How does curve sprint evolve across different age categories in soccer players?

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ABSTRACT: Research has shown that soccer players regularly execute curved sprints during matches. The purpose of this study was to determine the age-related effects on curve sprint (CS) performance to both sides, asymmetry, and association with linear sprint (LS). Eighty-four soccer players (aged 16.1 ± 1.6 categorized in U15, U17, and U20) were recruited, who performed CS and LS tests. One-way analysis of variance (ANOVA) and effect size (ES) were used to compare CS performance between age categories, and relationships between physical performance measures were calculated using Pearson's correlation coefficient. The main findings of this study were that: 1) there were significant differences in the "good" side CS among age groups ($p < 0.001$; ES from moderate to large), but not in the "weak" side CS, 2) curve asymmetry was significantly higher in U20 than U15 ($p < 0.05$; ES large) and U17 players ($p < 0.05$; ES moderate), and 3) relationships between CS and LS times decreased with age (from significant and very large [$p < 0.001$] to non-significant and small-moderate [$p > 0.05$]). This study highlights the importance of assessing and training CS in different age categories, an action that becomes less correlated with LS as age increases, with the aim of mitigating the increase in asymmetries as a result of the specialization process, focusing interventions mainly on improving the CS "weak" side.

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INTRODUCTION

Sprint actions are crucial during soccer matches, especially when players are pressing, dribbling, finishing, and counter-attacking [1]. However, time-motion analysis in soccer has shown that sprinting is very rarely linear, but instead, the majority of sprints (i.e., ~85% of all sprints, considering all positions) are performed in curve trajectories during the match [2, 3]. Furthermore, a previous study suggested that practitioners should consider curved sprinting as a specific testing and training modality in the senior stage [4].

Sprint ability in soccer can be conditioned by age category, since in the youth categories, sprint running performance depends on factors related to growth and maturation processes [5]. Méndez-Villanueva et al. reported that under (U) 18 players recorded faster 10-m, higher maximum velocity, and lower 40-m times than U16 and U14 players, with U16 players being faster than U14 players in all sprint running distances [5]. In this respect, it is known that the sprint ability of male soccer players continues to improve until approximately 16–17 years of age [6, 7]. Recently, it has been shown that curved sprint (CS) in senior soccer players presents from a large to very large relationship with linear sprinting speed [4, 8]. However, no study has analysed age-related differences in CS performance of high-level soccer players from a professional squad.

Although physical performance improves with age [9, 10], the increase is not similar in all performance variables and is not proportionally related (e.g., an improvement in linear sprint [LS] does

not mean an improvement with the same proportions in change of direction [COD] ability). In this sense, some researchers [11, 12] suggested that some locomotor specialization in sprinting can occur over the years, which would probably cause a stronger relationship between performance variables in adolescents than in older and more specialized players. In fact, the higher relationship between COD and acceleration (10-m) reported in younger players in comparison to adults [12] could also be explained as part of this specialization process. At an early age, game position is not yet fully defined, so physical demands of the competition could contribute to improving several actions simultaneously and therefore could be treated and tested as similar motor abilities among competitive-level young male soccer players [13]. Conversely, higher stages contribute to specialization through greater repetition of the same stimulus (e.g., lateral wingers frequently perform long LS but few shallow COD). These data suggest that the two abilities may have many common influencing factors in young soccer players, but may become less correlated as a consequence of the specialization process [14]. In this regard, analysing the association between curved and linear sprints in different age groups could suggest the importance of training and testing both tasks in isolated conditions as age categories increase.

The concept of interlimb asymmetries refers to the difference in function or performance in isolated tests between limbs [15, 16]. In addition, recent literature has also aimed to quantify the integrated team sports tasks as two-sided COD [17]. Although these COD asymmetries have not been related to a negative effect on performance [18], it would be interesting to perform the same analysis during CS. Given the importance of CS as a prerequisite to enhance high-intensity actions during match play [2], the detection of existing curve speed imbalances seems justified in soccer players due to the high volume of these actions performed in soccer [3]. Although reducing asymmetries would not result in faster speed or COD times, from a performance viewpoint, being equally fast in both directions would provide an advantage, given the unpredictable nature of soccer actions.

The aim of this study was to investigate the possible age-related variations during CS and LS performance in highly trained soccer players. Specifically, our aims were to: (a) examine the influence of age category on curve performance, (b) analyse imbalances between curve sides (asymmetries), and (c) investigate the relationship between CS and LS performance as specialization increases (from U15 to U20). We hypothesized that (a) there are differences in CS performance between age groups, (b) imbalances between curve sides increase with age/specialization state, and (c) the association between CS and LS decreases as specialization increases.

MATERIALS AND METHODS

Participants

Eighty-four soccer players (aged 16.1 ± 1.6) were recruited. Only outfield players were tested, with goalkeepers excluded. All participants trained in a high-performance soccer academy and completed on average five training sessions and one competitive match per week. Players were categorized by chronological age as follows: U15 = 13.0–14.9 years, U17 = 15.0–16.9 years, and U20 = 17.0–19.9 years. Different player positions were considered for the study to avoid homogeneity in the sample. Table 1 presents the descriptive analysis with age categories and playing position characteristics.

TABLE 1. Age category and playing position descriptive data.

	N	%
Age category		
U15	39	46.4
U17	27	32.1
U20	18	21.4
Playing position		
Forward	27	32.1
Midfielder	28	33.3
Full-back	21	25.5
Centre-back	8	9.5

Study design

In this cross sectional study, we sought to determine the possible age-related differences in CS and LS and to analyse the relationship between CS and LS according to age categories in a professional soccer squad. Given the lack of information, a large sample of soccer players was required to perform both assessments: LS and CS tests. The data collection formed part of the team's normal routines in which players are assessed across the season, and were analysed a posteriori. This study was performed in accordance with the ethical standards of the Helsinki Declaration and the participants signed an informed consent form.

Firstly, all participants performed a warm-up involving 5 minutes of jogging at a self-selected pace followed by a series of dynamic warm-up drills. Two submaximal trials were performed only in the CS on the same test route for both sides before the formal test. The players performed the CS test following the guidelines proposed by Filter et al. [4], and then the LS test. Soccer players performed three trials for each test, starting from a standing position 1 m behind the first timing gate. Each sprint was interspaced by 3 minutes of passive recovery. Verbal encouragement was provided during the tests. All tests were applied by two trained raters and performed under similar environmental conditions (25–28ºC, and 55–60% relative humidity), on natural grass.

TABLE 2. Mean differences (Mean ± SD) in curve sprint "weak" side, curve sprint "good" side, curve sprint average, and curve sprint asymmetry between U15, U17, and U20 categories with effect size (ES) data.

Variables	Age categories			U15 vs. U17 Effect Size	U15 vs. U20 Effect Size	U17 vs. U20 Effect Size
	U15	U17	U20			
Curve sprint "weak" (s)	2.728 ± 0.110	2.672 ± 0.089	2.668 ± 0.108	-	-	-
Curve sprint "good" (s)	2.656 ± 0.105	2.589 ± 0.074*	2.491 ± 0.122#†	0.74 (Moderate)	1.45 (Large)	0.97 (Moderate)
Curve sprint average (s)	2.692 ± 0.104	2.630 ± 0.070*	2.579 ± 0.101#	0.70 (Moderate)	1.10 (Moderate)	-
Curve sprint asymmetry (%)	-2.710 ± 2.135	-3.270 ± 3.369	-7.246 ± 4.808#†	-	1.21 (Large)	0.96 (Moderate)

Note: *Significant difference ($p < 0.05$) between U15 and U17 players; #Significant difference ($p < 0.05$) between U15 and U20 players; †Significant difference ($p < 0.05$) between U17 and U20 players.

Linear sprint

The running completion time of players was determined using a 20-m speed effort with three timing gates (0, 15, and 20-m) (Witty, Microgate, Bolzano, Italy). A previous study showed good reliability data with this method [4]. Three trials were performed and the fastest time of the three trials was used for analysis. Each trial was separated by a 180-s passive recovery period.

Curved sprint

This test followed the guidelines described by Filter et al. [4], using the penalty arc as a reference line to measure the ability to accelerate on a curved trajectory. Two timing gates (0 m, and 17 m) were used. Each player performed 3 trials and the best was retained for analysis. CS was categorized as "weak" (slowest side), "good" (fastest side), and "average" ([weak + good] / 2). Reliability data were previously reported [4].

The formula (good – weak / good x 100) [17] was used to measure the asymmetry index. The curve direction with the fastest completion time was defined as dominant curve speed performance, whereas the slower side was defined as the non-dominant side. There is no threshold categorization regarding curve asymmetries, and the aim of this study was not to analyse the imbalance *per se*, but rather its evolution over time.

Statistical analysis

The statistical analysis was performed using SPSS 21.0 (IBM Corp., Armonk, NY). Descriptive statistics (means ± standard deviations) are reported. One-way analysis of variance (ANOVA) was used to compare CS performance between age categories (U15-U17; U15-U20; U17-U20). When ANOVA showed a significant group effect, between-group differences were highlighted using Bonferroni post hoc tests.

The magnitude of the differences was assessed (pairwise comparisons) using standardized mean differences (Cohen effect size, ES). The criteria used to interpret the magnitude of the effect size were: ≤ 0.2 trivial, > 0.2–0.6 small, > 0.6–1.2 moderate, > 1.2–2.0 large, and > 2.0–4.0 very large [19]. The relationships between the physical performances were determined by Pearson correlations. The level of significance was set at $p < 0.05$. The following criteria were adopted for interpreting the magnitude of 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 [20].

RESULTS

The mean values of groups analysed in the ANOVA and Bonferroni methods are presented in Table 2. No significant differences were found in CS performance of the "weak" side between different age groups. All three groups presented significant ($p < 0.05$) differences in terms of CS performance of the "good" side, with moderate to large ES, with the greatest magnitude of difference between U15 and U20. As age increases, players became faster in the "good" side CS (U20 > U17 > U15), but not in the "weak" side CS.

The CS average performance analyses revealed significant between-group differences in the U15 vs. U17 (moderate ES) and in the U15 vs. U20 (moderate ES).

Table 2 displays data on the asymmetries. The U20 group demonstrated significant differences (from moderate to large) from the

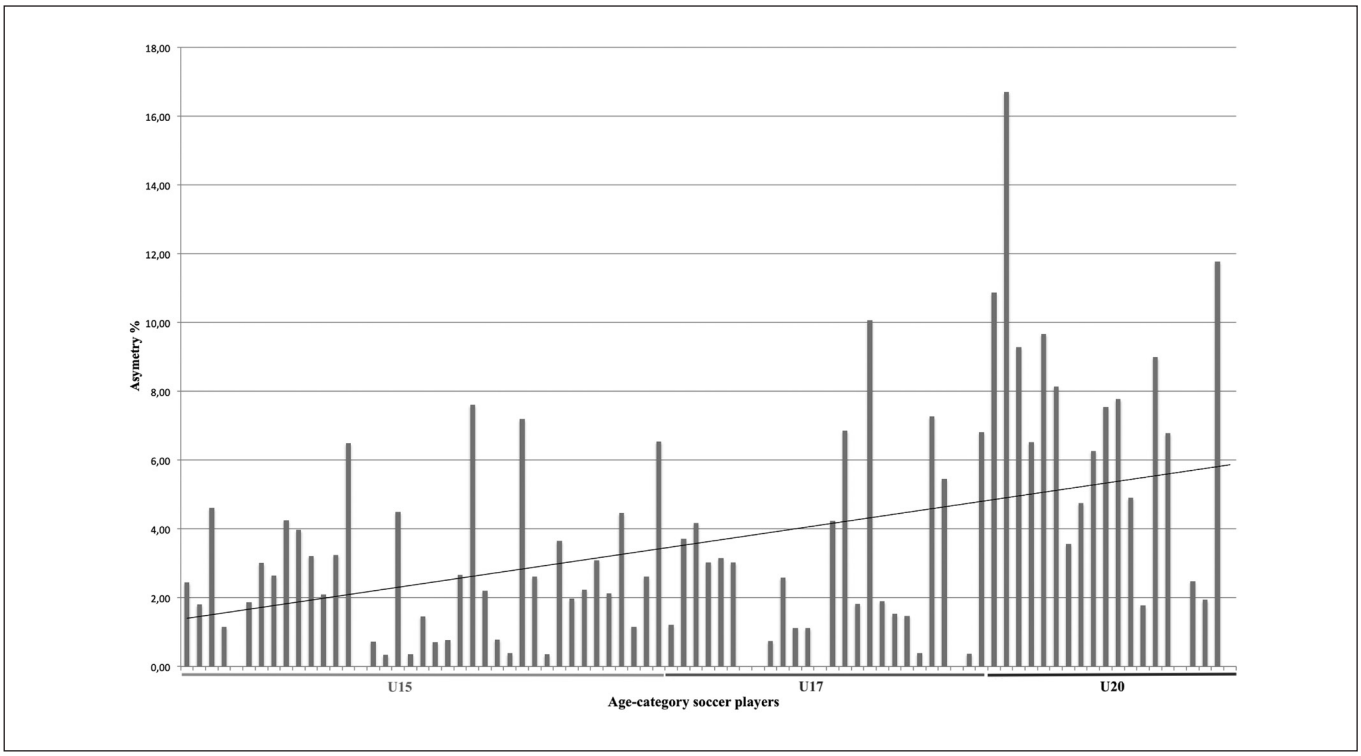

FIG. 1. Evolution of the individual asymmetry percentages in curve sprint as age category increases.

TABLE 3. Correlation coefficient (interpretation) between different variables studied.

		Curve sprint "weak"	Curve sprint "good"	Curve sprint average
Curve sprint "good" (s)	U15	0.87† (*very large*)	-	-
	U17	0.46* (*moderate*)	-	-
	U20	0.54* (*large*)	-	-
Curve sprint average (s)	U15	0.97† (*almost perfect*)	0.97† (*almost perfect*)	-
	U17	0.88† (*very large*)	0.82† (*very large*)	-
	U20	0.86† (*very large*)	0.89† (*very large*)	-
Linear 20 m (s)	U15	0.75† (*very large*)	0.76† (*very large*)	0.78† (*very large*)
	U17	0.38* (*moderate*)	0.59† (*large*)	0.56† (*large*)
	U20	0.27 (*small*)	0.41 (*moderate*)	0.39 (*moderate*)

Note: *$p < 0.05$; †$p < 0.01$.

other groups (U17 and U15, respectively). Significant differences ($p < 0.05$) in asymmetry between age groups showed greater imbalance as the age of soccer players increased (Table 2). Figure 1 presents individual asymmetry percentages for the curved sprint test and its tendency to increase as the age category rises.

Correlation analysis was performed to determine the strength of relationships among the variables in LS and CS in different age categories. Table 3 shows the Pearson's correlation between all variables tested by different age groups. The results showed a decrease in the relationship between CS ("good", "weak", and "average") and LS times (r = from 0.78 [$p < 0.05$] to 0.27 [$p > 0.05$]) as players' age increased. The greatest modification in association was demonstrated between the LS and the "weak" side CS (from very large in U15 to small and non-significant [$p > 0.05$] in U20).

DISCUSSION

The main findings of this study were that throughout age: 1) there was significant improvement in "good" CS, but not in "weak" CS, 2) curve asymmetry was increasing, and 3) the CS-LS relationship was decreasing.

A previous study found significant improvements in linear sprinting as age increased in age ranges (U14-U18) [5]. In the same line, this study reported substantial improvement in the CS "good" side, and moderate enhancement from U15 to U17 (earliest stage assessed) without changes during the late stage (U17-U20) in CS "average" (Table 2). This can be explained, at least in part, as the development of sprinting speed in this age category (U15) being influenced by growth and maturation factors [21]. Based on the literature [5], this result can be interpreted as follows: CS performance may vary depending on age groups in adolescence and these differences become smaller in the late stages of adolescence.

However, the non-improvement of "weak" CS (Table 2) suggests that CS development may not be fully influenced by age category. This led to an increase in asymmetry as age rises (Figure 1), which makes sense given the age-related performance changes, improving "good" but not "weak" CS. Unlike the current results, some authors concluded that asymmetry appears to emerge around periods associated with rapid growth (i.e., U16), possibly due to the demands of accumulated soccer-specific training and competitions, and the "motor awkwardness" phase that adolescents experience [22]. However, this study reported higher asymmetry values in older ages. This could be explained by the nature of the measured tasks, since the asymmetry is task-dependent [23], and by the specialization processes of the analysed club, in which player position is clearly established from 13 to 15 years, suggesting that long-term specific exposure to asymmetrical manoeuvres (e.g., good > weak curve) would contribute to increase CS asymmetries [24]. Previous research showed that lower limb muscle asymmetry is a by-product of playing sport, noting that positional differences are also a contributing factor to the prevalence of asymmetry [25–27]. In this sense, evident relationships between levels of training exposure (less experienced vs more experienced) and asymmetrical loading exposure have been reported [25]. In addition, player dominance could influence preferential use of one side of the body when performing a motor task, typically resulting in a more skilful and, therefore, dominant side [28, 29]. Furthermore, performing these measurements in different age categories would elicit the ideal period to introduce CS training. The presented results suggest the need to include interventions oriented at reducing CS asymmetries as age increases in order to achieve the same performance on both curve sides.

Regarding the CS-LS relationship, this is the first study to show the evolution (decline) in the LS-CS association as player age increases (Table 3). This may suggest that the percentage of common influencing factors between both actions decreases with increasing sport specialization. According to recent results, when athletes reach physical maturation and proficient experience, skills that seemed similar (e.g., COD and agility) manifest as independent skills [30]. Indeed, it has been shown that agility, jumping ability, and sprint time could represent the same motor abilities in competitive-level young team sports athletes [13]. However, these abilities seem unrelated to each other in professional and senior players [14, 31, 32]. In this sense, Loturco et al. [33] demonstrated a gradual increase in COD deficit (difference between LS and COD sprint) as age increases, which seems to be in line with the results of the present study indicating differentiation in skills as age categories increase. Nevertheless, the non-correlation found in U20 (Table 3) could be explained by low sample size, which could have underrated the association values. Previous studies have shown a meaningful and strong relationship between CS and LS [4, 8]. Regardless of the relationship between both actions, CS could offer valuable information, as it not only provides data on possible imbalances between dominance sides, but also provides acceleration performance data that are more representative of those performed during soccer matches [2, 3].

The main limitations of the present study were the focus on CS performance and its evolution in different ages in one single elite club and the difference in the sample size between the age categories analysed. In fact, the gradual decrease in CS-LS relationship values (Table 3) may be associated with aforementioned limitations. Further studies are required to replicate similar measurements in other soccer clubs from different countries, involving larger sample sizes, and testing the relationship with equal sized groups. Moreover, it would be interesting to include biological maturation data to analyse the influence of growth, since biological age can be different in players with the same chronological age [34].

CONCLUSIONS

In summary, the results of the present study show that CS performance improves throughout the age of young soccer players, with a notable improvement in the "good" side but not the "weak" side, leading to increases in CS asymmetry. Data also show that the LS-CS relationship decreases as age increases, which implies that LS and CS become less related skills, especially "weak" CS. These data highlight the importance of assessing CS throughout the soccer academy processes, as well as older age categories, in order to manage imbalances. Practitioners should monitor the CS "weak" side development and implement training programmes aiming at improving CS performance in order to equalize the imbalances produced by specialization of the training process (i.e., playing position demands).

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Conflict of interest statement

Our paper does not contain funding. The authors declare that they have no conflict of interest.

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