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RELATIONSHIP BETWEEN SPRINT PERFORMANCE AND STRIDE PARAMETERS IN CURVED SPRINTING

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The purpose of this study was to investigate the relationship between sprint performance and stride parameters in curved sprinting. Nine athletes performed 60 m maximal sprinting. Correlation coefficients between sprint time and stride parameters were calculated in three conditions, namely straight, right leg and left leg in curved sprinting separately. Significant correlations were found in contact time, step time and step frequency of right step of curved trials. The left step of curved path and straight had significant correlations in the same variables (SL and SS). Step length and step speed had significant correlations in all steps. The right step of curved path would be important for curved sprinting performance.

KEY WORDS: contact time, flight time, step time, step length, step frequency, step speed.

INTRODUCTION: The curved path of 400 m track is longer than the straight path despite any 400 m track designs; the straight and curved path lengths of outdoor track are approximately 80 m and 120 m respectively (Quinn, 2009). Therefore the curved running techniques are important for the running performance. Curved running differ from straight running in that the centripetal force acts on runner's body, especially with high velocity like sprinting: centripetal force is estimated by $F = mv^2/r$; where F is the centripetal force, m is the mass of runner's body, v is the running velocity and r is the radius of curvature. Some studies dealing with curved running reported the common findings that functions of the inside and outside legs were different (Stoner & Ben-Sira, 1979; Hamill, Murphy & Sussman, 1987; Smith, Dyson & Hale, 1997; Smith, Dyson, Hale & Janaway, 2006; Chang & Kram, 2007; Ishimura & Sakurai, 2010; Churchill, Salo & Trewartha, 2011; Churchill, Salo, Trewartha & Bezodis, 2012). The mechanics of curved running as adaptations to the centripetal force have been clearly. However there are few studies to investigate the variables directly related to the curved sprinting performance. Thus, this study aims to investigate the relationships between sprint performance and stride parameters in the curved sprinting for development of curved sprinting performance. In this study, we chose the stride parameters including contact time (CT), flight time (FT), step time (ST), step length (SL), step frequency (SF) and step speed (SS), which are familiar for coaches and athletes.

METHODS: Experiments were conducted on two paths—straight and curved—of outdoor track. In each experiment, lane 4 (average radius: 43.51 m) was used. Nine athletes (five male: 20.6 ± 2.1 years, 65.9 ± 5.8 kg, 1.75 ± 0.05 m and 100 m personal best 11.08 ± 0.56 s; four female: 19.0 ± 0.0 years, 53.4 ± 3.1 kg, 1.62 ± 0.03 m and 100 m personal best 12.37 ± 0.33 s) volunteered for this study. Informed consent was obtained from all, and the protocol was approved by the institutional research ethics committee. The subjects wore lycra cap, shirts, tights and their own spike shoes. Forty-one retro-reflective markers (diameter: 14 mm) were placed on body landmarks. 3-D positional data of the markers were recorded using Vicon motion capture system (250 Hz) with nineteen or twenty infrared cameras (ten Vicon-MX13 and nine or ten Vicon-MX-T20, Oxford Metrics Inc., Oxford, UK). Each subject ran 60 m with maximal effort. The running time of the latter 30 m was recorded with a photocell system (PhotoGate, BROWER Timing Systems Inc., Draper, USA). Three successful experimental trials were conducted with sufficient inter-trial intervals to prevent fatigue,and one of them with fastest running time was chosen for analysis. 3-D raw positional data was smoothed using singular spectraum analysis techniques with window length L =

n/10 and first 3 principal components for data reconstruction (Alonso, Castillo & Pintado, 2005; Ishimura & Sakurai, 2012). A rigth step was defined from right foot touchdown to left foot touchdown and a left step was define from left foot touchdown to right foot touchdown. The stride parameters were defined as Table 1. These parameters were calculated as average of two steps. No differences between the right and left stride parameters were verified with paired t-test in straight path trials. Hence, the average values of the right and left variables were used as the representative values of straight path trials. The stride parameters of straight, right and left in curved path were compared with paired t-test respectively. Pearson's correlation coefficients were calculated between stride parameters and 30 m sprint time. Significance level was set at 5% in all statistical tests.

Table 1
Definitions of Stride Parametesrs

Variable Name	Definitions
Contact Time :CT (s)	Duration time form foot touchdown to foot off.
Flight Time :FT (s)	Duration time from foot off to subsequent foot touchdown.
Step Time :ST (s)	Duration time during step (CT + FT).
Step Length :SL (m)	Distance from foot touchdown point to subsequent one in horizontal plane.
Step Frequency :SF (Hz)	Reciprocal number of step time (1 / ST).
Step Speed :SS (m/s)	Product of SL and SF.

RESULTS: Contact time of the left step in curve was longer than in the straight and right step. Flight time of the right step in curve was shorter than in the straight and left step. Step time of the left step in curve was longer than in the straight and right step of curve, and the right step in curve was shorter than in the straight. There were no significant differences between step lengths of curve, but the right step in curve was shorter than in the straight. Step frequency of the left step was lower than the straight and right step in curve, and the right step in curve was faster than in the straight. There was no significant difference between step speed of the straight and right step in curve, but the left step in curve was lower than the straight and right step (Table 2).

Table 2
Results of Stride Parameters (mean±SD)

	Straight	Curve		
		Right	Left	
Contact Time (s)	0.102±0.006	0.105±0.006	0.112±0.007	*2,*3
Flight Time (s)	0.107±0.008	0.098±0.006	0.106±0.008	*1,*3
Step Time (s)	0.209±0.007	0.203±0.009	0.217±0.007	*1,*2,*3
Step Length (m)	1.983±0.163	1.926±0.122	1.962±0.150	*1
Step Frequency (Hz)	4.794±0.172	4.944±0.209	4.606±0.143	*1,*2,*3
Step Speed (m/s)	9.511±0.911	9.536±0.891	9.034±0.700	*2,*3

*1,*2 and *3 show significant differences for straight vs. right in curve, straight vs. left in curve and right vs. left in curve respectively.

The correlation between the strides parameters and the sprint performance were shown in Figure 1. There were no correlations in CT, ST and SF of the straight path trials (CT: r =

0.483, ST: = 0.539 and SF: r = -0.534). However, the correlation was found in these of right step in the curved path trials (CT: r = 0.799, ST: r = 0.810 and SF: r = -0.806). There were no correlations in FT (straight: r = 0.131, right: r = 0.318 and left: r = -0.392). There were correlations in SL and SS of each step (SL; straight: r = -0.936, right: r = -0.906 and left: r = -0.929, SS; straight: r = -0.995, right: r = -0.978 and left: r = -0.978).

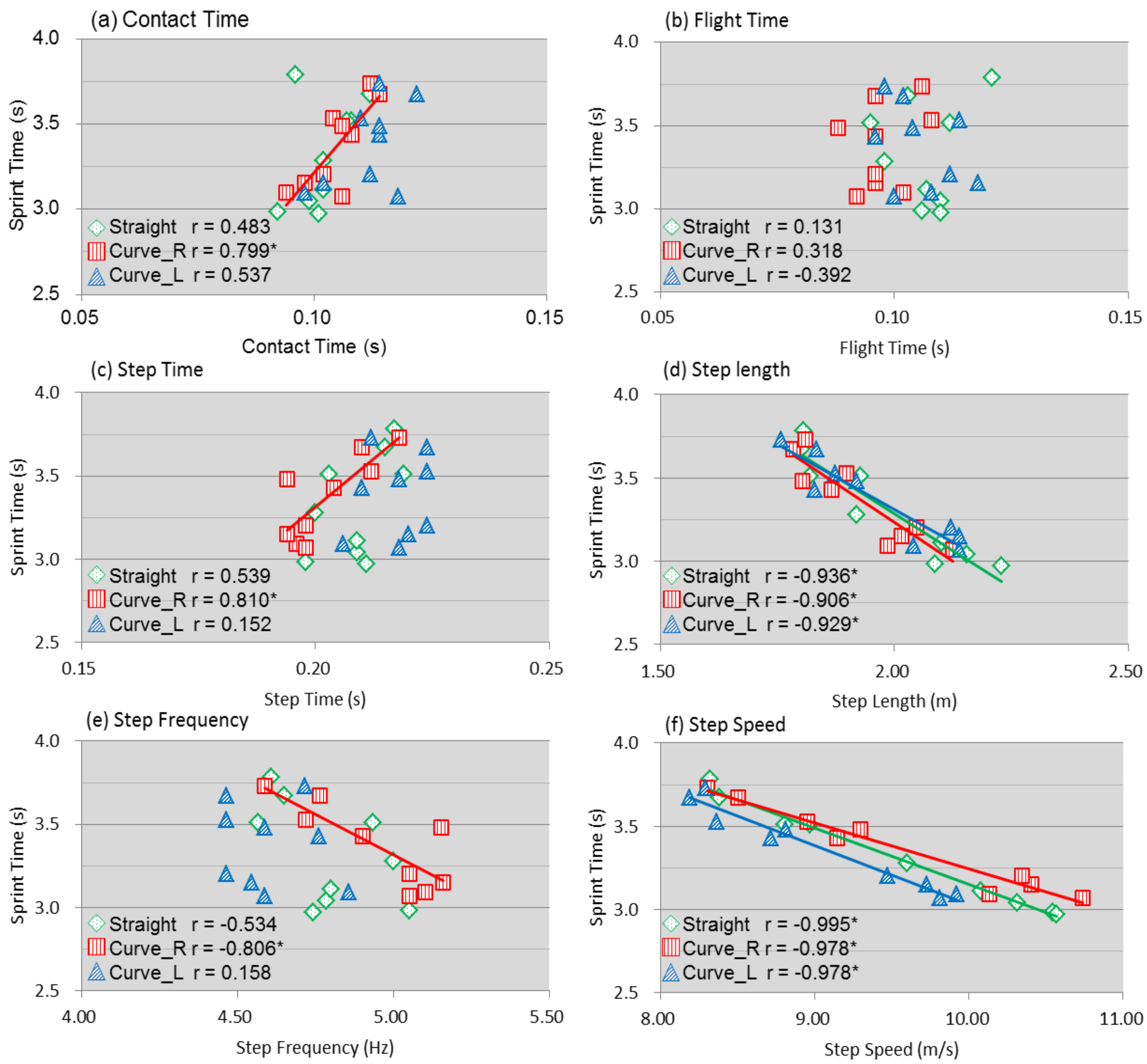

Figure 1: Scatter plots of stride parameters: (a) contact time; (b) flight time; (c) step time; (d) step length; (e) step frequency; (f) step speed vs. sprint time. Green diamond, red square and blue triangle shows step in straight path, right step and left step in curved path respectively. Asterisk indicates significant correlation between two variables.

DISCUSSION: Results of the stride parameters in this study were similar with previous studies (Stoner & Ben-Sira, 1979; Churchill, Salo & Trewartha, 2011; Churchill, Salo, Trewartha & Bezodis, 2012). The differences among steps would be adaptations to the curved path and the centripetal force. There were no correlations in CT, ST, and SF of the straight. Nevertheless, significant correlations were found in these of right step of curve. CT and FT are included in ST. Because FT has no correlation with the sprint performance, ST would be affected mainly by CT. Therefore, it makes sense that ST has significant correlation. It was indicated that SL is important factor for the sprint performance. SF has correlation only in the right step of curve. SS was indicated highest correlations, and related directly to the sprint performance. Because the left step of curved path had significant correlations in the same variables as the step in straight (SL and SS), the left step in curve would be important for the sprint performance as same as the straight. SS is determined by SL and SF. That SF is reciprocal number of ST, and ST includes CT and FT. In the light of no correlations between FT and sprint performance, sprint performance would be influenced greatly by CT of the right step in curved sprinting. To summarise these results, the functions of right leg would be key factor for curved sprinting performance.

CONCLUSION: This study investigated the relationship between stride parameters and sprint performance. There were significant correlations in CT, ST and SF with in the right step of curved path, though these in the straight step had no significant correlations. The left step of curved path and the straight step had no correlations in CT, FT, ST and SF. As a result, the right step showed distinctive characteristic in the curved sprint performance. These results of this study would be useful for coaching to develop the curved sprinting technique, because these variables are simple and intelligible for coaches and athletes.

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