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Longitudinal Development of Match-running Performance in Elite Male Youth Soccer Players

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Running Head: Match-running Performance in Youth Soccer

Abstract

This study longitudinally examined age-related changes in the match-running performance of retained and released elite youth soccer players aged 8-18 years. The effect of playing position on age-related changes was also considered. Across three seasons 263 elite youth soccer players were assessed in 1-29 competitive matches (988 player-matches). For each player-match, total distance and distances covered at age-group-specific speed zones (low-speed, high-speed, sprinting) were calculated using 1 Hz or 5 Hz GPS. Mixed modelling predicted that match-running performance developed non-linearly, with age-related changes best described with quadratic age terms. Modelling predicted that playing position significantly modified age-related changes ($p<0.05$) and retained players covered significantly more low-speed distance compared to released players ($p<0.05$), by 75 ± 71 $m \cdot h^{-1}$ (mean ± 95% CI) (effect size ± 95% CI: 0.35 ± 0.34). Model intercepts randomly varied, indicating differences between players in match-running performance unexplained by age, playing position or status. These findings may assist experts in developing training programmes specific to the match-play demands of players of different ages and playing positions. Although retained players covered more low-speed distance than released players, further study of the actions comprising low-speed distance during match-play is warranted to better understand factors differentiating retained and released players.

Introduction

The match-running performance of elite male senior soccer players has been extensively described (e.g. Di Salvo et al., 2007; Bradley et al., 2009; Carling, 2011). Indeed, a recent study of English male Premier League players showed that during a 90 minute match, mean ± SD distance covered was 10714 ± 991 m, of which 2492 ± 625 m was at high-speed (> 4 $m \cdot s^{-1}$) (Bradley et al., 2009). Moreover, these playing characteristics have been shown to distinguish between players of differing standards, for example, Mohr et al. (2003) showed that top-class professional players performed more high-speed running (> 4.17 $m \cdot s^{-1}$) and sprinting (> 8.33 $m \cdot s^{-1}$) during match-play than moderate-ability professional players. However, to date very few studies have considered the match-running performance of elite youth soccer players, which is surprising considering the potential such information could have in providing insight into talent identification and development processes in soccer. Indeed, understanding age-related changes in the match-running performance of elite youth soccer players would have implications for the assessment of match performance, the design of effective training programmes, and the development of relevant physiological testing procedures (Carling et al., 2008). Moreover, examining match performance characteristics that discriminate more and less successful elite youth soccer players may aid the process of identifying players with the potential to become senior professionals (Waldron & Murphy, 2013).

The findings of the limited number of studies that have considered the match-running performance of elite male youth soccer players suggest, through cross-sectional comparison of 8-10 years (Goto et al., 2013), 11-16 years (Harley et al., 2010), and 12-18 year old players (Pereira Da Silva et al., 2007; Buchheit et al., 2010; Mendez-Villanueva et al., 2013), that there is a general trend for total distance covered during match-play to increase with age. These total distances ranged from 4356 ± 478 m in U9 players (Goto et al., 2013) to 8867 ± 859 m in U18 players (Buchheit et al., 2010). However, match durations are shorter for younger players and so it is considered appropriate to normalise distances covered to match-time (Carling et al., 2008). When adjusted to match-time, differences between age groups in distance covered still exist but are less apparent, especially at older ages (Buchheit et al., 2010). Nevertheless, to confirm age-related changes in distance covered during match-play, studying a group of elite youth players across an age range that encapsulates an entire talent development programme is required.

The age-related changes in distance covered at various speeds by elite youth soccer players during match-play are less clear than changes in total distance covered. Buchheit et al. (2010) showed that when adjusted to match time, U18 players covered more sprinting distance (> 5.31 $m{\cdot}s^{-1}$) compared to U13-U17 players. However, when mean 10 m flying peak speed of each specific age group was used to categorise speed zones only limited differences in high-speed distance covered per minute during match-play were evident in elite youth players aged U9-U10 (Goto et al., 2013) and U12-U16 (Harley et al., 2010). Conversely, Mendez-Villanueva et al. (2013) used individualised speed zones and showed that in the first half of match-play elite youth players aged U13 covered more distance at very high relative speeds compared to U15-U18 players. Thus, the age-related changes in distance covered at varying speeds during match-play of elite youth soccer players remain unclear and require further investigation, across a wider age range.

Another major shortcoming of research assessing age-related changes in match-running performance of elite youth players is that study designs have been cross-sectional in nature, that is, comparisons made between different players in each age category (Strøyer et al., 2004; Pereira Da Silva et al., 2007; Buchheit et al., 2010; Goto et al., 2013; Mendez-Villanueva et al., 2013). Multiple observations of the same individuals are needed to allow changes within and differences between young players to be identified more accurately (Williams et al., 2011). The use of repeated measures multi-level statistical techniques to assess longitudinal changes in match-running performance characteristics would also support this type of study design (Brink et al.,2010).

Match-running performance of elite youth players is known to be influenced by playing position. In elite youth players aged 12-18 years, centre backs cover the least, and centre midfielders the most, total distance (Buchheit et al., 2010). Despite differences in speed zone definitions between studies, it appears that centre backs also cover the least, and wide midfielders and centre forwards the most, high-speed distance (Pereira Da Silva et al., 2007; Aslan et al., 2010; Buchheit et al., 2010; Mendez-Villanueva et al., 2013,). These differences suggest a mature tactical understanding of position-specific tasks (Buchheit et al., 2010). Whether these findings extend to younger elite youth players remains unclear.

There have been some attempts to differentiate between elite and sub-elite youth soccer players on the basis of match-running performance (Strøyer et al., 2004, Waldron & Murphy, 2013). However, to date, only Goto et al. (2013) have examined the match-running performance of a group of highly selected, homogenous players, involved in elite talent development programmes, from a talent identification perspective. The authors examined 36 elite youth soccer players aged U9 and U10 and showed no differences between retained and released players in total distance covered per hour, but retained players completed more low-speed running distance compared to released players. The promising work of Goto et al. (2013) needs to be extended to provide insight into any differences between released and retained elite youth players across a wider age range.

The aim of the present study was to employ a longitudinal design to examine age-related changes in match-running performance of retained and released elite male youth soccer players aged 8-18 years. A secondary aim was to examine how playing position affects the age-related changes in match-running performance of elite male youth soccer players age 8-18 years.

Material and methods

Participants

A total of 263 elite male youth soccer players aged 8-18 years, belonging to three professional academies participated in the study. The U9-U14 age groups averaged three 90 minute training sessions a week, the U15 and U16 age groups averaged four 90 minute training sessions a week and, the U17-U19 age groups averaged six 90 minute training sessions a week. Players participated in a competitive match once a week. The mean ± SD age, height, and body mass of players within each age group are displayed in Table 1.

Ethical approval for the study was obtained from the Ethical Advisory Committees at Nottingham Trent University and Loughborough University. Prior to taking part in the study, players and parents or guardians were provided with a written and verbal summary outlining the purpose, procedures involved, possible risks and benefits, and the voluntary and confidential nature of the research. Written assent was obtained from players and written consent was obtained from parents or guardians. Prior to undertaking sprint tests, players went through a health screening process to identify any reasons that may prevent any players from taking part in the study.

INSERT TABLE 1 HERE

Design

Across three soccer seasons from 2010/11 to 2012/13 (mean ± SD duration range per player: 0.72 ± 0.85 years), the match-running performance of 263 elite youth soccer players was assessed in 1-29 competitive inter-academy matches (mean ± SD number of matches per player: 3.77 ± 4.46 matches), resulting in a total of 988 player-matches. To evaluate match-running performance, total distance covered, and distance covered in low-speed (<45% age group mean peak flying speed), high-speed (≥45% age group mean peak flying speed), and sprinting (≥75% age group mean peak flying speed) zones were calculated for each player-match, using a GPS system. Distances were adjusted for match time to allow comparisons between ages. This repeated measures design allowed age-related changes in each match-running performance characteristic to be assessed. Playing position for each player-match was recorded to allow the effect of playing position on the age-related changes in match-running performance of elite youth players to be considered. At the end of the study the playing status of players was categorised as released or retained depending on whether they were signed to their academy on 1st Feb 2014, resulting in 97 players being categorised as released and 166 players being categorised as retained. Differences between released and retained elite youth players in the age-related changes in match-running performance characteristics were then examined.

Experimental Procedures

Match configuration.

The matches analysed were part of the regular series of inter-academy matches between Premier League academies during a season. The configuration of matches varied depending on age group. Indeed, U9 and U10 matches were small-sided games, that ranged from 5-a-side to 7-a-side and U11 matches ranged from 7-a-side to 11-aside. These matches were formed of four periods, with total match duration between 60-80 minutes. For the U12 age group and older, matches were 11-a-side. The U12 and U13 matches were formed of three or four periods, with total match duration between 75-80 minutes. For the U14 age group and older, matches were formed of two periods, with total match duration between 80-90 minutes. Matches were played on pitches with dimensions in accordance with recommendations made by the Football Association (n.d.) for a given age group / match configuration. For example, U10 7 v 7 matches took place on pitches with dimensions of ~ 35 m x ~ 55 m.

The playing position of each player was recorded for every match. Goal keepers were excluded from the analysis. Players were categorised as a centre back (CB), full back (FB) centre midfielder (CM), wide midfielder (WM) or centre forward (CF). Players who changed position mid-match were categorised as multi positional (Multi). For small-sided games teams did not employ centre backs or wide midfielders.

Match analysis.

Each player's match-running performance was assessed using a 1 Hz or 5 Hz GPS system (GPSport, Australia). Both systems have been validated for use by team players (Macleod et al., 2009; Waldron et al., 2011). Possible differences between the two GPS systems in measuring distances were controlled for statistically by including the GPS sampling rate as a covariate during data analysis (Cummins et al., 2013). During match-play, each player wore a harness containing a GPS unit positioned between the shoulder blades. Post-match, each GPS unit was downloaded to a laptop computer and analysed using commercially available software (Team AMS, v 2.1). Total distance and distance covered within age specific speed zones were calculated (see below). All distances were adjusted to 60 minutes of match-play to allow for differences in match duration due to substitutions and match configurations. Players were only included for analysis if they had played at least half of a given match. For all data, mean ± SD satellite coverage was 8.8 ± 1.1.

Distance covered by players during match-play was classified into different categories on the basis of age group sprint performance to provide more detailed information regarding speed of movement. Speed zones were normalised to age using the mean peak 10-20 m flying sprint speed of each age group (procedural details below). Player activity was classified into three speed zones: low-speed, high-speed and sprinting. The low-speed zone represented any distance covered at less than 45 % of the age group mean peak 10-20 m flying speed and included standing, walking, jogging, and slow-running activity. The high-speed zone represented any distance covered at 45 % or more of the age group mean peak 10-20 m flying speed and included cruising, fast-running, and sprinting activity. The sprinting zone represented any distance covered at 75 % or more of the age group mean peak 10-20 m flying speed and included sprinting activity (Table 2).

INSERT TABLE 2 HERE

Peak 10-20 m flying sprint speed.

The 10-20 m flying sprint speed of 107 players from the study population, in addition to 161 other elite youth soccer players, was repeatedly assessed across five soccer seasons (2007 to 2011) resulting in 1,119 player-sprints for elite youth soccer players aged 8-18 years. Participants completed a 20 m sprint test with a split at 10 m, on an indoor new-generation synthetic surface. Times were measured to the nearest 0.01 s using infrared photoelectric cells (Brower timing system, Utah, USA). Sprint tests were preceded by a familiarisation and standardised warm-up procedure. Three 20 m sprints were performed; each effort was separated by a 2-5 minute recovery period. The sprint with the shortest time between 10 and 20 m was used to calculate peak 10-20 m flying sprint speed for each player. The mean peak 10-20 m flying speed for each age group was calculated.

Data Analysis

Due to the hierarchical structure of the data, mixed modelling was used to predict the development with age of each match-running performance characteristic (MLwiN v 2.22, Bristol, U.K.). For each variable, a two-level hierarchical structure was defined with repeated measures (level 1) nested within players (level 2). Unlike traditional longitudinal data analysis techniques, such as the repeated measures ANOVA, mixed modelling does not require the same number of measurement occasions per individual. Moreover, the temporal spacing of measurements may vary between players (Rasbash et al., 2009). Hence, this statistical technique is well suited to the current data structure. A mixed model is able to describe the underlying trends of a particular component in the population (fixed part), and also models the unexplained variation around the mean trend for that component (random part) (Twisk, 2003).

Each match-running performance characteristic was modelled in turn. Relevant parameters were systematically added to a null model and were accepted or rejected on the basis of changes in model fit as indicated by differences in -2 loglikelihood between models, and the effect of predictor variables on the outcome variable as indicated by z-scores. Firstly, to investigate the variance between players, the intercept was allowed to vary randomly between players. Then the effect of age (centred at 13 years) on the variable was modelled. Quadratic age terms were then modelled. Subsequently, the effect of playing position and being retained or released was modelled. Finally, the effect of the sampling frequency of the GPS unit used was controlled for. Following each analysis, the assumption that variation in intercepts were normally distributed with an average of zero, was checked (Twisk, 2003). Statistical significance was accepted at the 95% confidence level ($p<0.05$). Where appropriate, pairwise comparisons between playing positions were conducted to identify where differences occurred. Mean ± SD were used to describe the average and variability of data. To calculate the range in which predicted values were likely to fall, 95% confidence intervals (CI) were reported. Effect sizes (ES) and associated confidence intervals were calculated using the method of Tymms (2004) to assess any meaningful effects, and these were interpreted as small (0.20-0.49), medium (0.50-0.79) or large (>0.80) effects (Cohen, 1988).

Results

Table 3 shows the final mixed models for the development of the match-running performance characteristics of total distance covered, and distance covered at low-speed, at high-speed, and sprinting, for players of different playing positions and different playing statuses.

The random part of the mixed models predicted that the fit of all models was improved by allowing the intercepts to vary randomly ($p<0.05$), as indicated by the between-player standard deviations displayed in Table 3. From the fixed part of the mixed models, Figures 1 & 2 display the predicted age-related changes in match-running performance for each playing position. The mean ± SD match-running performance for each age group is also displayed for each playing position on Figures 1 & 2 (see Supplementary table for mean ± SD match-running performance by age group and positon). Modelling indicated that age-related changes were non-linear; each match-running performance characteristic best described with a quadratic age term ($p<0.05$). Models predicted that total distance, low-speed distance, high-speed distance, and sprinting distance all increased with age, but at a constant negative rate, resulting in an eventual plateau and subsequent decrease in total distance, high-speed distance, and sprinting distance with age at 17.7 years, 16.1 years, and 17.3 years, respectively. Conversely, low-speed distance continued to increase throughout the age range without plateau (Figures 1 & 2).

INSERT TABLE 3 HERE

INSERT FIGURES 1 & 2 HERE

Modelling predicted that playing position affected the age-related changes of all match-running performance characteristics ($p<0.05$) (Table 3). Pairwise comparisons revealed significant differences between most playing positions in match-running performance ($p<0.05$). However, for total distance there were no significant differences between: CB vs. FB, CM vs. WM, and CM vs. Multi ($p>0.05$), with CB completing the least and WM the most, total distance. For low-speed distance there were no significant differences between: CB vs. FB, CB vs. WM, CB vs. CF, CB vs.

Multi, FB vs. CF, WM vs. CF, and WM, vs. Multi ($p>0.05$), with FB covering the least and CM covering the most, low-speed distance. For high-speed distance there were no significant differences between: CM vs. CF, CM vs. Multi, and CF vs. Multi ($p>0.05$), with CB completing the least and WM the most, high-speed distance. For sprinting distance there were no significant differences between: CB vs. CM and CF vs. Multi ($p>0.05$), with CB covering the least and WM covering the most, sprinting distance. When the differences in the distances completed by performers based on their playing position were evaluated, the range of effect sizes (with associated 95% CI) were: Total distance: CB vs. WM, 1.6 ± 0.6; CB vs. FB, 0.3 ± 0.4; Low-speed distance: FB vs. CM, 1.0 ± 0.4; FB vs. CF, 0.1 ± 0.4; Low-speed distance: CB vs. WM, 2.0 ± 0.6; CB vs. FB, 0.6 ± 0.4; Sprinting distance: CB vs. WM, 1.9 ± 0.7; CB vs. CM, 0.1 ± 0.5.

Models predicted that retained players completed significantly more low-speed running compared to released players, ($p<0.05$) by 75 ± 36 $m \cdot h^{-1}$ (95% CI: ± 71, ES ± 95% CI: 0.35 ± 0.34). There were no other significant or meaningful differences between released and retained players in match-running performance ($p>0.05$), with effect sizes (± 95 % CI) of 0.14 ± 0.32, 0.10 ± 0.32, and 0.08 ± 0.37 for total, high-speed, and sprinting distances respectively.

It is possible to calculate the performance of players of differing ages, playing positions and playing statuses using the coefficients from Table 3. For example, the prediction equation for total distance for a 12.2 year-old, wide midfielder, measured with 5 Hz GPS system who is retained is: Wide midfielder intercept + (β_1*age centred at 13 y) + (β_2*age centred at 13 y^2) + (β_3*5 Hz sampling rate) + (β_4*retained), which is: 6510 $m \cdot h^{-1}$ + (270 $m \cdot h^{-1}$*-0.8 y) + (-29 $m \cdot h^{-1}$*0.64 y) + (-296 $m \cdot h^{-1}$) + (50 $m \cdot h^{-1}$) = 6030 $m \cdot h^{-1}$.

Discussion

The aim of the present study was to employ a longitudinal design to examine age-related changes in the match-running performance of retained and released elite male youth soccer players aged 8-18 years. The mixed models suggested that match-running performance characteristics changed with age in a non-linear manner and there was significant variation between players (between-player SD). Modelling also suggested that match-running performance characteristics were influenced by playing position and that retained players covered more low-speed distance compared to released players.

Age-Related Changes

Predictive modelling suggested that total distance increased with age at a constant negative rate, which resulted in a plateau and subsequent decrease at 17.7 years (Figure 1). Total distance increasing with age and then differences disappearing at older ages is a pattern similar to that seen in previous research (Buchheit et al., 2010; Harley et al., 2010). For example, Buchheit et al. (2010) showed that in U13-U18 elite youth players, when adjusted for match time, U13 players covered significantly less distance than U16-U18 players, but there were no differences in distance covered between any of the older age groups. A combination of growth, training, and tactical factors may account for the pattern of change in distance covered with age.

The increase in distance covered during match-play with age may be due to the improving physiological capacity of players associated with growth and training.

Indeed, Armstrong and Welshman (1994) indicated that $\dot{V}O_2$ peak ($l \cdot min^{-1}$) in boys increases linearly from the age of 8 to 16 years of age. Moreover, performance on an intermittent exercise test has been shown to increase with age in elite youth soccer players aged 14-18 years (Roescher et al., 2010), and this improving physiological capacity may allow older players to cover more distance during match-play. The preceding argument is strengthened by studies showing that intermittent exercise test performance is related to total distance covered during match-play in elite youth players (Castagna et al., 2009). However, for this argument to be valid, it would be expected that the age-related changes in intermittent exercise test performance would mirror the age-related changes in match-running performance, which does not appear to be the case. Indeed, the intermittent exercise test performance of elite youth soccer players increases in a linear manner with age (Roescher et al., 2010), whereas the current study shows that total distance covered during match-play increases at constantly negative rate with eventual plateau at age 17.7 years. Why does match-running performance start to decrease at older ages despite intermittent exercise test performance continuing to increase? It is possible that at older ages the technical and tactical aspects of match-play are also changing, meaning that there is not requirement or opportunity for players to perform to their maximal capacity. However, it is also possible that the discrepancy in development between intermittent exercise test performance and match-running performance is due to differences between countries in playing style. Indeed the aforementioned studies involved players from across Europe and it has been shown that different countries display differences in physical and technical performance during match-play, hence possibly modifying the relationship between fitness test performance and match-running performance (Dellal et al., 2011).

Summation of the low-speed distance curve and high-speed distance curve is approximately equal to the total distance curve (see Figure 1). Therefore, examination of these curves can identify specific patterns of age-related change in distance covered at various speeds. In general terms, as per total distance, there was a trend for an increase in distance covered at varying speeds with age. Also, players completed more low-speed distance relative to high-speed distance. For example, at age 12 years, players were predicted to cover a total distance of 5627-6257 m, of which 24-30 % (1359-1913 m) was at high-speed. Similarly at age 16 years players were predicted to cover a total distance of 6475-7105 m, of which 25-31 % (1651-2205 m) was at high-speeds. Whilst cautioning comparisons between studies applying different speed zones thresholds, Harley et al. (2010) showed 30% of total distance was covered at high-speed in elite youth players aged U12-U16.

There were different patterns of age-related changes in distance covered at different speeds. Indeed, whereas low-speed distance continued to increase throughout the age range there was a decrease in high-speed distance from age 16.1 years and sprinting distance from age 17.3 years. Age-related changes in distance covered at given speed zones are age group specific. Therefore at older ages, players are less likely to produce distance at speeds close to their highest capabilities compared to slightly younger players, suggesting that it is high-speed running and sprinting that are especially constrained by the increased tactical demands of match-play at older ages. The pattern of age-related change in high-speed running between players U13-U18 observed in the current study is similar to previous cross-sectional data. Mendez-Villanueva et al. (2013) used individualised speed thresholds and showed that in the first half of match-play elite youth players aged U13 covered more very high-speed distance compared to U15-U18 players and there were no differences between older age groups. However, the current study is the first to provide insight into age-related changes in distances covered at varying speeds during match-play across a wide age range of elite youth players.

Playing Position

According to the predictive models, playing position influenced total distance and distance covered at varying speed zones. There were significant differences between most playing positions in match-running performance and whilst effect sizes were generally *small*, clear activity profiles according to positional role emerged and these were similar to those seen in elite youth players (Buchheit et al., 2010) and professional senior players (Di Salvo et al., 2007). Indeed, midfielders covered the most total distance probably due to their linking role between attack and defence within the team (Di Salvo et al., 2007). Whilst wide midfielders covered the most high-speed distance and sprinting distance, centre midfielders covered the most low-speed distance. The reason for this may be that due to their central position on the pitch, centre midfielders have less space in which to attain high speeds on a regular basis. Conversely, wide midfielders are often required to produce high-speed runs in order to create goal scoring opportunities. Similarly, centre forwards covered the second most distance sprinting suggesting that very high-speed running is required for tasks such as capitalising on goal scoring opportunities (Faude et al., 2012). Centre backs covered the least total distance, high-speed distance, and sprinting distance, potentially because their major aim is to prevent goals being conceded and so they restrict their movements to certain strategic areas on the pitch (Buchheit et al., 2013). Full back's main duties are defensive, hence these players covered similar total distances to centre backs. However, their wider position means they are less constrained in their movements and can be involved in attacking build-up play and this was reflected by them completing more high-speed and sprinting distance compared to centre backs. The current study is the first to assess the positional match-play demands of elite youth players across an age range that includes both children and adolescents approaching adulthood. That there was an effect of playing position on all match-running performance characteristics suggests that from as young as eight-years-old, elite youth players are able to adjust their match-running performance based upon the tactical requirements of their playing position.

Playing Status

There was no significant or meaningful difference between released and retained players in total distance covered, which is contrary to previous work showing that U14 elite players cover more distance compared to sub-elite players (Waldron & Murphy, 2013). However, in support of the current results, Goto et al. (2013) showed that in elite youth players aged U9-U10, there was no difference between released and retained players in distance covered. Taken together, this suggests that in a more homogenous groups of players, total distance covered may not be sensitive enough to differentiate between playing standards. Moreover, there were no differences between released and retained players in high-speed distance and sprinting distance in the current study.

Previous research has suggested that high-speed running is an important aspect of performance as it may aid key activities such as successful attempts at scoring, losing a marker, reaching a ball before an opponent, gaining more time on-the-ball etc (Carling et al., 2008; Faude et al., 2012). Waldron and Murphy (2013) showed some support for this proposition when they revealed U14 elite players covered more high-speed distance (3.64-5.28 $m \cdot s^{-1}$) compared to sub-elite players. However, they found no difference between groups in very high-speed movement (>5.28 m·s^{-1}). Therefore it appears that whilst high-speed distance may be moderately effective in discriminating between elite and sub-elite players, when players have already been identified as elite and subjected to systematic talent development programmes, these factors are not sensitive enough to discriminate between players. The previous suggestion is supported by the current study and Goto et al. (2013) who showed no difference in moderate or high-speed running distance between released and retained elite youth players aged U9-U10. That playing status had a limited effect on total, high-speed, and sprinting distances suggests that other factors, such as anthropometric, physiological, psychological, technical, and tactical characteristics may need to be included in future studies of soccer talent. Indeed, Huijgen et al. (2012) recently showed that in 16-18 year-old elite youth soccer players, retained players were discriminated from released players on the basis of a combination of superior sprint speed, dribbling skill, and tactical skill (positioning and deciding). However, it is also possible the 1 Hz and 5 Hz GPS sampling rate used in the present study may be too low to capture some of the high-speed movements performed by elite youth soccer players, making it a possible limitation of the study.

In the current study, retained players did cover significantly and meaningfully more low-speed distance compared to released players, which seems rather counterintuitive as it is difficult to see why low-speed activity would influence success. Nevertheless, whilst previous findings are equivocal there is some support for this result. Indeed, Waldron and Murphy (2013) showed elite U14 players covered more low-speed distance (<1.67 m·s^{-1}) compared to sub-elite players, but this difference did not extend to moderate-speed distance (1.67-3.63 m·s^{-1}). Goto et al. (2013) showed increased low-speed running distance in retained versus released players, but this difference did not extend to walking and jogging.

One possible explanation for low-speed distance differentiating between released and retained players in the current study is that players performing high amounts of low-speed activity are completing tactically astute movements. This supports the evidence of Huijgen et al. (2012) who showed that in 16-18 year-old elite soccer players, retained players had superior deciding and positioning tactical skills compared to released players. Indeed, retained players constantly adjusting their position at low speeds in relation to the ball, their teammates, and the opposition may result in less need to produce high-intensity bursts to be in an appropriate playing position (Waldron & Murphy, 2013). There is limited support for this theory at this stage but future research should consider tactical aspects of match-running performance characteristics.

Another reason retained players produced more low-speed distance than released players may relate to the classifications of movement employed in the current study. Low-speed running was defined on the basis of age-group-specific sprint speed, but high intensity actions can occur at low speeds (Stølen et al., 2005). For example, quick accelerations and decelerations, directional changes, jumping actions, and sustaining forceful contractions to maintain balance and control of the ball against defensive pressure, are all high intensity activities that may have been classified as low-speed running in the current study. It is possible that retained players engage in these key activities more frequently and therefore accrue more low-speed distance compared to released players. Future research is required to investigate this phenomenon.

Random Variation Between Players

Modelling revealed that there was random variation between players in total distance, low-speed distance, high-speed distance, and sprinting distance that was not explained by age, playing position or playing status. Differences between players in maturity status, physiological training status, match circumstance, and technical and tactical abilities may be responsible for this unexplained variation. For example, previous research into elite youth match-play has shown differences in match-running performance between conventional centre forwards and centre forwards playing slightly behind a strike partner (Buchheit et al., 2010), whereas this distinction was not considered in the current study. Regardless, it is clear that there is variation between successful players in match-running performance characteristics, highlighting the complex nature of match-play in elite youth soccer.

Perspectives

Results from the current study show that match-running performance characteristics change non-linearly with age and playing position influences development. These findings may allow talent development experts to plan training programmes specific to the demands of match-play at different ages and for different playing positions. This result supports the work of Buchheit et al. (2010) who also showed match-running performance changed with age and was highly dependent on playing position in elite youth soccer players aged 12-18 years. However, another key finding in the current study was that there was considerable variation between players in the development of match-running performance characteristics, suggesting a need for flexibility when developing training programmes. Indeed factors such as growth, physiological training status, and technical and tactical abilities probably influence match-running performance characteristics and so need to be considered in any talent development programme. Although retained players covered more low-speed distance compared to released players it is not recommended that this be a focus of talent identification procedures. Further study of the actions comprising low-speed running distance in elite youth soccer match-play is warranted in order to better understand factors that differentiate retained and released players.

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LIST OF FIGURES:

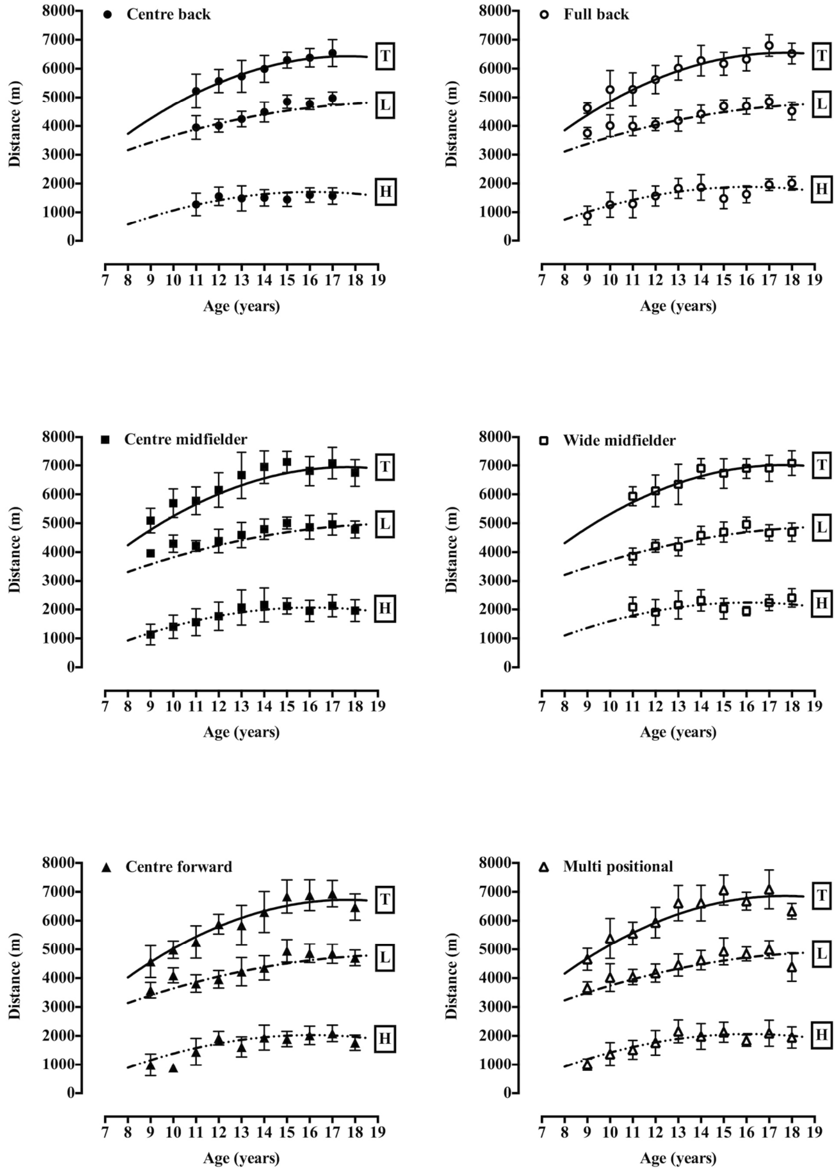

Figure 1. Total [T], low-speed [L], and high-speed [H] distance covered (m.h-1) during match-play in elite youth soccer players age 8-18 years. Curves are based on predicted growth curves from mixed models of longitudinal data. Points are the based on the 'raw' age group data (mean ± SD). Data are presented by playing position during match-play.
165x233mm (300 x 300 DPI)

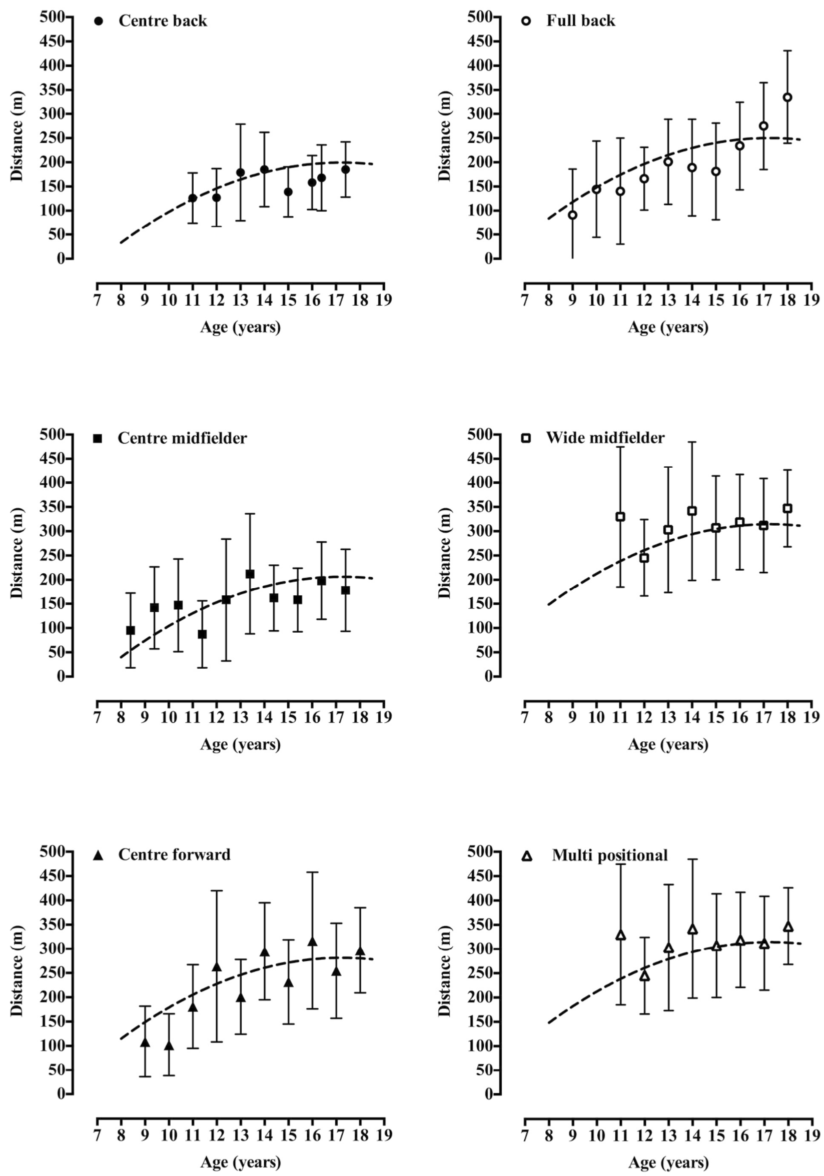

Figure 2. Sprinting distance covered (m.h-1) during match-play in elite youth soccer players age 8-18 years. Curves are based on predicted growth curves from mixed models of longitudinal data. Points are the based on the 'raw' age group data (mean ± SD). Data are presented by playing position during match-play.
166x238mm (300 x 300 DPI)

Table 1. Basic characteristics of elite youth football players according to age

Age Group	Age (y)	Height (cm)	Mass (kg)
U9	9.2 ± 0.3	137.6 ± 5.4	31.4 ± 5.0
U10	10.2 ± 0.3	142.8 ± 5.6	35.5 ± 6.7
U11	11.1 ± 0.3	146.9 ± 4.9	38.1 ± 4.8
U12	12.2 ± 0.3	154.0 ± 7.2	42.8 ± 6.6
U13	13.1 ± 0.3	161.9 ± 9.4	49.8 ± 9.3
U14	14.1 ± 0.3	170.7 ± 6.8	59.1 ± 8.5
U15	15.0 ± 0.4	175.7 ± 6.2	65.8 ± 7.1
U16	16.0 ± 0.4	178.0 ± 6.4	70.1 ± 6.5
U17	17.0 ± 0.3	178.2 ± 6.8	73.6 ± 5.8
U18	18.0 ± 0.3	179.8 ± 5.3	73.3 ± 5.7
Total	14.5 ± 2.6	162.1 ± 16.0	53.0 ± 16.1

Note. Data are displayed as mean ± SD.

Table 2. Age group specific speed zone thresholds ($m \cdot s^{-1}$) as a percentage of mean peak 10-20 m flying speed

Age Group	Low-speed Zone (<45%)	High-speed Zone (≥45%)	Sprinting Zone (≥75%)	Mean ± SD Peak 10-20 m Flying Speed
U9	<2.74	≥ 2.74	≥ 4.56	6.08 ± 0.32
U10	<2.84	≥ 2.84	≥ 4.73	6.31 ± 0.34
U11	<2.91	≥ 2.91	≥ 4.85	6.47 ± 0.35
U12	<3.05	≥ 3.05	≥ 5.08	6.78 ± 0.38
U13	<3.19	≥ 3.19	≥ 5.31	7.08 ± 0.45
U14	<3.34	≥ 3.34	≥ 5.6	7.42 ± 0.41
U15	<3.49	≥ 3.49	≥ 5.81	7.75 ± 0.33
U16	<3.51	≥ 3.51	≥ 5.85	7.81 ± 0.36
U17	<3.59	≥ 3.59	≥ 5.98	7.97 ± 0.27
U18	<3.59	≥ 3.59	≥ 5.98	7.97 ± 0.36

Notes. The speed values displayed for a given age group were calculated as a percentage of the mean peak 10-20 m flying speed for that age group. This was <45%, ≥45%, and ≥75% of the age group mean peak 10-20 m flying speed for low-speed, high-speed, and sprinting zones respectively.

Table 3. Mixed models for the longitudinal development of match-running performance characteristics.

Parameter	Total Distance ($m \cdot h^{-1}$)	Low-Speed Distance ($m \cdot h^{-1}$)	High-Speed Distance ($m \cdot h^{-1}$)	Sprinting Distance ($m \cdot h^{-1}$)
	Estimate ± CI	Estimate ± CI	Estimate ± CI	Estimate ± CI
Centre back	5930 ± 140[cdef]	4417 ± 86[c]	1510 ± 100[bcdef]	160 ± 25[bdef]
Full back	6040 ± 120[cdef]	4364 ± 73[cdf]	1680 ± 86[acdef]	211 ± 22[acdef]
Centre midfield	6440 ± 120[abe]	4570 ± 76[abdef]	1866 ± 90[abd]	167 ± 24[bdef]
Wide midfield	6510 ± 130[abef]	4466 ± 80[bc]	2039 ± 94[abcef]	275 ± 25[abcef]
Centre forward	6220 ± 130[abcdf]	4391 ± 80[cf]	1828 ± 94[abd]	242 ± 24[abcd]
Multi positional	6350 ± 110[abde]	4488 ± 71[bce]	1865 ± 82[abd]	240 ± 22[abcd]
Age	270 ± 24	162 ± 16	108 ± 18	17 ± 4
Age^2	-29 ± 6	-11 ± 4	-17 ± 4	-2 ± 1
GPS rate	-296 ± 67*	-392 ± 43*	96 ± 49*	13 ± 14
Status	50 ± 110	75 ± 71*	-27 ± 84	-5 ± 21
Random Effects				
Between-player SD	350 ± 250	220 ± 160	270 ± 190	60 ± 45
Within-player SD	380 ± 170	240 ± 110	280 ± 120	80 ± 36

Notes. Independent intercept estimates (at age 13 y) for each playing position are displayed. Main effect of age, age^2 and playing position for all models ($p<0.05$). Between position differences ($p<0.05$): [a] significant difference vs CB, [b] vs FB, [c] vs CM, [d] vs WM, [e] vs CF, [f] vs Multi. For Status, the effect of being retained is displayed (*$p<0.05$). For GPS rate, the effect of a 5 Hz sampling rate is displayed (*$p<0.05$). Between-player SD: the stable between-player differences within playing positions. Within-player SD: the typical variation in a player's value from match to match. ± 95% confidence intervals (CI) are displayed for parameter estimates.

Supplementary Table. Match-running performance characteristics by age group and position

Age Group	Position	N	Total Distance (m·h^{-1})	Low-speed Distance (m·h^{-1})	High-speed Distance (m·h^{-1})	Sprint Distance (m·h^{-1})
U9	FB	5	4620 ± 180	3750 ± 200	880 ± 340	91 ± 95
	CM	6	5090 ± 430	3960 ± 120	1130 ± 360	95 ± 77
	CF	4	4580 ± 560	3590 ± 270	990 ± 380	109 ± 73
	Multi	8	4660 ± 380	3660 ± 220	1000 ± 200	100 ± 56
	Total	23	4750 ± 430	3740 ± 240	1010 ± 300	98 ± 69
U10	FB	9	5280 ± 660	4010 ± 380	1260 ± 440	140 ± 100
	CM	8	5700 ± 490	4290 ± 300	1400 ± 400	142 ± 85
	CF	3	4990 ± 300	4100 ± 260	895 ± 42	102 ± 64
	Multi	41	5380 ± 700	4020 ± 480	1360 ± 400	170 ± 100
	Total	61	5390 ± 660	4060 ± 440	1330 ± 400	156 ± 99
U11	FB	17	5280 ± 580	3990 ± 340	1280 ± 480	140 ± 110
	CB	5	5230 ± 590	3950 ± 410	1280 ± 390	126 ± 52
	CM	15	5780 ± 480	4220 ± 190	1560 ± 470	147 ± 96
	WM	9	5940 ± 330	3850 ± 290	2080 ± 340	330 ± 150
	CF	11	5260 ± 570	3810 ± 310	1450 ± 470	181 ± 86
	Multi	27	5560 ± 390	4040 ± 270	1520 ± 330	175 ± 92
	Total	84	5520 ± 520	4010 ± 310	1520 ± 460	180 ± 110
U12	FB	15	5620 ± 490	4050 ± 220	1570 ± 350	166 ± 65
	CB	16	5580 ± 400	4010 ± 230	1560 ± 320	127 ± 60
	CM	14	6150 ± 600	4390 ± 410	1760 ± 490	87 ± 69
	WM	11	6120 ± 550	4220 ± 220	1900 ± 440	245 ± 79
	CF	13	5880 ± 340	3960 ± 310	1920 ± 240	260 ± 160
	Multi	21	5940 ± 530	4170 ± 320	1760 ± 430	240 ± 130
	Total	90	5870 ± 530	4130 ± 320	1730 ± 400	190 ± 120
U13	FB	22	6020 ± 420	4190 ± 370	1830 ± 350	201 ± 88
	CB	23	5730 ± 560	4240 ± 270	1490 ± 440	180 ± 100
	CM	16	6660 ± 810	4590 ± 440	2070 ± 610	160 ± 130
	WM	16	6350 ± 700	4190 ± 310	2160 ± 490	300 ± 130
	CF	14	5840 ± 690	4220 ± 490	1620 ± 350	201 ± 77
	Multi	26	6610 ± 610	4450 ± 380	2160 ± 400	290 ± 140
	Total	117	6210 ± 710	4320 ± 400	1890 ± 510	230 ± 120
U14	FB	24	6280 ± 530	4410 ± 320	1860 ± 450	190 ± 100
	CB	22	6000 ± 470	4490 ± 350	1510 ± 290	185 ± 77
	CM	29	6950 ± 570	4790 ± 350	2160 ± 590	210 ± 120
	WM	18	6900 ± 350	4580 ± 310	2320 ± 370	340 ± 140
	CF	19	6300 ± 710	4360 ± 420	1940 ± 430	300 ± 100
	Multi	20	6610 ± 620	4630 ± 340	1980 ± 450	250 ± 110
	Total	132	6520 ± 650	4560 ± 380	1960 ± 510	240 ± 120

Supplementary Table cont.

Age Group	Position	N	Total Distance ($m \cdot h^{-1}$)	Low-speed Distance ($m \cdot h^{-1}$)	High-speed Distance ($m \cdot h^{-1}$)	Sprint Distance ($m \cdot h^{-1}$)
U15	FB	11	6170 ± 400	4690 ± 220	1480 ± 360	180 ± 100
	CB	15	6300 ± 280	4850 ± 240	1450 ± 240	139 ± 52
	CM	15	7130 ± 380	5010 ± 210	2120 ± 280	162 ± 68
	WM	11	6730 ± 520	4700 ± 350	2030 ± 360	310 ± 110
	CF	17	6840 ± 570	4950 ± 390	1890 ± 270	232 ± 87
	Multi	10	7060 ± 520	4930 ± 470	2130 ± 350	290 ± 140
	Total	79	6710 ± 570	4870 ± 330	1840 ± 410	210 ± 110
U16	FB	31	6320 ± 400	4700 ± 280	1630 ± 300	234 ± 91
	CB	31	6380 ± 320	4770 ± 200	1610 ± 250	158 ± 56
	CM	25	6810 ± 520	4860 ± 410	1950 ± 370	158 ± 66
	WM	18	6700 ± 350	4960 ± 260	1940 ± 160	319 ± 98
	CF	21	6890 ± 540	4870 ± 330	2020 ± 320	320 ± 140
	Multi	12	6680 ± 310	4840 ± 250	1840 ± 200	259 ± 71
	Total	138	6620 ± 480	4820 ± 300	1800 ± 330	230 ± 110
U17	FB	13	6800 ± 370	4850 ± 240	1960 ± 200	275 ± 90
	CB	10	6540 ± 470	4970 ± 220	1570 ± 290	168 ± 68
	CM	12	7090 ± 560	4960 ± 370	2130 ± 380	198 ± 80
	WM	35	6910 ± 460	4670 ± 280	2240 ± 270	312 ± 97
	CF	34	6940 ± 460	4850 ± 340	2090 ± 290	255 ± 98
	Multi	8	7090 ± 670	5000 ± 310	2090 ± 460	230 ± 100
	Total	112	6900 ± 490	4830 ± 320	2080 ± 350	260 ± 100
U18	FB	35	6520 ± 360	4520 ± 310	2000 ± 240	335 ± 96
	CB	32	6470 ± 350	4800 ± 290	1670 ± 250	185 ± 57
	CM	37	6750 ± 480	4780 ± 290	1960 ± 380	178 ± 85
	WM	23	7090 ± 440	4690 ± 320	2400 ± 320	347 ± 79
	CF	18	6470 ± 450	4710 ± 270	1770 ± 270	297 ± 88
	Multi	5	6330 ± 270	4390 ± 500	1950 ± 370	233 ± 70
	Total	150	6640 ± 460	4690 ± 320	1950 ± 380	260 ± 110
Total	FB	182	6090 ± 670	4400 ± 420	1690 ± 440	220 ± 110
	CB	155	6130 ± 550	4580 ± 410	1560 ± 310	166 ± 70
	CM	178	6610 ± 740	4680 ± 430	1930 ± 510	165 ± 97
	WM	141	6740 ± 580	4560 ± 410	2180 ± 370	320 ± 110
	CF	154	6380 ± 820	4530 ± 530	1850 ± 420	250 ± 120
	Multi	178	6040 ± 870	4320 ± 510	1730 ± 500	220 ± 120
	Total	988	6320 ± 760	4510 ± 470	1810 ± 470	220 ± 120

Notes: FB = full back, CB = centre back, CM = centre midfielder, WM = wide midfielder, CF = centre forward, Multi = multi positional player. Data normalised to one hour of match-play. Data are displayed as mean ± SD.