Maturity Associated Differences in Match Running Performance in Elite Male Youth Soccer Players

Journal:	*International Journal of Sports Physiology and Performance*
Manuscript ID	IJSPP.2020-0950.R1
Manuscript Type:	Original Investigation
Date Submitted by the Author:	04-Jun-2021
Complete List of Authors:	Parr, James; Manchester United Football Club Winwood, Keith; Manchester Metropolitan University Hodson-Tole, Emma; Manchester Metropolitan University Deconinck, Frederik; Universiteit Gent Faculteit Geneeskunde en Gezondheidswetenschappen, Movement and Sport Science Hill, James; The University of Manchester Cumming, Sean; University of Bath
Keywords:	adolescent, gps, running, maturity, soccer, PHV

Maturity Associated Differences in Match Running Performance in Elite Male Youth Soccer Players

Original Investigation

James Parr[a,b], Keith Winwood[a], Emma Hodson-Tole[a], Frederik J.A. Deconinck[c], James P. Hill[d], Sean P. Cumming[e].

[a]Musculoskeletal Sciences and Sports Medicine Research Centre, Department of Life Sciences, Manchester Metropolitan University, Manchester, United Kingdom, [b]Manchester United Football Club, Manchester, United Kingdom, [c]Department of Movement & Sports Sciences, Ghent University, Ghent, Belgium, [d]Department of Electrical and Electronic Engineering, The University of Manchester, Manchester, United Kingdom, [e]Department for Health, University of Bath, Bath, UK.

Corresponding author:

James Parr,

Manchester United Football Club,

Carrington,

Manchester,

M31 4BH

Email: james.parr@manutd.co.uk

Word count: 3530

Running Head: Maturity Influence on Running in Youth Soccer

7 Tables and 3 Figures.

Abstract.

Purpose. To investigate the influence of maturation on match running performance in elite male youth soccer players. ***Methods.*** Thirty-seven elite male youth soccer participants from an English professional soccer academy from the U14s, U15s, and U16s age groups were assessed over the course of one competitive playing season (2018 – 2019). Relative biological maturity was assessed using percentage of predicted adult height (PPAH). A global positioning system (GPS) device was used between 2 and 30 (mean = 8 ± 5) times on each outfield player. The position of each player in each game was defined as defender, midfielder or attacker and spine or lateral. Five match running metrics were collected: total distance covered; high speed running distance (HSR); very high-speed running distance (VHSR); maximum speed attained and number of accelerations. ***Results.*** Relative biological maturity was positively associated with all GPS running metrics for U14s. The U15/16s showed variation in the associations amongst the GPS running metrics against maturity status. A multi-level model which allowed slopes to vary was the best model for all parameters for both age groups. In the U14 age group, advanced maturation was associated with greater HSR. However, maturation did not contribute towards variance in any of the indices of running performance in the U15/16s. In the U15/16 age group, significance was observed in the spine / lateral playing positions when undertaking actions that required covering distance at high speeds. ***Conclusions.*** Maturation appeared to have an impact on match running metrics within the U14s cohort. However, within the U15/16s, the influence of maturation on match running metrics appeared to have less of an impact.

Keywords: maturation, soccer, running, adolescent, GPS

Introduction

The identification and development of talented young soccer players are the primary aims of professional soccer academies. Individual differences in maturation have been shown to impact player selection, fitness, and performance, making it challenging to identify those players with the most potential to succeed at adult level[1].

Male soccer players who are advanced in maturation have been shown to present greater height, weight, mass-for-stature, and also demonstrate superior performance on tests of speed, strength, power, agility, and endurance[2,3]. The physical and athletic advantages associated with earlier maturation emerge at the onset of puberty and remain relatively stable through mid and late adolescence. Longitudinal data suggests that it is only in early adulthood that these advantages are attenuated or, in some cases, reversed (i.e. over 20 years of age)[4].

Within elite soccer academies, there appears to be a bias towards boys that are advanced in maturity, with this bias becoming more apparent in older age groups[5]. Previous studies of academy soccer players reported that approximately 60 – 80% in the U16 and U17 age groups had a skeletal age that was at least one year greater than their chronological age[6,7]. In contrast, there is a systematic exclusion of individuals who are the youngest / least mature in soccer academies[2], with late maturing individuals more likely to be overlooked or released regardless of the technical, tactical and / or psychological competency[8,9].

Buchheit, Mendez-Villanueva, Simpson, Bourdon [10] suggested that biological maturation was positively associated with locomotor capacity during competitive play in highly trained youth soccer players (U13 – 18). For example, they highlighted that earlier maturing compared to later maturing boys presented significantly higher values for maximum speed, distance covered at high-speed and absolute higher intensity actions during competition. Accordingly, players delayed in maturity may possess a significant athletic disadvantage during competition. This observation may contribute towards the overrepresentation of early maturing in comparison to late maturing boys during the adolescent phase of development [9]. Note that there are three classifications of maturity status; pre-, circa-, and post-pubescent.

In a second study, Buchheit, Mendez-Villanueva [11] highlighted the influence of maturation on match running metrics and specific tests with running capability over the course of two successive playing seasons. In contrast to the former study[10], only U15s were considered but the results still highlighted that the players who were advanced in their maturity status demonstrated greater peak speeds and distances covered at greater speeds (>16 $km \cdot h^{-1}$) in a match. However, between the two maturity groups, no differences in total distance covered were identified. Moreover, a moderate to very large (0.5 – 1.0) magnitude of correlation between advanced maturity status and match running metrics was identified in midfielders and wingers.

Additionally, two studies have investigated match running metrics after grouping players by playing position[10,12]. Measures of match running metrics in youth soccer players, in particular high-speed running (HSR), were shown to be associated with playing position within youth soccer players aged between 12.2 – 14.0 years[10]. More recently, Lovell, Fransen, Ryan, Massard, Cross, Eggers, Duffield [12] examined the influence of maturity timing and the interaction with playing position upon match running metrics amongst U15 soccer players. This study showed that maturity timing was influential across all playing positions i.e. for each position, later maturing players covered greater distances. Therefore, it is important to consider position when assessing relationships between maturity and match running metrics.

The focus of the present study was to investigate the variation in match running metrics caused by differences in maturity status. Unlike previous studies[10-12], which have relied on either the Mirwald maturity offset[13] or maturity ratio[14] for determining maturity status, this study uses percentage of predicted adult height (PPAH) at the time of observation. The method assumes that among youth of the same chronological age, a youth that is relatively closer to their predicted mature height is biologically older (i.e. more advanced in maturity at the time of observation) than a youth that is relatively further removed from their predicted adult height than expected for age [4]. It has previously been shown that maturity does influence elements of match running metrics, and there may also be a further interaction with playing position[11,12]. However, a limitation of these studies is that they used match running metrics collected from either half games[11] or shortened-match tournament games[12], and so may not be directly relatable to a typical full match. This is a gap in understanding that will also be addressed here.

Therefore, the current study aimed to investigate the influence of maturity (determined by PPAH) and playing position on match running metrics for participants covering the full range of maturity categories. Full game data will be considered; this will ensure that tactical and fatigue effects are accounted for, particularly due to the demands of different positions. By analysing a cohort of participants that cover three age groups, and displaying position specific results, this study will reveal the different demands placed on players as they move between age groups and assess the influence of playing position in each age group.

Methods

Prior to the study commencing, ethical approval was obtained from the Ethics Committee of Faculty of Science & Engineering, at Manchester Metropolitan University. Parents / guardians of the participants were notified of the aim of the study, research procedures, requirements, benefits, and risks and provided written informed consent. The participants also provided assent.

Participants

Thirty-seven elite male youth soccer players (born between 2001 and 2005) from an English professional soccer academy (15.1 ± 1.4 years, height 172.5 ± 9.4 cm, weight 61.2 ± 11.0 kg) participating in the U14s, U15s, and U16s age groups were assessed over the course of one competitive playing season (2018 – 2019). Throughout the course of the season, anthropometric variables (heights and masses) for each participant were collected every two months and each player competed in between two and 30 full matches (mean = 8 ± 5 matches), resulting in 274 player files. All participants were outfield players.

Methodology

The U14s consisted of 21 participants. As a number of players from the U15s are frequently asked to 'play up' in U16s, these two groups were combined to make a single U15/16s group, totalling 16 participants. The analyses for the U14s and U15/16s samples were conducted separately as each sample included players at different stages of maturation. For example, all of the players in U15/16s were in the later stages of post-peak height velocity (PHV); in contrast, the U14s included players that were pre-, circa-, and post-PHV. Players from the U14s participated in approximately 8 hours of combined soccer specific training sessions per week, players in U15/16s undertook approximately 10 hours of combined specific training sessions per week, shown in Table 1.

******INSERT TABLE 1 NEAR HERE******

Measurement and Estimate of Maturity

Biological maturity status for each player was estimated and expressed as a 'z-score' relative to their group mean and standard deviation; these were specific to their age group, calculated based on the most recent three years of anthropometric data collected within the academy. Anthropometric measures were taken at two-month intervals during the respective seasons. The approach was the same as the method in[15], however, specific sample means and standard deviations were used as they differed from the population data, demonstrated in Table 2.

******INSERT TABLE 2 NEAR HERE******

Matches were performed on outdoor natural grass fields (85 × 64 m^2 (U14s) and 105 × 68 m^2 (U15/16s)), with 11 players per side. Playing time was 2 × 40-minute halves. Participants were assigned an outfield playing position (defender, midfielder or attacker and also whether they were a spine [central] or lateral [wide] player) in each game. Playing positions were defender (*n*=14), midfielder (*n*=15) or attacker (*n*=8); and spine (*n*=20) or lateral (*n*=17) for both groups (U14s and U15/16s combined). Tactically, all teams played in a 4-3-3 formation, as shown in Figure 1. GPS metrics for each fixture were aligned to the nearest anthropometric data collection point.

******INSERT FIGURE 1 NEAR HERE******

Match Running Metrics

All outfield players wore their own individual GPS device for every match (10-Hz, Viper Units; STATSports, Newry, Ireland). The GPS device sampled at 10-Hz with an integrated accelerometer with a sampling rate of 100-Hz.

It has previously been highlighted that there can be high variability in match-to-match running metrics (e.g. HSR can vary by 15 – 29%)[16]. Therefore, data obtained was taken only for players who performed in at least two complete matches. Following each match, data were downloaded to a computer and analysed using STATSports software package (Viper Version 1.2, 2012). Five match running metrics were collected, the details of these metrics are shown in Table 3.

******INSERT TABLE 3 NEAR HERE******

Only data where participants played for at least 80 minutes of a match were used. To allow all data to be compared on the same basis, all metrics (except for maximum speed) were divided by the total playing time of that player (e.g. 80 + minutes) in each match and then multiplied by 80 to give these metrics on a per 80-minute basis only.

Statistical Analysis

Descriptive statistics were calculated for growth and maturation characteristics and GPS metrics, with normality indicated through Kolmogorov-Smirnov and Shapiro-Wilk tests. Multilevel modelling using maximal likelihood estimation, examined predictive associations between biological maturity status, position (defender, midfielder or attacker), spine or lateral position and the GPS metrics amongst the U14s and U15/16s age groups. Correlation plots were created using Microsoft Excel (2010 Excel, Microsoft Corporation, USA), all other analysis was carried out using IBM SPSS 24 (SPSS Inc., Chicago, USA) software, with the level of significance set at $p < 0.05$.

A series of linear multilevel models were generated to examine the predictive associations of biological maturation. Playing position was also included in the statistical models as a categorical variable in order to disambiguate their effects from those of maturation. In accordance with processes described and recommended by Field [17], a stepwise approach was used ~~whereby additional predictors were subsequently added to the model~~. The baseline model included ~~with~~ only the dependent variable (GPS metrics), ~~was initially tested~~ (Model 1). Following evaluations of Model 1, Model 2 introduced a random intercept to account for participants ~~model that took into account participants and~~ repeated measures across matches ~~was evaluated~~ (Model 2). During Model 3, ~~Thirdly, the~~ slopes describing the relationship between biological maturation and the match running metrics were allowed to vary; maturation, playing position and spine / lateral were introduced ~~remained~~ as fixed factors ~~(Model 3)~~. A final model where slopes were allowed to vary for the position and the spine / lateral positions was tested (Model 4). Any modifications to the models beyond Model 3 were only accepted if they significantly improved the model fit. Model fit was evaluated using the Akaike Information Criterion (AIC)[18].

Maturity remained fixed throughout all models as this was treated as a continuous variable. The number of matches in which participants competed were entered as the repeated factor in the models.

Results

Descriptive statistics for chronological age, biological maturation and GPS match running metrics are segregated by age group (U14s and U15/16s) are reported in Table 4. Participants in the older age groups (U15/16s) were on average 12.0 cm taller, ~~(7%)~~, 16.1 kg heavier ~~(24%)~~ and were more advanced in maturation ~~(5.6%)~~ than players in the U14s cohort. Likewise, per 80 minutes, the U15/16s participants presented greater match running metrics; on average they displayed greater total distance in competitive matches, 484 m ~~(5.5%)~~, HSR, 185 m ~~(34.0%)~~, VHSR, 49 m ~~(52.0%)~~, were quicker, 1.9 km·h^{-1} ~~(6.4%)~~ and typically made 14 ~~(24.6%)~~ more accelerations than the U14s. Note that this could be a factor of the different pitch sizes. Match running metrics segregated by playing position are displayed in Table 5.

******INSERT TABLE 4 NEAR HERE******

******INSERT TABLE 5 NEAR HERE******

On average, midfielders typically covered greater total distance, however, attackers covered greater distances at higher speeds (HSR and VHSR), and also achieved the greatest maximum speed and number of accelerations. There was also a split between the spine and lateral participants, when it came to HSR and VHSR, lateral participants appeared to complete more of these types of actions.

Correlation plots (1-tailed) of relative biological maturity and match running metrics are presented in Figure 2 (U14s) and Figure 3 (U15/16s) where each completed 80 minute match for every participant was plotted. Relative biological maturity was positively associated with all of the GPS metrics for U14s (though with low correlation values), but this was not the case for all of the GPS metrics for the U15/16s.

******INSERT FIGURE 2 NEAR HERE******

******INSERT FIGURE 3 NEAR HERE******

Multilevel models were generated to examine the predictive associations of biological maturation and playing position upon match running metrics. Parameters associated with the best fitting model are presented in Table 6 for U14s and Table 7 for U15/16s. Coefficients (β), standard errors (SE), significance values (*p*) and confidence associated with each of the final models (95% CI) are presented in Table 6 and Table 7, respectively. In both of the tables, attackers and lateral positions are the respective base against which the other positions are compared.

******INSERT TABLE 6 NEAR HERE******

******INSERT TABLE 7 NEAR HERE******

For all of the indices of match running metrics in the U14s and U15/16s cohorts, Model 3 provided the best fit. That is, Model 4, which allowed the slopes to vary randomly for position and spine / lateral, did not result in improvements in model fit.

Discussion

The purpose of the present study was to investigate the influence of biological maturity and playing position associated variations on match running metrics amongst elite youth male soccer players from U14 – U16 age groups. Significant effects on HSR were seen from maturity when studied across the range of maturity classifications (i.e. U14s age group), but not when only considering individuals of a single maturity classification (i.e. U15/16s age group).

The findings of the current study (shown in Table 4) are in line with previous research in youth soccer whereby older age groups displayed higher total distances, greater HSR and VHSR distances, and were also quicker than the younger age groups[19]. These results reflect the superior physical and athletic attributes of the older participants and the greater physical demands associated with competing in older age groups.

The correlations and associated scatterplots between maturation and match running metrics were of particular interest (Figure 2 and Figure 3). Across the competitive season, there appears to be a positive association between relative maturation status and the majority of the GPS metrics in the U14s (Figure 2). While some of the highest maximum speeds were distributed across the maturity range, participants that were more advanced in maturity typically covered greater distances at high speed, were quicker and made more accelerations. It is likely that this association exists due to the repeated dominance of the most mature players across games. That is, the same athletic advantages afforded to early maturing boys on tests of speed[20] seem to exist in match conditions also. Similar findings have been observed in Australian Rules Football players, with more mature players demonstrating superior performance on match running metrics than their less mature counterparts[21]. However, this association was not as apparent amongst the U15/16s, whereby there was lower R^2 between maturity status and match running metrics (Figure 3). This may be a reflection of the fact that there is a much greater variation in maturity status amongst the U14 participants (86.4 – 96.6%, pre-, circa-, post-PHV) than the U15/16s (93.0 – 99.6%, mostly post-PHV). Many of the individuals in the U15/16s are much closer to reaching the mature state, reflected by much less variation in maturity. As individuals approach the point of reaching the mature state, differences in maturity become less. Another consideration is that on moving from the U14s to U15s age group, progression and retention decisions are made. If, as shown here, less mature players perform less well than their more mature counterparts, then they are more likely to be released and hence not present in the older age groups, which will also contribute to the smaller range of maturity seen in U15/16s.

Within the multi-level regression models for the U14s, maturity only had a significant effect on HSR. The rest of the match running metrics were not impacted by maturity (Table 6). This may suggest that much of what was observed amongst the correlation scatter plots (Figure 2) could have been down to the most and least mature players repeatedly over or under performing on the match running metrics across the season (i.e. effect of nesting). Consistent with the correlational analyses, maturation was found to be unrelated to GPS metrics in the models conducted for the U15/U16s (Table 7). The lack of association between maturation and match running metrics may be due to a number of factors. Firstly, variation in maturation within these age groups was more limited with less disparity between the most and least mature players within the U15/16s age group. Further, all of the players within the U15/U16s were well beyond the mean percentage of adult stature associated with PHV (91%). Maximum gains in speed and lean muscle mass tend to fall just before and after predicted age at PHV, respectively[22].

Similar findings were observed by Buchheit, Mendez-Villanueva, Simpson, Bourdon [10] in games involving players aged 12.2 – 14 years where older and / or more mature players consistently outperformed their younger more immature counterparts, covering greater distances at higher speeds. This could suggest that maturation may impact positively on match running metrics, in particular, those that require an action performed at high speeds. In turn, this may translate to more playing opportunities in matches and the possibility of competing at a higher standard. Rampinini, Impellizzeri, Castagna, Coutts, Wisløff [23] highlighted this in the Italian Serie –A elite adult male league. It was identified that better players typically covered more high speed distance with the ball. The selection bias, whereby older and / or more mature players are selected into soccer academies[2], but also national teams[24,25] could be somewhat described by the aforementioned data. Amongst the U15/16s, the multi-level models (Table 7) were consistent with correlations; maturation had no significant effect. However, significance was observed in the spine / lateral playing positions when undertaking actions that required covering distance at high speeds.

The influence of playing position has a well-established effect on youth soccer match running performance[10], an effect that surpasses other factors such as chronological age[10] and physical fitness[26]. Therefore, the influence of position was analysed within the current study to help interpret the effect of maturity on match running metrics. The present study identified positional differences in match running metrics, in particular amongst the U14s, with attackers and lateral players performing more total distance, HSR, VHSR, and accelerations (Table 5).

In the U14s age group, defenders demonstrated the lowest total distance covered in a match, lowest distance covered at very high speed and lowest number of accelerations, with similar findings being reported by[10]. Midfielders produced the lowest amount of HSR and lowest maximum speeds, contrasting results reported in[27], who showed that midfield players ran the most amount of HSR during a match. Bradley, Sheldon, Wooster, Olsen, Boanas, Krustrup [28] reported that central midfielders produced highest total distances, this may be due to the positional role of these players, whereby they often link the defence with attack, and are commonly involved in both phases of play, however, in the current study, this was not the case. The differences between the results of the present study and those of Dellal, Chamari, Wong, Ahmaidi, Keller, Barros, Bisciotti, Carling [27], Bradley, Sheldon, Wooster, Olsen, Boanas, Krustrup [28] could be due to the differences in demand of the tactical roles of the lateral players between the teams analysed in the respective studies. In the U15/16s age group, attackers performed the least amount of total distance covered in a game, with midfield players again covering the most, and similar findings were reported by[12]. Central defenders and midfielders operate in highly congested areas of the pitch, therefore, the opportunity to achieve high speeds unopposed can prove somewhat challenging[29], potentially explaining the fact that they do not achieve the same distances covered at HSR as attacking players (Table 7), which is consistent with previous research[30].

The positional differences in accelerations has been reported by Ingebrigtsen, Dalen, Hjelde, Drust, Wisløff [31] whereby a higher frequency of accelerations seemed to occur in lateral players compared to central players. The results of the current study indicate similar findings where lateral players in both age groups experienced on average more accelerations throughout a match (Table 5). This may be due to the frequent requirement of wide positions to achieve high speeds, with rapid acceleration necessary to reach this.

Due to these differences in playing positions, a one-boot fits all training approach would be unreasonable. Amongst the various playing positions, each one requires a bespoke emphasis on the physical components[32]. For example, according to Bangsbo, Mohr, Krustrup [33], central (spine) defenders undergo the least amount of physical demand in a competitive match (as found in the current study). This in turn equates to a greater emphasis on volume of tactical and technical training, something which is important for the position. Moreover, relative maturity must be accounted for when comparing match running metrics of two players playing in similar positions.

The two age groups have a difference in their weekly training programme (Table 1). This was not expected to have a large impact on the results of this study, mainly because the two age groups were treated separately. The additional hours dedicated to training in the U15/16 age group may contribute to the lack of relationship between performance and maturity. Likewise, the two age groups play on pitches of different dimensions. Again, this is expected to have minimal impact on the results due to the approach of analysing the age groups separately. Future research in this area could consider these as additional factors in the modelling, especially if they could be varied within an age group or age groups are considered together. Although data were collected on a routine basis within the academy, a limitation of the present study was that it was not always possible to have an equal distribution of measurements across participants. For example, some participants had two measurements, whereas others had up to 30 measurements. This was an unavoidable outcome of the study design (where a minimum playing time was set), but this did restrict the number of points taken for some players which was undesirable. Having a more even distribution of matches represented across individuals might reduce repeated measure effects whereby the same individuals over / underperform in matches.

Practical Applications

Within an age group, using GPS metrics as part of player assessment should be done with caution. Maturity status and positions (playing and spine / lateral) have an influence on outputs affecting direct comparisons.

As the older age group was seen to outperform the younger age group and particularly high-speed actions scored low within the U14s, it is advisable to use age, maturity and position specific bands for all of the match running metrics.

Conclusions

The results of this study are of particular interest to practitioners involved in the development of youth elite soccer players. There is a suggestion that maturation does have an impact on match running metrics within the U14s, however much of the variance may be attributable to individuals under / over performing consistently in matches. Furthermore, within the U15/16s, the influence of maturation on match running metrics appeared to have less of an impact. From a practical perspective, such as bio-banding which has previously been used to address factors of growth and maturation[1,9], this concept may be better suited towards individuals between the ages of 11 – 14 years, where those factors are going to be more important / influential.

References:

1. Cumming SP, Brown DJ, Mitchell S, et al. Premier League academy soccer players' experiences of competing in a tournament bio-banded for biological maturation. *Journal of Sports Sciences.* 2018;36(7):757-765.

2. Figueiredo AJ, Goncalves CE, Coelho ESMJ, Malina RM. Characteristics of youth soccer players who drop out, persist or move up. *Journal of Sports Sciences.* 2009;27(9):883-891.

3. Malina RM, Rogol AD, Cumming SP, Coelho-e-Silva MJ, Figueiredo AJ. Biological maturation of youth athletes: assessment and implications. *British Journal of Sports Medicine.* 2015;49(13):852-859.

4. Malina RM, Bar-Or O, Bouchard C. *Growth, maturation, and physical activity.* Champaign, IL: Human Kinetics.; 2004.

5. Faigenbaum AD, Lloyd RS, Oliver JL. *Essentials of Youth Fitness.* Human Kinetics Publishers; 2019.

6. Johnson A. Monitoring the immature athlete. *Aspetar Sports Medicine Journal.* 2015;4(1):114-118.

7. Johnson A, Doherty PJ, Freemont A. Investigation of growth, development, and factors associated with injury in elite schoolboy footballers: prospective study. *BMJ.* 2009;338:b490.

8. Zuber C, Zibung M, Conzelmann A. Holistic patterns as an instrument for predicting the performance of promising young soccer players–a 3-years longitudinal study. *Frontiers in Psychology.* 2016;7:1088.

9. Cumming SP, Lloyd RS, Oliver JL, Eisenmann JC, Malina RM. Bio-banding in sport: Applications to competition, talent identification, and strength and conditioning of youth athletes. *Strength and Conditioning Journal.* 2017;39(2):34-47.

10. Buchheit M, Mendez-Villanueva A, Simpson B, Bourdon P. Match running performance and fitness in youth soccer. *International Journal of Sports Medicine.* 2010;31(11):818-825.

11. Buchheit M, Mendez-Villanueva A. Effects of age, maturity and body dimensions on match running performance in highly trained under-15 soccer players. *Journal of Sports Sciences.* 2014;32(13):1271-1278.

12. Lovell R, Fransen J, Ryan R, et al. Biological maturation and match running performance: A national football (soccer)

federation perspective. *Journal of Science and Medicine in Sport.* 2019.

13. Mirwald RL, Baxter-Jones AD, Bailey DA, Beunen GP. An assessment of maturity from anthropometric measurements. *Medicine and Science in Sports and Exercise.* 2002;34(4):689-694.

14. Fransen J, Bush S, Woodcock S, et al. Improving the prediction of maturity from anthropometric variables using a maturity ratio. *Pediatric Exercise Science.* 2018;30(2):296-307.

15. Bayer LM, Bailey N. Growth diagnosis: Selected methods for interpreting and predicting development from one year. In: Chicago IL: Chicago University Press; 1959.

16. Gregson W, Drust B, Atkinson G, Salvo V. Match-to-match variability of high-speed activities in premier league soccer. *International Journal of Sports Medicine.* 2010;31(4):237-242.

17. Field A. *Discovering statistics using SPSS.* London: Sage Publications; 2005.

18. Akaike H. A new look at the statistical model identification. In: *Selected Papers of Hirotugu Akaike.* Springer; 1974:215-222.

19. Harley JA, Barnes CA, Portas M, et al. Motion analysis of match-play in elite U12 to U16 age-group soccer players. *Journal of Sports Sciences.* 2010;28(13):1391-1397.

20. Parr J, Winwood K, Hodson-Tole E, et al. The main and interactive effects of biological maturity and relative age on physical performance in elite youth soccer players. *Journal of Sports Medicine.* 2020:1957636.

21. Gastin PB, Bennett G, Cook J. Biological maturity influences running performance in junior Australian football. *Journal of Science and Medicine in Sport.* 2013;16(2):140-145.

22. Viru A, Loko J, Harro M, Volver A, Laaneots L, Viru M. Critical periods in the development of performance capacity during childhood and adolescence. *European Journal of Physical Education.* 1999;4(1):75-119.

23. Rampinini E, Impellizzeri FM, Castagna C, Coutts AJ, Wisløff U. Technical performance during soccer matches of the Italian Serie A league: Effect of fatigue and competitive level. *Journal of Science and Medicine in Sport.* 2009;12(1):227-233.

24. Buchheit M, Mendez-Villanueva A, Mayer N, et al. Locomotor performance in highly-trained young soccer players: Does body size always matter? *International Journal of Sports Medicine*. 2014;35(6):494-504.

25. Gissis I, Papadopoulos C, Kalapotharakos VI, Sotiropoulos A, Komsis G, Manolopoulos E. Strength and speed characteristics of elite, subelite, and recreational young soccer players. *Research in Sports Medicine*. 2006;14(3):205-214.

26. Mendez-Villanueva A, Buchheit M, Simpson B, Bourdon P. Match play intensity distribution in youth soccer. *International Journal of Sports Medicine*. 2013;34(2):101-110.

27. Dellal A, Chamari K, Wong dP, et al. Comparison of physical and technical performance in European soccer match-play: FA Premier League and La Liga. *European Journal of Sport Science*. 2011;11(1):51-59.

28. Bradley PS, Sheldon W, Wooster B, Olsen P, Boanas P, Krustrup P. High-intensity running in English FA Premier League soccer matches. *Journal of Sports Sciences*. 2009;27(2):159-168.

29. Di Salvo V, Baron R, Tschan H, Montero FC, Bachl N, Pigozzi F. Performance characteristics according to playing position in elite soccer. *International Journal of Sports Medicine*. 2007;28(3):222-227.

30. Bradley PS, Di Mascio M, Peart D, Olsen P, Sheldon B. High-intensity activity profiles of elite soccer players at different performance levels. *The Journal of Strength & Conditioning Research*. 2010;24(9):2343-2351.

31. Ingebrigtsen J, Dalen T, Hjelde GH, Drust B, Wisløff U. Acceleration and sprint profiles of a professional elite football team in match play. *European Journal of Sport Science*. 2015;15(2):101-110.

32. Dalen T, Jørgen I, Gertjan E, Havard HG, Ulrik W. Player load, acceleration, and deceleration during forty-five competitive matches of elite soccer. *The Journal of Strength & Conditioning Research*. 2016;30(2):351-359.

33. Bangsbo J, Mohr M, Krustrup P. Physical and metabolic demands of training and match-play in the elite football player. *Journal of Sports Sciences*. 2006;24(7):665-674.

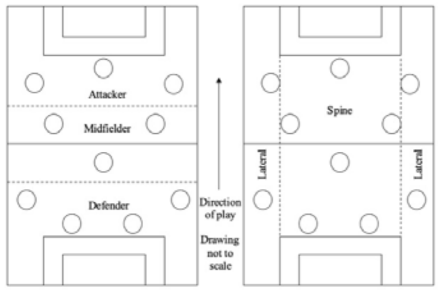

Figure 1. Schematic diagram of 4-3-3 playing formation.

Schematic diagram of 4-3-3 playing formation.

419x593mm (72 x 72 DPI)

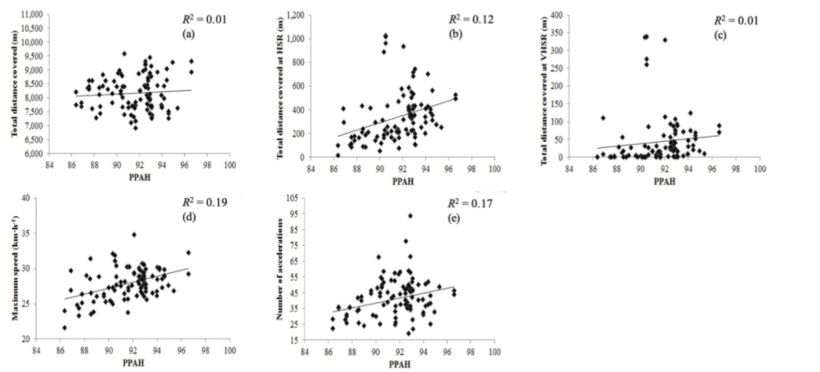

Figure 2. U14 scatter pots and correlation coefficients between percentage of predicted adult height (PPAH) and (a) total distance per 80 minutes; (b) total distance at HSR per 80 minutes; (c) total distance at VHSR per 80 minutes; (d) maximum speed; and (e) count of accelerations per 80 minutes.

U14 scatter pots and correlation coefficients between percentage of predicted adult height (PPAH) and (a) total distance per 80 minutes; (b) total distance at HSR per 80 minutes; (c) total distance at VHSR per 80 minutes; (d) maximum speed; and (e) count of accelerations per 80 minutes.

593x419mm (72 x 72 DPI)

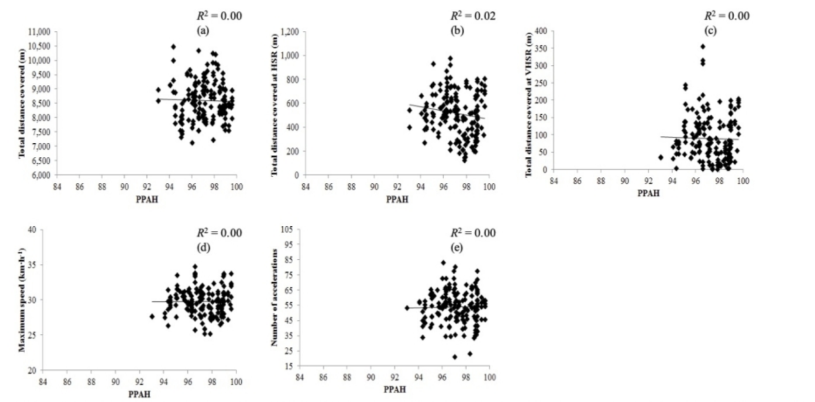

Figure 3. U15/16s scatter pots and correlation coefficients between percentage of predicted adult height (PPAH) and (a) total distance per 80 minutes; (b) total distance at HSR per 80 minutes;(c) total distance at VHSR per 80 minutes; (d) maximum speed; and (e) count of accelerations per 80 minutes.

22

U15/16s scatter pots and correlation coefficients between percentage of predicted adult height (PPAH) and (a) total distance per 80 minutes; (b) total distance at HSR per 80 minutes;(c) total distance at VHSR per 80 minutes; (d) maximum speed; and (e) count of accelerations per 80 minutes.

593x419mm (72 x 72 DPI)

Table 1. Weekly training and match programme for U14 and U15/16s throughout the season.

	U14	U15/16
Number of soccer training sessions	2 – 4	3 – 6
Number of athletic development / conditioning sessions	2	3 – 4
Number of competitive matches	1 – 2	1 – 2

Table 2. Comparison of attained adult height for 13.0 year olds in population[16] and for sample used in the present study.

	Mean	SD
Attainment of percentage of predicted adult height for population at 13.0 years of age[16]	87.3	3.0
Attainment of percentage of predicted adult height within the current academy at 13.0 years of age	91.4	2.5

Table 3. Definition of GPS metrics used.

GPS Metric	Definition
Total distance	The total distance covered at all speeds
High speed running distance	The distance covered at ≥ 5.5 m.s^{-1}
Very high speed running distance	The distance covered ≥ 7.0 m.s^{-1}
Maximum speed	The maximum speed attained during the match
Accelerations	The number of accelerations above 3.0 m.s^{-2} with a minimum duration of 0.5s, that start from an initial speed of 5.5 m.s^{-1}

Table 4. Mean (SD) physical characteristics and match running metrics shown for U14 and U15/16 age groups.

	U14 (*n*=21)	U15/16 (*n*=16)
Anthropometric and maturity characteristics		
Chronological age (years)	14.1 (1.4)	15.6 (1.4)
Height (cm)	164.8 (7.2)	176.8 (5.7)
Mass (kg)	51.1 (7.0)	67.2 (6.7)
PAH (cm)	180.0 (6.5)	182.1 (6.5)
PPAH	91.6 (2.3)	97.2 (1.5)
Match running metrics#		
Total distance (m)	8521 (964.9)	9005 (733.0)
High speed (m)	355 (224.8)	540 (196.9)*
Very high-speed running (m)	45 (72.9)	94 (68.4)*
Maximum speed ($km.h^{-1}$)	27.9 (2.2)	29.8 (2.9)*
Accelerations	42.7 (13.8)	57.0 (12.4)*

PAH – Predicted adult height; PPAH – Percentage of predicted adult height. #Match running metrics shown on a per 80-minute basis. *$p < 0.05$.

Table 5. Mean (SD) physical characteristics and match running metrics shown across playing positions.

Physical characteristics	Defender (*n*=14)	Midfielder (*n*=15)	Attacker (*n*=8)	Spine (*n*=20)	Lateral (*n*=17)
Anthropometric and maturity characteristics					
Height (cm)	175.5 (8.5)	166.3 (8.5)	179.0 (9.6)	172.8 (8.5)	171.9 (8.5)
Mass (kg)	65.0 (10.5)	54.8 (10.3)	66.5 (10.4)	60.5 (10.3)	62.3 (10.4)
PAH (cm)	182.8 (4.8)	178.0 (4.8)	184.6 (5.3)	181.7 (4.8)	180.5 (4.8)
PPAH	96.0 (3.3)	93.4 (3.3)	97.0 (3.7)	95.1 (3.3)	95.2 (3.3)
Match running metrics[#]					
Total distance (m)	8280 (664)	8665 (680)	8372 (591)	8407 (663)	8477 (668)
High speed running (m)	447 (219)	395 (215)	641 (246)	384 (217)	540 (218)
Very high-speed running (m)	68 (72)	54 (70)	151 (85)	58 (71)	92 (71)
Maximum speed ($km.h^{-1}$)	29.3 (2.3)	28.3 (2.0)	30.7 (3.0)	28.8 (2.2)	29.5 (2.3)
Accelerations	51 (14)	46 (14)	52 (13)	46 (14)	53 (14)

[#]Match running metrics shown on a per 80-minute basis.

Table 6. U14 multilevel models (final Model) explaining biological maturation and the effect on match running metrics.

Multilevel models	β	SE	*p*	95% CI
Total Distance (Model 3)				
Intercept	7402.4	397.2	<0.001	6562.7,8242.1
Maturity	40.9	61.5	0.51	-81.2, 162.9
Defenders	-810.8	285.0	0.01	-1416.7, 204.8
Midfielders	-188.3	265.2	0.49	-748.3, 371.7
Attackers	-	-	-	-
Spine	-56.4	167.9	0.74	-417.3, 304.5
Lateral	-	-	-	-
High speed running (Model 3)				
Intercept	-85.8	145.1	0.56	-389.6, 218.0
Maturity	32.4	16.2	0.04	0.3, 64.6
Defenders	-332.5	103.3	0.01	-548.6, 116.4
Midfielders	-338.3	97.2	0.01	-541.3, 135.3
Attackers	-	-	-	-
Spine	-139.0	56.6	0.13	-257.3, -20.6
Lateral	-	-	-	-
Very high speed running (Model 3)				
Intercept	-100.6	.49.5	0.06	-203.7, 2.5
Maturity	9.4	4.8	0.06	-0.2, 18.9
Defenders	-126.5	34.1	<0.001	-197.9, -55.1
Midfielders	120.8	32.1	<0.001	-187.7, -53.8
Attackers	-	-	-	-
Spine	-37.2	18.7	0.06	-76.3, 1.9
Lateral	-	-	-	-
Maximum speed (Model 3)				
Intercept	25.3	1.6	<0.001	21.9, 28.7
Maturity	0.2	0.2	0.25	-0.2, 0.6
Defenders	0.7	0.8	0.38	-0.9, 2.3
Midfielders	-2.1	1.3	0.12	-4.9, 0.6
Attackers	-	-	-	-
Spine	-0.8	0.72	0.29	-2.3, 0.7
Lateral	-	-	-	-
Accelerations (Model 3)				
Intercept	25.0	6.9	<0.01	9.4, 40.7
Maturity	2.2	1.4	0.11	-0.5, 5.0
Defenders	-7.3	5.7	0.22	-19.6, 4.9
Midfielders	-4.6	5.5	0.42	-16.2, 7.1
Attackers	-	-	-	-
Spine	-6.4	3.1	0.06	-13.1, 0.4
Lateral	-	-	-	-

Table 7. U15/16s multilevel models (final Model) explaining biological maturation and the effect on match running metrics.

Multilevel models	β	SE	*p*	95% CI
Total Distance (Model 3)				
Intercept	7934.6	645.8	<0.001	6567, 9301.3
Maturity	63.4	91.6	0.49	-117.6, 244.4
Defenders	339.7	605.7	0.58	-947.7, 1627.1
Midfielders	703.2	638.2	0.29	-645.2, 2051.6
Attackers	-	-	-	-
Spine	315.4	298.5	0.31	317.4, 948.1
Lateral	-	-	-	-
High speed running (Model 3)				
Intercept	780.2	136.1	<0.001	484.4, 1075.9
Maturity	7.3	25.4	0.77	-43.2, 57.8
Defenders	-190.9	126.2	0.16	-467.2, 85.3
Midfielders	-167.3	135.3	0.24	-460.0, 125.4
Attackers	-	-	-	-
Spine	-171.1	62.8	<0.05	-307.3, -34.8
Lateral	-	-	-	-
Very high speed running (Model 3)				
Intercept	172.9	57.7	<0.01	49.9, 295.8
Maturity	11.4	9.4	0.23	-7.2, 29.9
Defenders	-67.7	53.9	0.23	-183.0, 47.7
Midfielders	-52.7	57.2	0.37	-174.2, 68.8
Attackers	-	-	-	-
Spine	-48.3	26.6	0.09	8.5
Lateral	-	-	-	-
Maximum speed (Model 3)				
Intercept	31.5	1.7	<0.001	27.9, 35.0
Maturity	0.2	0.3	0.43	-0.3, 0.8
Defenders	-1.3	1.6	0.40	-4.7, 2.0
Midfielders	-1.3	1.7	0.45	-4.8, 2.2
Attackers	-	-	-	-
Spine	-0.9	0.8	0.29	-2.5, 0.8
Lateral	-	-	-	-
Accelerations (Model 3)				
Intercept	56.9	6.5	<0.001	42.7, 71.1
Maturity	1.6	1.6	0.33	-1.7, 4.9
Defenders	0.8	5.9	0.89	-12.1, 13.8
Midfielders	-0.5	6.6	0.94	-14.7, 13.7
Attackers	-	-	-	-
Spine	-6.7	3.1	<0.05	-13.2, -0.13
Lateral	-	-	-	-