RUNNING HEAD: Maturation & Athlete Development in Soccer

When does the influence of maturation on anthropometric and physical fitness characteristics increase and subside?

By

Christopher Towlson[1], Stephen Cobley[2], Guy Parkin[3], & Ric Lovell[4]

[1] Sport, Health and Exercise Science, School of Life Sciences Faculty of Health Science, University of Hull, UK,

[2] Exercise & Sport Science, Faculty of Health Sciences, The University of Sydney, Australia

[3] Pro Football Support, Huddersfield, UK

[4] School of Science and Health, Western Sydney University, Penrith, Australia

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Corresponding Author:

Dr. Stephen Cobley

Discipline of Exercise & Sport Science,

Faculty of Health Sciences, The University of Sydney,

Cumberland Campus, 75 East Street, Lidcombe, NSW, 2141, Australia;

Email: stephen.cobley@sydney.edu.au.

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Abstract

The relationships between maturation and anthropometric and physical performance characteristics are dynamic and often asynchronous; confounding the capability to accurately evaluate performance during adolescence. This study aimed to (i) examine the influence of chronological age (CA) and somatic maturation (YPHV) upon anthropometric and physical performance parameters, and (ii) identify the transition/change time-points in these relationships using segmental regression. N=969 soccer players (8-18 years of age) completed anthropometric and physical test assessments, including a counter-movement jump (CMJ), agility T-test, 10 and 20m sprints, and multi-stage fitness test (MSFT). When modelled against CA and YPHV, results identified time-point phases with increased rates of stature (CA - 7.5, YPHV - 8.6 cm·year^{-1} at 10.7-15.2 years or -3.2 to +0.8 YPHV) and body mass gain (CA - 7.1, YPHV - 7.5 kg·year^{-1} at 11.9-16.1 years or -1.6 to +4.0 YPHV); followed by gain reductions. Increased rates of sprint performance development (31-43% gains) occurred at 11.8-15.8 CA or -1.8 to +1.2 YPHV; with gains subsiding thereafter. CMJ, T-test, and MSFT gains appeared relatively linear with no change in developmental rate apparent. Developmental tempos did again however subside at circa (CMJ and T-Test) to post-PHV (MSFT). Based on our sample and analysis, periods of increased developmental rates (stature, mass, sprint) were apparent alongside progressive gains for other physical measures, before all subsided at particular age and maturation time-points. Findings highlight dynamic asynchronous development of players, physical attributes, and the need to account for the influence of maturation on athletic performance until post-PHV.

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Introduction

Across sporting organizations, the identification and development of exceptional youth sport performers has become a progressively professionalized[1]. Nonetheless, researchers in this field consistently highlight the complexity and limited accuracy (at present) in being able to systematically identify exceptional young athletes that associate with senior athlete success[2, 3]. To illustrate, less than 1% of boys recruited to player development centres in English youth soccer go on to forge a professional career[4]. Data in other contexts also highlights that only relatively low percentages (~30%) of youth athletes remain within a development system for ≥3 years[5]. Together, both theoretical positions and existing evidence suggest that the failure to consider the holistic, multi-factorial nature of athlete development are key reasons for inaccuracy and limited success[6, 7]. Athlete development is predicted to involve non-linear progression [8] and complex interactions over time between technical (e.g., motor coordination and skill control), physical (i.e., aerobic and anaerobic capacities), social (e.g., relationships within the family; coaching expertise) and environmental factors (e.g., quality and structure of training). These interactions are considered to contribute toward selection [9, 10], progression and deselection[9, 11] within sports systems.

Within potential interactions, athlete development research has highlighted how physical and performance capacities in youth are substantially confounded by biological maturation[12]. However, confounding is personified by participation, selection, and

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performance benefits from being 'relatively older' and/or 'earlier maturing' within chronological age groups and developmental stages of sport systems (see Lovell et al[10]; Cobley et al[13]). However, such advantages do not necessarily translate into long-term senior adult success[14]. Although normative ages and stages of maturation exist, maturation can substantially vary between individuals and its impact has somewhat dissimilar and asynchronous relationships with athletic performance over time.[15].

Driven by biological sub-system development (e.g., hormonal, neural, bone and muscle tissue), there appears to be dynamic (i.e., (in)decreasing) relationships with athletic measures, although a dearth of information is available regarding the characteristics of these interactions. Features of interest between maturation and athleticism include the magnitude and rate (tempo) of improvement, but also the inception and termination (or waning) time-points of developmental change (timing). Using classic polynomial regression models to determine non-linear relationships, studies have attempted to model the development of various athletic characteristics related to maturation, such as anthropometry, explosive leg power, agility, endurance capacity and sprint performance[15-17]. However, these analytical approaches do not necessarily and specifically consider transition-points in the maturity-physicality relationship, and the regression parameters are not directly interpretable[18].

The aim of the present study was to examine the influence of chronological age alongside somatic maturation upon several anthropometric and physical performance parameters in a large cross-sectional sample of youth soccer players aged 8-18 years of age. The study aimed to specifically identify the chronological age and maturational time-points for when the influence of maturation increases, subsides or ceases to exist on examined variables. To achieve this, an analytical approach of segmental regression was purposefully

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utilised for two primary reasons: 1) to identify generic time or break-points where the dynamic influence of maturation on dependent measures could be detected; and 2) to help establish a better understanding of the sometimes asynchronous relationships between maturation and a range physical performance variables. Together such an analysis could help inform sports systems and practitioners when to consider preventing, tempering or delaying player evaluation and (de)-selection, without the concerns of maturational confounding. Likewise, such data could help researchers and practitioners identify mitigation strategies (e.g., sport system policy) that prevent maturation from affecting athlete development experiences and processes.

Methods

Using a standardised battery of field-tests, assessment of anthropometric and physical fitness characteristics were performed, accompanied by estimations of somatic maturation on 969 young elite soccer players', participating in 1 of 23 elite youth soccer TID programmes (governed by the Elite Player Performance Plan[19]) located within UK professional soccer clubs. All assessments had institutional ethical approval, and data was obtained between January and July of the respective soccer seasons (i.e., 2011/12, 2012/13, 2013/14 and 2014/15). Players' were divided in to 10 decimal age groups (Under [U] 9`s [n = 61]; U10`s [n = 112]; U11`s [n = 113]; U12`s [n = 126]; U13`s [n = 106]; U14`s [n = 212]; U15`s [n = 126]; U16`s [n = 26]; U17`s [n = 94]; U18`s [n = 27]) and dependent on their age and stage of development, players' typically received either 3-5 (U9 to U11), 6-12 (U12 to 16) or 16 hours (U17 to U21) of coaching each week at respective centres[19] including potential competitive matches. Each player was previously habituated with each component of the

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field test battery. Players' performed a standardised battery of three anthropometric and four physical fitness assessments during a regular training session. The battery of anthropometric and physical fitness assessments adopted were used to estimate somatic maturation, and to examine discreet physical attributes considered relevant for the long-term athletic development of soccer performance. The composition of the battery was deemed suitable by the Football League at the time of testing, to fulfil the requirements of the Elite Player Performance Plan (EPPP) mandate to track youth players' physical development trajectories.

Anthropometrics

Previously determined as reliable[20] and following ISAK recommendations[21], a portable stadiometer (seca© 217,Chino, U.S.A) measured player stature. Players' were required to put their shoeless feet together and heels touching the scale, whilst their head was positioned in the Frankfort plane to perform the stretch stature method. Players were required to take a deep breath in and hold the position of their head whilst duplicate measures were recorded to an accuracy of 0.1 cm. Following similar procedures, seated height was measured (seca© 217, Chino, U.S.A) on a standardised plinth with players hands resting on their thighs. Players again adhered to the stretch stature method when seated height was measured. Estimated leg length was recorded as stature minus seated height[22]. Body-mass (seca© Robusta 813, Chino, U.S.A) was recorded whilst players wore their normal training attire with shoeless feet using previously outlined procedures. If the duplicate anthropometric measures varied ≥ 0.4 cm or 0.4 kg, a third measure was taken and the median value recorded. The test-retest reliability (coefficient of variation [%]) for measures of stature, seated height and body mass were 0.4, 1.1 and 0.7%, respectively (typical error: stature = 0.6 cm; seated height: 0.9 cm; body mass: 0.3 kg).

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Somatic Maturation

Anthropometric measures (stature, seated height, body-mass) and decimal age were used to estimate player somatic maturation. Estimated years to/from peak height velocity (YPHV) was calculated using a cross-validated algorithm (to an accuracy of 0.24 years) based on a longitudinal analysis of the interaction between somatic components (stature, seated height, and leg length) and calendar age of 79 Canadian boys aged 8 to 16 years[23]. The test-retest reliability of the predicted age at peak height velocity was 0.1 years (typical error), or 0.8% when expressed as a coefficient of variation.

Vertical counter movement jump

Explosive leg power was assessed using a Counter Movement Jump (CMJ) on a digital contact mat (SmartJump©, Fusion Sport, Cooper Planes, Australia). Players were instructed to maximally jump vertically, having performed a self-selected countermovement that preceded the jump whilst keeping their hands placed on their hips throughout. Players performed a warm-up consisting of one 50 and 75% of self-perceived maximal CMJ, before performing three maximal CMJ`s interspaced by a 3 min passive recovery. If the range of the best three jumps varied ≥ 2 cm, then repeated attempts were performed until the criterion was achieved (up to a maximum of 8). The mean of the highest three jumps provided CMJ height.

Agility T-test

Timed agility performance was established using the T-test and using the Brower Timing System (Salt Lake City, Utah, U.S.A). Agility was determined by the time taken for

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each player to navigate the course. Players' were instructed to sprint forwards 9.14m (10 yards), side shuffle left 4.75m (5 yards; maintaining a forward facing position), return to the mid-line and repeat for the opposite side of the course before backward running 9.14m (10 yards) to finish. Each player completed two warm-up efforts at 75% of self-perceived maximum, prior to completing four (2 x left, 2 x right) maximal and timed efforts interspaced by 3 min passive recovery. The fastest attempt recorded for each direction (left and right) was recorded, and averaged to determine agility performance.

Maximal sprint speed

Following a standardised re-warm-up consisting of three 10 and 20m runs at 50, 75 and 90% of their self-determined maximal sprint pace, players performed a 20m maximal sprint test. Three timed (Brower Timing System, Salt Lake City, Utah, U.S.A.) maximal 20m sprints were interspersed by 3-min passive recovery and the mean time was recorded. To identify players 10 and 20m sprint time, digital timing gates were placed at 0, 10 and 20m.

Endurance capacity

The MSFT assessed player endurance capacity and has been deemed valid and reliable for this purpose[24]. The MSFT was adapted, with an experienced test administrator acted as pacer to ensure players' achieved the correct timings during speeds 6-11 km.h^{-1} and the test began thereafter with speed increasing by 1.0 km.h^{-1} every ~1 min until test cessation. Failure to complete the 20m track in the allotted time for the shuttle resulted in a verbal warning from the test administrator(s), with test cessation determined from a subsequent failure. Total distance covered (m) was used as the outcome measure to assess endurance capacity as maximal aerobic speed is underestimated by ~ 3 km.h^{-1} [25] the MSFT, due to the multiple accelerations, decelerations and changes of direction required during 20 m shuttle running.

Statistical analysis

Statistical analysis was conducted using R (v 3.0.2). *A priori*, data from participants whose YPHV exceeded the tolerance limits of the somatic maturation prediction equation (± 4 years[23]) were discarded (n=20). Next, linear regressions of the dependent variables (i.e., anthropometric/performance data) versus explanatory (chronological age - CA, somatic maturation - YPHV) variables were visually inspected and examined empirically (Davies test) to test for abrupt response variable changes. For each individual regression, Davies tests identified non-constant regression parameters (p < 0.05), with the exception of CA-CMJ (p=0.295). Whilst acknowledging this isolated trend, we continued with further analysis of this relationship to enable comparisons to YHPV-CMJ. Using the 'Segmented' package (v 0.3-0.0) in R, segmented regression analyses were performed to identify the time-point(s) of increasing or decreasing change in the development tempos of the targeted variable (aka – breakpoint[s][18]). The precision of break-point estimates was calculated using Wald-based 95% confidence intervals (CI). Slope coefficients and their estimated precision (95% CI's) are reported, and significant slopes were detected using alpha set at 0.05. The variance explained by each of the segmented regression models was quantified using r^2.

Results

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Time point(s) of increasing and decreasing development change along with the estimated rates of anthropometric and physical fitness characteristic development according to player decimal CA are presented in Table 1. A similar representation of data according to somatic maturation (YPHV) is summarised in Table 2. Graphical representations (breakpoints [95% CI]) of anthropometric and physical fitness characteristic development according to decimal CA and YPHV are depicted in Figure 1 and Figure 2 respectively.

Athropometric characteristics

With two identfied trajectory breakpoints after approximately 10.7 CA or -3.2 YPHV, stature increases were greater between 10.7 to 15.2 years or -3.2 to +0.8 YPHV. Annual growth rates of 7.5cm year^{-1} were estimated by CA, or 8.6cm·year^{-1} by YPHV. After 15.2 years or +0.8 YPHV stature gains reduced to estimates of 1.8-3.8cm·year^{-1} according to CA and YPHV, respectively. In terms of body mass, an increased development tempo (i.e., breakpoint) was identified at 11.9 years, or -1.6 YPHV, with body mass estimated to gain at a rate of 7.1kg·year^{-1} between 11.9-16.1 years. When modelled against YPHV, body-mass increases were estimated at 7.5kg·year^{-1} from -1.6 to +4.0 YPHV without signs of plataeu in the sample. For both stature and body-mass, model strength and coefficient estimate precision (95% CI width) were slightly higher in YPHV (r^2 = 0.89) versus decimal age (r^2 = 0.81).

Physical fitness characteristics

For CMJ, Agility T-Test, and MSFT, segmental regression identified only one trajectory time point of change (or breakpoint) in the rate of development across the age and maturation ranges examined. These breakpoints occurred at estimates of 15.2, 15.8, and 16.4

years or +0.6, +0.4 and +2.1 YPHV respectively, suggesting that prior developmental gain prior was linear.

For CMJ, developmental gains were estimated at 1.9 to 2.5 cm·year^{-1} until 15.2 years or +0.6 YPHV respectively. Thereafter, development tempo decreased by ~48% in terms of YPHV to 1.3cm·year^{-1} circa-PHV (+0.6 YPHV; 95%CI's = -0.4 to +1.6 YPHV). Whilst a similar pattern (< development tempo ~ 26%) was identified in the CA-CMJ relationship, the precision of the breakpoint estimate was weaker (15.2 years; 95%CI's = 12.9-17.4 years), and the 95%CI of the two adjacent slopes overlapped. In modelling CMJ trajectories, r^2 = 0.52 and 0.53 for CA and YPHV respectively were not strong when compared to other variables examined.

For the agility T-test, gains were estimated at -0.39 to 0.49s·year^{-1} until 15.8 years or +0.4 YPHV respectively. These uniform development gains slowed thereafter, for example by ~43% from -0.49 to -0.21s·year^{-1} at +0.4 YPHV. Both CA and YPHV modelled agility moderately well (CA-T-test r^2 = 0.72; YPHV-T-test r^2 = 0.68). In relation to players' endurance capacity (MSFT), performance gains were estimated at 169-185m·year^{-1} until 16.4 years of age (r^2 = 0.61) and 2.1 years post PHV (r^2 = 0.58), repectively. After these age and maturation time points, MSFT performance change was not significant (p = 0.16 - 0.25) and plateued.

Finally for both 10 and 20m sprints, two changes in trajectory breakpoints were identified with consistent trend estimates across age and maturation (r^2 = 0.71 to 0.76). Sprint performance was estimated to improve at -0.04s·year^{-1} (10m) and -0.08s·year^{-1} (20m) until 11.8 years of age, or by -0.05s·YPHV^{-1} (10m) and -0.11s·YPHV^{-1} (20m) until -1.8 YPHV. At this breakpoint, sprint performance development tempo then increased by 31 to 43% until

15.8 years (10m = -0.07s·year^{-1}; 20m = -0.14s·year^{-1}) or +1.2-1.3 YPHV (10m = -0.08s·YPHV^{-1}; 20m = -0.16s·YPHV^{-1}). Thereafter, gains in sprint performance were not further apparent in the sample (p = 0.18-0.96), though with the exception of YPHV-20m. Here subtle continued improvements were apparent (-0.02; 95%CI's = -0.05 - 0.01s·YPHV^{-1}).

Discussion

The aim of the present study was to examine the changing relationships between chronological age and somatic maturation upon anthropometric and several physical performance parameters in a large cross-sectional sample of youth soccer players (aged 8-18 years). We specifically focused our analysis upon identifying transition time-points where the influence of age and maturation increased or waned, and where development tempos of key physical characteristics could be identified. The key findings were as follows. Firstly, the development tempo of height, weight and sprint performance began to markedly increase at 10.7, 11.9 and 11.8 years of age or -3.2, -1.6 and +1.8 YPHV in this sample respectively; illustrating asynchronous development. At 15.2, 16.1 and 15.8 years (or approximately +1.0 YPHV) the rate of gain in these specific indices markedly decreased, highlighting dynamical trends over time. Second, and by comparison, lower-limb power, agility and endurance performance illustrated more linear progressive trajectories from <10 years of age (or approximately -3.5 YPHV), and without notable accelerated phases. Again however, their developmental tempo waned circa- to post-PHV (CMJ = 15.2; T-test = 15.8; MSFT = 16.4 years of age, or CMJ = +0.6; T-test = +0.4; MSFT = +2.1 YPHV). These findings highlight staggered, asynchronous, decreasing trajectories after YPHV. Third, the predictive strength of physical fitness parameters did not differ according to chronological age and somatic maturation; though somatic maturation modeled basic anthropometric indices marginally better than chronological age given the present sample and analysis approach.

Firstly, it is important acknowledge that within our sample, an earlier onset of the stature growth spurt (10.7 years, or 3.2 years before PHV) was apparent compared to both population norms (~12 years; Tanner et al.[26]) and other youth soccer populations (11.8 years; Malina, Bouchard et al.[22]). The growth rates derived circa-PHV (stature: 7.5-8.6 cm·year^{-1}; body mass: 7.1-7.5 kg·year^{-1}) also somewhat exceed those taken from population growth norms over equivalent durations (stature: ~6.4 cm·year^{-1}; body mass: ~4.5 kg·year^{-1}; Royal College of Paediatrics & Child Health[27]). Such findings could relate to the nature of the cross-sectional sample, and the inclusion of participants from across stages of the talent developmental life-cycle. Alternatively, our previous work related to the sample did identify a strong over-representation of relatively older players in age-categorised squads; the magnitude of which was greater than previously reported in other youth soccer populations[10]. Either way, what is more clear at time-points circumventing the PHV period is that advanced 'early' somatic maturation is associated with accelerated development in anthropometric and physical parameters relative to others (e.g., 'later maturers') as previous findings have identified (e.g., Till et al., 2014[28]; 2015[29]).

In relation to identifying the time points of developmental change, a distinct increase in the rate of development for sprint performance was identified for 11.8-15.8 years of age, or circa-PHV (-1.8 to +1.3 YPHV), and with a decreasing trajectory beyond these points. This finding is tangibly supported by longitudinal observations of soccer sprint performance during PHV (e.g., Philippaerts et al., 2006[15]), and notions of heightened training sensitivity

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adaptation for strength during and after PHV[30, 31]. In alignment, the negligible benefit of sprint performance training prior to PHV has been highlighted, with only steady increments prior to maturation onset apparent[32, 33]. It has been proposed that the increased development tempo of sprint circa-PHV likely reflects the influential role of growth[34, 35] and associated increases in stride length[36] considering that both inception (-1.8 YPHV) and subsiding (+1.2-1.3 YPHV) breakpoints coincide with timing of the adolescent growth spurt[26]. Further, given the association between strength and lower-limb power[37], accelerated trajectories might be expected circa-PHV, and in fact has been previously reported in youth football players[15,16]. Therefore, sprint development seems most closely aligned to the inter-related array of maturation related physiological changes (e.g., neural, growth, muscle strength).

Despite the increase in developmental tempo for sprint observed circa-PHV, there also remains conjecture as to whether a period of heightened training sensitivity exists during or immediately post-maturation. Recent meta-analyses examining sprint[32] and mixed-method training (incorporating plyometric and/or strength training)[33] has indicated only modest gains, with a return to prior sprint capacities when training is ceased circa-PHV[30], versus post-adolescent youths for which sprint training responses were increased and retained. However in our data, we only observed a plateauing effect post YPHV, and such a discrepancy may be explained by the lack of specifically targeted training activities administered to our sample. Further, post-PHV plateauing may reflect a diminishing return based on present training profiles. Thus, only with sustained increases in specific sprint training could sprint performance be further enhanced.

In relation to lower-limb power, agility and endurance, findings identified consistent linear improvements from childhood until 15.2-16.4 years of age, or 0.4-2.1 years post PHV.

In each case, and while staggered, only single trajectory breakpoints in the rate of development were apparent and these occurred post PHV, suggesting that somatic maturation changes were not necessarily concomitantly associated with changes in lower limb power, agility and endurance. However, post 15.8-16.4 years of age (or +0.4-2.1 YPHV) developmental tempo typically did slow akin to anthropometric and sprint measures. These findings sit somewhat in contrast with elite-youth soccer studies which have identified accelerated development for lower-limb power, agility and cardio-respiratory endurance around PHV[15,16] and potentially challenge 'windows of trainability' propositions popularized in Long-Term Athlete Development (LTAD) models[38]. Nevertheless, there could be multiple reasons accounting for such discrepancies. Firstly, it is possible that lower-limb power, agility and endurance lag behind normative changes in maturation associated anthropometric and sprint gains as reflected by our data, potentially because of the importance of pre-adolescent motor control and co-ordination[15] in CMJ, agility and MSFT tasks. Each of these tasks do have technical skill requirements (e.g., turning in MSFT and T-Test). Thus, if such coordination and skills underlying movement are not developed alongside anthropometric and muscular change circa-PHV, then only minor (steady) body size associated increments may occur over time. Second, considering that heightened training adaptations have also been reported during and after PHV[30-32], either a lack of specific conditioning may be inferred, or that our sample is already high performing (i.e., ceiling effect for age and maturation). Finally, differential findings may associate with experimental designs deployed. Our large-scale cross-sectional study maybe less sensitive to the individualized timing and nature of the adolescent growth spurt, and so longitudinal player tracking would provide greater validity.

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Of interest in the present analysis was the similarity to which segmented regression modeled outcome measures, irrespective of whether chronological age or somatic maturation was used as explanatory (predictor) variables. Given the highly individualized on-set of the adolescent growth spurt and the asynchronous relationships with differing athletic performance indices, we expected the estimates of YPHV to explain greater variance in the regression models. However, the number, timing and precision of break-points identified - together with estimates of development tempo - were typically consistent. That said, slightly enhanced model strength and coefficient estimates (confidence interval width) occurred when anthropometric data was predicted using YPHV. This might be better explained by the accompanying and direct anthropometric changes that occur close to PHV [22, 23], and which then subsequently relate to athletic performance indices[34,35]. It may also be partly accountable by the nature of the sample, who were more likely to be relatively older and/or early maturing, reflecting a potentially homogenous already highly selective sample.

The main limitation of this study relates to the maturation offset prediction equation used to determine somatic maturity. It has been shown to underestimate APHV for boys 3 years (-0.32 years) prior to PHV, and overestimate (+0.56 years) those 3 years post PHV[39]. Mills et al., (2016)[40] has suggested that PHV onset is over-estimated when determined from somatic measures, due to possible over-fitting of the original prediction model[41]. These biases should be considered when interpreting the change-points presented in the current data-set. However, considering the concordance of the maturation offset versus radiography gold-standard techniques is equivalent to other non-invasive estimates[42] that require additional stature recordings of both biological parents[43], we considered the Mirwald method to be most feasible when conducting a large-scale 'in the field' study. Even though providing one of the

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most substantive data-sets available to date in youth soccer, a second limitation relates to the cross-sectional nature of the sample, suggesting caution relative to the greater accuracy provided by longitudinally tracked samples. Finding generalizability should also be considered. The present sample already reflects a highly selected subgroup of the sporting and more normative population, and could be affected by the selection criteria and policies of talent identification practitioners. Together with the training regimes adopted by coaches and trainers, both could vary according to program and stage of development[44].

Overall, these limitations had to be accepted given the large sample of elite youth soccer players examined, procedures required in data collection and feasibility of tracking players in a large sample.

Perspectives

Findings identified chronological age and somatic maturation time-points of increased and subsiding developmental trajectories for anthropometric development and sprint performance. By comparison, lower-limb power, agility and endurance performance development showed linear improvement trajectories from <10 years (approximately -3.5 YPHV). However, all trajectories subsided in their rate of development circa- to post 16 years (~PHV). Findings highlight the need for practitioners and sport policy-makers to (i) be cognizant of the dynamic, asynchronous and staggered trajectories apparent in player (anthropometric and physical) development[19] (ii) assess, monitor and control for the influence of growth and maturation on athletic performance and development until at least post 16 years of age (and post PHV) in a relatively earlier maturing sample; (iii) consider that growth and maturation trajectories may occur later in presently non-selected (soccer participating)

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samples; (iv) and avoid (de)selection of soccer players due to transient developmental trajectories. Whilst a number of soccer federations have adopted initiatives to address the temporary bias afforded to earlier maturing players such as bio-banded tournaments and routine auditing of maturation, further work is warranted to: determine the efficacy of intervention strategies; improve the accuracy of currently adopted non-invasive maturation estimates; and determine the utility of physical training according to maturation.

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List of Table & Figure Titles

Table 1. Anthropometric and physical fitness development trajectories of UK elite youth soccer players according to chronological decimal age (years).

Table 2. Anthropometric and physical fitness development trajectories of UK elite youth soccer players according to somatic maturity (YPHV).

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Figure 1. Anthropometric characteristic development according to player chronological decimal age (years) and somatic maturity (YPHV), accompanied by a frequency distribution tally depicted along the 'X' axis. Pane A = Stature (cm); Pane B = Body-mass (kg). See Tables 1 and 2 for identification of breakpoints A, B, C and D.

Figure 2. Physical fitness characteristic development according to player chronological decimal age (years) and somatic maturity (YPHV), accompanied by a frequency distribution tally depicted along the 'X' axis. Pane A = Counter movement jump (cm); Pane B = Agility (s); Pane C = 10m sprint (s); Pane D = 20m sprint (s); Pane E = Multi-stage Fitness Test (MSFT) (m). See Tables 1 and 2 for identification of breakpoints A, B, C and D.

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Table 1. Anthropometric and physical fitness development trajectories of UK elite youth soccer players according to chronological decimal age (years).

		Breakpoints in development (years)		**Rate of player development**						
Variable	*n*	Breakpoint 1. (95% CI)	Breakpoint 2. (95% CI)	Slope A-B (95% CI)	*p*	Slope B-C (95% CI)	*p*	Slope C-D (95% CI)	*p*	r^2
Stature (cm)	969	10.7 (10.2 to 11.2)	15.2 (14.8 to 15.7)	1.8 (-0.1 to 3.8)	$p = 0.031$	7.5 (7.0 to 7.9)	$p \leq 0.001$	1.8 (0.9 to 2.7)	$p \leq 0.001$	0.81
Body-mass (kg)	969	11.9 (11.5 to 12.3)	16.1 (15.5 to 16.7)	2.5 (1.6 to 3.3)	$p \leq 0.001$	7.1 (6.6 to 7.6)	$p \leq 0.001$	2.9 (1.2 to 4.7)	$p = 0.001$	0.81
CMJ (cm)	774	15.2 (12.9 to 17.4)	- - -	1.9 (1.7 to 2.1)	$p \leq 0.001$	1.4 (0.7 to 2.0)	$p \leq 0.001$	- - -	- - -	0.53
T-Test (s)	926	15.8 (15.2 to 16.4)	- - -	-0.39 (-0.41 to -0.37)	$p \leq 0.001$	-0.07 (-0.18 to 0.05)	$p = 0.13$	- - -	- - -	0.72
10m sprint (s)	875	11.8 (11.2 to 12.5)	15.8 (15.3 to 16.3)	-0.04 (-0.05 to -0.02)	$p \leq 0.001$	-0.07 (-0.08 to -0.07)	$p \leq 0.001$	0.01 (0.01 to 0.02)	$p = 0.34$	0.73
20m sprint (s)	875	11.8 (11.2 to 12.4)	15.8 (15.3 to 16.3)	-0.08 (-0.09 to -0.06)	$p \leq 0.001$	-0.14 (-0.15 to -0.13)	$p \leq 0.001$	-0.01 (-0.03 to 0.03)	$p = 0.96$	0.76
MSFT (m)	876	16.4 (15.9 to 17.0)	- - -	169 (158 to 179)	$p \leq 0.001$	-44 (-132 to 44)	$p = 0.16$	- - -	- - -	0.61

Table Notes: 95%CI = 95% confidence interval; Statistically significance set at $p \leq 0.05$.

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Table 2. Anthropometric and physical fitness development trajectories of UK elite youth soccer players according to somatic maturity (YPHV).

		Breakpoints in development (years)		Rate of player development						
Variable	*n*	Breakpoint 1. (95% CI)	Breakpoint 2. (95% CI)	Slope A-B (95% CI)	*p*	Slope B-C (95% CI)	*p*	Slope C-D (95% CI)	*p*	r^2
Stature (cm)	969	-3.2 (-3.5 to -2.9)	0.8 (0.5 to 1.1)	1.8 (-3.1 to 6.6)	$p = 0.24$	8.6 (8.3 to 9.0)	$p \leq 0.001$	3.8 (3.0 to 4.5)	$p \leq 0.001$	0.89
Body-mass (kg)	969	-1.6 (-2.1 to -1.1)	- - -	5.2 (4.4 to 6.0)	$p \leq 0.001$	7.5 (7.2 to 7.7)	$p \leq 0.001$	- - -	- - -	0.89
CMJ (cm)	774	0.6 (-0.4 to 1.6)	- - -	2.5 (2.2 to 2.8)	$p \leq 0.001$	1.3 (0.7 to 1.9)	$p \leq 0.001$	- - -	- - -	0.52
T-Test (s)	926	0.4 (-0.1 to 0.9)	- - -	-0.49 (-0.53 to -0.45)	$p \leq 0.001$	-0.21 (-0.28 to -0.15)	$p \leq 0.001$	- - -	- - -	0.68
10m sprint (s)	875	-1.8 (-2.5 to -1.0)	1.3 (0.8 to 1.8)	-0.05 (-0.07 to -0.04)	$p \leq 0.001$	-0.08 (-0.09 to -0.08)	$p \leq 0.001$	-0.01 (-0.03 to 0.01)	$p = 0.18$	0.71
20m sprint (s)	875	-1.8 (-2.5 to -1.0)	1.2 (0.9 to 1.6)	-0.11 (-0.14 to -0.08)	$p \leq 0.001$	-0.16 (-0.12 to -0.14)	$p \leq 0.001$	-0.02 (-0.05 to 0.01)	$p \leq 0.001$	0.74
MSFT (m)	876	2.1 (1.6 to 2.5)	- - -	185 (173 to 198)	$p \leq 0.001$	-38 (-148 to 73)	$p = 0.25$	- - -	- - -	0.58

Table Notes: 95% CI = 95% confidence interval; Statistically significance set at $p \leq 0.05$.

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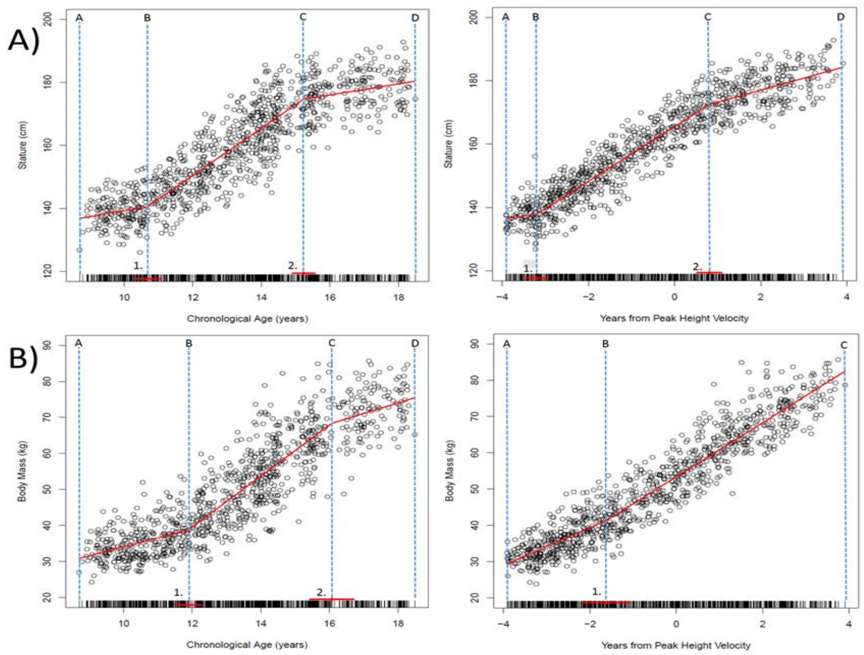

Figure 1. Anthropometric characteristic development according to player chronological decimal age (years) and somatic maturity (YPHV), accompanied by a frequency distribution tally depicted along the 'X' axis. Pane A = Stature (cm); Pane B = Body-mass (kg). See Tables 1 and 2 for identification of breakpoints A, B, C, and D.

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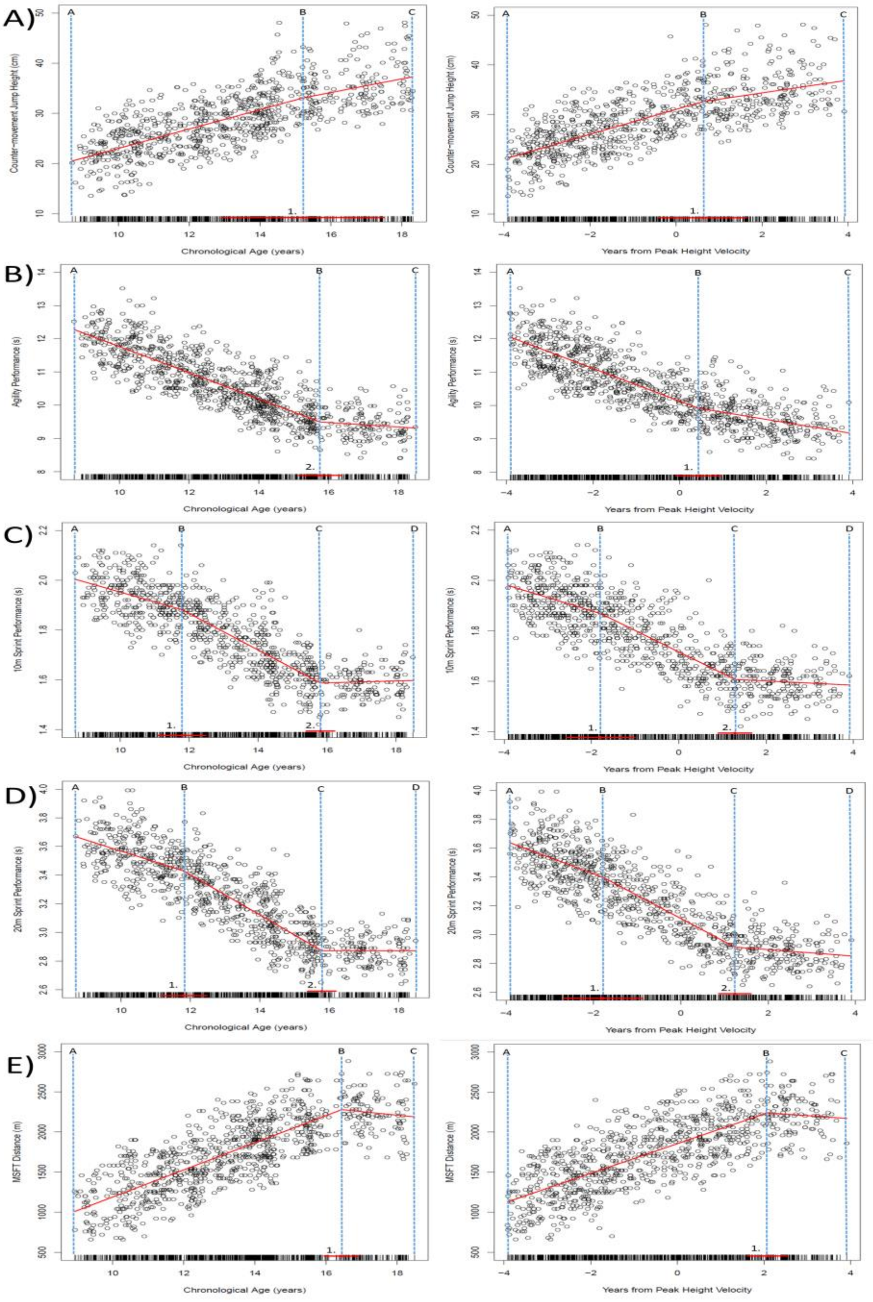

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