BEND SPRINTING AT DIFFERENT RADII OF AN OUTDOOR ATHLETICS TRACK

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Athletes in the inners lanes may be at a disadvantage during sprint races that contain a bend portion. This study investigated the effect on performance when sprinting on the different radii of an outdoor track. There was an approximately 2% reduction in mean race velocity from lane 8 (left step: 9.56 m/s, right step: 9.49 m/s) to lane 5 (left step: 9.36 m/s, right step: 9.30 m/s), with only slight further reductions from lane 5 to lane 2 (left step: 9.34 m/s, right step: 9.30 m/s). This was mainly due to reductions in step frequency as radius decreased. The disadvantage of the inner lane compared to the outer lane may be greater than previously suspected. Larger race velocity standard deviations as radius decreased may be indicative of athletes being differently able to accommodate running at tighter radii than others. This may have implications for training and competition.

KEY WORDS: Radius, curve, track and field, three-dimensional kinematics, 200 m.

INTRODUCTION: Anecdotal evidence and mathematical models (Jain, 1980; Greene, 1985) have suggested that athletes running in inner lanes in sprint races which include a bend portion may be disadvantaged compared with those in the outer lanes, due to the tighter bend radius. Also, velocity has been empirically shown to decrease as bend radius decreases when running on curves with very small radii (1-6 m; Chang & Kram, 2007). However, there is a lack of experimental data to establish the effect of the lane on bend running performance on surfaces and at radii typical of those of athletic sprint events.
Our previous work has shown velocity to be slower on the bend compared with the straight during maximal effort running (Churchill, Salo & Trewartha, in press). This is mainly due to increased ground contact time leading to reduced step frequency during the left step on the bend compared with the straight and due to decreased flight times leading to reduced step length during the right step on the bend. We suggest that during maximal effort bend sprinting the left and right steps have functionally different roles (Churchill et al., in press). Differences between left and right steps have also been observed at submaximal velocities on the bend (Alt, Heinrich, Funken & Potthast, 2014; Stoner & Ben-Sira, 1979). It is possible that these effects of the bend attenuate as the tightness of the bend decreases, i.e. in the outer lanes, due to reduced requirement for centripetal force generation to produce the turn. However, empirical evidence of the effect of the lane on sprint performance indicators is lacking in the literature. Thus, the purpose of this study was to understand how performance and step characteristics are affected by the lane in which an athlete is running using lanes with radii that are typical of those experienced in athletic sprint events.

METHODS: Nine male sprinters (21.5 ± 3.2 years, 79.4 ± 10.1 kg, 1.82 ± 0.06 m, 200 m or 400 m specialists) gave written informed consent to participate in the study. The athletes performed six 60 m maximal effort sprints around the bend of an outdoor track; two each in three different lanes (2, 5 and 8; radii: 37.72 m, 41.41 m and 45.10 m, respectively) in a blocked random order. Full recovery (approximately eight minutes within the lane and 15 minutes between lanes) were allowed. Videotaping for three dimensional analysis (3D) occurred at the 40-48 m section of the run using two high speed video cameras (200Hz, 1/1000 s shutter speed; MotionPro HS-1, Redlake, USA). Camera A was positioned at the origin of bend radius to provide a "side view" and Camera B was positioned 'ahead' 30.00 m away from the centre of lane 2 and 1.50 m to the left and provided a "front view". Camera position remained consistent for all trials, but the focus and field of view was adjusted for each running lane. Synchronising was carried out through genlocking the cameras, apart from one data collection session, in which the genlocking failed. These video clips were synchronised using 1 ms interval LED displays (Wee Beasty Electronics, UK) visible in the fields of view. An 18-point 3D calibration volume (6.50 m long × 1.60 m wide × 2.00 m high) was recorded in each lane to allow 3D-DLT reconstruction of coordinates. Touchdown and take off were identified by visual inspection of the front view video. A 20-point, 16-segment human model was manually digitised by estimating joint centres in both camera views using Vicon Motus software (Version 9.2, Vicon, UK). 3D coordinates were filtered with a low pass 2^{nd} order, zero lag, recursive Butterworth filter with a 20 Hz cut-off. Inertia data was adjusted from de Leva (1996) to include a two segment foot and allow the addition of 0.2 kg to each foot to account for the mass of a typical spiked shoe.

Variables were calculated for left and right steps separately. A step was defined as touchdown of one foot to next touchdown of the contralateral foot. Steps were determined as 'left' or 'right' based on the initial touchdown foot. The following variables were analysed (described fully in Churchill et al., in press): race velocity (the velocity with respect to the official race distance), race distance (the length of the race distance covered in the step), step frequency, ground contact time and flight time.

A one-way repeated measures ANOVA was performed to identify significant effects ($p<0.05$) of the lane on each variable for the left and right steps separately. Where a main effect for lane was found, pairwise comparisons were conducted. Paired samples t-tests were used to identify significant differences between left and right steps within a lane for each variable.

RESULTS AND DISCUSSION: Race velocity decreased as radius decreased (Table 1) equating to a 2.1% and 2.0% decrease in race velocity from lane 8 to lane 5 for the left and right steps, respectively. There was a further, but only very slight, reduction in race velocity between lane 5 and 2 for the left step only (0.2%). The standard deviations of the race velocity showed that as bend radius decreased, the variation in performance between participants increased (Table 1). This suggests that that some athletes were better able to maintain their velocity as the bends got tighter than others. This may be indicative of 'better bend running' ability, or a better ability to cope with the demands of the bend.

Mathematical models have suggested that differences in 200 m race times in lane 1 (radius 38.50 m) compared with lane 7 (radius 45.72 m) could be 0.069 s (Jain, 1980) or 0.123 s (Greene, 1985). Using the data from the current study, the effect on a race time could be predicted as follows. The bend portion of a standard outdoor track is approximately 115 m for all lanes (IAAF, 2008). The average race velocity across the two analysed steps in lane 8 was 9.53 m/s. Assuming athletes were at top speed by 40 m and maintained it for the rest of the bend, this would equate to a time of 7.87 s to cover the 75 m maximal speed phase on the bend. A similar calculation for lane 5 would provide a time 0.170 s slower than lane 8 and for lane 2 a 0.180 s slower time in comparison to lane 8. Athletes, though, would not be able to maintain the same maximum effort velocity throughout the rest of the bend, which could slightly reduce this difference. Nevertheless, these estimates are larger than the predicted difference between lanes 1 and 7 in Jain (1980) and Greene (1985). Further, the estimates from the current data do not include the finding that athletes have been shown to be slower in the inner lanes compared to the outer lanes during the acceleration phase (Stoner & Ben-Sira, 1979). Nor do they account for the fact that velocity entering the final straight would be lower for those athletes in the inner lanes, which would potentially make differences in race time between the inside and outside lanes even larger. We need to remember, that these are just estimates based on some untested, but reasonable, assumptions. It is also acknowledged that the magnitude of the effect of the bend will likely differ between athletes. However, the challenges facing athletes allocated the inner lanes are evident and these estimations suggest that the level of disadvantage of being in the inner lanes may be greater than previously suspected.

Table 1.
Left and right step mean (± SD) performance and step characteristics in lanes 8, 5, and 2.

	Lane 8		Lane 5		Lane 2	
	Left	Right	Left	Right	Left	Right
V (m/s)	9.56±0.43	9.49±0.41†	9.36±0.51*****	9.30±0.51*****†	9.34±0.61*****	9.30±0.63
SL (m)	2.13±0.08	2.12±0.11	2.10±0.11	2.10±0.10	2.15±0.09#	2.13±0.12
SF(Hz)	4.48±0.19	4.48±0.18	4.45±0.21	4.43±0.17	4.35±0.25#	4.36±0.22
CT (s)	0.116±0.006	0.109±0.006†	0.119±0.009	0.111±0.009†	0.121±0.008*	0.111±0.008†
FT (s)	0.113±0.009	0.109±0.009	0.112±0.010	0.109±0.006	0.117±0.012	0.111±0.008

V: race velocity; SL: race step length; SF: step frequency; CT: ground contact time; FT: flight time; ***** significantly different to lane 8, # significantly different to lane 5, † significantly different to left step within lane (p<0.05)

Reductions in race velocity for the inner lanes were due to a general trend for step frequency to decrease as radius decreased for both the left and right steps, which was significant between lane 5 and 2 for the left step (Table 1). The theoretical model by Usherwood and Wilson (2006) assumed that the step contact times must increase when running on the bend due to the additional requirement of centripetal force generation, which would consequently reduce step frequencies. The reduced step frequency results for the left step in this study support this assumption. However, for the right step the contact times were very similar between the lanes, and the reduced step frequency (mainly in lane 2) was due to increased flight times. Thus, the mechanism for changes in step frequency was different between the legs. The results showed that the bend radius had an effect on step length, however it did not necessarily decrease as radius decreased. Step lengths were shorter in lanes 5 and 2 than in lane 8, but left step length in lane 2 was 0.05 m longer than in lane 5. This significant increase was combined with a significant decrease in left step frequency. Perhaps athletes running in lane 2 may have tried to increase the step length to compensate for the tightness of the bend which consequently reduced step frequency, or vice versa. This type of negative interaction has been demonstrated in straight line sprinting (e.g. Hunter, Marshall & McNair, 2004). This interaction between step length and step frequency at maximum effort is challenging to every athlete and it is unknown which is a better strategy at tighter bends: to increase step length rather than step frequency, or to maintain step frequency in trying to avoid velocity drop. Further research into the strategies used by these athletes may provide better insight to bend sprinting.

Larger standard deviations in race velocity at tighter bend radii (Table 1) provides evidence that some athletes could be better able to 'cope' with the increased demands of the tighter radius than some other athletes. This could have practical implications for athletes' training. For example, if an athlete has a larger deterioration in performance as bend radius decreases then more bend specific training may be required. Additionally, this information could and perhaps should be taken account for running rounds in major competitions. IAAF (2014) rules of outdoor competitions state that during the first round, lanes are randomly assigned. Based on the times on the first round, athletes are then assigned to the next round groups (e.g. semi-final groups). Within the each group, the four fastest athletes of the previous round are allocated lanes three to six at random, the fifth and sixth fastest athletes allocated lanes seven and eight at random, and the final two athletes allocated lanes one and two at random. Thus, it can be important to 'qualify well' for subsequent rounds (although only the better athletes realistically can utilise this).

As the above demonstrates, there are indications that some athletes are 'better bend runners'. This means that their velocity decreases less with tighter radii than by other athletes (or their relative performance is closer to their straight line maximum sprinting; Churchill et al., in press). Investigation of the technique by both type of athletes could potentially reveal further key factors on successful bend sprinting.

The requirement to have high calibre experienced bend sprinters for this study meant that the sample size was rather limited. It is possible that a greater sample size would have resulted in more of the differences between lanes reaching statistical significance. However, to increase the sample size with less experienced athletes was not desirable and the novelty of the task could have masked the real issues of bend sprinting. We analysed three separate lanes (due to practicalities of athletes' limited training runs during the competition season). The findings indicate a possible non-linear effect of different radii on performance. However, to fully establish this, data should be collected from more lanes. Despite of these limitations we believe that the paper provides important information on bend sprinting at radii and on surfaces typical of a standard outdoor track and how the lane allocation potentially affect the performance during sprinting. Also, while this study provides useful information to explore this area of research further, it has also offered practical and useful information about the effect of changing bend radius on performance.

CONCLUSION: The analysed race velocity (performance) during the bend sprinting reduced from lane 8 to 5 to 2. The further calculations demonstrated that the effect of lane allocation on race times could potentially be greater than previous mathematical models have suggested. A six lane difference may cause even up to 0.180 s difference to the time. The velocity changes occurred mainly due to lower step frequencies on inner lanes. Perhaps surprisingly, the shortest step lengths were obtained from lane 5. There were some indications that athletes coped differently with the reduction on the bend radii, i.e. some athletes may be better able to maintain their velocity when the radius gets smaller. This provides an interesting area of further research, but more importantly it can have clear training implications to those athletes (e.g. training more on bend and in inner lanes) who are not as good at bend sprinting (but still wish to compete in 200 m and 400 m events).

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