BILATERAL DIFFERENCES IN STEP CHARACTERISTICS WHEN SPRINTING ON THE STRAIGHT AND BANKED BEND OF AN INDOOR 200 M TRACK

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Sprinting around a bend is thought to be limited by an athlete's ability to create force. Bilateral differences in technique in athletes sprinting on an indoor banked 200 m track are not yet fully understood. Four experienced male 400 m runners were studied during sprints on the straight and at the bend apex of lanes one and four. Step time, length, frequency and velocity were calculated using an automatic tracking system operating at 200 Hz. Group mean values were calculated for each contact limb and lane condition. Velocity on the bend compared to the straight decreased in steps from the left (inside) leg to a markedly greater extent (approx. 5%) than in steps from the right (outside) leg (approx. 1%). This may be linked to previously reported differences in force production capacity between inside and outside legs during maximal bend running.

KEY WORDS: track and field athletics, velocity, step length, step frequency

INTRODUCTION:

The indoor 400 m sprint race is unique amongst individual sprint events in that the participants may have to negotiate bends of varying radii as well as straights. These changes in track conditions throughout the run place varying mechanical demands on the athlete. Sprinting on a bend increases average ground reaction force necessary due to the increased centripetal acceleration requirement, and if contact times are increased to facilitate this force production, velocity can decrease as a result (Usherwood and Wilson, 2006).

Athletes' mean velocity throughout a race will determine the result, and each step's velocity (SV) is the product of step length (SL) and step frequency (SF). A single step is defined between contra-lateral foot touchdown events. Previous studies of sprinting on banked bends have reported joint kinematics for individual legs (Ryan and Harrison, 2003), but SV, SL and SF values averaged only over steps from ground contacts with both legs (Greene, 1987; Ryan and Harrison, 2003). A study of middle distance athletes running around a flat outdoor track (radius = 31.5 m) at 6.31 m/s found significant differences in ground reaction force and joint kinematic variables between legs, but did not report step characteristics (Hamill *et al.*, 1987). Chang and Kram (2007) studied maximal running on flat bends (radius $\leq$ 6.0 m) and found that velocity decreased with bend radius. As radius decreased, SL decreased, and was generally lower in the inside (left) than the outside (right) leg, whilst SF remained unchanged, but was generally higher in the inside than the outside leg. Chang and Kram (2007) also found that, runners experienced smaller peak resultant ground reaction forces on bends comprising a relatively smaller radius ($\leq$ 6.0 m), which was particularly evident for the inside leg. To date, however, the authors are not aware of any studies that have investigated the step characteristics of individual legs in the performance-specific location of an indoor banked 200 m track. Thus the primary purpose of this study was to understand differences in step characteristics in both left and right legs on the straight and bend of a regulation indoor 200 m athletics track.

METHODS:

Data collection: Four regional to national level male 400 m sprinters (height = 1.83 ± 0.03 m, mass = 76.0 ± 8.3 kg, age = 20.5 ± 0.6 yrs, 400 m personal best = 50.34 ± 1.28 s) gave written informed consent to participate in this study. Ethical approval for the study was given by the School's Research Ethics Committee. The subjects reported no recent injuries, and were fit and healthy at the time of data collection, which took place in the National Indoor Athletics Centre, Cardiff. Athletes were required to undertake their own warm-up.

Two Codamotion CX-1 scanners (Charnwood Dynamics, UK), operating at 200 Hz, were aligned 6.0 m apart and 4.2 m from the centre of the lane of interest on the straight track, to give a field of view of 10.0 m of the left lateral aspect of the subjects in the direction of the run. Active CODA markers were attached to the lateral aspect of the fifth metatarsal head on the left foot and the medial aspect of the first metatarsal head on the right foot. Subjects performed a 40 m sprint before the CODA volume, and were instructed to continue to run at approximately 95% of maximum, or 'back straight pace' through the measured volume. Four successful trials per subject were gathered on the straight after each of which the subject was allowed normal training recovery. Following the straight running data collections, the scanners were realigned to be centred on the apex of the banked bend in lane one (radius = 15.0 m; banking = 12°) and later realigned to the apex of the bend in lane four (radius = 18.0 m; banking = 12°). Due to the curve of the bend, a field of view slightly greater than 10.0 m was achieved (Kerwin *et al.*, 2007). The trial procedures from the straight were repeated for each bend condition resulting in four trials per subject gathered for each condition. A total of twelve trials per subject were gathered across the three conditions, giving a total of 48 steps per subject.

Data Processing: The three-dimensional coordinate data (x-mediolateral, y-anteroposterior and z-vertical) were low-pass filtered at 15 Hz. Four individual steps were identified in each trial using the vertical acceleration data of the toe marker of the first step touchdown leg to identify initial ground contacts (Bezodis *et al.*, 2007). A single step was defined between contra-lateral foot touchdown events, and was identified either left [L] or right [R] according to the ground (contact) leg side during that step cycle.
Step characteristic variables for the straight runs were determined for each individual step as follows: Step time [ST = time between successive touchdowns], step length [SL = y displacement between successive touchdown foot marker locations], step frequency [SF = 1/time between successive touchdowns] and velocity [SV = SL*SF]. Step characteristic variables were calculated in an identical manner on the bend, with the exception of SL, for which the change in displacement of the resultant coordinate was used:

$$SL_B = \sqrt{(L_x - R_x)^2 + (L_y - R_y)^2}$$

where R_x and R_y were the x and y coordinate of a right foot touchdown and L_x and L_y were the x and y coordinate of the subsequent left foot touchdown. Steps were grouped across all four athletes according to lane condition (straight, bend 1 or bend 4) and contact limb (left or right). For each of these six groups of steps, between subject mean and standard deviation of ST, SL, SF and SV were calculated. The percentage changes in each mean value between the straight and the two bend conditions were also calculated. Due to the small sample size of this data set, a more complex statistical analysis was not employed.

RESULTS:

Group mean (± standard deviation) values for ST, SL, SF and SV for each lane condition and side of contact leg are displayed in Figure 1. Mean ST and SF were greater in the left (inside) than the right (outside) leg for each lane condition, whereas mean SF and SV were greater in the right than the left leg in each lane condition. The percentage change in variables in the two bend conditions when compared to the straight are shown in Table 1. There was little or no change in SV in steps from the right leg on the bend compared to the straight. However, steps from the left leg decreased in SV by approximately 5% from the straight to both bend conditions. This was associated with decreases in SL (-1.4 to -1.7%) and SF (-2.4 to -3.7%).

DISCUSSION:

Across all variables and lane conditions there were differences between steps from the left and right leg contact limbs. Steps from the left leg contact were consistently slower than

those from the right. This resulted mainly from differences in SF between the legs, since the SLs measured from the left leg were marginally longer than those measured from the right.
The largest within-variable differences that were apparent were in the decreases in SV in steps from the left leg contact on the bend (lane one: -4.9%; lane four: -5.1%) when compared to the straight. In contrast, the steps from the right leg contact changed in SV by only +0.1 and -1.6% from the straight to lanes one and four on the bend, respectively. The decreases in SV in the left leg contact steps were attributed to a decrease in SL of -1.4 to -1.6% combined with a decrease in SF of -2.4 to -3.7%. The changes in SV in the right leg contact steps were a combination of decreases in SL (-1.6 to -2.3%) and increases in SF (0.7 to 1.2%).

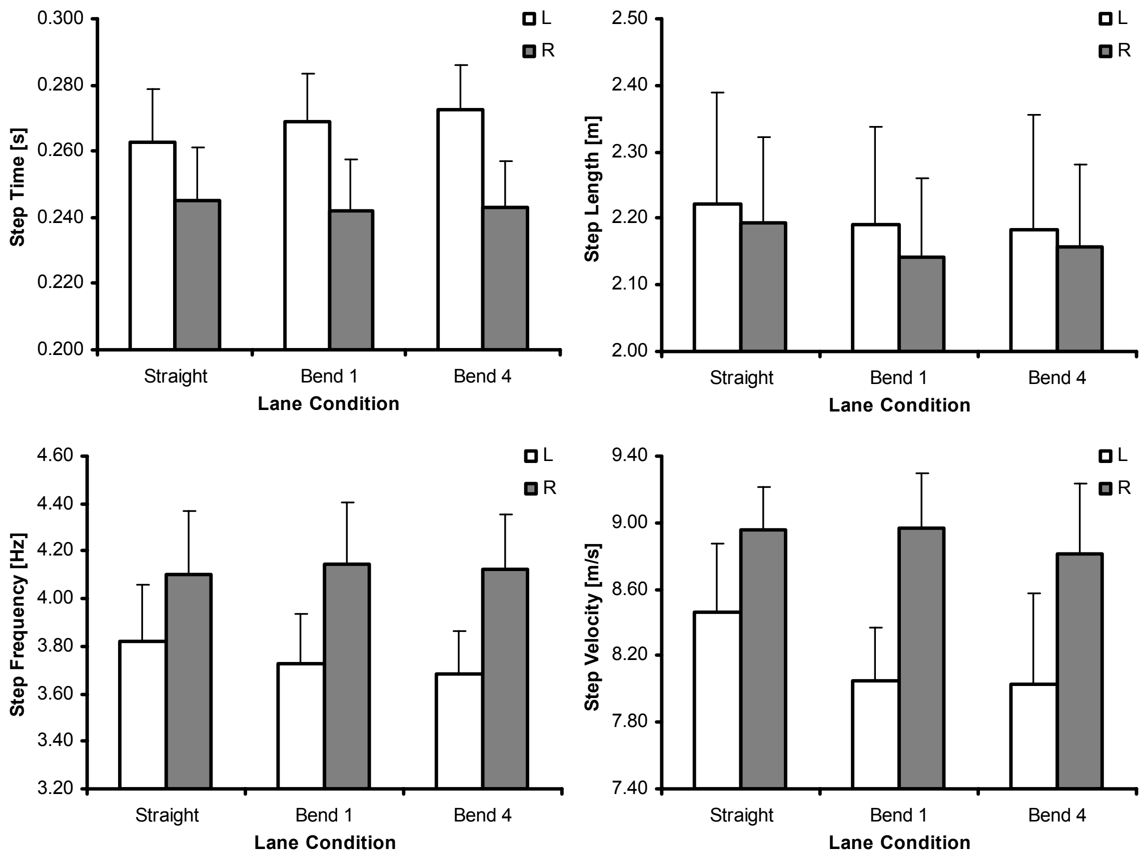

Figure 1. Step time, step length, step frequency and step velocity for each side and lane condition. Values are mean ± standard deviation across all subjects.

Table 1. Percentage changes in mean step time, step length, step frequency and step velocity on the bend compared to the same contact limb on the straight

Lane Condition	Contact Limb	ST [%]	SL [%]	SF [%]	SV [%]
Bend 1	R	-1.2	-2.3	1.2	0.1
	L	2.3	-1.4	-2.4	-4.9
Bend 4	R	-0.8	-1.6	0.7	-1.6
	L	3.7	-1.7	-3.7	-5.1

Insight into the previously unreported bilateral differences in SV and associated step characteristics when sprinting on banked bends were achieved in this study. Differences in joint kinematics (Ryan and Harrison, 2003) and ground reaction force profiles (Hamill *et al.*, 1987), but not step characteristics, have previously been shown between contact legs in both banked and flat bend running situations. Furthermore, the larger decreases in SV in the left (inside) leg reported in this study compared to the right (outside) leg may partially be

explained by the findings of Chang and Kram (2007). These authors investigated maximal running on flat curves of a tight radius ($\leq$ 6.0 m), and found that the peak resultant ground reaction forces of the inside leg were more sensitive to track radius than the outside leg. Chang and Kram (2007) also suggested that since force generation has been shown to be correlated with straight line sprint speed (Weyand *et al.*, 2000), the critical limit to curved sprinting speed is likely to be found in the forces generated by the inside leg. Whilst this current study was unable to measure ground reaction forces, it has clearly shown that the velocities of steps from the left (inside) leg are lower than those from the right (outside) leg in the same sprint run around the banked bend of an indoor 200 m athletics track.
Looking to the future, a more detailed kinematic and kinetic study could be used to further explain some of the initial insights from this study. This would help athletes and coaches to further understand the bilateral differences that occur when sprinting around a banked bend, and may lead to the development of specific technical and conditioning training programs for individual limbs in order to best overcome the differing mechanical requirements placed on the legs by sprinting around a banked bend.

CONCLUSION:
An investigation into the bilateral differences in step characteristics in 400 m runners sprinting on the straights and banked bends of an indoor 200 m athletics track revealed between leg differences. Steps taken from the inside leg on the bend were markedly lower in velocity than those taken from the outside leg, which may be due to previously reported differences in force production profiles between the legs when running maximally on a curve. More detailed kinematic and kinetic study may help to inform specific individual training interventions for each separate leg that would improve performance when sprinting around a banked bend.

REFERENCES:
Bezodis, I.N., Thomson, A., Gittoes, M.J.R. and Kerwin, D.G. (2007). Identification of Instants of Touchdown and Take-Off in Sprint Running Using an Automatic Motion Analysis System. In H.-J. Menzel and M.H. Chargas (Eds). *Proceedings of the XXVth Symposium of the International Society of Biomechanics in Sports* (pp 501-504). Ouro Preto, Brazil. ISBS.
Chang, Y.-H. and Kram, R. (2007). Limitations to maximum running speed on flat curves. *Journal of Experimental Biology,* 210, 971-982.
Greene, P.R. (1987). Sprinting with banked turns. *Journal of Biomechanics, 20*, 667-680.
Hamill, J., Murphy, M. and Sussman, D. (1987). The Effect of Track Turns on Lower Extremity Function. *International Journal of Sports Biomechanics*, *3*, 276-286.
Kerwin D.G., Irwin, G and Bezodis, I.N. (2007). Reduced 3D Marker Set Tracking of Elite Sprint Training. In H.-J. Menzel and M.H. Chargas (Eds). *Proceedings of the XXVth Symposium of the International Society of Biomechanics in Sports* (pp 497-500). Ouro Preto, Brazil. ISBS.
Ryan, G.J., and Harrison, A.J. (2003). Technical adaptations of competitive sprinters induced by bend running. *New Studies in Athletics, 18*(4), 57-67.
Usherwood, J.R. and Wilson, A.M. (2006). Accounting for elite indoor 200 m sprint results. *Biology Letters*, *2*, 47-50.
Weyand, P.G., Sternlight, D.B., Bellizzi, M.J. and Wright, S. (2000). Faster top running speeds are achieved with greater ground forces not more rapid leg movements. *Journal of Applied Physiology, 89*, 1991-1999.

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