Seasonal Monitoring of Sprint and Jump Performance in a Soccer Youth Academy

Craig A. Williams, Jon L. Oliver, and James Faulkner

Purpose: The aim of the study was to longitudinally assess speed and jump performance characteristics of youth football players over a 3 y period. Methods: Two hundred players across five age squads (U12–U16) from an English Football League academy participated. Sprint performance (10 and 30 m) and countermovement jump height were assessed at 6 mo intervals. Pairwise analyses determined the level of change in performance between consecutive intervals. Results: Sprint performance changes tended to be greatest during the early teenage years, with observed changes exceeding the smallest worthwhile effect (1.0% for 10 and 30 m sprints). Changes in jump performance were above the smallest worthwhile effect of 1.8% for all but one interval. Large individual variability in the magnitude of change in sprint and jump performance, perhaps due to the confounding effect of growth and maturation, revealed few significant differences across the 6 mo intervals. Cumulative changes in performance demonstrated strong linear relationships, with a yearly rate of change of 6.9% for jump height, and 3.1 and 2.7% for 10 m and 30 m sprint time respectively. The magnitude of change in performance tended not to differ from one interval to another. Conclusions: The results of this study may primarily be used to monitor and predict the rate of progression of youth football players. In addition, these results may be used as a benchmark to evaluate the effectiveness of a current training program.

Keywords: boys, performance, testing, talent development

Talent development in association football (soccer) is a pertinent issue around the world as professional clubs endeavor to identify and nurture potentially elite players. It is widely agreed that an interdisciplinary approach between soccer coaches and sport scientists—one that includes the continuous measurement and evaluation of physiological, psychological, biomechanical, and sociological competencies—is necessary to detect and monitor the early development of young athletes. If measured appropriately, these competencies can provide coaches with important information concerning the current and potential ability of young athletes. Performance tests are frequently and systematically implemented within
a senior or junior athlete’s training program to enable coaches and sport scientists to objectively determine and monitor performance adaptations.²

Falk et al⁵ stated that retrospective and prospective studies are two approaches that may be implemented in empirical investigations to identify, monitor, and develop young athlete’s talent. Previous studies have been used to provide a retrospective picture of the fundamental processes that can enable the detection and development of individuals who have reached a high standard.⁶,⁷ Prospective, longitudinal studies require the collection of data from the same individuals on the same or comparable variables for two or more distinct time periods.⁵ Not only are prospective studies expensive to conduct, but also the investigators involved in the research process may lack control over certain variables.⁵ However, multiple observations of the same individuals can allow changes within and among young athletes, teams, and age groups to be recorded and identified more easily.²,⁵ Despite these limitations, longitudinal studies that have focused on the growth, maturation, and performance of young athletes are limited.⁸

Within most ball games, the motor and technical skills of an individual are primarily used in the early stages of talent identification and development.³ The technical components of soccer, which fundamentally includes a players physical fitness (speed, agility, explosive power) and motor (passing, dribbling, shooting) abilities, can enable coaches to differentiate between players within a team. Sprinting and jumping performances are consistently utilized during competitive matches and are distinguishing fitness characteristics of soccer.⁹ As noted by Clark et al,⁹ approximately 96% of all sprints during competitive games are < 30 m, with the majority of these < 10 m.¹⁰,¹¹ Performance in a single sprint effort has also been shown to be a strong predictor of performance in sets of both brief and prolonged repeated sprints in youth soccer players.¹² Research has also demonstrated a strong relationship between vertical jump height and soccer performance.¹¹,¹³ Consequently, the advantages of field-based testing, such as measuring sprint performance and vertical jump height, is that these tests can provide specific and useful information to players and coaches in a sport-specific environment. Field-based tests are typically cheaper, less time consuming, and less reliant upon specialist equipment than are laboratory-based exercise tests.

To the best of our knowledge, there are very few longitudinal studies on elite youth soccer players.⁸,¹⁴ The purpose of this study was to examine the variation of fitness and anthropometric characteristics of elite youth soccer players (age under 12 to under 16 y), at the start and end of a playing season, over a 3 y period, and where possible identify discernable interseasonal performance changes. The study also aimed to identify the magnitude of change for different performance variables (sprint times, vertical jump height), and whether normative standards could be established over a variety of ages.

Method

Participants

The data are from a 3 y longitudinal study on the growth and performance of youth soccer players attending a center of excellence at a professional English soccer club. Players in the under-12 to under-16 (U12, U13, U14, U15, and U16) age
categories were monitored throughout the study. All players participated in 3 h of training per week (over two sessions) and were normally involved in one competitive match per week. Data were collected over a total of three seasons, with new players at the youngest age (U12) joining the program at the beginning of each new season and the oldest players (U16) leaving the program at the end of each season. Subsequently, players may have been included in data collection from one to three seasons. Sample size and descriptive data for the total number of players in each age category over the three-season period is presented in Table 1. All participants were healthy and asymptomatic of illness and preexisting injuries. Written informed consent was obtained from parents/guardians before participation in the study. The research was approved and conducted in agreement with the guidelines and policies of the institutional ethics committee.

Procedures

Data was collected in October and April during each of the three seasons. This period represented the majority of the playing season, while the period from April to October primarily represented the off-season and preseason. Before the start of each assessment session, the stature, sitting stature, and body mass (SECA, Hamburg, Germany) of each soccer player was ascertained. Stature was measured with a fixed stadiometer to the nearest 0.1 cm and body mass was measured to the nearest 0.1 kg, leg length was calculated by subtracting sitting stature from stature. Following approximately a 10 min dynamic warm-up with a qualified youth soccer coach, participants completed three 30 m sprints and three vertical jumps. To ensure a consistency of surface, an artificial turf pitch was selected and all participants wore artificial surface football boots for all tests. All players were tested in their age group categories within the same week, at the start of one of their evening training sessions. All measures were recorded within the same 45 min period, commencing at either 18:00 or 19:30.

30 m Sprint Test

As the professional soccer academy trained on the artificial turf throughout the season, all 30 m sprint tests were performed on this surface. The 30 m sprint tests were performed using infrared timing gates (Brower Timing Systems: Speedtrap 2; Utah, USA). The timing gates were positioned at 0 m, 10 m, and 30 m, enabling a sprint time to be recorded between 0 and 10 m, 10 and 30 m, and 0 and 30 m. Previous research has reported reliability coefficients of variation of approximately 2% for youth team-sport players performing all-out repeated sprints over similar distances and on a similar surface.15 Each sprint began from a stationary start, 1 m behind (–1 m) the first timing gate (0 m). Each participant was provided with a 3 s verbal countdown before commencing the maximal sprint. Participants were instructed to sprint the 30 m course as fast as possible. A 10 m deceleration zone (30–40 m) was positioned to promote acceleration through the final timing gate. Verbal encouragement was provided throughout the sprints by investigators located at start and end of the track. Following completion of a sprint, all players slowly walked back to the start position. The sprint tests were performed three times, with approximately a 5 min rest period between trials. To minimize the effect of either a head- or tail-wind, the timing gates were positioned so that the sprint tests would be
Table 1  Body size characteristics and performance variables of all players within each age group at the start of the season (mean ± SD)

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Height (cm)</th>
<th>Body mass (kg)</th>
<th>10 m (s)</th>
<th>10-30 m (s)</th>
<th>30 m (s)</th>
<th>Vertical jump (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 12 (n = 40)</td>
<td>147.1 ± 5.9</td>
<td>39.9 ± 5.7</td>
<td>1.98 ± 0.09</td>
<td>3.05 ± 0.12</td>
<td>5.04 ± 0.20</td>
<td>44.9 ± 3.2</td>
</tr>
<tr>
<td>Under 13 (n = 47)</td>
<td>153.2 ± 7.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>45.1 ± 8.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.97 ± 0.14</td>
<td>2.98 ± 0.19</td>
<td>4.97 ± 0.33</td>
<td>47.9 ± 5.7</td>
</tr>
<tr>
<td>Under 14 (n = 40)</td>
<td>162.3 ± 10.6&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>51.8 ± 10.0&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>1.89 ± 0.08&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>2.80 ± 0.17&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>4.71 ± 0.25&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>50.5 ± 4.8&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Under 15 (n = 41)</td>
<td>170.3 ± 8.7&lt;sup&gt;a,b,c&lt;/sup&gt;</td>
<td>58.2 ± 9.4&lt;sup&gt;a,b,c&lt;/sup&gt;</td>
<td>1.79 ± 0.09&lt;sup&gt;a,b,c&lt;/sup&gt;</td>
<td>2.65 ± 0.16&lt;sup&gt;a,b,c&lt;/sup&gt;</td>
<td>4.46 ± 0.23&lt;sup&gt;a,b,c&lt;/sup&gt;</td>
<td>53.1 ± 4.5&lt;sup&gt;a,b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Under 16 (n = 32)</td>
<td>175.1 ± 5.0&lt;sup&gt;a,b,c&lt;/sup&gt;</td>
<td>66.5 ± 6.6&lt;sup&gt;a,b,c,d&lt;/sup&gt;</td>
<td>1.77 ± 0.06&lt;sup&gt;a,b,c&lt;/sup&gt;</td>
<td>2.51 ± 0.10&lt;sup&gt;a,b,c,d&lt;/sup&gt;</td>
<td>4.29 ± 0.15&lt;sup&gt;a,b,c&lt;/sup&gt;</td>
<td>57.3 ± 5.3&lt;sup&gt;a,b,c,d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>Significantly different from Under 12, P < .01.
<sup>b</sup>Significantly different from Under 13, P < .01.
<sup>c</sup>Significantly different from Under 14, P < .01.
<sup>d</sup>Significantly different from Under 15, P < .05.
Williams, Oliver, and Faulkner performed against a crosswind. The fastest sprint time reported for 0–10, 10–30, and 0–30 m across the three trials for each participant were used for further analyses.

### Vertical Jump

The vertical jump has been demonstrated to be a valid and reliable measure of explosive power performance. The vertical jump test took place immediately after completing the three 30 m sprint tests. An investigator involved with the research study verbally informed and demonstrated the correct technique required to perform the test. The three vertical jumps were performed on a jump mat (Probiotics Inc, Alabama, USA), two-footed, with participants instructed to jump as high as possible, bending their knees on their downward countermovement, and jumping vertically in the air with straight legs. Countermovement depth was self-selected by the participant to maximize jump height. Participants were advised to try to jump from and land on the same spot on the jump mat. The test was performed with a countermovement arm swing to replicate the action used to head a ball during a soccer game. Jump height during each trial was automatically calculated from flight time by the measurement equipment. The internal calculation of flight time to vertical jump height was based upon the following equation: 

\[ H = \frac{T^2 \times G}{8}, \]

where \( H \) is height, \( T \) is the total flight time, and \( G \) is the gravitational constant of 9.81 m/s\(^2\), under the assumption that time to peak height is the same as the time from peak height to landing. Participants had approximately a 2 min recovery between trials. The highest vertical jump recorded for each participant was used for further analyses.

### Statistical Analyses

In the first analyses a comparison of results across each age group at the start of the season was made. In this analysis data from the start of each three seasons was collated into one data set and results reported based on player age category, providing a total sample pool of \( n = 200 \). A one-way ANOVA was used to determine if any significant differences existed between different age categories. Post hoc analysis using a Bonferroni adjustment was used to identify where any differences occurred. This data was also used to estimate the smallest worthwhile effect for a change in performance. The smallest worthwhile effect was calculated for each age group as 0.2 of the between participant standard deviation with an overall value then calculated as the mean smallest worthwhile effect across all age groups.

A pairwise analysis was then employed to establish the percentage change in test scores between consecutive test sessions. The percentage change was calculated as the mean change across all individuals. Only players with results for consecutive test sessions were included in each pairwise analysis. This procedure provided a total sample of \( n = 175 \) pairs of data. This approach provided results showing the percentage change during and between each season (with one test session toward the start and end of each playing season). Data across all three seasons were pooled and separated into the various age categories to show the mean change in performance for a given age group during a season and between seasons. A one-way ANOVA was again used to determine if there were any significant differences in the magnitude of the change at different ages. A Pearson’s product moment correlation coefficient was used to establish the strength of the relationship between the cumulative group
mean percentage change in performance and age. The association between changes in body size and changes in performance across all sets of paired data was also examined using correlation coefficients. Significance for all statistical tests was set at the $P < .05$ level. All data were analyzed using the statistical package SPSS for Windows, version 15 (SPSS Inc., Chicago, IL, USA).

Results

Mean measures of body size and performance variables at the start of a season are shown by age for all players in Table 1. All measures of body size showed significant differences across all age groups, with the exception of stature between the two oldest groups of players. There was an overall trend for all performance variables to improve with increasing age. However, performance variables showed no significant difference between players in the U12 and U13 teams. Conversely, players in the older age categories (U14, U15, and U16) were able to run significantly faster and jump significantly higher than all of their younger counterparts (Table 1).

Pairwise analysis of the mean percentage change in both stature and body mass between consecutive test sessions is shown in Figure 1. Body mass increased by at least 4% during each 6 mo interval. While there was a trend for increases in body mass to peak in the early teens (peak change of 7.22 ± 2.97% between the end of the U13 season and start of the U14 season), there were no significant differences in the mean percentage change in body mass at any age. Percentage changes in stature were considerably less than those for body mass (Figure 1). Players grew significantly more ($P < .05$) in stature during each interval from the start of the U12 season to the start of the U14 season, when compared with the changes in stature that occurred from the end of U15 season to the end of the U16 season. The U12 season was the only period when the mean change in leg length

![Figure 1](image) — Percentage change in stature (triangles) and body mass (squares) during the season (filled symbols) and between seasons (open symbols) for different age groups. *Significantly different, $P < .05$
was significantly greater than the mean change in sitting stature (2.65 ± 1.44 vs 1.16 ± 1.12%, \( P < .05 \)).

Performance variables showed much greater variability in the magnitude of the change between individuals when compared with changes in body size (Figures 1 and 2, respectively). The change in sprint performance is shown in Figures 2A and 2B. Although there was a tendency for greater improvements in within-participant sprint performance in the early teenage years, the level of variability prevented the detection of any significant differences in the change in 10 m performance across any intervals. The only significant difference (\( P < .05 \)) in the change in 30 m sprint time was between the increase in sprint time during the U12 season (1.03 ± 2.58%), and the large decrease in sprint time when progressing from the U15 to the U16 age group (–2.55 ± 2.30%). The smallest worthwhile effect for a change in performance was calculated to be 1.0% for both 10 m and 30 m sprints.

Mean changes in jump performance were all positive in direction, with most of these changes above the 1.8% identified as the smallest worthwhile change in performance (Figure 2C). The small improvement in jump performance during the U15 season was significantly lower (\( P < .05 \)) than the improvement experienced in the proceeding interval and also during the U12 season. Even though the percentage changes in performance during any 6 mo interval were generally low, the cumulative percentage change in performance over a longer time period was obviously greater in magnitude. Correlation coefficients showed a strong positive relationship for all cumulative changes in performance and increasing age (Figure 2; all \( r^2 \geq .97, P < .001 \)). The slope of the gradients for the linear relationships shown in Figure 2 predict that 10 m sprint time will improve at a rate of 3.1% per year, 30 m sprint time by a rate of 2.7% per year and jump height by a rate of 6.9% per year. While there were some significant relationships between the change in body size (stature or body mass) and the change in performance (10 m, 30 m or vertical jump), the strength of these relationships was always weak (\( r \leq .25 \) in all instances).

**Discussion**

The aim of the study was to determine the magnitude of change over a 3 y period for speed and jump performance for a group of well-trained youth soccer players. As expected, our results showed significant differences in measures of body size, speed, and jump ability across youth football players in U12 to U16 age categories. Generally there were nonsignificant differences in the magnitude of the change in performance scores across the different age groups, both during and between seasons. This may be attributable to the individual variation observed in the present study and the likely continual conditioning of players throughout the year. As a result of the small but consistent changes there were strong linear relationships between the cumulative change in performance and age, which provide a useful indication of expected progression of sprinting and jumping in youth team players.

Cross-sectional analysis of the performance capabilities of players within the different age groups revealed improvements in performance with increasing age. This study provides normative data for coaching staff regarding the expected sprint and jump performance levels of youth footballers in different age categories. The authors acknowledge that such individual fitness characteristics may not lead to successful soccer performance by themselves, but must be collectively utilized with
Figure 2 — Mean individual percentage change in performance at different age categories during a season (filled symbols) and between seasons (open symbols), for (A) 10 m sprint time, (B) 30 m sprint time, and (C) vertical jump. Shaded areas represent a trivial change in performance. Crosses and dashed lines represent the cumulative change in performance with age.
other soccer-specific components of fitness (eg, endurance training, repeated sprint ability), skill development and the acquisition of tactical knowledge.\textsuperscript{20} Players in the youngest age group recorded 30 m sprint times of 5.04 s, which is considerably slower than the times of 4.44–4.69 s reported by Janssens et al\textsuperscript{21} for 11- to 12-year-old soccer players of varying standards. Conversely, 30 m sprint times for the U16 players (4.29 s) were similar to that previously reported for elite 16-year old players,\textsuperscript{4} although they were still slower than sprint times reported for elite adult players over the same distance.\textsuperscript{22} The comparative change in sprint performance, from being relatively slow at the youngest age to being relatively fast at the oldest age, may reflect a bias toward more mature and physically developed players by the time players reach the U16 age group. Malina et al\textsuperscript{23} previously concluded that soccer systematically excludes late-maturing boys and favors early-maturing boys as chronological age increases. Comparisons to previous jump data are difficult given the lack of standardization in jump protocols. However, the improvement in jump height with age is in agreement with previous cross-sectional data for youth soccer players\textsuperscript{24} and junior rugby league players\textsuperscript{25} of a similar age range to the present study.

Even though longitudinal data exists for growth rates of various performance capabilities throughout childhood in general populations,\textsuperscript{26,27} research is limited with regards to assessing youths involved in a continuous period of systematic training. In the present study, changes in performance were aligned to chronological age rather than maturity. This provided a practical approach and reflects recent suggestions that development of sprint ability is related to chronological age and not maturity.\textsuperscript{27,28} Due to the limited time the investigators had with the youth soccer players, growth and maturation was limited to monitoring changes in body stature and mass. This was considered a more practical approach than applying the Tanner scale and avoided the error associated with estimating maturation from anthropometric variables,\textsuperscript{28} yet also reflecting the methods suggested in a popular and current long-term athlete development model.\textsuperscript{29}

Significant differences between the change in stature across age groups was not reflected in the longitudinal performance data. Furthermore, relationships between changes in body size and changes in performance were weak at best. Similarly, Gravina et al\textsuperscript{14} reported nonsignificant relationships between the change in stature and both the change in 30 m sprint and countermovement jump performance over a 6 mo period in junior soccer players. The authors did, however, note significant relationships between the change in salivary testosterone levels and sprint and jump performance and consequently suggested a maturational role for improved performance. While this may be the case, correlations with the change in testosterone were only \( r = .34\) with the change in sprint times and \( r = .48\) with the change in jump height, suggesting that factors other than increased circulating testosterone also influenced performance gains.

The magnitude of the change in sprint performance over 6 mo intervals is in agreement with previous research with junior soccer players.\textsuperscript{14} Changes in both 10 and 30 m sprint times followed a similar trend, with overall improvements greater than the smallest worthwhile effect occurring during each 6 mo interval from the start of the U13 season to the start of the U15 season. This finding may provide some support for the concept of a period of optimal trainability of speed based on chronological age, which has been suggested to occur between the ages of 13–15/16 years in boys.\textsuperscript{27,29} However, the large variability in the magnitude of the change in
sprint performance for each age group meant that no differences were observed across the 6 mo interval assessments. Changes in sprint performance around this age have been speculated to be linked to chronologically associated development of the central nervous system; however, maturational factors, such as increased muscle mass and changes in muscle-tendon architecture, are also likely to influence the development and trainability of speed. Of interest was the finding that both 10 and 30 m sprint performances were impaired during the U12 season. Although this may be due to external factors, such as an excessive training load or environmental conditions, it may also reflect a maturational effect. Philippaerts et al reported that sprint velocity during a 30 yard dash was reduced in the 12 moleading up to peak height velocity. The temporary decline in performance has been attributed to “adolescent awkwardness” disrupting motor coordination during periods of accelerated physical growth. This suggestion is supported by the accelerated growth of the lower limbs relative to the trunk during the U12 season. The fact that impaired sprint performance was not simultaneously accompanied by impaired jump performance is also supported by previous research.

Improvements in jump performance in boys have been suggested to peak in the year following peak height velocity, coinciding with peak gains in muscle strength. Improvements in jump performance were consistently above the smallest worthwhile effect, which was also reflected in consistently large increases in body mass. However, the relationships between changes in height and body mass with jump performance were weak. This highlights the value of a longitudinal approach. The weak correlations again reflect the complexity of the development of vertical jump performance, which will not only be dependent on increased muscle mass, but also changes in qualitative muscle-tendon properties (ie, changes in muscle fiber pennation angles and intrinsic stiffness of the muscle-tendon complex) and neural control and coordination.

A large improvement in jump performance was observed between the U15 and U16 seasons, although little improvement was observed between the second U14 assessment (April) and the first U15 assessment (October). The large change observed between the U15 and U16 season could be expected to be related to large increases in muscle mass during this time; however, the trend for changes in overall body mass do not support this. Instead, the large change may simply reflect a correction for the limited change in the previous 6 mo. This finding, based on regular assessments over a period of 3 y, highlights the need for long-term fitness evaluation and interpretation of changes in performance in youth soccer players. It is clear that for both sprinting and jumping there were no consistent differences between the rates of change observed during and outside of the playing season. The 6 mo period outside of the playing season included the preseason, when there is likely to be a considerable amount of conditioning. Statistically there were no periods of accelerated adaptation. This may again be aligned with the large amount of individual variability. In one of the few previous studies to objectively examine accelerated adaptation, Lloyd et al identified periods of accelerated adaptation spanning 3 y in both pre and postadolescent development of the stretch-shortening cycle. The authors attributed these observations to the prolonged development of motor coordination during childhood, which is likely to be highly individualized. Therefore, it is not surprising that periods of accelerated adaptation were not observed in the present study, when using 6 mo intervals.
The consistency of improvements at the group level resulted in strong correlations between the cumulative improvement in performance and age. These findings reinforce the strength of the prospective design of the research, with results providing a description of expected longitudinal gains in performance with respect to age. Results showed an improvement of approximately 3% per year in sprinting and 7% per year in jumping. Results of the present study may provide a guideline of expected longitudinal gains in jumping and sprinting ability of soccer players aged 12 to 16 y. Future research should aim to establish whether specific training regimes can improve performance over and above normal growth patterns and to assess how long any additional training gains last.

Conclusion

As expected cross-sectional data showed large differences in both body size and sprint and jump performance across players in different age groups. More interestingly this study is one of the few to provide longitudinal data on the development of sprint and jump performance. Generally the magnitude of any change in performance did not differ from one 6 mo interval to another between the ages of 12 and 16 y. This is not surprising given the number of developmental factors that will influence performance, a suggestion supported by the weak relationships observed between changes in body size and changes in performance. Consequently, some caution should be taken when planning player development around measures such as peak height velocity. What the results did show was a strong linear relationship between the cumulative change in performance and age, findings that may be helpful when monitoring future development and the effectiveness of the training of soccer players in U12 to U16 age categories.

References


