AN INVESTIGATION INTO THE EFFECT OF LANE RADIUS ON STEP CHARACTERISTICS IN INDOOR BEND SPRINTING

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The aim of this study was to identify the effect of radius on step characteristics during indoor bend sprinting. Eight well-trained sprinters undertook two ~80 m sprints, in two different conditions through capture areas on straight and bend, collecting whole-body kinematic data. Right (outside) Step Frequency was greater in Lane 2 than both Straight and Lane 4 due to lower Step Times. Left (inside) Step Frequency was lower in Lane 4 than the straight due to greater Step Times, no differences were observed for left step SF in Lane 2. Inter-limb differences within lanes were: Step Time was greater for the left step in lane 2 resulting in lower left Step Frequency in lanes 2 and 4. Lane radii typical of indoor competition elicits differing changes in step characteristics between limbs during bend sprinting, warranting further biomechanical analysis.

KEYWORDS: Athletics, Step frequency, Step length.

INTRODUCTION: Whilst the research body for the biomechanics of bend sprinting continues to grow, the consideration of bend radii of indoor athletics tracks remains relatively unresearched. Indoor athletics tracks are typically 200 m in length, with 4-6 lanes of radius of 12-18 m and many possess lateral banking on the bends. Therefore, the environmental conditions are considerably different to that of outdoor tracks, with these being 400 m in length with lanes having a radius from 31.5 – 39 m, whilst possessing no lateral banking.

The analysis of step length (SL) and step frequency (SF) has been used to determine the different phases of sprinting (von Lieres und Wilkau et al., 2018), identify potential inter-limb asymmetry (Exell et al., 2017) and describe differences between bend and straight sprinting (Churchill et al., 2015). It is generally accepted that step velocities (SV) are lower on the bend in comparison to the straight (Churchill et al., 2015) with this a result of increases in total Step Time (ST), reductions in SF and commonly, increases in ground contact time (GCT) for the left step. For the right step however, reductions in SV are brought about by reduced flight times (FT), with this leading to smaller SLs (Churchill et al., 2015).

Recent research has demonstrated an effect of lane radius on performance, with tighter radii resulting in greater reductions in performance (Churchill et al., 2018; Usherwood & Wilson, 2006). Churchill et al., (2018) found the reduction in performance to be as a result of reduced SF in both left and right steps. Furthermore, variability in performance increased between participants, suggesting athletes possess differing abilities to negotiate tighter radii (Churchill et al., 2018). This concept has been explored further by grouping athletes by the extent of velocity reduction on the bend compared to the straight, with “poor” and “good” bend sprinters (Ohnuma et al., 2018). Nonetheless, this has yet to be investigated on radii typical of indoor competition. Therefore, the aim of this investigation was to determine the effect of lane radius on step characteristics during bend sprinting on radii typical of indoor competition.

METHODS: Following institutional ethical approval six male and two female participants provided informed consent (Age = 19.8 ± 2.1, Mass = 69.8 ± 10.2 kg, Height = 175.8 ± 8.1

cm). Participants were well-trained long sprinters (200 – 400 m) with 200 m personal bests of 23.35 ± 0.86 s (females = 25.49 ± 0.91 s). Twenty-four optoelectronic cameras (Vicon, Oxford, 250 hz) were set up in two custom capture areas to ensure two consecutive steps on both the bend and the straight (Figure 1.). Participants were prepared with an adapted plug-in gait marker set previously validated for bend sprinting (Judson et al., 2017) with additional technical marker clusters and the placement of upper body markers. A banked indoor 200 m track with radius of 13.98 m for Lane two and 15.94 m for Lane four was used for testing. In order to avoid the effects of fatigue, participants were asked to undertake two 80 m efforts in both lane two and four at 85 % of their perceived maximum (Alt et al., 2015). This was carried out in a randomised counter-balanced order. Kinematic data were captured approximately at 15-25 m into the effort for the straight and at the apex of the curve 50 – 60 m. Rigid-body and pattern gap-filling were used where appropriate, with the spline function only utilized for gaps < 10 frames (0.04 s) Data were exported for further processing using Visual 3D software (C-Motion Inc, Germantown, USA). Custom MATLAB (MathWorks, USA, 2018a) code were used to determine foot contact events: Touchdown was identified using peak vertical accelerations of the toe marker, and toe-off was identified as the first frame after the minimum toe position (Nagahara & Zushi, 2013). Spatiotemporal variables were defined in line with Churchill et al., (2015) including race step length for the bend trials. To determine the difference between the lane conditions (straight, lane two and lane four), one-way repeated measures ANOVAs with Bonferroni correction were run for both left and right steps. To identify any differences between limbs within a condition, paired-t tests were run. For non-normally distributed variables, Friedman's test and Wilcoxon Signed rank were run. Significance was set at $p < 0.05$. Effect sizes were calculated using partial eta squared for condition (small = 0.01, medium = 0.06, large = 0.14) and Hedges G for inter-limb asymmetry (small = 0.2, medium = 0.5, large = 0.8).

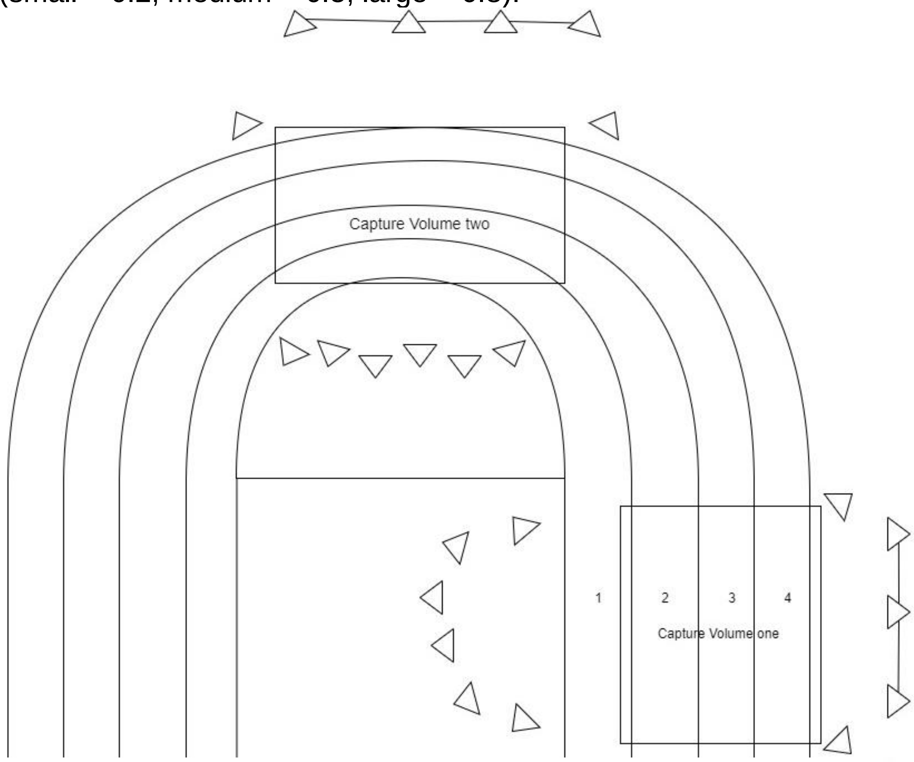

Figure 1. Plan view of the experimental set up (not to scale).  ***= Camera***

RESULTS: Mean (± SD) Step Characteristics for left and right steps on Straight and in Lane 2 and Lane 4 are shown in Table 1. No significant differences were observed between lane conditions for SL, GCT and FT.

For the left step, significant interactions were observed for ST ($p = 0.021$, ES = 0.426) and SF ($p = 0.016$, ES = 0.448). Post hoc comparisons revealed that SF in Lane 4 was lower than on the straight (p = 0.029, ES=0.499) as a result of a significantly greater step time (p = 0.025, ES = 0.328). For the right step, significant interactions were observed for ST (p = 0.001, ES = 0.686), SV (p = 0.025, ES = 0.409) and SF (p = 0.001 ES = 0.678). Post-hoc comparisons highlighted that ST were lower in L2 than both straight (0.01 ES = 0.6562) and L4 (0.014 ES = 0.5938), whilst for SF was greater in Lane 2 than both straight ((p = 0.001 ES = 0.4821), and Lane 4 (0.023, ES = 0.2831). For SV, pairwise comparisons showed no significant differences between conditions. For inter-limb differences within each lane, significantly lower SV for left step in both Lane 2 (p = 0,003, ES = 0.8623) and Lane 4 (p = 0.036, ES = 0.4689). For Lane 2 Left SF was lower than the right step for SF (p = 0.013, ES = 0.5861) due to a greater ST (p = 0.013, ES = 0.3047).

Table 1: Mean (± SD) Step Characteristics for left and right steps on Straight and in Lane 2 and Lane 4.

Variable	Straight	Lane 2	Lane 4
SV (m/s)	Left: 7.50(0.47) Right: 7.44 (0.50)	Left: 7.35 (0.40) [d] Right: 7.73 (0.44) [d]	Left: 7.34 (0.47) [d] Right: 7.58 (0.51) [d]
SL (m)	Left: 1.88 (0.13) Right: 1.90 (0.12)	Left: 1.89 (0.09) Right: 1.90 (0.11)	Left: 1.92 (0.10) Right:1.91 (0.11)
SF (hz)	Left: 4.00 (0.36) [b] Right: 3.93 (0.30) [a]	Left: 3.90 (0.26) [d] Right: 4.07 (0.31) [a c d]	Left: 3.83 (0.27) [b] Right: 3.98 (0.32) [c]
GCT (s)	Left: 0.120 (0.012) Right: 0.121 (0.013)	Left: 0.123 (0.017) Right: 0.115 (0.013)	Left: 0.123 (0.014) Right: 0.122 (0.013)
FT (s)	Left: 0.133 (0.018) Right: 0.135 (0.014)	Left: 0.134 (0.013) Right: 0.129 (0.010)	Left: 0.148 (0.005) Right: 0.136 (0.005)
ST (s)	Left: 0.252 (0.0226) [b] Right: 0.256 (0.0192) [a]	Left: 0.257 (0.0166) [d] Right: 0.247 (0.0181) [a c d]	Left: 0.262 (0.0186) [b] Right: 0.253 (0.0203) [c]

*key [a] = difference between Straight vs Lane 2, [b] = difference between Straight vs Lane 4, [c] = difference between Lane 2 vs Lane 4, [d] = difference between Left vs Right within condition.

DISCUSSION: The aim of this investigation was to determine the effect of lane radius on step characteristics during bend sprinting on radii typical of indoor competition. The main findings from this investigation were that SF was significantly greater in Lane 2 than the straight and Lane 4 for the right step (both small ES), whilst for the left step, SF was lower only in Lane 4 than the straight (small ES) but not for Lane 2. This confirms initial observations from Bezodis & Gittoes, 2008 who investigated step characteristics under similar conditions (Straight, Lane 1 and Lane 4 of an indoor track). Right SF was found to be slightly greater in both bend conditions compared to the straight (0.7-1.2 %) whereas, for the left step, SF were 2.4 % lower in Lane 1 and 3.7 % in Lane 4 (Bezodis & Gittoes, 2008). These findings contrast with previous research on outdoor athletics tracks where a general trend for reduced SF in tighter lanes was observed (Churchill et al., 2018). The more impacted left step SF in Lane 4 could be as a result of the lateral banking on the bend, which despite being shown to be beneficial in terms of performance (Greene, 1987), may depend on the amount of bend running undertaken on tracks with lateral banking by participants and may have resulted in unanticipated reductions in SF due to unfamiliar conditions. However, comparison of kinematics on equal radii but both flat and banked is yet to be described in the literature.

Bend sprinting is an asymmetrical movement task, with the left and right limbs having slightly different roles (Churchill et al., 2015). In this study, differences were observed for SV being greater for the right step in both Lane 2 (large ES) and Lane 4 (small ES). Further differences for ST for the left step in lane 2 (small ES), and for SF in lanes 2 (medium ES) and 4 (small ES). Ishimura & Sakurai (2016) reported left SF to be lower than right SF on a flat outdoor bend whilst Churchill et al., (2018) reports no significant differences for left and right SF within lanes on an outdoor athletics track. Nevertheless, these differences are likely due to the large difference in radii and the inclusion of banked bends. Therefore, future research should seek to address the effect of lateral banking on radii of equal length to further understanding of bend sprinting typical of indoor competition.

CONCLUSION: Similar to previous indoor bend sprinting research, right step SF was greater in Lane 2 than both Straight and Lane 4 due to lower ST. For the left step SF was lower in Lane 4 than the straight due to greater ST, no differences were observed for left step SF in Lane 2. Within lanes, ST was greater for the left step in Lane 2 resulting in lower left step SF. Greater SV for the right step was observed in Lanes 2 and 4. Future research should explore more detailed kinematics and a comparison of banked verses flat bends of equal radii to greater understand the demands of indoor athletic competition.

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