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Variable long-term developmental trajectories of short sprint speed and jumping height in English Premier League academy soccer players: an applied case study

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23 **Variable long-term developmental trajectories of short sprint speed and**
24 **jumping height in English Premier League academy soccer players: an applied**
25 **case study**

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Abstract

Growth and maturation can affect physical performance over the long term, making the appraisal of athletic ability difficult. Using a previously published method, we sought to longitudinally track youth soccer players to assess the developmental trajectory of athletic performance over a six-year period in an English Premier League academy. Age-specific z-scores were calculated for sprint and jump performance from a sample of male youth soccer players (n = 140). A case study approach was used to analyse the longitudinal curves of the six players with the longest tenure. A regression equation for each fitness variable facilitated comparison of participants to the wider sample. The trajectories of the sprint times of players 1 and 3 were characterised by a marked difference in respective performance levels up until peak height velocity (PHV) when player 1 achieved a substantial increase in sprint speed and player 3 experienced a large decrease. Player 5 was consistently a better performer than player 2 until PHV when the sprint and jump performance of the former markedly decreased and he was overtaken by the latter. Fluctuations in players' physical performance can occur quickly and in drastic fashion. Coaches must be aware that suppressed, or inflated, performance could be temporary and selection and deselection decisions should not be made based on information gathered over a short time period.

Keywords: Youth, football, talent, running velocity, muscular power

68 INTRODUCTION

69 Growth and maturation refer to the processes that characterise a youth's progression
70 towards a mature state ¹. Growth is simply an increase in body dimensions that is
71 characterised by increases in fat and fat free mass whilst maturation refers to qualitative
72 biological changes to tissues and organs ¹. Progressing growth and maturation can result in
73 increased or decreased physical performance and because of this, can make it difficult to
74 determine the true ability and potential of a young athlete prior to full maturity ². For example,
75 greater stride length, due to growth of the lower limbs, can result in enhanced sprint speed in
76 youth ³. However, a high rate of growth has also been associated with impaired movement
77 coordination which could negatively affect sprint speed ⁴. Accordingly, the accurate appraisal
78 of athletic ability and potential is difficult in the maturing youth athlete making the
79 identification of talent a challenging process.

80 Related to this issue is the concept of the 'relative age effect'. The relative age effect refers
81 to the preferential selection of children born in the earlier part of the sporting year ⁵. This
82 means that those individuals who are chronologically older than their peers are favoured by
83 coaches due to being more physically developed. For example, in some cases, there can be
84 an age gap of almost an entire year between youths who compete at the same age grade of
85 a given sport and this can result in a competitive imbalance that can have implications on
86 individuals' ability to thrive and sustain involvement in sport ⁶. For example, a relatively
87 young under 13 soccer player might be closer in age to a comparatively older under 12
88 player than he is to a relatively older peer in the under 13 age group. If growth and
89 maturation are progressing in these players at an average rate, the relatively younger under
90 13 player is likely to be less physically accomplished than their older peer and could
91 therefore be at a disadvantage for talent selection, regardless of soccer ability.

92

93 Previous case study approaches have demonstrated the highly variable trajectories of
94 fitness qualities in youth athletes as they biologically mature. Cobley et al. ⁷ presented
95 longitudinal data in youth rugby league players spanning a two year period, reporting that
96 late-maturing players could ultimately improve performance levels, thereby “catching up”
97 with their early-maturing peers in the fullness of time. In light of this finding, the authors
98 advocated an inclusive form of talent development which incorporates multiple fitness
99 assessments over the long term and the avoidance of deselection at too early a stage in a
100 youth athlete’s developmental journey.

101 This concept of non-linear physical development in youth athletes has been discussed in the
102 literature. However, what has not been explored in depth is the erratic, and quite drastic,
103 fluctuations that can occur in the physical development of youth soccer players ⁸. This can
104 have implications for long term selection and deselection decisions with the relative age
105 effect persisting into adulthood ⁶. Given the erratic dynamism of developing motor
106 competencies in youth athletes, the current study seeks to build on previous work ⁷ by
107 comparing single subjects in a case study approach to demonstrate the non-linear
108 development of performance (sprint speed and jump height) over the long term (6 seasons)
109 in English Premier League youth soccer players. In doing this we describe scenarios which
110 soccer coaches could potentially be confronted with, highlighting the challenges associated
111 with developing talent in a holistic manner. To date, longitudinal data on such players is
112 exceedingly rare.

113 **METHODS**

114 For this study, data from a wider sample of 140 youth soccer players from the English
115 Premier League were analysed, with six individuals serving as the subjects for the case
116 analysis which was supported by the formulation of performance z-scores based on the
117 entire cohort. These individuals were chosen because their tenure at the club spanned the
118 entire **six-year** study period, the only players in the cohort to achieve such longevity.

119 Descriptive data for the group and individual players at the beginning and the end of the
120 case study period are shown in Tables 1 and 2.

121 *****Tables 1 and 2 near here*****

122 Sprint and jump testing was carried out by practitioners from the soccer club's sports
123 science department in September, January and April of each season. All players were
124 familiar with the utilised tests which were a regular part of their programmes of physical
125 preparation. To estimate participant maturity status, anthropometric measurements (stature,
126 sitting stature and body mass) were entered into an equation to predict maturity offset ⁹:
127 Maturity Offset = $-9.236 + (0.0002708 \times \text{leg length and sitting height interaction}) + (-$
128 $0.001663 \times \text{age and leg length interaction}) + (0.007216 \times \text{age and sitting height interaction}) +$
129 $(0.02292 \times \text{weight by height ratio})$. The equation can measure maturity offset within an error
130 of ± 1 year, 95% of the time ⁹.

131 To measure sprinting speed, electronic timing gates were used (Fusion Sport, Canberra,
132 Australia) on an indoor astroturf surface. This equipment has shown excellent test-retest
133 reliability (ICC = 0.88 to 0.97) in the measurement of linear sprint speed in athletes ¹⁰.
134 Participants began each sprint in a front-facing, crouched standing position with the
135 dominant hand on a start cone placed 0.25 m in front of the start line. Participants sprinted
136 straight through each timing gate line (10 m, 20 m) maximally until they were past target
137 markers placed five metres beyond the finishing line. The best of three trials was recorded
138 for each distance and used in the analyses. There was three minutes recovery between
139 trials.

140 To measure countermovement jump (CMJ), participants performed a jump on an electronic
141 jump height calculator mat (Fusion Sport, Canberra, Australia). This equipment has shown
142 excellent test-retest reliability (ICC > 0.9) in the measurement of CMJ in athletes ¹¹.
143 Participants started in a standing position with the hands positioned on the hips and the feet
144 flat on the floor. They descended into a squat position to a self-selected depth before

145 ascending into a maximal vertical jump with the torso upright. At the maximal height of the
 146 jump, the hips, knees and ankles must have been fully extended, with no tuck or pike
 147 position allowed at any point of the movement. Participants were required to land back in the
 148 starting position and the best of two trials was recorded for analysis. There was two to three
 149 minutes recovery between trials.

150 **CASE DESCRIPTION**

151 As case study designs represent an effective means to reduce the gap between research
 152 and practice, through the presentation of a rich form of qualitative information, we chose to
 153 utilise such an approach ¹². Across the full sample of players (n = 140), the statistical method
 154 recently described by Till et al. ¹³ was used. Briefly, rolling averages for sprint speed (10 m
 155 and 20 m) and CMJ, over a **near-six-year** period, were calculated with respect to the
 156 maturity offset ⁹, a traditional way to gauge biological maturation in youth athletes. This
 157 produced a regression equation for each variable facilitating the comparison of participants
 158 to their peers at a specific stage of maturity, measured in years from PHV. To do this, a z-
 159 score for each variable was calculated using the following formula:

$$160 \qquad \qquad \qquad \text{Z-score} =$$

$$161 \qquad \qquad \qquad \frac{\text{Participant's score} - \text{mean score}}{\text{Standard deviation}}$$

$$162 \qquad \qquad \qquad \text{Standard deviation}$$

164 In the above equation, the mean score is substituted for the regression equation for each
 165 anthropometric or fitness variable and the standard deviation is that which was calculated for
 166 each squad as a whole over the six-year period of the case study (i.e. under 10s, under 11s,
 167 under 12s etc.). This reduces the greater variability associated with the calculation of a
 168 standard deviations across a dataset whose youngest participant was eight years old and
 169 whose oldest was sixteen ¹³. Once missing data were removed, longitudinal curves (Figures
 170 1 through 9) were formed in Microsoft Excel. In each graph, a secondary y-axis was included
 171 on the right hand side to demonstrate the trajectory of fitness variables, relative to

172 progressing maturity status, over time. From the wider dataset, and for the final analysis, we
173 included only players ($n = 6$) whose tenure at the club academy spanned the entire case
174 study period of ~six years. This period comprised of between eleven and 13 fitness testing
175 occasions on which participants had their sprint and CMJ performance measured.

176 **Comparison of Trajectories Between Players**

177 Longitudinal curves for the group ($n=6$) and player versus player comparisons are displayed
178 in Figures 1, and Figures 2 and 3 respectively. Figure 1 shows the group-level development
179 of 10 m sprint speed, 20 m sprint speed and CMJ. Figures 2 and 3 display player vs. player
180 comparisons for each of the physical qualities.

181 **Group comparisons**

182 The group-comparison of longitudinal curves ($n=6$) is displayed in Figure 1. There is
183 variability in the performances of players for much of the six-year study period, though sprint
184 speed converges in all players near the time of PHV. Of note, player 5 transitions from being
185 one of the fastest players, to being one of the slowest after PHV (10 m and 20 m sprint). It is
186 also notable that across an approximate one year period from -1 years before PHV to +0.15
187 years after PHV, players 1 and 2 graduate from being two of the worst performers in the 20
188 m sprint, to being the two best. Figure 1 also shows the changes in CMJ performance over
189 time. Of note are the scores of players 1 and 6 who occupy last and first place respectively
190 at around -1 to -1.5 years before PHV, being separated by around four standard deviations.
191 However, prior to the final CMJ test, the players occupy second (Player 6) and third (Player
192 1) place in this group and are separated by less than one standard deviation.

193 **Figure 1. 10 m sprint time, 20 m sprint time and countermovement jump for all six**
194 **players**

195 **Player versus player comparisons**

196 *Player 1 vs. player 3*

197 Figure 2 shows the comparisons of players 1 and 3 over the six-year study timescale. The
198 trajectories of both 10 m and 20 m sprint times of players 1 and 3 are characterised by a
199 marked difference in respective performance levels up until PHV when player 1 achieves a
200 substantial increase in sprint speed and player 3 experiences a decrease. When their
201 trajectories converge, both players experience a decrease in performance before displaying
202 trends of recovery. Following the substantial difference in sprint performance up to PHV, the
203 players are relatively well matched towards the end of the timeframe in question. A similar
204 trend is seen for CMJ but both players are more closely aligned over their time in the
205 academy system.

206 **Figure 2. 10 m sprint time, 20 m sprint time and countermovement jump comparison**
207 **for Player 1 vs. Player 3**

208 Figure 3 shows the comparisons of players 1 and 3 over the six-year study timescale.
209 Though player 5 is consistently a better performer than player 2 throughout the time in the
210 academy system, there is relative linearity in how these individuals progress over time.
211 Development is linear until around the time of PHV when the performance levels of player 5,
212 in all measured variables, markedly decreases and he is overtaken by player 2 who
213 maintains a consistent level of performance relative to his peers as seen in Figure 1.

214 **Figure 2. 10 m sprint time, 20 m sprint time and countermovement jump comparison**
215 **for Player 2 vs. Player 5**

216 **DISCUSSION**

217 The purpose of this study was to demonstrate the varying and irregular trajectories in the
218 development of sprint speed and jump height in English Premier League male youth soccer
219 players. Our comparisons show that the time around PHV appears to be a key period of
220 development that does not always favour the individual player with both increases and
221 decreases in performance being possible. This is well-exemplified by the comparison of
222 players 1 and 3 whose disparity in sprint speed was eliminated at this time. This is also

223 typified by player 5 whose apparent physical superiority prior to PHV was completely
224 eradicated after PHV. The case study demonstrates the highly erratic nature of physical
225 development trajectories over the long term in male youth academy soccer players in the
226 English Premier League. The findings of this work demonstrate that an individual player can
227 lag behind his peers in terms of athletic ability but can rapidly improve his standing alongside
228 changes in maturation status. This work adds to the very small body of longitudinal literature
229 in this population and demonstrates to coaches the erratic nature of physical development in
230 youth players. This can enable such coaches to make more informed decisions on selection
231 and deselection to elite squads. To our knowledge, no study has previously used a case
232 study of players from an English Premier League club to present such data over an
233 extensive period of time (~6 years) and longitudinal research, in general, is unfortunately
234 rare in youth players. Crucially, this allowed us to observe developmental trajectories of
235 sprint speed and jump height prior to, during, and after the important mid-PHV stage of
236 maturation.

237 A common criticism of talent development programmes in youth sport is the rejection of late
238 maturing players before they have a chance to realise the full extent of their athletic
239 potential. This could cause psychological harm to the rejected player and drop-out from
240 sport, and can also prevent a team from being able to select their best available players in
241 the future, given that late maturing players can ultimately achieve similar performance levels
242 as their early maturing peers¹⁴. On this, it has been previously shown that a player whose
243 physical performance levels lag behind those of her or his peers, similar to that in the case
244 of Player 1 in the current study, can ultimately match or surpass other individuals if given the
245 time and physical development support to do so⁷. This could point to an upper limit on
246 performance above which further increases are slower, or less likely to occur, in early
247 maturing players. On this basis, the physical advantages enjoyed by early maturing soccer
248 players in the pre-PHV phase of development, may not be apparent at the post-PHV stage
249 when growth and maturation have slowed⁷. Hypothetically, this could result in the

250 preferential selection bias of a player whose potential is falsely inflated at a relatively
251 younger age, and the deselection of one whose full potential has not yet been achieved. For
252 much of the study period in question, the sprint speed and jump height of Player 1 does not
253 compare favourably to those of his peers. However, at the final observation, this deficit has
254 been closed as the player converges with his teammates and matches their performance
255 levels. The retention of this player in the talent pipeline allows this scenario to play out and
256 gives coaches a longer period of time within which to make an important selection decision
257 that is based on tangible data rather than educated guesswork.

258 It is important to indicate that even a coach's appreciation of the erratic nature of fitness
259 testing results over time may not be sufficient to prevent negative outcomes in a scenario
260 such as that described above: if relatively poor fitness tests manifest as lower technical
261 performance on the field of play, players could still be deselected on the basis that they are
262 considered to not be of the required standard to continue playing at a professional academy.
263 To this end, fitness practitioners must liaise closely with skills coaches to determine the
264 optimal course of action in relation to the selection or deselection of a particular player.
265 Relatively poorer performance may not be permanent, nor is it necessarily unresponsive to
266 the right type of training at the right time of development ¹⁵⁻¹⁷. Indeed, even with an
267 appropriate training programme in place, its effectiveness could be undermined by some
268 negative elements of the developmental process, such as impaired motor coordination or
269 decreasing relative strength levels ^{4,18,19}. In relation to these points, it has previously been
270 shown that the athletic superiority enjoyed by early maturing players was eliminated by the
271 time that all players exited a soccer academy, with technical development cited as a key
272 component in the equalisation of physical abilities over time ¹⁴. In light of such evidence,
273 coaches should be cognisant that physical attributes in the youth player are inherently
274 unstable and can improve or deteriorate at key times during the maturation process. **As**
275 **demonstrated by the comparisons of players 1 and 3, and players 2 and 5, physically inferior**
276 **players have a reasonable expectation of performance improvement over time. Moreover,**

277 their performance relative to their peers could be further enhanced as physically superior
278 players can undergo marked decreases in performance as they mature, thus “levelling the
279 playing field”.

280 In our dataset, there seems to be an inherent trend that in tasks that require high relative
281 strength, performance decreases are common around the time of PHV. To varying degrees,
282 all six case players display erratic developmental trajectories that are commonly
283 characterised by a decrease in performance around PHV, most markedly seen here in the
284 10 m and 20 m sprint tests. As youths mature and gain bodyweight, relative strength can
285 decrease. If the gaining of weight outpaces that of relative strength, a decrease in
286 performance can result as an individual becomes relatively less capable of propelling their
287 own body mass ¹⁷. The comparison between players 2 and 5 is interesting in this regard. In
288 the sprint tests, player 5 is consistently superior to player 2 until the time of PHV when his
289 performance drastically decreases and he falls behind player 2. Following these decreased
290 performance levels, player 5 does not demonstrate a trend of recovery as player 2 continues
291 to progress. Such decreases in performance could also be attributed to temporary growth-
292 related disruptions to motor coordination, termed adolescent awkwardness ⁸, and coaches
293 should therefore allow a player sufficient time to come to terms, and correct, such issues.
294 This could potentially involve amendments to the player’s training programme whereby an
295 increased emphasis is placed on movement quality whilst contraindicated forms of training,
296 or training volume, are reduced or discontinued. At this particular time, coaches should also
297 be cognisant of the higher potential for young athletes to sustain injuries during PHV ²⁰.

298 The above example demonstrates the delicate nature of the key period in and around the
299 growth spurt in youth athletes. Whereas one individual can experience drastically lower
300 performance at this time, others’ progression can be enhanced due to the underlying
301 maturational processes, such as increasing stride length ²¹. To date there are few viable
302 tests to determine which individuals are likely to suffer from impaired performance at this
303 time and this should be a focus of future research. Selection decisions should therefore be

304 delayed until coaches can make a more informed appraisal of a player. However, this also
305 has implications outside competitive sport where selection or deselection by coaches is not
306 an influencing factor. For example, in the school environment, if children perform poorer at
307 sport due to temporary declines in physical capabilities, they may become discouraged and
308 avoid certain types of physical activity. Despite being encouraged to partake in sport,
309 overweight children can tend to avoid more traditional forms of exercise such as aerobic
310 training, which includes soccer ²². Moreover, engagement in this type of exercise could lead
311 to overuse injury in this population ²². It is the task of the coach and physical education
312 practitioner to direct children towards tasks that they can excel at and to educate children on
313 the possible changes that can occur non-linearly as they grow, and which can negatively
314 affect performance. To this end, the direction of overweight or movement-impaired children
315 to alternative forms of exercise, such as resistance training, could be beneficial as it
316 provides an opportunity for this group to outperform their underweight or understrength
317 peers ^{23,24}. Such a strategy can also be utilised in the high-performance academy
318 environment where players experiencing rapid increases in bodyweight can be exposed to
319 resistance training which can help them to overcome any movement-related impairments
320 due to this stage of maturation. At such times, it is also important for coaches to appreciate
321 the differences between absolute and relative strength. As a youth matures, absolute
322 strength will likely increase ²⁵ meaning that an individual would be better prepared to move
323 increasingly heavy external loads. However, relative strength, which is correlated to the
324 ability to overcome one's body mass during a task such as sprinting, may not increase as
325 rapidly due to maturation-related gains in bodyweight ²⁵. In this way, a player could
326 theoretically become relatively slower as he becomes stronger, a rather paradoxical
327 scenario that coaches must be cognisant of.

328 Given the above points, the value of single-occasion fitness testing as a talent-identification
329 and development tool in the youth athlete can be questioned ⁷. Moreover, the benefit of
330 having players within an academy environment for a longer period facilitates a greater

331 likelihood of the identification of elite traits such as those mentioned, alongside psychological
332 capabilities such as robustness, resilience, leadership and autonomy. Developmental
333 trajectories seem too variable and recoverable to justify making selection decisions on
334 limited information gained at a single fixed point in time. It is therefore important for coaches
335 to be cognisant of the impact that performance in common fitness tests, such as those
336 presented in the current study, can have on technical play. For example, it is interesting to
337 note that two investigations by Trecroci et al. ^{26,27} showed that sprint and agility tests and
338 CMJ were significant differentiators between elite and sub-elite soccer players. Short sprints
339 are a common and important determinant of performance in youth sport ²⁸ and Mendez-
340 Villanueva et al. ²⁹ have previously reported youth soccer players reaching speeds of up to
341 29.5 ± 1.4 (km · h⁻¹) in match play. Moreover, straight sprints have been shown to be the
342 most common type of movement prior to goal-scoring ³⁰, underlining the importance of
343 training sprint speed, though not necessarily using it as a selection tool, from a young age.
344 Trecroci et al. ^{26,27} found that 10 m sprint and CMJ could discriminate between elite and sub-
345 elite under 15 soccer players. However, for under 16 players, they found that only CMJ and
346 agility could discriminate the level of play. On this basis, coaches should be aware that as
347 youth players progress through the age grades, the dynamic nature of their physical
348 development makes it difficult to determine talent based on singular test types.

349 An arguable weakness of this case study is the lack of a measure of relative or maximal
350 strength over the observed study period. We have suggested that one of the reasons for the
351 common decrease in performance levels in and around the growth spurt could be due to
352 decreasing relative strength precipitated by increased bodyweight and a lagging ability to
353 propel that bodyweight. Alternatively, decreased motor coordination due to an individual's
354 rapidly heightened centre of gravity due to growth could also play a vital role. The addition of
355 a measure of strength in a similar investigation could assist coaches and researchers in
356 identifying which of these factors, if any, are most prominent as a youth player matures. The
357 case study research design used here makes it somewhat difficult to generalise the results

358 to a wider population of soccer players but, conversely, it also facilitates the observation of
359 precise trajectories of individual development that were not disadvantaged by the smoothing
360 effect of pooling data. In this way, the player cases presented here could be demonstrative
361 of typological developmental trajectories that are reminiscent of those seen across the
362 soccer-playing youth population. Indeed, the calculation of z-scores from a wider population
363 of 140 players reinforces this point.

364 **CONCLUSION**

365 To maximise the development of soccer players and to ensure that club academies fully
366 leverage the benefits of operating an academy system, both fitness and technical coaches
367 must work in close collaboration to track the developmental trajectories of their players over
368 time. Fluctuations in players' physical performance can occur quickly and in drastic fashion
369 but this does not necessarily represent a decline in footballing ability. An essential element
370 in achieving positive outcomes in talent development is an awareness that suppressed, or
371 inflated, performance could be temporary and selection and deselection decisions should
372 not be made based on the information gathered over a short period of time. The longitudinal
373 curves presented in the current study demonstrate the unstable nature of physical
374 development in youths and coaches can use our data to discourage the early deselection of
375 youth players, safe in the knowledge that depressed performance can recover in time.
376 Coaches must be cognisant of the connection between physical and technical skills in that
377 the former can affect the latter and, to this end, it is worthwhile educating players on how
378 their bodies develop during the academy years. Educational efforts of this type are more
379 likely to assist players in understanding the natural fluctuations in performance and could
380 potentially result in the reduction of self-deselection from the sport. To facilitate this, coaches
381 are encouraged to longitudinally apply the method proposed by Till et al. ¹³. There are ways
382 in which researchers can expand on our approach in the future. We observed trends
383 indicating temporary growth-related disruptions to motor coordination, termed "adolescent
384 awkwardness" ⁸, and we believe this can have a negative outcome on player performance

385 and welfare. On this basis, a longitudinal investigation of motor coordination is warranted
386 using tests that may be more conducive to identifying growth-related disruptions as a player
387 matures. Such information could further assist coaches in the strategic structuring of
388 programmes of physical development for youth soccer players. This additionally emphasises
389 the importance of frequently assessing each player's biological maturity status.

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