using repeated and periodic assessment would be a more appropriate method in the identification, selection and development of junior players. Compared to cross-sectional assessments this approach may lead to changing perceptions of capability, future potential and potential decision of (de)selection within such developmental programmes. Likewise, coaches could use this approach to evaluate an individual’s strengths and weaknesses, in comparisons with population data, to prescribe appropriate training, conditioning and lifestyle interventions that are essential for optimal player development in youth rugby league and other youth sport contexts.

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Figure 1. Anthropometric and Fitness Profile for Player 1

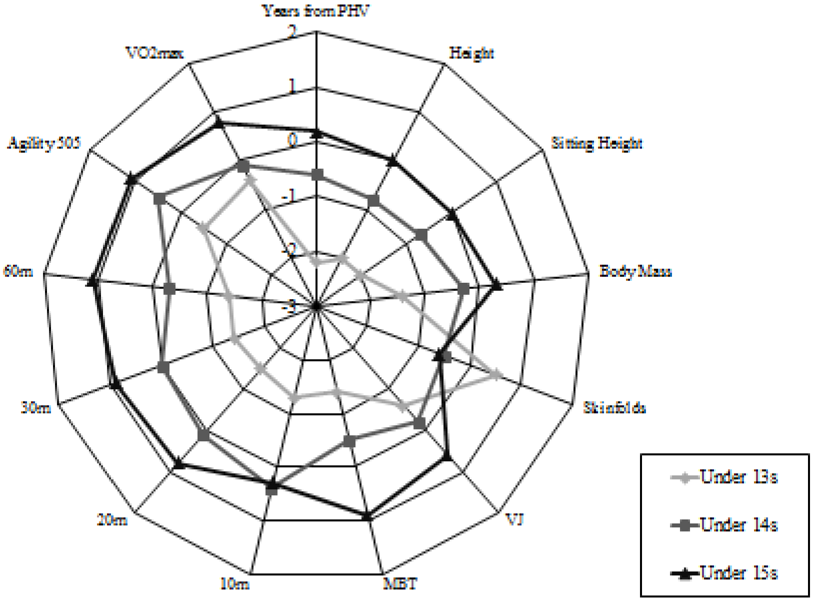


Figure 2. Anthropometric and Fitness Profile for Player 2

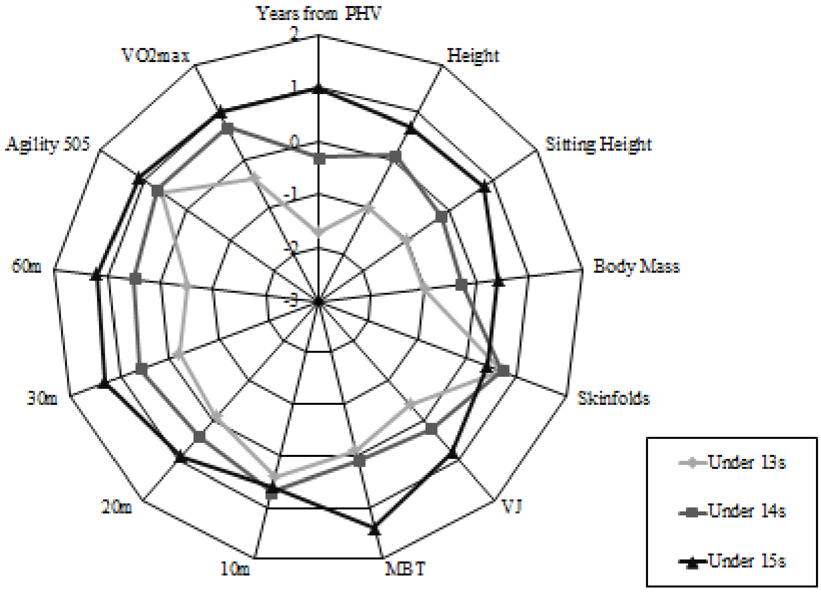
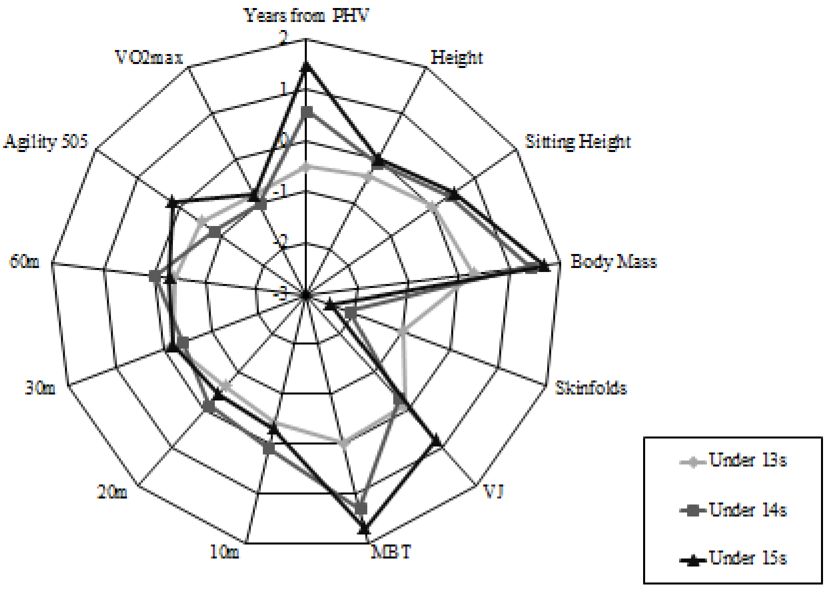


Figure 3. Anthropometric and Fitness Profile for Player 3



1 **FIGURE**