LOWER EXTREMITY JOINT KINEMATICS DURING INDOOR BEND SPRINTING

Jonathan White[1,] Gillian Weir[2], Hannah E. Wyatt[3], Hans von Lieres und Wilkau[4], Cassie Wilson[5], Timothy Exell[1], Gareth Irwin[4], and Joseph Hamill[2]

[1] University of Portsmouth, UK
[2]University of Massachusetts Amherst, USA
[3] Auckland University of Technology, NZ
[4]Cardiff Metropolitan University, UK
[5]University of Bath, UK

The aim of this study was to identify the effect of radius on lower extremity joint kinematics during indoor bend sprinting. Kinematic data (250 Hz) were collected from eight well-trained sprinters during two ~80 m sprints in banked lanes 2 and lane 4. One-dimensional Statistical Parametric Mapping was used to analyse lower extremity joint kinematics during the stance phase. Similar to previous bend sprinting research, this study found the left limb appears to adopt an adduction and eversion strategy during left stance to control the movement demands of bend sprinting. Furthermore, significant inter-limb asymmetry occurred primarily in lane 2, highlighting that tightening the radii of the lane brought about increased inter-limb asymmetry.

KEYWORDS: Athletics, asymmetry, technique

INTRODUCTION: Indoor athletics tracks are typically 200 m in length, with 4-6 lanes of radius between 12-18 m. Many indoor athletics tracks possess lateral banking on the bends. Differing bend conditions have been shown to affect whole-body postural control and step characteristics (White et al., 2021; Wyatt et al., 2021). For example, left step frequency was found to be lower for the left step compared to the right in both lane 2 and lane 4 (radius of 13.98 m and 15.94 m), whilst no differences were observed for step lengths (White et al., 2021). Wyatt et al., (2021) found centre of mass to be positioned more laterally from the base of support in the banked lane 2 condition in comparison to the banked lane 4 suggesting altered frontal plane kinematics as a result of the tighter radius.

Previous bend sprinting research has identified frontal and transverse plane adaptations when comparing discrete kinematic variables (Alt et al., 2015; Churchill et al., 2015), and across the stance phase (Judson et al., 2020). For example, Churchill et al., (2015) found greater body lateral lean, greater hip adduction at touchdown for the left step, whilst Alt et al., (2015) found that maximum values of left ankle, hip adduction and hip external rotation were significantly higher than the right. Large ankle eversion and lateral centre of pressure position during the left stance has been proposed to have both performance and injury implications (Judson et al., 2019). Nonetheless, research on differing lane conditions has been carried out on outdoor athletic radii which is over double that of indoor tracks (Churchill et al., 2018) and the bias between lanes has been suggested to be greater during indoor bend sprinting (Usherwood & Wilson, 2006). Other than research on performance descriptors (step characteristics) (Bezodis & Gittoes, 2008) or two-dimensional kinematics (Ryan & Harrison, 2003), three-dimensional joint kinematics have yet to be described on radii typical of indoor competition. Therefore, the aim of this investigation was to determine the effect of lane radius on lower extremity joint kinematics and inter-limb differences during indoor bend sprinting.

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 males - 23.35 ± 0.86 s and females = 25.49 ± 0.91 s. Twelve optoelectronic cameras (Vicon, Oxford, 250 hz) were set up to ensure two consecutive steps on the bend (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 (banking = 12°) indoor 200 m track with radius of 13.98 m for Lane 2 and 15.94 m for Lane 4 was used for testing. In order to avoid the effects of fatigue, participants were asked to undertake two 80 m efforts in both Lane 2 and 4 at 85 % of their perceived maximum (Alt et al., 2015). This was carried out in a randomised counter-balanced order. Kinematic data were captured at the apex of the curve 50 – 60 m into the sprint effort. 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). Joint rotations were determined using Cardan sequencing, where motion about the X axis was defined as flexion/extension at the hip and knee and plantar flexion/dorsiflexion for the ankle. Motion about the Y axis was defined as abduction/adduction at the hip and knee and inversion/eversion at the ankle. Motion about the Z axis was defined as internal/external rotation. Custom MATLAB (MathWorks, USA, 2019a) 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, 2014). Stance phases were normalised to 101 data points. To determine the interaction between lane conditions (Lane 2 and Lane 4), and limb (left and right), two-way repeated measures ANOVAs were run using one-dimensional Statistical Parametric Mapping (Pataky et al., 2013). This was repeated for sagittal, frontal and transverse axes for the hip, knee and ankle joints. To identify any differences between conditions, and between limbs within a condition, post-hoc independent two-tailed non-parametric t-tests were run (Pataky et al., 2013). A criterion alpha of 0.05 was set a priori for all statistical tests.

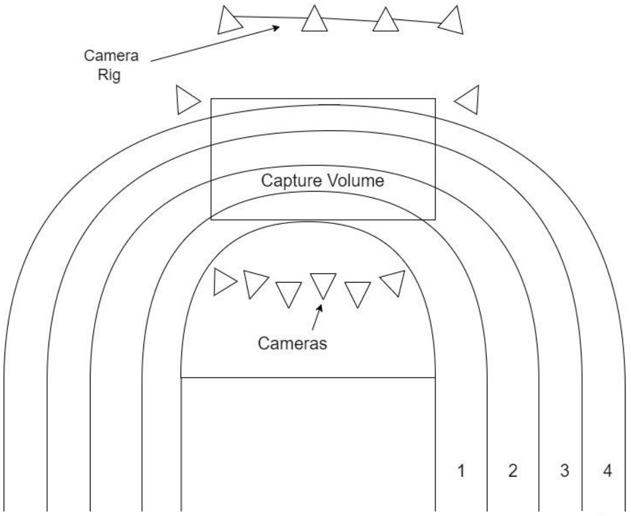

Figure 1. Plan view of the experimental set up (not to scale). ◁ ***= Camera***

RESULTS: Frontal plane joint kinematics during the stance phase are displayed in Figure 2. No significant limb*condition interactions were observed between Lane conditions. A main effect of Condition for internal/external ankle rotation was observed during early stance (0-11 %; $p < 0.001$), however, no post-hoc differences between lane conditions or between limbs were observed. For the effect of Limb, main effects were observed for hip abduction/adduction, where mid-stance (16-77; $p = 0.002$) showed significant effect. Post-hoc tests revealed that the left hip was more adducted than the right in Lane 2 (21- 67 %; $p < 0.001$). A main effect for Limb was also observed for knee abduction/adduction (15-60 %; 0.0018), where the left knee was more adducted in Lane 2 (0-62 %; $p < 0.001$). For the ankle, no main effects were observed but post-hoc testing revealed the left ankle to be more everted than the right in Lane 2 during mid-stance (14-72 %; $p < 0.001$). No significant interactions or main effects were observed in the sagittal plane across hip, knee and ankle.

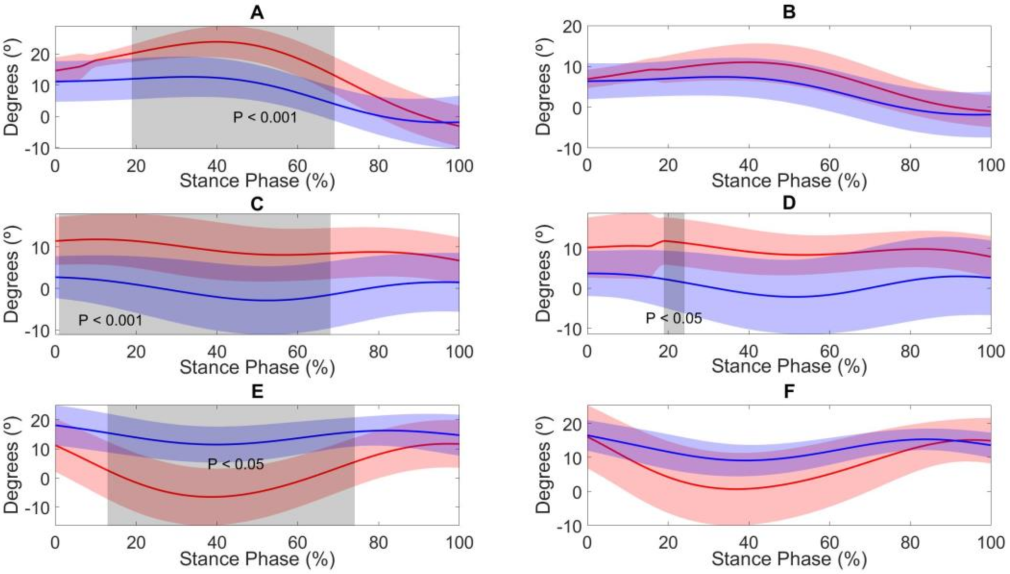

Figure 2. Left (red) and Right (blue) mean (solid line) ± SD (shaded area) for Frontal Plane joint angles during normalised stance for the hip (A, B), knee (C, D) and ankle (E, F). Lane 2 on the left-hand side and Lane 4 on the right-hand side. *Grey shaded regions indicate regions of significant difference between Left and Right.

DISCUSSION: The aim of this investigation was to determine the effect of lane radius on lower extremity joint kinematics during bend sprinting on radii typical of indoor competition. The main findings were that radius appeared to have minimal effect on joint kinematics for left and right steps, however tightening radii appeared to increase inter-limb asymmetry. Only internal/external rotation of the ankle showed a main effect for condition. Alt et al., (2015) showed peak external rotation in the right ankle to reach values three times greater than those of the left, going on to suggest that the right limb adopted a rotation strategy to control the movement. However, in this study no post-hoc differences were found between conditions for left or right ankle internal/external rotation. Similar to Alt et al., (2015), no interactions or main effects were observed in the sagittal plane; however, it has previously been noted that modifications across frontal and transverse planes places joints in a less optimal position for sagittal plane force production. For example, on the bend athletes push off the oblique axis of the metatarsophalangeal joint which has potential to result in reductions in force production (Judson et al., 2019). Therefore, whilst no sagittal plane differences were observed in this study, larger frontal plane adaptations has the potential to impact force production and thus, sprinting velocity. It is possible that the limited within-limb differences between Lanes 2 and 4 is a consequence of the tracks lateral banking. Lateral banking has been shown to minimise the amount of body lateral lean required (Greene, 1987). Reduced lateral lean has the potential to reduce frontal and transverse kinematic alterations when bend sprinting. Nonetheless, this cannot be confirmed without exploration of banked and flat bends of equal radii.

It is commonly accepted that bend sprinting is an asymmetrical movement task (Churchill et al., 2015). Furthermore, this asymmetry appears to increase on tighter radii (Chang & Kram, 2007). In this study, significant differences between left and right stance phase kinematics were primarily observed in the frontal plane in Lane 2. Left hip and knee were more adducted throughout early to mid-stance (21 – 67 %; 0 – 62%), whilst the left ankle displayed greater eversion during stance than the right from early stance towards late stance (14-72 %). Whilst no differences between Lanes 2 and 4 were observed for left or right steps, the increase in inter-limb asymmetry in Lane 2 suggests that athletes respond to tighter radii by increasing inter-limb asymmetry. These findings supports previous suggestions that greater medial-lateral force requirements are needed to follow tighter radii (Chang & Kram, 2007), therefore it is reasonable to suggest athletes adapt to this demand by adopting a greater adduction-eversion strategy during left stance (Alt et al., 2015). Whilst this investigation reports joint kinematics for the hip, knee and ankle during sprinting on radii typical of indoor competition, multi-segment kinematics have been shown to be of importance during bend sprinting warranting further analysis (Judson et al., 2019). Therefore, future research should address the effect of lateral banking on radii of equal length and investigate multi-segment foot kinematics to further understanding of bend sprinting typical of indoor competition.

CONCLUSION: The main findings that the change in radius appears to have minimal effect on lower extremity joint kinematics. However, inter-limb differences occurred only in Lane 2, suggesting that tightening radii led to an increase in on inter-limb asymmetry. Similar to previous bend sprinting research on outdoor tracks, the left limb appears to adopt an adduction and eversion strategy during left stance to control the movement and force demands of bend sprinting. Future research should explore a comparison of banked verses flat bends of equal radii to greater understand the demands of indoor athletic competition.

REFERENCES

Alt, T., Heinrich, K., Funken, J., & Potthast, W. (2015). Lower extremity kinematics of athletics curve sprinting. Journal of Sports Sciences, 33(6), 552–560.

Bezodis, I. N., & Gittoes, M. J. R. (2008). Bilateral differences in step characteristics when sprinting on the straight and banked bend of an indoor 200 m track. Proceedings of the 26th International Conference on Biomechanics in Sports, 673–676.

Chang, Y.-H., & Kram, R. (2007). Limitations to maximum running speed on flat curves. Journal of Experimental Biology, 210(6), 971–982. https://doi.org/10.1242/jeb.02728

Churchill, S. M., Salo, A. I. T., & Trewartha, G. (2015). The effect of the bend on technique and performance during maximal effort sprinting. Sports Biomechanics, 14(1), 106–121.

Churchill, S. M., Trewartha, G., & Salo, A. I. T. (2018). Bend sprinting performance: New insights into the effect of running lane. Sports Biomechanics, 18(4), 437–447.

Greene, P. R. (1987). Sprinting with banked turns. Journal of Biomechanics, 20(7), 667–680. https://doi.org/10.1016/0021-9290(87)90033-9

Judson, L., Churchill, S., Barnes, A., Sone, J., & Wheat, J. (2017). Simplified marker sets for the calculation of centre of mass location during bend sprinting. 35th Conference of the International Society of Biomechanics in Sports.

Judson, L. J., Churchill, S. M., Barnes, A., Stone, J. A., Brookes, I. G. A., & Wheat, J. (2019). Horizontal force production and multi-segment foot kinematics during the acceleration phase of bend sprinting. Scandinavian Journal of Medicine & Science in Sports, 29(10), 1563–1571. https://doi.org/10.1111/sms.13486

Judson, L. J., Churchill, S. M., Barnes, A., Stone, J. A., Brookes, I. G. A., & Wheat, J. (2020). Kinematic modifications of the lower limb during the acceleration phase of bend sprinting. Journal of Sports Sciences, 38(3), 336–342. https://doi.org/10.1080/02640414.2019.1699006

Nagahara, R., & Zushi, K. (2014). Determination of Foot Strike and Toe-off Event Timing during Maximal Sprint Using Kinematic Data. International Journal of Sport and Health Science, 11, 96–100.

Pataky, T. C., Robinson, M. A., & Vanrenterghem, J. (2013). Vector field statistical analysis of kinematic and force trajectories. Journal of Biomechanics, 46(14), 2394–2401. https://doi.org/10.1016/j.jbiomech.2013.07.031

Ryan, G. J., & Harrison, A. J. (2003). Technical adaptations of competitive sprinters induced by bend running. New Studies in Athletics, 18(4), 11.

Usherwood, J. R., & Wilson, A. M. (2006). Accounting for elite indoor 200 m sprint results. Biology Letters, 2(1), 47–50. https://doi.org/10.1098/rsbl.2005.0399

White, J., Wyatt, H. E., Weir, G., Exell, T., Irwin, G., Wilson, C., Hamill, J., & von Lieres und Wilkau. (2021). An investigation into the effect of lane radius on step characteristics in indoor bend sprinting. ISBS Proceedings Archive, 39, 4.

Wyatt, H. E., Weir, G., Lieres, H. V., Irwin, G., White, J., Exell, T., Wilson, C., & Hamill, J. (2021). Whole body dynamic postural control during bend running. ISBS Proceedings Archive, 39 4.