# Changes in running speed during a linear and a curved sprint with a radius of 9.15 metres: implications for choosing the appropriate distance when monitoring a specific curvilinear sprint performance

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**Speed performance | Curvilinear | Testing | Sprint**

## Headline

Previous research has shown that most maximum-speed sprints in team sports occur on curved paths (i.e., curvilinear sprints) (1). Because curvilinear sprinting has unique biomechanical characteristics per se (2–6), recent study proposed a 17-meter sprint test with a 9.15 m radius (7). The test has been shown to be highly reliable (7,8), and is widely used by practitioners and researches to assess athletes sprint performance in curvilinear context (9–11). However, there is currently no data available to determine whether this test measures curvilinear sprint acceleration performance, maximum speed ability or both.

## Aim

Therefore, this study analyses sprinting speed over 40-meter linear and curvilinear sprints with a 9.15-m radius. The goal was to compare the differences in peak speed (PS) and the distance at which PS was achieved ($PS_{distance}$) between linear sprints (LS), dominant side curvilinear sprints ($CS_{dom}$), and non-dominant side curvilinear sprints ($CS_{non\text{-}dom}$). Furthermore, sprinting speed reached at 17 m ($S_{17}$) was assessed. These findings will provide insights into the optimal execution of the specific 9.15-m radius curvilinear sprint test, providing valuable information for both researchers and team sports practitioners.

## Methods

### Design

A within-subject, cross-sectional study was conducted to compare the performance of LS and curvilinear sprints. Participants completed three 40-meter sprints under each condition in a single session. Sprint speed over distance was assessed using an 18 Hz GPS system (GPEXE lt System, Exelio SRL, Udine, Italy). The outcome variables were calculated from sprints where the highest PS was achieved. Whereas curvilinear sprint dominance was set according to higher PS achieved during left and right curvilinear sprint.

### Participants

The study involved 14 male amateur athletes (age = 24.64 ± 4.53 years; body mass = 79.50 ± 6.69 kg; height = 182.21 ± 5.56 cm) from soccer, handball, weightlifting, and track & field. Only healthy individuals without musculoskeletal injuries in the past 9 months participated. Informed consent was obtained, and the study was conducted in accordance with the Declaration of Helsinki, with approval from the Medical Ethics Committee (approval number 0120-690/2017/8).

## Methodology

### Testing protocol

Sprints were conducted on an artificial grass soccer field, with participants wearing soccer shoes. Before testing, a standardized warm-up was performed, including 10 min of moderate-pace running, strengthening and dynamic stretching exercises, and three submaximal 20-m sprints. Participants then completed three maximal 40-m LS and curvilinear sprints to the left and to the right in a balanced and randomized order with five-min rest between trials. Sprint start was performed from two-point crunched position. The curvilinear sprint tests were conducted around the circumference of the centre spot of the soccer field, with a radius of 9.15 meters. Participants were asked to sprint following a line. In order to easily visualize the track, cones were placed at one m width on 0, 10, 20, 30, and 40 m distances.

### Data acquisition

According to the manufacturer, GPEXE lt devices were worn in a vest on the upper back and were activated 20 min prior to testing. During the tests, a mean ± standard deviation number of satellites used to capture the data was 10.12 ± 0.63. Distance-speed signals of 40-m sprints were recorded, automatically filtered, and exported using GPEXE web app (version 8.2.41, Exelio SRL, Udine, Italy). Since each individual measurement represented continuous data throughout the entire testing procedure, a MATLAB software (Version R2020B, MathWorks, Natick, Massachusetts, USA) code was employed to discern between LS and curvilinear sprint trials and to calculate the outcome variables. From distance-speed plots of each sprint, the PS (in $m \cdot s^{-1}$), the $PS_{distance}$; (in m), and the $S_{17}$; (in % of PS) were calculated.

### Statistical analysis

Data analyses were conducted using SPSS version 25.0 (SPSS, Chicago, IL, USA) with the significance level set at 0.05. Results are presented as mean and standard deviation (SD). The Shapiro-Wilk test was used to determine the normality of the data distribution. A one-way ANOVA was used to evaluate differences in PS and $PS_{distance}$ between sprint types. When sphericity assumptions were violated, Greenhouse-Geisser adjusted p-values were reported. If a significant effect of sprint type was detected, pairwise comparisons among LS, $CS_{dom}$, and $CS_{non\text{-}dom}$ were conducted using the Bonferroni post hoc test.

## Results

The Shapiro-Wilk test confirmed normal distribution of PS and $PS_{distance}$ presented in Table 1.

**Table 1. Descriptive statistics presented as mean ± standard deviation.**

| | LS | $CS_{non\text{-}dom}$ | $CS_{dom}$ |
|---|---|---|---|
| PS ($m \cdot s^{-1}$) | 8.27 (0.52) | 6.84 (0.24) | 6.91 (0.23) |
| $PS_{distance}$ (m) | 30.31 (4.62) | 21.07 (4.61) | 20.24 (3.35) |

**Abbrevations**. PS = peak speed; $PS_{distance}$ = distance at which peak speed was achieved; LS = linear sprint; $CS_{non\text{-}dom}$ = non-dominant side curvilinear sprint; $CS_{dom}$ = dominant side curvilinear sprint.

One-way ANOVA revealed significant effect of sprint type for PS ($F(2, 13) = 344.6$, $p < 0.0001$) and $PS_{distance}$ ($F(2, 13) = 35.52$, $p < 0.0001$). Differences in the variables between sprint types are depicted in Figure 1. Post-hoc analysis showed that the PS was significantly greater in LS than in $CS_{dom}$ (MD = 1.41, 95% CI = 1.19 – 1.63 $m \cdot s^{-1}$) and $CS_{non\text{-}dom}$ (MD = 1.48, 95% CI = 1.28 – 1.68 $m \cdot s^{-1}$), and at the same time greater in $CS_{dom}$ than in $CS_{non\text{-}dom}$ (MD = 0.07, 95% CI = 0.02 – 0.12 $m \cdot s^{-1}$). Similarly, the $PS_{distance}$ during LS was significantly longer as during $CS_{dom}$ (MD = 10.27, 95% CI = 7.23 – 13.31 m) and $CS_{non\text{-}dom}$ (MD = 9.44, 95% CI = 6.04 – 12.83 m).

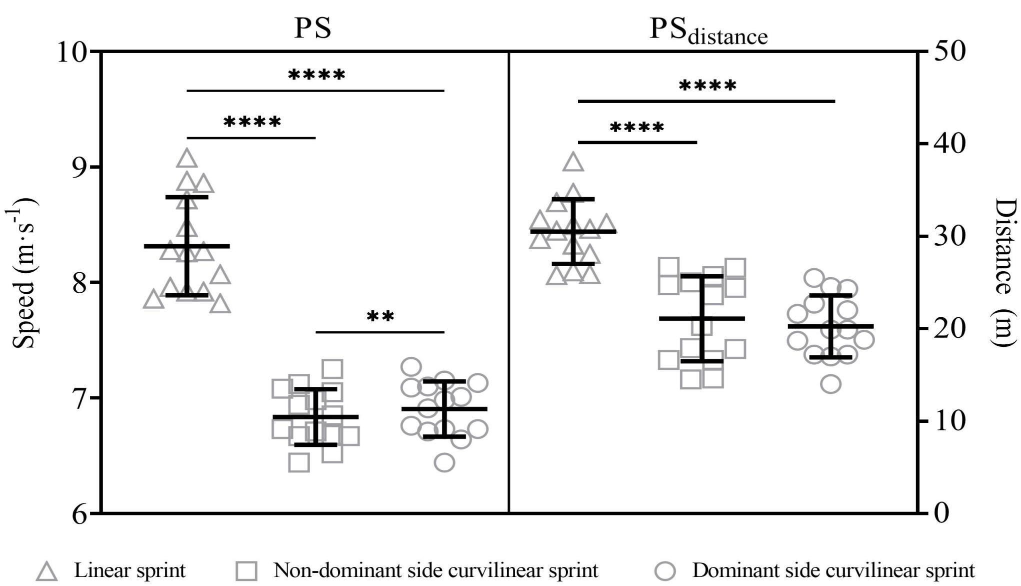


**Fig. 1. Differences in peak speed (PS) and distance to PS ($PS_{distance}$), between linear (LS), dominant ($CS_{dom}$), and non-dominant curvilinear sprints ($CS_{non\text{-}dom}$).**

During the LS all individuals reached PS after 17 m. On average, $S_{17}$ was 91.93 ± 3.03 % of PS. In $CS_{dom}$ one individual achieved PS prior 17 m, and average $S_{17}$ of the rest was 98.69 ± 1.18 %. In $CS_{non\text{-}dom}$ three individuals achieved PS prior 17 m distance, after excluding them from analyses, average $S_{17}$ was 98.20 ± 1.03 %.

## Discussion

This pilot study demonstrates that sprinting speed is significantly different when running along a 9.15-m radius curve compared to a straight line, highlighting the importance of evaluating sprint performance in these specific conditions. The findings indicate that PS during 40-m sprint is lower on the curve compared to sprinting in line, and that PS during curved sprint is typically reached at distances longer than 17 m.

There are limited evidences on sprinting speed changes over distance when performing curvilinear sprint tests (12). This gap may be due to the scarcity of tools capable of accurately capturing instantaneous speed on curved paths, especially in field settings. For this purposes we found GPS device to be a practical solution (13). Our results showed that PS, measured with the GPEXE lt, was higher during LS than $CS_{dom}$ and $CS_{non\text{-}dom}$. This was expected, and can be attributed to the more complex and asymmetrical biomechanics involved in curved sprinting (9,14). Specific biomechanics of the movement is probably also responsible for reaching the PS during $CS_{non\text{-}dom}$ and $CS_{dom}$ earlier than during LS. These findings confirm previous observation about curved sprinting being specific (10), and furtherly suggest that the neuromuscular system operates more effectively under biomechanical demands of late acceleration and maximal speed phases of linear rather than curved sprinting.

On average PS was reached at 21.07 ± 4.61 and 20.24 ± 3.35 m for $CS_{non\text{-}dom}$ and $CS_{dom}$, respectively. These distances exceed 17 m used in specific curvilinear sprint test (7). Interestingly, athletes in our study achieved approximately 98% of their PS at this specific distance when performing $CS_{non\text{-}dom}$ and $CS_{dom}$. This implies that performing 9.15 m radius curvilinear sprint test over 17 m might not fully capture athlete's late acceleration and maximal speed performance during curved sprinting. In team sports like soccer, curvilinear sprints are often executed when athlete is already moving, most often initiating high-speed linear running or sprinting. Therefore, late acceleration and maximal speed curved sprint performance could be a crucial factor in game situations. To test this ability, it is advised to perform specific 9.15 m curvilinear test should be performed on over distances longer than 20 m.

## Practical applications

- Changes in running speed confirm that sprinting in curve is different from linear, thus specific curvilinear sprint tests should be utilized in sports where this type of running is common.
- To evaluate late acceleration and maximal curved sprint performance, we recommend to conduct the 9.15-m radius sprints over a distance of at least 20 m, or preferably 25 m.

## Limitations

While the results of this study are promising, they should be interpreted with caution due to certain limitations. First, the small sample size of amateur athletes restricts the generalizability of the findings to elite-level athletes. Nonetheless, since faster athletes typically reach PS later during LS (15), a similar pattern may be expected in curved sprinting, which further underscores the significance of this study's indications. Additionally, it must be considered that speed and distance were measured using a GPS system, which is known to be less reliable for assessing sprint distance (16). Thus, future research should validate these findings using gold-standard methods, such as kinematic analysis, to provide a more accurate assessment of sprinting speed during curvilinear sprinting.

## Data availability statement

The data that support the findings of this study are available from the authors ( MS, ŽL, and DS) upon reasonable request.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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