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**BEND SPRINTING PERFORMANCE: NEW INSIGHTS INTO THE EFFECT OF
RUNNING LANE**

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1 **Bend sprinting performance: new insights into the effect of running lane**

3 **Abstract**

4 Athletes in inner lanes may be disadvantaged during athletic sprint races containing a bend
5 portion because of the tightness of the bend. We empirically investigated the veracity of
6 modelled estimates of this disadvantage and the effect of running lane on selected kinematic
7 variables. Three-dimensional video analysis was conducted on nine male athletes in lanes 8, 5
8 and 2 of the bend of an outdoor track (radii: 45.10, 41.41 and 37.72 m, respectively). There
9 was over 2% ($p < 0.05$) reduction in mean race velocity from lane 8 (left step 9.56 ± 0.43
10 m/s, right step: 9.49 ± 0.41 m/s) to lane 5 (left step: 9.36 ± 0.51 m/s, right step: 9.30 ± 0.51
11 m/s), with only slight further reductions from lane 5 to lane 2 (left step: 9.34 ± 0.61 m/s, right
12 step: 9.30 ± 0.63 m/s). Race velocity decreased mainly because of reductions in step
13 frequency as radius decreased. These unique data demonstrate the extent of the disadvantage
14 of inner lane allocation during competition may be greater than previously suspected.
15 Variations in race velocity changes might indicate some athletes are better able to
16 accommodate running at tighter radii than others, which should have implications for athletes'
17 training.

18 (Word count: 198)

20 Keywords: Athletics, curve, track and field, three-dimensional kinematics, 200 m

23 **Introduction**

24 Lane allocation may disadvantage runners in the inner lanes in sprint races that include a
25 bend portion because of the requirement to run on a tighter bend radius (Jain, 1980; Greene,
26 1985). Mathematical models have estimated the effect that running the inner lanes compared
27 with the outer lanes might have on competition times. Jain (1980) reported the disadvantage
28 is approximately 0.069 s in lane one as opposed to lane seven for a 200 m race. However,
29 Greene (1985) estimated a substantially greater disadvantage of 0.123 s. Empirical evidence
30 at very small radii (1-6 m) has shown running velocity to decrease as bend radius decreases
31 (Chang & Kram, 2007). However, to our knowledge, there have been no robust experimental
32 studies which have aimed to quantify the effect that running lane has on bend running
33 performance on surfaces and at radii typical of those of athletic sprint events.

34

35 Maximal-effort sprinting produces lower velocity on the bend compared with straight line
36 sprinting (Churchill, Salo & Trewartha, 2015). This is mainly because of increased ground
37 contact time leading to a significant reduction in step frequency during the left step on the
38 bend compared with the straight, and because of decreased flight times leading to a reduced
39 step length during the right step on the bend (Churchill et al., 2015). Furthermore, bend
40 sprinting is asymmetrical in nature between left and right steps (Churchill et al., 2015;
41 Ishimura & Sakurai, 2016). Churchill et al. (2015) reported greater values for the left step for
42 ground contact time, touchdown distance, body sagittal lean range of motion (ROM) and the
43 amount of turning achieved during the contact phase. Additionally, greater inward lean was
44 reported during the right step compared with the left step (Churchill et al., 2015). Indeed, left
45 step ground contact time has been shown to be longer than the right at maximal (Churchill et
46 al., 2015; Ishimura & Sakurai, 2016) and submaximal velocities on the bend (Alt, Heinrich,
47 Funken & Potthast, 2015; Stoner & Ben-Sira, 1979). It is likely that the effect of the bend on

48 these variables lessens as the tightness of the bend radius decreases, i.e. in the outer lanes,
49 because of less requirement for centripetal force generation to produce the turn. However,
50 empirical evidence of the effect of the bend radius on sprint performance variables is lacking
51 in the literature.

52

53 Thus, the aim of the present study was to investigate the effect of running in different lanes
54 on bend sprinting performance at radii that are typical of those experienced in athletic sprint
55 events. Specifically, we considered how well previously presented mathematical models from
56 the literature matched the experimental data. Additionally, the study aimed to assess the
57 effect of the lane on selected kinematic variables which have been shown to be affected by
58 bend sprinting. It was hypothesised that velocity would decrease as bend radius decreased.
59 Further, it was hypothesised that this would be due to right step length and left step frequency
60 decreasing from outside lanes to inside lanes, as bend radius decreased. These changes were
61 envisaged to occur mainly because of longer contact time on the left step and shorter flight
62 time on the right step, when the radius decreases, in line with previous literature comparing
63 bend and straight sprinting.

64

65 **Methods**

66 *Participants*

67 Nine male sprinters (mean age, 21.5 ± 3.2 years; mass, 79.4 ± 10.1 kg; height, 1.82 ± 0.06 m)
68 participated in the study. All were experienced in bend sprinting (200 m or 400 m) and
69 regularly competed in national and/or international competitions. Personal best (PB) times for
70 the 200 m ranged from 21.1 s to 22.6 s for eight of the athletes. The ninth athlete, who had no
71 recent 200 m time, had a 400 m PB of 47.36 s. Examination of data for this athlete running in
72 lane 2 in the present study ranked him third fastest within the participant group indicating that

73 his 200 m time would be well within the group range. The study procedures were approved
74 by the Bath Local Research Ethics Committee and all participants provided written informed
75 consent before data collection.

76

77 ***Data collection***

78 Using a repeated measures design, three dimensional (3D) video analyses were performed on
79 the athletes undertaking two 60 m maximal-effort sprints around the bend in each of lanes 8,
80 5 and 2 (radii:45.10, 41.41 and 37.72 m, respectively) of a standard outdoor polyurethane
81 running track. The order in which the lanes were run was pseudo-randomised for different
82 athletes based on which data collection sessions they took part in. Trials were completed
83 following the athletes' typical competition warm up. Athletes wore tight leggings/shorts and
84 vest tops and their own spiked sprint shoes. They started from a standing start or three-point
85 start, as per personal preference. Recovery time between trials within a lane was
86 approximately 8 min and between the lanes approximately 15 min. Generally, all six trials
87 were undertaken during a single training session. For two athletes this was not possible and
88 consequently four trials were completed in one training session with the remaining two trials
89 being completed in their next training session.

90

91 Two high-speed video cameras (MotionPro HS-1, Redlake, USA) recorded the athletes
92 running in each lane at the 40-48 m section of the 60 m enabling analysis of two consecutive
93 steps (Figure 1). The cameras operated at a 200 Hz frame rate with a shutter speed of
94 1/1000 s, and recorded with an image resolution of 1280 × 1024 pixels. An 18 point 3D
95 calibration volume (6.50 m long × 1.60 m wide × 2.00 m high) was recorded before the
96 athletes' trials taking place in each lane.

97

98 ****Figure 1 near here****

100 *Data processing*

101 All trials were manually digitised using Vicon Motus software (Version 9.2, Vicon, UK). A
102 $2 \times$ zoom function was used during digitisation which increased the effective resolution of
103 the screen to 2560×2048 pixels. For most trials the two video cameras were genlocked.
104 However, on one data collection session the genlocking failed. In this case, the two video
105 streams were synchronised using two sets of synchronised 20 LED displays (Wee Beasty
106 Electronics, UK) as in Churchill et al. (2015). Digitising of calibration and running trial
107 videos, identification of gait events, filtering, creation of the kinematic model and calculation
108 of body centre of mass (CoM) followed exactly the methods of Churchill et al. (2015).

109

110 *Calculation of variables*

111 Variables measured were constrained by those identified by Churchill et al. (2015) as being
112 affected by maximum sprinting on the bend (in comparison with straight line sprinting). Left
113 and right steps were measured separately with a step being defined from touchdown of one
114 foot to next contralateral touchdown. Steps were assigned 'left' or 'right' based on the
115 touchdown limb that initiated the step. The following variables were analysed (full methods
116 for their calculation can be found in Churchill et al., 2015): race velocity (the velocity with
117 respect to the official race distance), race step length (the magnitude of the race distance
118 covered during the step), step frequency, ground contact time, flight time, touchdown
119 distance, turn of the CoM during ground contact (the change in trajectory of the CoM during
120 the ground contact phase of each step), body lateral lean at touchdown and take-off, and body
121 sagittal lean ROM.

122

123 *Statistical analysis*

124 Individual mean values for each variable in each lane were calculated for all athletes. These
125 values were then used for further statistical analyses (SPSS v 14.0, SPSS Inc., USA). A one-
126 way repeated measures ANOVA was performed to measure the effect of the lane on each
127 variable for the left and right steps separately. Where a main lane effect was found, pairwise
128 comparisons were conducted. To assess the presence of any asymmetries within a lane, left
129 step variables were compared with right step variables within that lane for each variable using
130 paired samples t-tests. Significance was set at $p < 0.05$. To reduce the chances of committing
131 a Type II error, and thus potentially missing important variables that might be affected by
132 bend radius, no adjustments for multiple comparisons were made. Effect sizes between lanes
133 and between left and right steps within a lane for each variable were calculated using Cohen's
134 d (Cohen, 1988). Interpretation of effect sizes was based on Cohen's guidelines, with $0.20 \leq$
135 $d < 0.50$ indicating a small difference, $0.50 \leq d < 0.80$ a moderate difference, and $d \geq 0.80$ a
136 large difference between the means.

137

138 **Results**

139 There was a general trend for mean race velocity to decrease as bend radius decreased from
140 lane 8 to lane 2 (Figure 2, Table 1). From lane 8 to lane 5 the reduction in race velocity was
141 0.20 m/s for the left step ($p = 0.010$, $d = 0.42$) and 0.19 m/s for the right step ($p = 0.029$, $d =$
142 0.40). However, there were no statistically significant reductions in performance in lane 2
143 relative to lane 5 at the group level. In each lane, race velocity was greater for the left step
144 than the right step and these asymmetries were statistically significant in lanes 8 ($p = 0.042$, d
145 $= 0.16$) and 5 ($p = 0.027$, $d = 0.11$; Table 1). The standard deviations of the race velocity
146 showed that as bend radius decreased, the variation in performance between participants
147 increased (Table 1, Figure 2).

148

149 ***Figure 2 near here***

150

151 The shortest race step lengths were observed in lane 5 for both the left and right steps
152 (Table 1). This was significant for lane 5 compared to lane 2 for the left step ($p = 0.005$,
153 $d = 0.44$). Step frequencies for left and right steps within a lane were similar in all lanes.
154 However, there was a general trend for step frequency to decrease as bend radius decreased.
155 While the only significant difference for step frequency was between lane 5 and 2 for the left
156 step ($p = 0.037$, $d = 0.47$, Table 1), moderate effect sizes were observed between lane 8 and
157 lane 2 for both the left and right steps (left: $d = 0.61$, right: $d = 0.56$).

158

159 There was a general trend for the left step mean ground contact time to increase as bend
160 radius decreased with a significant difference observed between lane 8 and 2 ($p = 0.004$,
161 $d = 0.69$). During the right step, ground contact time was similar across lanes. However,
162 statistically significant asymmetries between left and right ground contact time were present
163 in all lanes ($p < 0.01$, Table 1).

164

165 Significantly more turning of the CoM was achieved during the left ground contact phase
166 compared with the right ground contact phase in all three lanes ($p < 0.01$, Table 1). For the
167 right step, there was significantly more turning of the CoM (37% and 45%, respectively) in
168 lanes 5 ($p = 0.013$, $d = 1.04$) and 2 ($p = 0.002$, $d = 1.44$) compared with lane 8. For the left
169 step, none of the turning of the CoM difference reached significant level or moderate effect
170 size. There was a trend of increased inward (more negative) body lateral lean at touchdown as
171 radius decreased for both the left and right steps. The only comparison for which this was not
172 statistically significant was between lane 5 and lane 2 for the left step ($p = 0.353$). A

173 significant difference between left and right steps within each lane was also found for inward
174 lean at touchdown, with more lean for the right step (Table 1).

175

176 ***Table 1 near here***

177

178 **Discussion and Implications**

179 We evaluated the effect of running in different lanes of a standard athletics track on bend
180 sprinting performance variables. Race velocity decreased as bend radius decreased and
181 variation between participants increased as the bend became tighter. The reductions in race
182 velocity equated to a 2.1% and 2.0% decrease in race velocity from lane 8 to lane 5 for the
183 left and right steps, respectively. There was a further 0.2% reduction in velocity from lane 5
184 to lane 2 for the left step only, meaning that differences between lane 5 and lane 2 were
185 negligible. Reductions in race velocity were because of a general trend for step frequency to
186 decrease as radius decreased for both the left and right steps. Additionally, step lengths were
187 shorter in lanes 5 and 2 than in lane 8, with the shortest step lengths being observed,
188 surprisingly, in lane 5 for both the left and right steps. These findings allow us to accept the
189 research hypotheses (reductions in performance variables as radius decreased) for velocity
190 and left step frequency, but not for right step length.

191

192 Race velocities similar to the present study have been reported in the literature for lane 2 (left
193 step: 9.34-9.40 m/s, right step: 9.29-9.34 m/s; Churchill et al., 2015; Churchill, Trewartha,
194 Bezodis & Salo, 2016) indicating the performances in the present study were comparable
195 with previous datasets. The decrease in race velocity as bend radius decreased shows that
196 athletes in the inner lanes are at a biomechanical disadvantage. These results provide
197 empirical evidence to add to previously proposed mathematical models. However, based on

198 these results, the discrepancy between running lanes might be much larger than had been
199 previously suspected. Depending on the model used, the difference between running a 200 m
200 sprint in lane 1 (radius 38.50 m) compared with lane 7 (radius 45.72 m) of an outdoor track
201 has previously been suggested to be 0.069 s (Jain, 1980) to 0.123 s (Greene, 1985). The
202 potential effect of decreases in race velocity on race performance can be estimated based on
203 the present experimental data using a number of assumptions and simplifications. The
204 average race velocity of the left and right steps in lane 8 was 9.53 m/s in this study. On a
205 standard outdoor track, the distance run on the bend is approximately 115 m for all lanes
206 (International Association of Athletics Federations, 2008). If we assume that the acceleration
207 at the start takes 40 m, it leaves a further 75 m for the rest of the bend. If we extrapolate the
208 aforementioned velocity of lane 8 for the rest of the bend, this equates to a time of 7.87 s to
209 cover the bend from 40 m to 115 m. The average race velocity over the left and right steps
210 was 9.33 m/s in lane 5 equating to a respective time of 8.04 s, and in lane 2 the average race
211 velocity was 9.32 m/s equating to 8.05 s. Using these estimates, the difference in race times
212 between lane 8 and lane 5 would be 0.170 s and between lane 8 and lane 2 it would be
213 0.180s. We acknowledge that it is unlikely that any athlete can keep the maximum velocity
214 for the whole 75 m. However, any slight decrease in the velocity is very likely to be relatively
215 similar to aforementioned values between the lanes resulting in a minimal change to these
216 estimated times.

217

218 The above estimates, based on real experimental data, are larger than the predicted
219 differences between lanes 1 and 7 given by Jain (1980) and Greene (1985). We recognise that
220 these are estimates based on some assumptions, but they still provide the first full
221 quantification of the challenges facing athletes allocated the inner lanes. Furthermore, these
222 workings do not yet take into account the likely negative affect that bend radius has on the

223 acceleration phase, given that velocity has been shown to reduce on the bend compared with
224 the straight during the acceleration phase of sprinting (Stoner & Ben-Sira, 1979).
225 Additionally, since the velocity would be lower coming off the bend into the straight in the
226 inner lanes, the straight line velocity would also be affected, further increasing the difference
227 between the inside and outside lanes. Thus, our estimates might even be at the lower end of
228 possibilities. The magnitude of the effect of the bend will likely be different between
229 individuals. Indeed the standard deviations for the race velocities in the present study showed
230 greater variation as bend radius decreased. This suggests that some athletes were better than
231 others at maintaining their velocity as the bends got tighter. Thus, while these initial estimates
232 of differences in 200 m race times because of different lanes might be larger or smaller for
233 different athletes, they do suggest that the magnitude of disadvantage of being in the inner
234 lanes might be greater than previously suspected.

235

236 There was a general trend for step frequency to decrease as radius decreased for both the left
237 and right steps, where mean step frequency reduced from 4.48 Hz for both left and right steps
238 in lane 8 to 4.35 Hz and 4.36 Hz, respectively, in lane 2 (Table 1), which represented a
239 moderate effect size. Usherwood and Wilson (2006) postulated that athletes would increase
240 ground contact times when bend sprinting to meet the additional requirement to generate
241 centripetal force and consequently reduce step frequencies. The observed decrease in step
242 frequency as bend radius decreased in the present study provides some support for
243 Usherwood and Wilson's (2006) model. However, while step frequency decreased because of
244 an increase in ground contact time for the left step, ground contact times for the right step
245 were actually similar between lanes, but flight times varied and this also affected step
246 frequency. Thus, the mechanism for changes in step frequency was different between left and
247 right steps. The trend for increased contact time for the left step when the radius decreased

248 followed our secondary hypothesis, although the difference only became statistically
249 significant between lanes 8 and 2.

250

251 The present study showed that the bend radius had an effect on step length, but perhaps
252 surprisingly it did not necessarily decrease as radius decreased. Left step length was 0.05 m
253 longer in lane 2 than in lane 5. This significant increase in left race step length from lane 5 to
254 lane 2 was accompanied by a significant decrease in left step frequency. It is possible that
255 when running in lane 2, the athletes might have tried to compensate for reductions in step
256 frequency caused by the tightness of the bend by increasing step length, or vice versa.
257 Negative interaction of this kind has been observed in straight line sprinting (Hunter,
258 Marshall & McNair, 2004). It is, therefore, important to question whether increasing step
259 length rather than step frequency at tighter bend radii is a beneficial strategy, or whether
260 strategies to maintain step frequency aiming to prevent reductions in velocity would be more
261 advantageous. Further research into the strategies employed by ‘better bend runners’, i.e.
262 those athletes whose performance decreases the least on the bend compared with their
263 straight line velocity, may aid this.

264

265 From a practical perspective this study has a number of implications. The standard deviations
266 revealed that there was an increase in the degree of variation between participants for race
267 velocity as bend radius decreased from lane 8 to lane 5 and then to lane 2. This might be
268 indicative of different athletes being better able to ‘cope’ with the demands of the tighter lane
269 than others. It is possible that this type of information could and perhaps should be used by
270 coaches to identify training needs. For example, if an athlete has a larger deterioration in
271 performance as bend radius decreases then more bend-specific training might be required.
272 Churchill et al. (2016) indicated bend sprinting to have large, specific and different force

273 demands to that of straight line sprinting. Based on training specificity, it can be speculated
274 that athletes' main way to learn to tolerate these forces is by sprinting on the bend at high
275 velocities. Additionally, this information might facilitate event choice for athletes and
276 coaches, or might influence how the athletes approach the different rounds of competition.
277 The usual process for lane allocation in outdoor competitions is that during first round lanes
278 are randomly assigned. Subsequent rounds are allocated based on the ranking of each athlete
279 within the heats, where the four highest ranked athletes are allocated lanes three to six at
280 random, the fifth and sixth ranked athletes allocated lanes seven and eight at random, and the
281 final two athletes allocated lanes one and two at random (International Association of
282 Athletics Federations, 2014). Thus, those athletes who are less able to maintain performance
283 in the inner lanes might have a greater requirement to 'qualify well' for subsequent rounds to
284 ensure a better lane draw.

285

286 There were some limitations to the study. The number of participants was limited because of
287 the requirement to have experienced bend sprinters of high calibre. Whilst more participants
288 would have been desirable, it was our aim to avoid testing less experienced athletes which
289 might have meant that the results were confounded by the novelty of the task. The limited
290 number of participants might have meant that stronger trends in the data were masked by low
291 statistical power. This might explain the fact that a number of the trends in the data yielded
292 only small effect sizes, although some of them might have a meaningful impact in
293 performance from an applied perspective. An example of this would be reductions in race
294 velocity from lane 8 to lane 2, where small effect sizes were seen for both steps (left: $d =$
295 0.42 , right: $d = 0.40$), but a 2% decrease in performance would be very important to an
296 athlete or coach. Although the results for race velocity suggest a possible non-linear effect of
297 running lane on performance, this cannot be fully established without data collected in more

298 lanes. There are clear challenges in trying to obtain more runs per athlete in the same session.
299 Thus, the practical constraints of the number of trials that could be completed by the athletes
300 meant that analysis of three lanes was considered sufficient to obtain an overall picture of the
301 effect of the lane. However, the possibility of a non-linear relationship warrants further
302 investigation. These limitations notwithstanding, this is the first study to empirically measure
303 the effect of running lane on performance during sprinting at radii and on surfaces typical of a
304 standard outdoor track and to provide ecologically valid between-lane differences.
305 Furthermore, the study provides practically useful information about the effect of altering
306 bend radius on performance and is a useful platform for further research.

307

308 **Conclusion**

309 Bend sprinting performance, as identified by race velocity, decreased as bend radius
310 tightened from lane 8 to 5 to 2. The results showed that the effect of running lane on race
311 times may be greater than previous mathematical models have suggested and may easily be in
312 the region of 0.180 s between lane 8 and lane 2 during a 200 m race. Increased variability in
313 performance between participants as bend radius decreased might be indicative of athletes
314 possessing different abilities to cope with the demands of the inner lanes, which might have
315 implications for training, event selection, or competition approach.

316

317 **Acknowledgement**

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319

320 **Disclosure statement**

321 The authors have no financial or personal conflicts of interest to declare.

322

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366 speeds are achieved with greater ground forces not more rapid leg movements.
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368
369
370

371 Figure captions:

372 Figure 1. Camera set-up for lane 2 trials (not to scale). Note that the cameras were in the
373 same position for lane 5 (radius: 41.41 m) and lane 8 trials (radius: 45.10 m), but the ‘front
374 view’ camera was adjusted in order that the centre of the lane of interest was in the centre of
375 the field of view, and the zoom of the side view camera adjusted to maintain the 8 m wide
376 field of view in the relevant lane. The start and end positions for the runs were adjusted so
377 that the athlete started 40 m from the filming area in each lane.

378

379 Figure 2. a) Left and b) right step race velocity on the bend in lanes 8, 5, and 2 for individual
380 participants (P1-P9).

Figure 1

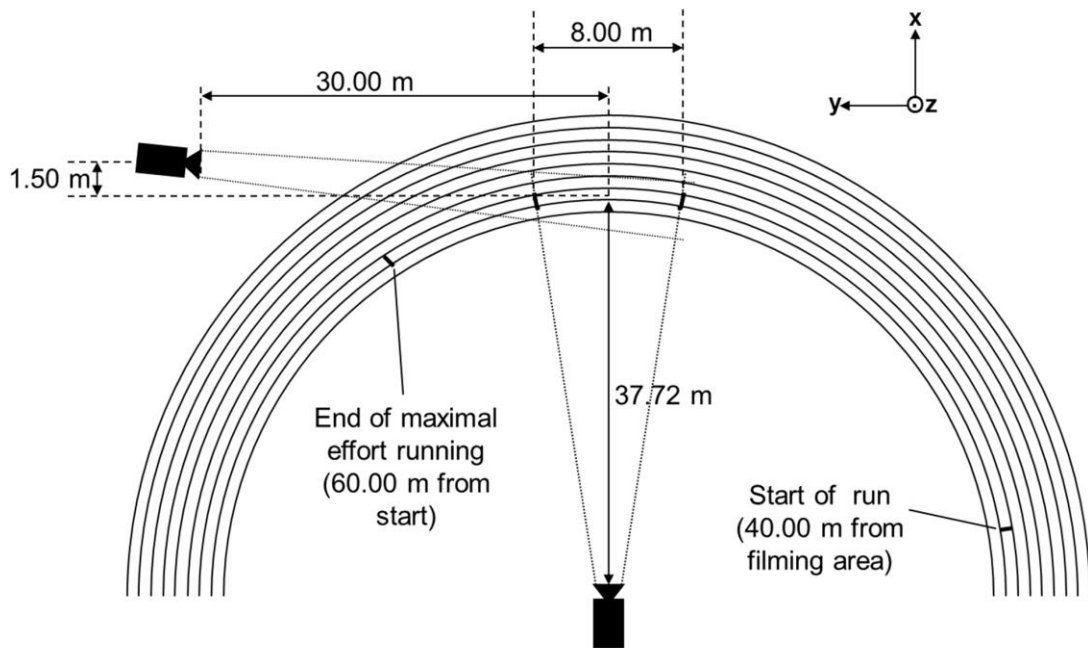


Figure 2

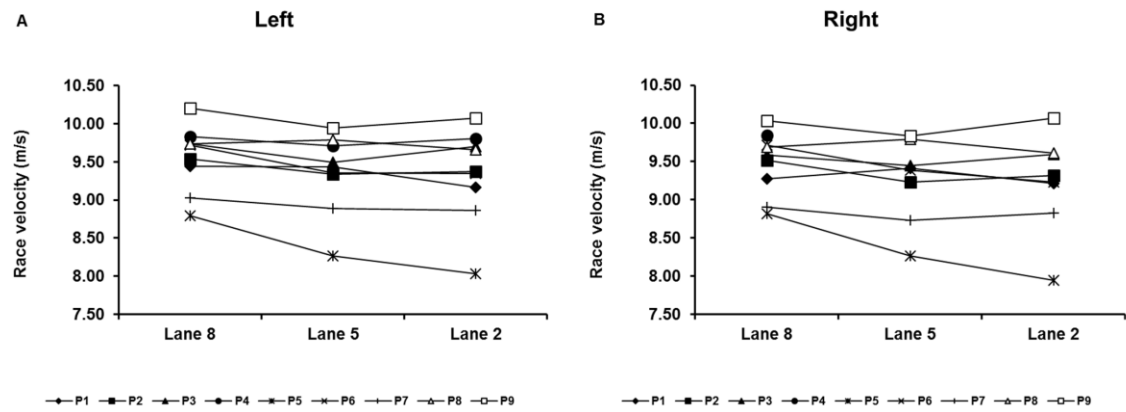


Table 1. Left and right step group mean values (\pm SD) and significant differences for selected kinematic variables during bend running in lanes 8, 5, and 2.

	Lane 8		Lane 5		Lane 2		Significant differences									
	Left	Right	Left	Right	Left	Right	Left vs. right L8	Left vs. right L5	Left vs. right L2	L8 vs. L5 Left	L8 vs. L5 Right	L8 vs. L2 Left	L8 vs. L2 Right	L5 vs. L2 Left	L5 vs. L2 Right	
Race velocity (m/s)	9.56 \pm 0.43	9.49 \pm 0.41	9.36 \pm 0.51	9.30 \pm 0.51	9.34 \pm 0.61	9.30 \pm 0.63	a	a		a	a	a				
Race step length (m)	2.13 \pm 0.08	2.12 \pm 0.11	2.10 \pm 0.11	2.10 \pm 0.10	2.15 \pm 0.09	2.13 \pm 0.12										a
Step frequency (Hz)	4.48 \pm 0.19	4.48 \pm 0.18	4.45 \pm 0.21	4.43 \pm 0.17	4.35 \pm 0.25	4.36 \pm 0.22										a
Ground contact time (s)	0.116 \pm 0.006	0.109 \pm 0.006	0.119 \pm 0.009	0.111 \pm 0.009	0.121 \pm 0.008	0.111 \pm 0.008	b	b	c			b				
Flight time (s)	0.113 \pm 0.009	0.109 \pm 0.009	0.112 \pm 0.010	0.109 \pm 0.006	0.117 \pm 0.012	0.111 \pm 0.008										
Touchdown distance (m)	0.38 \pm 0.04	0.34 \pm 0.04	0.39 \pm 0.04	0.33 \pm 0.04	0.39 \pm 0.03	0.32 \pm 0.05	c	c	c							
Turn of CoM ($^{\circ}$)	4.0 \pm 0.7	1.7 \pm 0.6	4.4 \pm 1.1	2.4 \pm 0.6	4.3 \pm 0.7	2.5 \pm 0.4	c	b	b		a		b			
Body sagittal lean ROM ($^{\circ}$)	57.0 \pm 3.2	53.6 \pm 3.6	58.0 \pm 3.0	53.9 \pm 3.7	58.4 \pm 3.2	53.4 \pm 3.5	c	c	c							
Body lateral lean at TD ¹ ($^{\circ}$)	-8.4 \pm 1.5	-12.7 \pm 2.4	-9.4 \pm 2.2	-14.2 \pm 1.8	-9.9 \pm 2.5	-15.1 \pm 1.9	b	c	c	a	a	a	b		a	
Body lateral lean at TO ¹ ($^{\circ}$)	-6.8 \pm 1.1	-12.3 \pm 2.2	-7.5 \pm 1.7	-13.2 \pm 1.8	-7.5 \pm 2.0	-14.1 \pm 2.0	c	c	c				b			

Note: ROM, range of motion; TD, touchdown; TO take off; L8, lane 8; L5, lane 5; L2, lane 2; ¹ a negative value for body lateral lean indicates inward lean; **a:** $p < 0.05$; **b:** $p < 0.01$; **c:** $p < 0.001$.