Match Running Performance and Fitness in Youth Soccer

Abstract

The activity profiles of highly trained young soccer players were examined in relation to age, playing position and physical capacity. Time-motion analyses (global positioning system) were performed on 77 players (U13–U18; fullbacks [FB], centre-backs [CB], midfielders [MD], wide midfielders [W], second strikers [2ndS] and strikers [S]) during 42 international club games. Total distance covered (TD) and very high-intensity activities (VHIA; > 16.1 km·h⁻¹) were computed during 186 entire player-matches. Physical capacity was assessed via field test measures (e.g., peak running speed during an incremental field test, Vᵥam-eval). Match running performance showed an increasing trend with age (P < 0.001, partial eta-squared (η²): 0.20–0.45). When adjusted for age and individual playing time, match running performance was position-dependent (P < 0.001, η²: 0.13–0.40). MD covered the greater TD; CB the lowest (P < 0.05). Distance for VHIA was lower for CB compared with all other positions (P < 0.05); W and S displayed the highest VHIA (P < 0.05). Relationships between match running performance and physical capacities were position-dependent, with poor or non-significant correlations within FB, CB, MD and W (e.g., VHIA vs. Vᵥam-eval: r = 0.06 in FB) but large associations within 2ndS and S positions (e.g., VHIA vs. Vᵥam-eval: r = 0.70 in 2ndS). In highly trained young soccer players, the importance of fitness level as a determinant of match running performance should be regarded as a function of playing position.

Introduction

Most professional soccer academies are seeking to optimize the early detection and physical development of their young players [39]. The assessment of the physical determinants of running performance during competitive matches according to age and playing position is therefore required to improve talent detection procedures and long-term training interventions. Nevertheless, while some information is available about the physical and physiological demands of highly trained young soccer players during match play [6,9,10,17,40], little is known about whether physical capacities are important determinants of physical match performance in these players. Several studies have reported significant correlations between field or laboratory test results and running performance during soccer matches, suggesting that individual physical capacities can account for game-related physical performance [10,17,23,34]. For example, in professional male soccer players, significant correlations have been reported between distance covered at high intensity during a match and both peak running speed during an incremental field test and mean sprint time on a repeated sprint ability (RSA) test [34]. Maximal oxygen uptake [23] and maximal performance for the Yo-Yo Intermittent Recovery Tests were also shown to correlate well with the amount of high intensity activities during games in adult females [23] and young male players [10]. However, these relationships have consistently been reported with all players from a team pooled together; none of the aforementioned studies considered the correlation between match running performance and physical capacities with regard to playing positions. In young [40] and in top-level adult soccer players [5,13,14,35], match analyses have demonstrated that match running performance, and especially high-intensity running, are position-dependent. Centre-backs generally undertake less high-intensity running, whereas midfielders and attackers generally display the most [5,13,14,35]. Therefore, if physical capacities
were to significantly account for match running performance, irrespective of playing positions [10, 23, 34], centre-backs would be expected to consistently present the poorest physical tests results, and conversely, midfielders and attackers, the best ones. While between-position differences in physical capacities have been reported for some physical capacities [15, 22, 44], such differences are not always apparent [20] or even absent [41]. For example, while fullbacks performed more distance in the Yo-Yo test than attackers [22], the mean sprint time on the RSA test conducted by Impellizzeri et al. [20] did not discriminate fullbacks, midfielders and forwards, despite the important differences in their match running performance [5, 13, 14, 35]. It is therefore unclear to what extent physical fitness and/or specific technical/tactical roles assigned to each playing position and playing style can dictate player’s running activity during the game. In addition, given the reported existence of different position-specific running patterns [13], it is also unclear which physical capacities (e.g., lower limb explosive strength, maximal aerobic function, RSA [34]) are related with match running performance for a given playing position.

The purpose of this study was therefore to 1) examine for the first time match running performance in a wide age range of highly trained young soccer players as a function of age and playing position, 2) determine whether individual differences in match running performances are related to differences in physical capacities (as evidenced via field tests results), and 3) evaluate the magnitude of these relationships for each separate playing position.

**Methods**

**Subjects**

Time-motion match analysis data was collected on 99 young football players belonging to 6 different age groups ranging from Under 13 to Under 18 in an elite soccer academy (Table 1). All the players participated on average in ~14h of combined soccer-specific training and competitive play per week (6–8 soccer training sessions, 1 strength training session, 1–2 conditioning sessions, 1 domestic game per week and 2 international club games every 3 weeks). All players had a minimum of 3 years of prior soccer-specific training. Written informed consent was obtained from the players and their parents. The study was performed in accordance with the ethical standards of the IJSM [16] and conformed to the Declaration of Helsinki.

**Antropometric measurements and maturity assessment**

Height (Harpended, Baty International, Burgess Hill, U.K.), body mass (ADE Electronic Column Scales, Hamburg, Germany) and the sum of 7 skinfold sites (triceps, subscapular, biceps, supraspinale, abdominal, thigh and medial calf; Harpenden skinfold caliper (Baty International, Burgess Hill, U.K.) were measured by an experienced tester [26]. Although the teams differed in chronological age, the possibility of an overlapping of some players’ maturity status was likely given the heterogeneity of biological and physical maturity of children around puberty [25]. The age at peak height velocity (PHV) is an indicator of somatic maturity representing the time of maximum growth in stature during adolescence. Maturity timing (yr) was calculated by subtracting the chronological age at the time of measurement from the age at estimated PHV [28].

**Experimental procedures**

Match analyses were performed on 42 matches against international club teams, played over a 4-month period. Each outfield player was assessed 1–9 times. The high level of the opposing teams and the same competition format likely reduced match-
by-match variability in running performance [35]. All matches were played on two 100 × 70 m standard outdoor natural grass fields with 11 players per side. Playing time was 2 × 35 min for U13 and U14, 2 × 40 min for U15, U16 and U17, and 2 × 45 min for U18. Since growth can potentially influence physical performance [25], all performance tests were reassessed at least once during the 4-month investigation period. To avoid fatigue unduly influencing the results, performance tests were performed over 2 testing sessions with at least 1 day between them. Speed and jump tests were completed on the first day, while the incremental running test was performed in the second testing session. All performance tests were performed in an indoor facility maintained at standard environmental conditions (23 ± 2 °C). All testing sessions were preceded by a 20-min standardized warm-up and players were familiar with all test procedures.

Activity pattern measurements
Materials
A Global Positioning System (GPS) unit capturing data at 1 Hz (SPI Elite, GPSports, Canberra, Australia) was fitted to the upper back of each player using an adjustable neoprene harness. All players, irrespective of age, wore the same equipment and the same GPS devices. Despite a possible underestimation of high-intensity running distance with the time-resolution of 1 Hz [37], good accuracy (r = 0.97) was reported for the assessment of short sprints for this GPS device compared with an infra-red timing system [4]. While the accuracy of the device for total distance has been reported to be good (3–7%), that for high-intensity running is only moderate (11–30%) [12]. However, in the absence of “a gold standard” method, the current system has been reported to be capable of measuring individual movement patterns in soccer [37]. More importantly for this study design, the GPS device utilized has been reported to have good reliability (i.e., CV = 1.7% [4] and < 5% [12]). Despite possible between-GPS variability [31], we were confident in the results observed since players always wore the same device.

Analyses
While 635 player-matches were assessed in total from 99 different players, only data from players who participated in the full game were retained (n = 186 files from 77 different players, Table 1). This unfortunately resulted in a small data set for the U13 players (n = 7), which was largely a consequence of the high substitution rate of players during games in this age group. Tactically, all teams used a 4-4-1-1 formation, a variation of 4-4-2 with 1 of the strikers playing as a “second striker”, slightly behind their partner. Since players’ roles within the team structure changed little during the games analysed, all players were assigned to 1 of 6 positional groups; fullbacks (FB, n = 15 players, yielding 36 files), centre-backs (CB, n = 16 players, yielding 54 files), midfielders (MD, n = 13 players, yielding 40 files), wide midfielders (W, n = 13 players, yielding 16 files), second strikers (2ndS, n = 9 players, yielding 19 files) and strikers (S, n = 11 players, yielding 21 files). All match data was analysed with a custom-made Microsoft Excel program designed to provide objective measures of physical match performance. Activity ranges selected for analysis were identical for all categories to allow direct between-age comparisons and were adapted from previous studies on young soccer players [6,10] as follows: 1) total distance covered (TD), 2) low-intensity running (LIR; running speed < 13.0 km.h⁻¹), 3) high-intensity running (HIR; running speed from 13.1 to 16 km.h⁻¹), 4) very high-intensity running (VHIR; running speed from 16.1 to 19 km.h⁻¹) and 5) sprinting distance (Sprinting; running speed > 19.1 km.h⁻¹). Very high-intensity activities (VHIA) were also calculated as VHIR plus Sprinting. Peak game running speed (i.e., the highest speed recorded during the game) was also collected. While previous studies have also analysed match running for fixed intervals throughout the game (e.g., 15-min periods) or reported the duration and occurrences of specific actions to assess fatigue development [5,8], we restricted our analyses to the game as a whole so as to focus on possible differences in match running performance as a function of age, playing position and physical fitness.

Physical performance assessment
Since football-specific tests (i.e., which replicate soccer movement patterns and efforts, such as Hoff [18], Yo-Yo [22] and shuttle RSA [20] tests) evaluate different physical qualities simultaneously (e.g., the performance at the Yo-Yo IR1 test is the results of, among others, cardiovascular fitness, intra-effort recovery capacities and change of direction ability), we chose, for the purpose of the present study, simple performance tests to evaluate and isolate basic physical qualities of each player.

Lower limb explosive strength
A vertical countermovement jump (CMJ; cm) with flight time measured with a contact mat (KMS, Fitness Technology, South Australia) to calculate jump height was used to assess lower limb explosive strength. Players were instructed to keep their hands on their hips with the depth of the counter movement self-selected. Each trial was validated by visual inspection to ensure each landing was without significant leg flexion. Athletes were encouraged to perform each jump maximally. At least 3 valid CMJs were performed separated by 25 s of passive recovery, with the best performance recorded.

Acceleration and peak running velocity
The player’s acceleration (Acc) as measured by their 10 m sprint time and their peak running velocity (PV) defined as the fastest 10-m split time were measured during a maximal 40-m sprint (dual-beam electronic timing gates set at 10-m intervals, Swift Performance Equipment, Lismore, Australia) [27]. Split times were measured to the nearest 0.01 s. Players commenced each sprint from a standing start with their front foot 0.5 m behind the first timing gate and were instructed to sprint as fast as possible over the 40-m distance. The players started when ready, thus eliminating reaction time and completed 2 trials with the best performances used as the final result.

Repeated-sprint performance
All players performed a RSA test following a 10-min rest break after the 40-m sprint trials. The RSA test consisted of 10 repeated straight-line 30-m sprints separated by 30 s of active recovery (i.e., jogging back to the starting line within approx 25 s, in order to allow 4–5 s of passive recovery before the commencement of the next sprint repetition). This test is similar to other RSA tests previously used with team sport athletes [33]. Time was recorded to the nearest 0.01 s using 2 sets of electronic timing gates (Swift Performance Equipment, Lismore, Australia). Players used a standing start 0.5 m behind the timing lights. Players were given verbal encouragement to run as fast as possible for each of the 10 sprints and constant verbal feedback was provided during the
Incremental field test
A modified version of the University of Montreal Track Test [24] (i.e., Vam-eval) was used to assess cardiorespiratory fitness [27]. Compared with other intermittent tests such as the Yo-Yo test, this test is a better predictor of maximal oxygen uptake, i.e., the correlation between maximal running speed and maximal oxygen uptake is 0.96 [24], while it is only 0.70 for Yo-Yo vs. maximal oxygen uptake [2]. The test begins with an initial running speed of 8 km·h⁻¹ with consecutive speed increases of 0.5 km·h⁻¹ each minute until exhaustion. The players adjusted their running speed according to auditory signals timed to match 20-m intervals delineated by cones around a 200-m long indoor athletics track. The test ended when participants twice failed to reach the next cone in the required time. During the test, players were verbally encouraged by testers and coaches. The average velocity of the last 1-min completed was recorded as the players’ V⃗_{Vam-eval} (km·h⁻¹). If the last stage was not fully completed, the V⃗_{Vam-eval} was calculated as V⃗_{Vam-eval} = V + (t/60-0.5), where V is the last completed velocity in km·h⁻¹ and t is the time in seconds of the uncompleted stage [27].

Position-related match running differences, according to their playing position. In addition to measures of statistical significance, the following criteria were adopted to interpret the magnitude of the correlation (r) between test measures: <0.1, trivial; >0.1–0.3, small; >0.3–0.5, moderate; >0.5–0.7, large; >0.7–0.9, very large; and >0.9–1.0, almost perfect. If the 90% confidence limits overlapped, small positive and negative values for the magnitude were deemed unclear; otherwise that magnitude was deemed to be the observed magnitude [19]. All analyses were carried out with Minitab 14.1 (Minitab Inc, Paris, France) and SPSS 12.0 (SPSS Inc, Chicago, USA) software with the level of significance set at P≤0.05.

Results

Age-related match running performances accounting for actual playing times are detailed in Table 1. There was a trend for the older players to cover greater TD and more distance in all running categories (e.g., \( r^2 = 0.44 \) for TD, and all P<0.01). Differences in Acc varied as a function of the physical capacities considered (e.g., MD have worse RSA_{mean} values than W and 2ndS despite similar V_{Vam-eval}). Position-related match running differences in performance, adjusted by age and playing time, were all rated as ‘large’ (Table 2). CB presented the lowest TD, which was associated with the lowest VHA values compared with all other positions (P<0.05). Conversely, MD, 2ndS and S covered the greatest TD (P<0.05); W and S showing the highest VHA values (P<0.05).

The correlations between match running performances and physical capacities were shown in Fig. 2. When players were all pooled together, TD was only significantly related to V_{Vam-eval}· VHA was significantly related to CMJ, PV, RSA_{mean} and V_{Vam-eval}. However, all correlations were only small to moderate (e.g., \( r = \) ranging from 0.17 (90% CI, 0.05; 0.29) for VHA vs. PV to 0.41 (0.30; 0.51) for VHA vs. V_{Vam-eval}). Relationships between match running performance and physical capacities were more clearly position-dependent, with trivial and non-significant correlations for FB, CB, MD and W (e.g., VHA vs. V_{Vam-eval}: \( r = 0.06 \) (−0.22; 0.33) and 0.022 (−0.01; 0.43) in FB and CB) but large associations for 2ndS and S (e.g., VHA vs. V_{Vam-eval}: \( r = 0.70 \) (0.43;
position and physical capacities. The main young soccer players are reported in relation to age, playing study were: 1) match running performance was slightly a groups, 2) match running performance was also playing posi-

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Mean anthropometric (± SD) values and least squared means (± SE) for counter movement jump (CMJ), acceleration (Acc), peak velocity (PV), mean sprint time on the repeated sprint test (RSA<sub>mean</sub>), and peak running speed during the incremental field test (V<sub>Vam-eval</sub>). Values are adjusted for age and playing time. a: significant difference vs. CB (P<0.05), b: vs. MD, c: vs. W, d: vs. 2ndS, e: vs. S. η<sup>2</sup>: effect size

Table 2: Physical capacities and match running performance according to playing positions.

Discussion

This is the first time that the activity profiles of highly trained young soccer players are reported in relation to age, playing position and physical capacities. The main findings of the present study were: 1) match running performance was slightly affected by age, with differences only apparent between the extreme age groups, 2) match running performance was also playing posi-

0.86) and 0.64 (0.35; 0.82) in 2ndS and S; VHIA vs. RSA<sub>mean</sub>: r=0.66 (−0.83; −0.36) in 2ndS).

Fig. 2 Correlation coefficients (90% confidence intervals, CI) between match running performance and performance in field tests, adjusted for age and individual playing time. Match running performance: total distance (TD), very-high-intensity running activities (VHIA), sprint running (Sprin) and peak game speed reached during the game. Playing positions: fullbacks (FB, n=36 files), centre-backs (CB, n=54 files), midfielders (MD, n=40 files), wide midfielders (W, n=16 files), second strikers (2ndS, n=19 files) and strikers (S, n=24 files). Field tests: counter movement jump (CMJ), acceleration (Acc), peak velocity (PV), mean sprint time on the repeated sprint test (RSA<sub>mean</sub>) and peak running speed during the incremental field test (V<sub>Vam-eval</sub>). *P<0.05; **P<0.01.
However, when adjusted for individual playing time, there was no difference in running performance between U14, U15, U16 and U17; differences in TD were only significant for the youngest (U13) vs. the 3 oldest teams (U16, U17 and U18), while the U18 differed from the younger teams (U14-U17) only by their greater total sprinting distance (Fig. 1). While we are not aware of any comparable data in the literature, these small age-related differences are in line with the lack of difference observed in game activity patterns between pre- and post pubertal elite soccer players [40]. A possible overlapping of some players’ maturity status between teams (as exemplified by the high standard deviations of the mean PHV values, Table 1) might also explain the lack of between-team differences observed. These between-team comparisons were however not adjusted for PHV to remain consistent with the way players are classified in soccer clubs. The present results therefore suggest for the first time that age/maturity itself (and the associated increase in physical capacities) is not a major determinant of actual match running performance in soccer. While speculative, it can be hypothesized that the complexity of the game itself may constrain a player’s actual running activity, with older players, due to their greater levels of experience, playing more tactically demanding games and therefore tending to be more restricted in using their full (greater) physical capacities than younger players (Table 1). It is also possible that the particularly high cardiorespiratory fitness levels of the younger players in the present study (V\(\text{Vam-eval}\) for U14 and U15 = 15.3 and 15.8 km.h\(^{-1}\), respectively, [3]) partly explains their ability to achieve high match running performances. Another explanation for the lack of differences in match running performance between the U14 and U17 can be related to the intermittent nature of high-intensity actions during soccer match play, which was likely more favourable to the youngest players [38]. Since using individualized speed thresholds to differentiate exercise intensities [1] would have probably weakened between-player differences, absolute speed thresholds were preferred to enable accurate examinations of the impact of physical capacities on match running performance. This also allowed easier comparisons with the existing literature in young players [6,10]. Further investigations are however required to assess the respective impact of physical/physiological changes resulting from aging/growth vs. match-related tactical aspects on match running performance.

In our young highly trained players, match running performance was significantly influenced by playing position (Table 2). CB covered the lowest TD and VHIA, while W and S showed the highest VHIA values. Since running distances were adjusted for age and total playing time to allow the inclusion of players differing by age, direct comparisons with data from the literature is not possible. The present results however extend the previous findings on positional differences in the occurrence of repeated-sprint sequences [8], as well as in the cardiorespiratory load of competitive games in young players [40]. They also confirm data on position-specific running patterns reported in adult soccer players [5,13,14,35]. The greater amount of high-intensity running in W and S in the present study is probably related to their need to complete sprints away from defending players in order to generate space or capitalize on goal scoring opportunities [14]. These specialized match running patterns appear to be indicative of a mature tactical understanding of position-specific tasks [40]; this is consistent with the highly trained player-group examined here. Since replicating competitive performance conditions is thought to be an effective training practice for preparing athletes for competition [13], the present information can be used to develop position-specific training strategies for developing soccer players. Another practical application that can derive from these position-specific match running responses is that playing position can be used as a means of manipulating physiological load during (training) soccer match simulations.

While the beneficial impact of good physical capacities on game match running performance has been shown in young moderately-trained [10], adult female [23], elite male [34] soccer players, and top-class referees [21,43], to our knowledge no study has also considered their effects taking into account playing positions. The respective impact on match running performance of individual physical capacities and/or specific technical/tactical roles assigned to each playing position (see above), was difficult to predict. We observed no difference in \(V_{\text{Vam-eval}}\) values between FB, MD, W, 2\(^{\text{nd}}\)S and S, despite important differences in game running performance (Fig. 2). Conversely, FB were slower than W on the RSA test, but presented similar high-intensity activities during games. Thus, position-related differences in physical capacities did not always match position-difference in match running performance (Table 2), and the magnitudes of the ‘position effect’ were also much lower for physical capacity than for match running performance (\(\text{n}^2<0.21\) vs. 0.30–0.40 for physical capacities vs. match running performance, respectively). Moreover, while correlations were moderately high when all players were pooled together (VHIA vs. \(V_{\text{Vam-eval}}\); \(r=0.41\), Fig. 2), we observed trivial and non-significant correlations within FB, MD and W (e.g., VHIA vs. \(V_{\text{Vam-eval}}\); \(r=0.06\) and 0.022 in FB and CB), but large-to-very large and significant associations within 2\(^{\text{nd}}\)S and S positions (e.g., VHIA vs. \(V_{\text{Vam-eval}}\); \(r=0.70\) and 0.64 in 2\(^{\text{nd}}\)S and S; VHIA vs. RSA mean: \(r=0.66\) in 2\(^{\text{nd}}\)S). Although present correlations should be considered with care given the limited sample size for some positions (e.g., 2\(^{\text{nd}}\)S), they suggest that playing soccer is likely to constrain defenders’ running activities; conversely, attackers (i.e., 2\(^{\text{nd}}\)S and S) have apparently more space and opportunity to express and use their full physical potential. For these latter positions, the fitter players (i.e., having greater PV and \(V_{\text{Vam-eval}}\)) are therefore likely to benefit the most from their higher physical capacities. The lack of large correlations between match running performance and physical capacities found for W was however surprising given the high-intensity nature of this position (see Table 2). We could however postulate that differences in individual playing style or specific tactical ploys within the 4-4-1-1 formation used by our teams, might partly explain these findings. Studies matching time-motion analyses to qualitative (technical/tactical) game examinations [36] should however be performed in the future to clarify these observations.

Despite the use of some less soccer-specific field tests (e.g., Vam-eval) compared with other studies [10,23], the present findings show for the first time that the general importance of physical capacities on match running performance is not as evident as previously reported [10,23,34]. Playing position and its associated tactical roles need to be taken into consideration when examining the relationship between physical capacities and match running performance. Although speculative with present data restricted to correlations, our results suggest that, from a talent identification and development perspective, physical capacities are more likely to be a limiting factor for players who are required to play as attackers. While the precise physical determinants of success in elite soccer are still debated [29,42], the present results suggest that physical training for highly
trained young soccer players should target the development of lower limbs explosive strength (influencing jumping height, maximal sprinting speed and repeated-sprint ability [7]) and/or maximal aerobic power (aimed at improving high-intensity intermittent exercise capacity [17]), especially for prospective attacking players.

Finally, defining the specific physical capacities that are most likely to predict position-specific match running performance is also likely to improve the selection/training process of talented soccer players. In elite adult players, Rampinini et al. [34] showed that peak running speed in an incremental field test, mean sprint time on a RSA test, but not jumping height, were predictive of performance (in all 18 ties). Older players, as well as W and S, generally cover greater distances with a greater impact than age (and its associated changes in physical capacities). In contrast, acceleration (inferred from a 10-m sprint time) showed the weakest correlations with game running performance (all correlations rated at least 0.25 % of TD, Vmax, and even peak running speed reached in 2SM and S). A less likely to be constrained by tactical tasks. It is however possible that larger correlations could have been reported with the use of more soccer-specific field tests (e.g., Yo-Yo [10,23] or shuttle RSA [34] tests) and individualized speed thresholds for assessing match running performance [1].

In conclusion, during international club games in highly trained young soccer players, match running performance is a predictor of game running performance (all correlations rated at least 0.25 % of TD, Vmax, and even peak running speed reached in 2SM and S). A less likely to be constrained by tactical tasks. It is however possible that larger correlations could have been reported with the use of more soccer-specific field tests (e.g., Yo-Yo [10,23] or shuttle RSA [34] tests) and individualized speed thresholds for assessing match running performance [1].

In conclusion, during international club games in highly trained young soccer players, match running performance is a predictor of game running performance (all correlations rated at least 0.25 % of TD, Vmax, and even peak running speed reached in 2SM and S). A less likely to be constrained by tactical tasks. It is however possible that larger correlations could have been reported with the use of more soccer-specific field tests (e.g., Yo-Yo [10,23] or shuttle RSA [34] tests) and individualized speed thresholds for assessing match running performance [1].

References