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

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Abstract

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

(Word count: 198)

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

Introduction

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

Maximal-effort sprinting produces lower velocity on the bend compared with straight line sprinting (Churchill, Salo & Trewartha, 2015). This is mainly because of increased ground contact time leading to a significant reduction in step frequency during the left step on the bend compared with the straight, and because of decreased flight times leading to a reduced step length during the right step on the bend (Churchill et al., 2015). Furthermore, bend sprinting is asymmetrical in nature between left and right steps (Churchill et al., 2015; Ishimura & Sakurai, 2016). Churchill et al. (2015) reported greater values for the left step for ground contact time, touchdown distance, body sagittal lean range of motion (ROM) and the amount of turning achieved during the contact phase. Additionally, greater inward lean was reported during the right step compared with the left step (Churchill et al., 2015). Indeed, left step ground contact time has been shown to be longer than the right at maximal (Churchill et al., 2015; Ishimura & Sakurai, 2016) and submaximal velocities on the bend (Alt, Heinrich, Funken & Potthast, 2015; Stoner & Ben-Sira, 1979). It is likely that the effect of the bend on these variables lessens as the tightness of the bend radius decreases, i.e. in the outer lanes, because of less requirement for centripetal force generation to produce the turn. However, empirical evidence of the effect of the bend radius on sprint performance variables is lacking in the literature.

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

Methods

Participants

Nine male sprinters (mean age, 21.5 ± 3.2 years; mass, 79.4 ± 10.1 kg; height, 1.82 ± 0.06 m) participated in the study. All were experienced in bend sprinting (200 m or 400 m) and regularly competed in national and/or international competitions. Personal best (PB) times for the 200 m ranged from 21.1 s to 22.6 s for eight of the athletes. The ninth athlete, who had no recent 200 m time, had a 400 m PB of 47.36 s. Examination of data for this athlete running in lane 2 in the present study ranked him third fastest within the participant group indicating that his 200 m time would be well within the group range. The study procedures were approved by the Bath Local Research Ethics Committee and all participants provided written informed consent before data collection.

Data collection

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

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

Figure 1 near here

Data processing

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

Calculation of variables

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

Statistical analysis

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

Results

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

Figure 2 near here

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

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

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

Table 1 near here

Discussion and Implications

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

Race velocities similar to the present study have been reported in the literature for lane 2 (left step: 9.34-9.40 m/s, right step: 9.29-9.34 m/s; Churchill et al., 2015; Churchill, Trewartha, Bezodis & Salo, 2016) indicating the performances in the present study were comparable with previous datasets. The decrease in race velocity as bend radius decreased shows that athletes in the inner lanes are at a biomechanical disadvantage. These results provide empirical evidence to add to previously proposed mathematical models. However, based on these results, the discrepancy between running lanes might be much larger than had been previously suspected. Depending on the model used, the difference between running a 200 m sprint in lane 1 (radius 38.50 m) compared with lane 7 (radius 45.72 m) of an outdoor track has previously been suggested to be 0.069 s (Jain, 1980) to 0.123 s (Greene, 1985). The potential effect of decreases in race velocity on race performance can be estimated based on the present experimental data using a number of assumptions and simplifications. The average race velocity of the left and right steps in lane 8 was 9.53 m/s in this study. On a standard outdoor track, the distance run on the bend is approximately 115 m for all lanes (International Association of Athletics Federations, 2008). If we assume that the acceleration at the start takes 40 m, it leaves a further 75 m for the rest of the bend. If we extrapolate the aforementioned velocity of lane 8 for the rest of the bend, this equates to a time of 7.87 s to cover the bend from 40 m to 115 m. The average race velocity over the left and right steps was 9.33 m/s in lane 5 equating to a respective time of 8.04 s, and in lane 2 the average race velocity was 9.32 m/s equating to 8.05 s. Using these estimates, the difference in race times between lane 8 and lane 5 would be 0.170 s and between lane 8 and lane 2 it would be 0.180s. We acknowledge that it is unlikely that any athlete can keep the maximum velocity for the whole 75 m. However, any slight decrease in the velocity is very likely to be relatively similar to aforementioned values between the lanes resulting in a minimal change to these estimated times.

The above estimates, based on real experimental data, are larger than the predicted differences between lanes 1 and 7 given by Jain (1980) and Greene (1985). We recognise that these are estimates based on some assumptions, but they still provide the first full quantification of the challenges facing athletes allocated the inner lanes. Furthermore, these workings do not yet take into account the likely negative affect that bend radius has on the acceleration phase, given that velocity has been shown to reduce on the bend compared with the straight during the acceleration phase of sprinting (Stoner & Ben-Sira, 1979). Additionally, since the velocity would be lower coming off the bend into the straight in the inner lanes, the straight line velocity would also be affected, further increasing the difference between the inside and outside lanes. Thus, our estimates might even be at the lower end of possibilities. The magnitude of the effect of the bend will likely be different between individuals. Indeed the standard deviations for the race velocities in the present study showed greater variation as bend radius decreased. This suggests that some athletes were better than others at maintaining their velocity as the bends got tighter. Thus, while these initial estimates of differences in 200 m race times because of different lanes might be larger or smaller for different athletes, they do suggest that the magnitude of disadvantage of being in the inner lanes might be greater than previously suspected.

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

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

From a practical perspective this study has a number of implications. The standard deviations revealed that there was an increase in the degree of variation between participants for race velocity as bend radius decreased from lane 8 to lane 5 and then to lane 2. This might be indicative of different athletes being better able to 'cope' with the demands of the tighter lane than others. It is possible that this type of information could and perhaps should be used by coaches to identify training needs. For example, if an athlete has a larger deterioration in performance as bend radius decreases then more bend-specific training might be required. Churchill et al. (2016) indicated bend sprinting to have large, specific and different force demands to that of straight line sprinting. Based on training specificity, it can be speculated that athletes' main way to learn to tolerate these forces is by sprinting on the bend at high velocities. Additionally, this information might facilitate event choice for athletes and coaches, or might influence how the athletes approach the different rounds of competition. The usual process for lane allocation in outdoor competitions is that during first round lanes are randomly assigned. Subsequent rounds are allocated based on the ranking of each athlete within the heats, where the four highest ranked athletes are allocated lanes three to six at random, the fifth and sixth ranked athletes allocated lanes seven and eight at random, and the final two athletes allocated lanes one and two at random (International Association of Athletics Federations, 2014). Thus, those athletes who are less able to maintain performance in the inner lanes might have a greater requirement to 'qualify well' for subsequent rounds to ensure a better lane draw.

There were some limitations to the study. The number of participants was limited because of the requirement to have experienced bend sprinters of high calibre. Whilst more participants would have been desirable, it was our aim to avoid testing less experienced athletes which might have meant that the results were confounded by the novelty of the task. The limited number of participants might have meant that stronger trends in the data were masked by low statistical power. This might explain the fact that a number of the trends in the data yielded only small effect sizes, although some of them might have a meaningful impact in performance from an applied perspective. An example of this would be reductions in race velocity from lane 8 to lane 2, where small effect sizes were seen for both steps (left: d = 0.42, right: d = 0.40), but a 2% decrease in performance would be very important to an athlete or coach. Although the results for race velocity suggest a possible non-linear effect of running lane on performance, this cannot be fully established without data collected in more lanes. There are clear challenges in trying to obtain more runs per athlete in the same session. Thus, the practical constraints of the number of trials that could be completed by the athletes meant that analysis of three lanes was considered sufficient to obtain an overall picture of the effect of the lane. However, the possibility of a non-linear relationship warrants further investigation. These limitations notwithstanding, this is the first study to empirically measure the effect of running lane on performance during sprinting at radii and on surfaces typical of a standard outdoor track and to provide ecologically valid between-lane differences. Furthermore, the study provides practically useful information about the effect of altering bend radius on performance and is a useful platform for further research.

Conclusion

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

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Disclosure statement

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

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Figure captions:

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

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

Figure 1

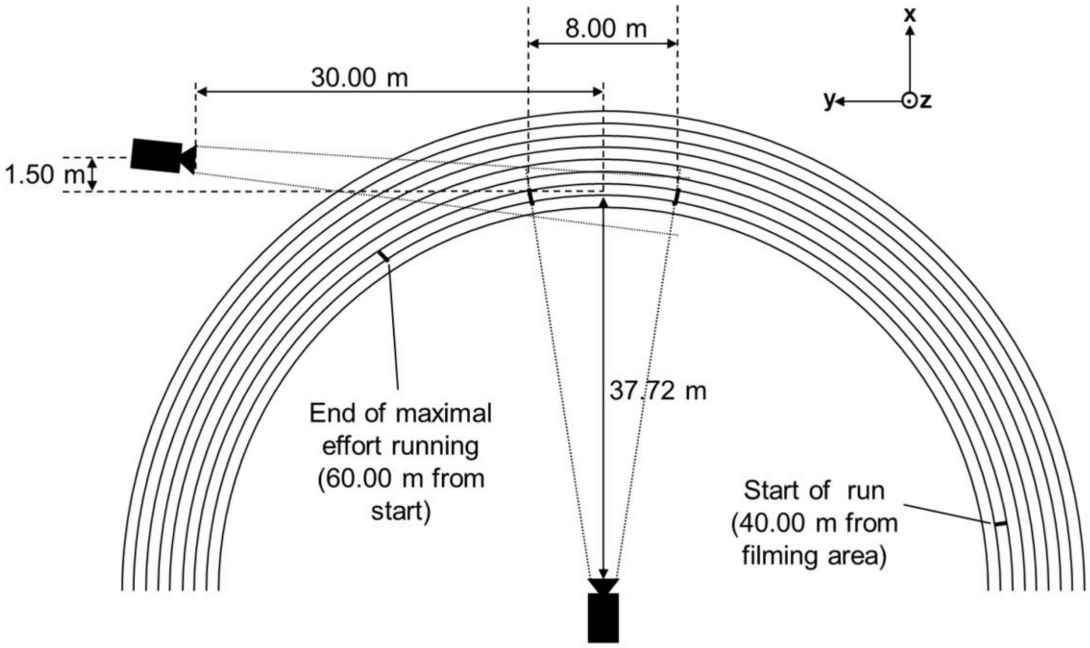

Figure 2

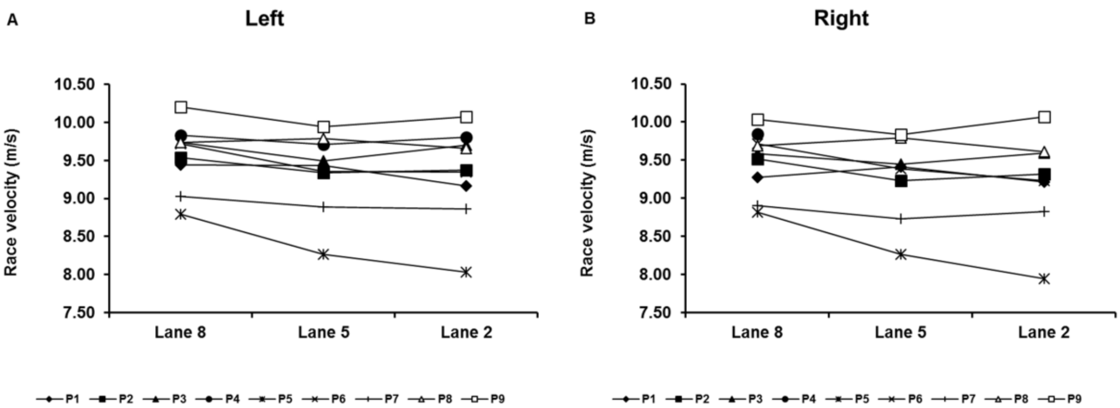

Table 1. Left and right step group mean values (± SD) and significant differences for selected kinematic variables during bend running in lanes 8, 5, and 2.

	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 ± 0.43	9.49 ± 0.41	9.36 ± 0.51	9.30 ± 0.51	9.34 ± 0.61	9.30 ± 0.63	**a**	**a**		**a**	**a**	**a**			
Race step length (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								**a**	
Step frequency (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								**a**	
Ground contact time (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	**b**	**b**	**c**			**b**			
Flight time (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									
Touchdown distance (m)	0.38 ± 0.04	0.34 ± 0.04	0.39 ± 0.04	0.33 ± 0.04	0.39 ± 0.03	0.32 ± 0.05	**c**	**c**	**c**						
Turn of CoM (°)	4.0 ± 0.7	1.7 ± 0.6	4.4 ± 1.1	2.4 ± 0.6	4.3 ± 0.7	2.5 ± 0.4	**c**	**b**	**b**		**a**		**b**		
Body sagittal lean ROM (°)	57.0 ± 3.2	53.6 ± 3.6	58.0 ± 3.0	53.9 ± 3.7	58.4 ± 3.2	53.4 ± 3.5	**c**	**c**	**c**						
Body lateral lean at TD[1] (°)	-8.4 ± 1.5	-12.7 ± 2.4	-9.4 ± 2.2	-14.2 ± 1.8	-9.9 ± 2.5	-15.1 ± 1.9	**b**	**c**	**c**	**a**	**a**	**a**	**b**		**a**
Body lateral lean at TO[1] (°)	-6.8 ± 1.1	-12.3 ± 2.2	-7.5 ± 1.7	-13.2 ± 1.8	-7.5 ± 2.0	-14.1 ± 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:** $p < 0.001$.