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New curve sprint test for soccer players: Reliability and relationship with linear sprint

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ABSTRACT

The speed performance is involved not only in linear sprints, but also in a wide spectrum of multi-directional movements, such as curve sprinting. Curved sprint can be defined as sprint with gradual and continuous change of direction (COD). Although ~85% of the actions performed at maximum velocity in a professional soccer league are curvilinear sprints, there is not any specific test to assess this ability. This study aimed to analyse the reliability of a new curve sprint test, and compare its results with those obtained by soccer players in linear sprint. Forty experienced soccer players performed 3 attempts of curve sprint (using the penalty arc) to right and left side (17 m), and 3 linear sprints (17 m) in two different days. The ICCs (inter-session reliability) were 0.93 for sprint curve right side (CSRS) and 0.89 for sprint curve left side (CSLS), considered “acceptable”. The CVs (intra-session reliability) were 0.87% in CSRS and 1.15% in CSLS. The coefficient of determination (R^2) between linear and curve sprinting was ~35%. The association between curve sides was “very large” ($r = 0.878$; $p < 0.01$). In summary, we showed that “curve sprint test” is highly reliable, and that curvilinear and linear sprints are different and independent actions.

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KEYWORDS

Non-linear sprint performance; assessment; semi-professional soccer player

Introduction

Soccer is characterised as an intermittent team-sport in which high-intensity activities (e.g., maximum sprints) are regularly intertwined with actions of low and moderate intensities (e.g., walking and jogging) (Burgess, Naughton, & Norton, 2006; Haugen, Tonnessen, Hisdal, & Seiler, 2013; Rampini, Coutts, Castagna, Sassi, & Impellizzeri, 2007). Importantly, the number of high-intensity running efforts per game has progressively increased across the years (Barnes, Archer, Hogg, Bush, & Bradley, 2014), more specifically during decisive match situations (Faude, Koch, & Meyer, 2012; Mohr, Krstrup, & Bangsbo, 2003). This reveals the critical importance of speed-related capabilities for soccer performance, especially because multiple and successive accelerations are frequently observed during official games (Bloomfield, Polman, & O'Donoghue, 2007; Rampini et al., 2007). In addition, it is known that professional players have better performance in sprints during matches (10, 20, 30, and 40 metres) than their less specialised counterparts (Bradley, Di Mascio, Peart, Olsen, & Sheldon, 2010), but the duration of these sprints during matches range from 2 to 4 s with respective distances lesser than 20 metres (Barnes et al., 2014).

In elite soccer, the acceleration capacity is involved not solely in linear sprints, but also in a wide spectrum of complex and multidirectional motor-tasks (e.g., nonlinear sprints). Accordingly, the “nonlinear sprint performance” appears to be able to differentiate between professional and young soccer players (Cardoso de Araújo, Baumgart, Freiwald, & Hoppe, 2017). In this regard, it has been consistently shown that soccer players execute hundreds of directional changes throughout

the game, with many of these actions being characterised by their less aggressive cutting turns and smoother angles (an arc) (e.g., $\leq 15^\circ$) (Bloomfield et al., 2007). Of note, approximately 85% of the manoeuvres performed at maximum velocity in a professional soccer league consist of curvilinear sprints (i.e., curve sprints), which may be defined as the upright running portion of the sprint completed with the presence of some degree of curvature (Caldbeck, 2019). Nonetheless, despite their critical importance, curve sprints have been largely overlooked by coaches and sport scientists.

From a general perspective, curvilinear motion regularly occur in soccer (Bloomfield et al., 2007; Caldbeck, 2019), regardless of playing position (except for goalkeepers), typically within a radius ranging from 3.5 to 11 m (Brice, Smith, & Dyson, 2008). For obvious reasons, curve sprint technique presents singular and unique kinetic and kinematic features (Churchill, Trewartha, & Salo, 2018). For example, when compared to maximum linear sprints, the velocity achieved during curvilinear trajectories is usually lower in sprinters, which significantly affects the neuromechanical demands and requirements during these actions (Churchill, Salo, & Trewartha, 2015; Churchill et al., 2018). Furthermore, since acceleration and speed increase with “trunk rotation” over curvilinear trajectories, meaningful biomechanical differences between curve and linear sprint techniques may be expected (Churchill et al., 2015; Churchill, Trewartha, Bezodis, & Salo, 2016; Churchill et al., 2018). As such, maximum linear and nonlinear sprint performances possibly embody different physical and technical capabilities and, consequently, should be independently assessed and trained.

There are many validated change of direction (COD) assessments and their relationships with other measurements such as linear sprint tests are well established and confirmed in soccer (Brughelli, Cronin, Levin, & Chaouachi, 2008). Curvilinear displacements have also been assessed in soccer players (Smith, Dyson, Hale, & Janaway, 2006; Smith, Dyson, & Hate, 1997), but only at submaximal speeds (e.g., jogging). Measuring speed and acceleration during curved sprints would be interesting and critical to understand the determinants of performance in these actions, which are frequent and decisive in soccer matches. Therefore, the objectives of this study were to (a) test the reliability of a new curvilinear sprint test for soccer players, and (b) compare curved sprints with linear sprints, considering their mechanical demands, and using the penalty arc of a soccer field as the “standard measure”. We hypothesised that best performances in linear sprint tests would not be necessarily associated with best performances in curvilinear sprints. Furthermore, we expected that the new “curve sprint test” would meet the reliability criteria.

Methods

Participants

Forty experienced soccer players (age: 22 ± 3.32 years; height: 177 ± 4.81 cm; mass: 73.2 ± 6.2 kg) from a semi-professional Spanish League were recruited for this study. All subjects had more than 15 years of soccer experience and were semi-professional players in the Second B and Third Division Spanish League. Inclusion criteria were: train four times a week, not having medical contraindications for the tests, and have availability to carry out them. The methodology used was approved by the Football Science Institute Ethics Committee and conformed to the policy statement with respect to the Declaration of Helsinki. All subjects were informed of the risks and benefits of the procedure and signed an informed consent for participation in the study.

Test setup

Procedure

48 h after a familiarisation session with the test (Sheppard & Young, 2006), subjects participated in two test sessions to assess the reliability of the data, with 48 h between sessions (Lockie, Schultz, Callaghan, Jeffriess, & Berry, 2013; Sheppard & Young, 2006). Soccer players attended three experimental sessions (one familiarisation and two identical testing sessions). The players first performed the linear sprint test and then, the curve sprint test. The only instructions before curve sprint test were: 1. Start the sprint from behind start line (1 m distance to the first timing gate set), 2. Follow the arc line of the area as a guiding line, 3. If you do not sprint on the guiding line, the test will not be considered valid and 4. After receiving the go ahead, you can start when you're ready. During data collection, three sets of timing gates were used over 17 m. This enables split times to be measured for 8.5 m and 17 m sprints. All the players recovered the same time between each sprint. Each of the repetition times was measured by a photoelectric cell system (Microgate Witty, Italy) set at 90 cm height all timing gates in both sides.

Setup

Prior to data collection in the first testing session, each subject's age, height and body mass were recorded. The warm-up exercises were: 5 min of jogging at a self-selected pace followed by a series of dynamic warm-up drills and three practice sub-maximal trials for linear and curve sprints. Subjects completed two different tests within a session: the 17 m linear sprint and curve sprint. All tests were performed under similar environmental conditions (13–16°C, and 35–39% of relative humidity), on artificial grass and executed them in a random order that was maintained across the two sessions.

The trial was considered “successful” when the subject ran on the guideline (arc of the area). All the trials were recorded for analysis. The subjects performed successfully three times each test (the average of the three attempts was recorded), with a total of nine tests with 3 min of recovery between each one and a minute and 30 s between sets: 3 x linear sprint + 3 x right curve sprint + 3 x left curve sprint.

Linear Sprint Test. Running speed was evaluated using 17 m sprint times (0–17 m) (standing start) with 8.5 m split times. The front foot was placed 1 m before the first timing gate in split standing start (Cronin, Green, Levin, Brughelli, & Frost, 2007).

Curve Sprint Test. The trajectory used to measure the sprint in curve was the arc of the area (regulation soccer field), which has the following characteristics (Figure 1 and Figure 2):

- Radius (from the penalty spot): 9.15 m.
- Distance from initial point to final point of the curve in a straight line: 14.6 m.
- Amplitude of the angle from the point of penalty spot: 105.84°
- Total distance of the sprint curve: 17 m (obtained through basic trigonometric analysis).

Running curve speed was evaluated by 17 m sprint times (0–17 m) (standing start) with 8.5 m (0–8.5 m) split time. The front foot was placed 1 m before the first timing gate and following the line of the arch of the area. Both sides were measured (left and right). According to the mean time spent for the three trials for each side, we considered the slowest as the “weak” side, and the fastest as the “good” side.

Statistical analyses

The statistical analysis was performed using the SPSS 17.0 (SPSS, Chicago, IL). Descriptive statistics are expressed as mean \pm standard deviations (SD), in addition to 95% confidence limits (95% CL). The normality of the data distribution was checked using the Kolmogorov–Smirnov test.

For the relative reliability analysis, intra-class correlation coefficients (ICC) were used. An ICC equal to or above 0.7 was considered acceptable (Baumgartner & Chung, 2001). Inter-session reliability was determined, using the best successfully (previously defined) data from each day and each variable obtained (8.5 m CSLS, CSRS and linear, and 17 m CSLS, CSRS, and linear), via ICCs and two other separate measures (Sheppard & Young, 2006).

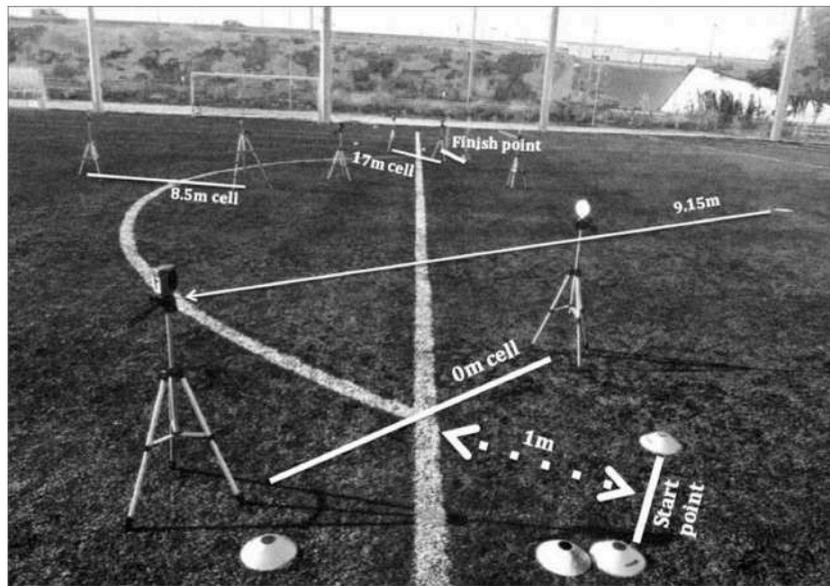


Figure 1. Characteristics of the area to measure the sprint in curve.

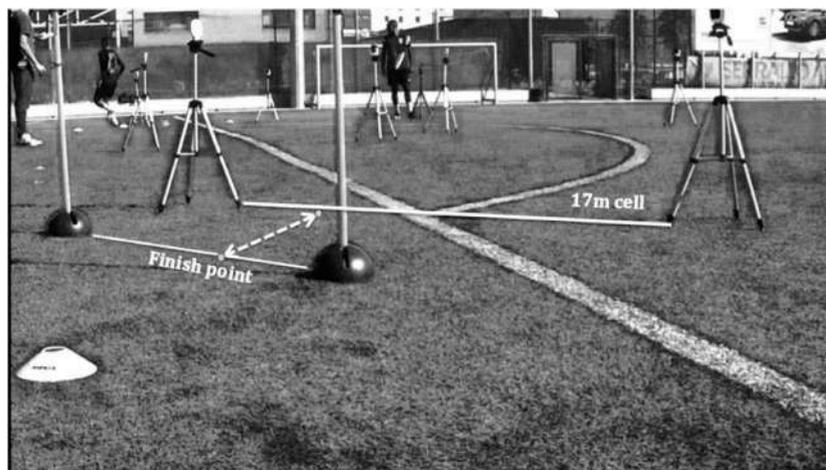


Figure 2. Soccer player performing new curve sprint test.

Absolute reliability is the degree to which repeated measurements vary for individuals and the spreadsheet of Hopkins (2000) (Hopkins, 2000) was used to determine the typical error (TE) (s), expressed as a coefficient of variation (CV, %) (Hopkins, Schabert, & Hawley, 2001). A CV of less than 5% was set as the criterion for reliability.

Association between variables to determine the relationships between curve sprint speed (in both “weak” and “good” sides) and linear sprint speed, to help coaches and sport scientists estimate the extent of variation in straight sprint performance to a given variation in curvilinear sprint performance (i.e., shared variance). Total variance was reported by the coefficient of determination (R^2) and the respective level of significance ($p < 0.05$). Additionally, a Pearson product moment correlation coefficient was used to test the correlation between “weak” and “good” curve sprint performances, which was classified according to the criteria defined by Hopkins et al. (Hopkins, Marshall, Batterham, & Hanin, 2009). The level of significance was set at $p < 0.05$.

Results

Table 1 presents the descriptive data of both session 1 and session 2, which also shows data about relative reliability statistics (mean, 95% confidence limit, p value and ICC). In terms of relative reliability of different sprint test, the ICC of each test was greater than 0.7, specifically 0.93 sprint curve right side (CSRS) and 0.89 sprint curve left side (CSLS), considered “acceptable”. There were no significant differences between the most of test attempts. However, there were statistical differences between session 1 and 2 in the CSRS (17 m) and CSLS (8.5 m). The effect size (ES) showed a “small effect” in both conditions and “non-effect” for the rest of the tests (Cohen, 1988; Hopkins, 2004).

Table 1 shows the data related to the absolute reliability of the different tests. Descriptive data of the two testing sessions and the TE values expressed as %CV calculated from two consecutive sessions are presented in Table 1. The mean CV was calculated from both the testing sessions 1 and 2. The CV of each test was less than 5%, specifically 0.87% in CSRS (17 m) and 1.15% in CSLS

Table 1. Descriptive data for testing sessions 1 and 2 to know relative and absolute reliability data with mean, p value for differences between the sessions, effect size (ES), reliability statistics (intra-class correlation coefficient [ICC], typical error [TE], coefficient variations [CV]) in semi-professional soccer players.

Sprints	Session 1 (s)	Session 2 (s)	Mean and 95% CL (s)	p value	ES	ICC (CL95%)	Relative reliability	TE	CV %	Absolute reliability
8.5m CSRS	1.43 ± 0.09	1.42 ± 0.09	1.43 (1.41–1.45)	.245	.13	.83 (.65 – .92)	Accep.	.04	1.43	Accep.
17m CSRS	2.59 ± 0.12	2.57 ± 0.12	2.58 (2.54–2.59)	.003*	.34	.93 (.85 – .97)	Accep.	.03	0.87	Accep.
8.5m CSLS	1.42 ± 0.1	1.39 ± 0.08	1.4 (1.32–1.42)	.005*	.32	.75 (.52 – .88)	Accep.	.05	1.74	Accep.
17m CSLS	2.56 ± 0.13	2.54 ± 0.11	2.55 (2.5–1.57)	.182	.15	.89 (.78 – .95)	Accep.	.06	1.15	Accep.
8.5m Lin	1.47 ± 0.13	1.48 ± 0.14	1.48 (1.4 – 1–53)	.218	.14	.89 (.75 – .95)	Accep.	.05	1.97	Accep.
17m Lin	2.53 ± 0.13	2.54 ± 0.13	2.54 (2.54–2.57)	.104	.18	.96 (.92 – .98)	Accep.	.03	0.5	Accep.

* Significant differences ($p \leq 0.05$) between sessions; CSRS: curve sprint right side; CSLS: curve sprint left side; Lin: Linear; Accep: acceptable; TE: typical error; CV: coefficient variations; CL: confidence limits; ES: effect size; ICC: Intra-class correlation coefficient.

(17 m). The data presented in Table 1 confirm the reliability of the test (reproducibility and temporary changes).

The coefficients of determination reveal that curve sprinting (in both good and weak sides) and linear sprinting performances are separate and specific physical capabilities in experienced soccer players (34% and 37% of shared variance, respectively) (Table 3). This indicates that players who ran faster in linear sprints were not necessarily faster in curvilinear trajectories. In contrast, a positive and “very large” ($r = 0.88$) correlation (Hopkins et al., 2009) was found between the curve sprint performances obtained in both “weak” and “good” sides; therefore, athletes who were faster to sprint to “one side” were equally able to sprint faster to “the other side”.

Discussion

The main findings of this study were (a) reliability criteria of a universally standardised curve sprint test (that uses the 9.15 radius penalty arc as a “guide-line”) were confirmed in experienced soccer players, and (b) performance in this curve sprint test showed limited relationship with performance in a same length lineal sprint, which suggest that curve and straight sprinting abilities are different physical qualities.

Relative and absolute reliability

Previous research has found good reliability for measures of linear sprint and COD speed, reporting acceptable ICCs (>0.7) and CVs ($<5\%$) in both linear sprint and COD tests (Little & Williams, 2005). In the present study, ICCs for the sprint CSRS and CSLS (17 m) tests were 0.93 and 0.89, respectively, indicating higher levels of relative reliability. Moreover, a small TE, expressed as %CV of 0.87% and 1.15% (for CSRS and CSLS, respectively) also shows higher absolute reliability. Interestingly, those values are quite similar than those reported in other studies regarding linear sprint assessments (CV $\sim 0.9\%$) (Hopkins et al., 2001).

Although it is first curved test is used and its comparison with other studies is difficult, intermediate reliability results between COD and linear sprint could be expected, since the curved path could imply a movement pattern less remote from the linear sprint, compared to the COD. However, it doesn't happen. Most of the nonlinear sprint trajectories in a soccer match are curved (Caldbeck, 2019) with small radius (from 3.5 to 11 m) (Brice, Smith, & Dyson, 2004) and less than 20 m long (Barnes et al., 2014). So, the specificity of our test (9.15 m radius, 17 m length) could be responsible, at least in

part, for this similarity of reliability values with those of the linear sprint.

Relationship with linear sprint performance

Comparing the linear relationship between curvilinear and linear sprints, shared variances between these capabilities were 34% and 37% for “good” and “weak” side, respectively. This indicates that straight sprint can explain only a very limited variability of curve sprint (i.e., $\sim 35\%$) and also confirms the hypothesis that faster soccer players in straight sprints are not necessarily faster in curvilinear trajectories. Previous research demonstrated the specificity of linear sprinting when compared to COD speed, describing moderate associations ($r = 0.35$) between 10 m sprint and Zigzag test (i.e., a 20 m COD test consisting of 3 turns at 100°) (Little & Williams, 2005), and also “low” and “moderate” correlations between linear sprint and different COD tests (Cinarli, Kafkas, & Kafkas, 2018). In the same way that these studies have led to the development of specific COD training, our results suggest that curve and lineal sprint should be assessed and (probably) trained as separate physical qualities, since they are different functional skills.

Lastly, our results showed a “very large” ($r = 0.878$) correlation between the curve sprint performance obtained by the subjects in both “good” and “weak” sides (Table 2), revealing that soccer players who run faster to one side (e.g., to the right side) possibly run fast to the other side (e.g., to the left side). Initially, it would make sense to expect differences between both sides due to the specialisation of each player based on

Table 2. Pearson's correlation and coefficient of determination (R^2) ($p \leq 0.05$) were used to define relationship between “good/weak” sprint curve.

	Sprint curve “good” side (17m)	
Sprint curve “weak” side (17m)	r	.878
	R^2	.77
	p	$< .001^\dagger$

† Significant ($p \leq 0.01$) relationship between variables.

Table 3. Coefficient of determination (R^2) ($p \leq 0.05$) was used to calculate the proportion of the curve sprint variance explained by the linear sprint.

		Sprint curve “good” side (17m)	Sprint curve “weak” side (17m)
Sprint curve “weak” side (17m)	R^2	.77	
	p	$< .001^\dagger$	
Linear sprint (17m)	R^2	.34	.37
	p	$< .001^\dagger$	$< .001^\dagger$

† Significant ($p \leq 0.01$) variance explained.

their position on the pitch. However, in the analysed team there was a similar proportion of left and right side midfielders, wingers and full-backs (heterogeneous sample), and the present study did not analyse categorising by player's position, which was the main limitation of this study. Future studies are necessary to know if within the same player's position there is relationship between "good" and "weak" side curve sprint performance.

Other relevant data regarding linear sprint

Another relevant data was the average of each variable. It has been reported lower speed in curve sprints than in linear sprints regardless of radii (1, 2, 3, 4 and 6 m) in sprinters (Chang & Kram, 2007). Briefly, when the radius decreases, the sprint performance tends to decrease. Likewise, Churchill et al. (2015) observed higher velocities in linear sprints than in curve sprint in track and field athletes. Curiously, for the first time, we recorded higher speeds during curvilinear than linear trajectories in 27 of 40 subjects, specifically when considering the "good side" measurement result within a distance of 17 m and a radius of 9.15 m (i.e., testing data: sprint curve "good" side = 2.5 s, linear sprint = 2.55 s, and sprint curve "weak" side = 2.63 s). This on the one hand suggests again the need to investigate the influence of player's position on "good" and "weak" sides performance, and on the other suggest that these differences regarding Churchill et al. study (Churchill et al., 2015) (with a sample of track and field athletes) could be partially due to the specificity of the test, since this curvilinear motion regularly occur more than linear in soccer (Bloomfield et al., 2007; Caldbeck, 2019). Anyway, our limited sample (40 experienced players) prevents us from understanding our results as reference values and requires further studies to confirm these results.

In summary, the coefficients of determination indicated that curve and linear sprint performances have a limited explained variance of ~35%, in both "good" and "weak" sides, in experienced soccer players. This suggests that curve and straight sprinting abilities are different physical qualities and, consequently, should be assessed and trained in isolated conditions. As the number of maximum curve sprints throughout soccer games seems to be influenced by matching demands (Bloomfield et al., 2007; Caldbeck, 2019), additional studies should be conducted to examine the differences in performance between distinct playing positions. Finally, due to the importance of curvilinear sprint performance in professional soccer, further studies are required to test the effectiveness of different training strategies in improving this ability in elite soccer players.

Practical applications

The proposed "curve sprint test" is a specific soccer speed measurement, performed in the arc of the area, within a radius of 9.15 m (official FIFA radius) and a distance of 17 m. The data reported herein confirm that, when executed under these standardised parameters, this universally standardised test can provide a very precise and reliable measure of curvilinear sprint performance. As curve sprinting is an essential and decisive action during soccer games and possess a limited relationship with linear sprinting speed (i.e., ~35% of shared

variance), and taking into account that the radius and length of the sprints vary in the real competition (which makes difficult a complete transfer of curve test performance to the competition performance), strength and conditioning coaches and sport scientists are encouraged to assess and train this capability in a separate way. These findings open new lines of research regarding the biomechanical (e.g., kinematic and kinetic factors), physiological and neuromuscular characteristics of maximal curvilinear sprinting actions in soccer players from different levels, genders and age-categories.

Disclosure statement

No potential conflict of interest was reported by the authors.

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