WHOLE BODY DYNAMIC POSTURAL CONTROL DURING BEND RUNNING

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Bend running on an indoor track is influenced by differing structural constraints including banking and radii of the curve. Regardless of these constraints, an athlete must preserve whole-body postural control to maintain their running speed. The purpose of this study was to investigate the extent to which banking (banked v flat) and radii (lane 2 v lane 4) of a 200m indoor track influences whole centre of mass (CoM) during sprint running. When running in both lane 2 and lane 4, athletes' CoM was closer to their inside foot when the track was banked compared to flat (p < 0.05, 0-100% of stance). In conjunction with increased CoM anterior velocity identified for the banked condition (p < 0.05, 0-100% of stance), the findings highlighted banking of the curve to be the preferable structural constraints for whole-body postural control, compared to a flat track.

KEYWORDS: centre of mass, sprinting, athletics, track, curve.

INTRODUCTION: Running around a bend requires the dynamic coordination of limbs and segments to control the translation and orientation of the whole-body, as represented by the centre of mass (CoM). The task of running around a bend presents a challenge to the mechanical system of the human body; individuals are required to continuously adapt their whole-body mechanics to accomplish the task, while attempting to maintain maximum speed. To effectively achieve the task, the maintenance of postural control is essential and requires the resistance of opposing forces. Specifically, theoretical analyses of curved path motion has demonstrated the tendency of the CoM to continue along a straight path (Dyson, 1968; Hay, 1978; Hamill et al., 1987). To manipulate the trajectory of the CoM, the runner must apply a shear force away from the centre of the curve, resulting in a centripetal force on the runner which produces a torque to rotate the body away from the centre of the curve. Through body positioning, the runner must counteract this torque and “lean in” to the curve.

Whole-body dynamical control enables the performance of a purposeful movement which emerges from interactions between the individual, task and environment (Newell et al., 1989). When running around a bend, the control of whole-body postural is further challenged when constraints are placed on the environment, for example though the addition of track banking and increased tightness of the bend (i.e. reduced track radius). Banked tracks in indoor athletic facilities have been introduced to reduced levels of stress at the ankle joint, while maintaining running speed, compared to flat curves (Greene, 1987). Additional mechanical differences are introduced when athletes are required to run in an inside (e.g. lane 2), compared to an outside lane (e.g. lane 4).

Research has demonstrated the effects of track banking (Greene, 1987) in addition to curve radius (Chang and Kram, 2007; Churchill et al., 2019) on joint and segment running biomechanics. Although localised mechanics have important implications for our understanding of running, the overarching aim of the individual is to achieve whole body re-orientation and maximise CoM velocity, which has yet to be investigated when running around a curve. Furthermore, understanding of the extent to which the biological system is able to respond to the environmental constraints through altered banking and radii of the curve would be of benefit to both our theoretical understanding of postural control, along with applied practice. Therefore, the aim of this study was to investigate the extent to which structural constraints, specifically banking (banked v flat) and radii (lane 2 v lane 4), of a curved track influences whole body dynamic postural control during sprint running.

METHODS: Ten participants participated in this study (age: 21.6±4.6 years, mass: 76.0±11.6 kg, height: 1.77±0.1 m), five had banked running experience and five were novices. All participants were free from injury and had no history of serious lower extremity injury or surgery within the previous year. Approval from this research was gained from the Cardiff Metropolitan University Human Research Ethics committee and written informed consent for all participants was obtained.

One hundred and four 14 mm retro-reflective markers were affixed to the skin in accordance with a customised bilateral full body model of the head, upper arms, forearms, trunk, pelvis, thighs, shanks and feet segments. Kinematic data were recorded using two 12 camera Vicon motion capture systems sampling at 250 Hz (Vicon, Oxford, UK). The motion capture area of 5 x 5 m volume was set up at the apex of the curve. Participants wore their own footwear to complete two sprinting trials at 80% of their most recent personal best competitive 200m pace for four conditions: 1) banked lane 2; 2) banked lane 4; 3) flat lane 2; 4) flat lane 4. Two trials of each condition were recorded for speed within a ±5% range.

Segment masses were scaled from whole-body mass with anthropometric weightings (Dempster, 1955). In combination with segment geometry, CoM was calculated within Visual 3D software (C-motion Inc., Rockville, MD) as the weighted average of the CoM of each of 13 segments. Three-dimensional kinematic trajectories were filtered with a zero-lag fourth-order low pass Butterworth filter at 8 Hz. Data were analysed for the closest left foot stance to the apex of the curve. All trials were completed in an anti-clockwise direction, with the left foot having closest proximity to the centre of the curve. For the left foot stance phase, key continuous CoM displacement (CoMdisp) variables included: (1) distance between medio-lateral (ML) CoM position and the fifth metatarsal head and (2) distance between anterior-posterior (AP) CoM position and the head of the hallux. The respective markers were selected to represent the medial and anterior base of support (BoS) boundaries of the stance foot. Non-normalised whole-body CoM velocity (CoMvel) was derived in ML and AP directions. Data were time normalised over the left foot stance phase (0-100%).

Given mixed normality, individual continuous time series CoMdisp and CoMvel data were analysed using independent two-tailed non-parametric t-tests for banking (banked v flat) and radii (lane 2 v lane 4) within one-dimensional Statistical Parametric Mapping (Pataky et al., 2013). A criterion alpha of 0.05 was set a priori for all statistical tests.

RESULTS: Banking of the track was found to have a greater influence on whole body dynamic postural control than curve radius. When sprinting around a curved track, athletes ran with a reduced distance between CoM and BoS when the track was banked compared to the flat track conditions (Fig. 1). The mean group maximum lateral displacement of the CoM from the left foot BoS during stance was lowest in the lane 4 banked condition (2.58 cm) and greatest in the lane 2 flat condition (17.93 cm). ML CoMdisp was significantly greater for trials performed on the banked track in lane 2 (p = 0.007, 0-100% of stance) and lane 4 (p < 0.001, 0-100% stance) compared to the flat track conditions. No significant differences were identified between lanes 2 and 4 for flat or banked conditions. However, large group standard deviations were found (Table 1), indicating substantial individual differences.

Anterior velocity was greater when running on the banked compared to the flat track in lane 2 (p <0.001, 0-100% of stance) and lane 4 (p = 0.018, 0-100% of stance). When running in lane 2, athletes increased their lateral velocity during the last 50% of stance in the flat compared to banked conditions (p = 0.03, 50-100% of stance) (Fig. 2). Large group standard deviations were additionally identified for CoM velocity (Table 1).

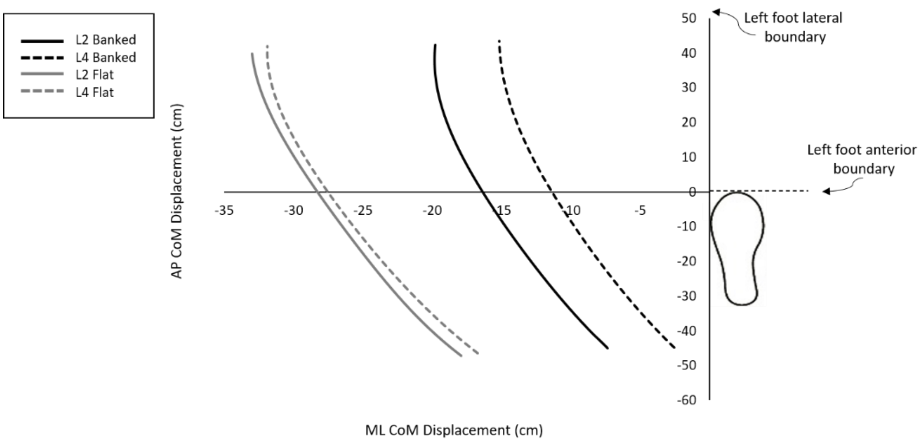

Figure 1: Whole-body CoM in relation to left foot motion throughout the stance phase.

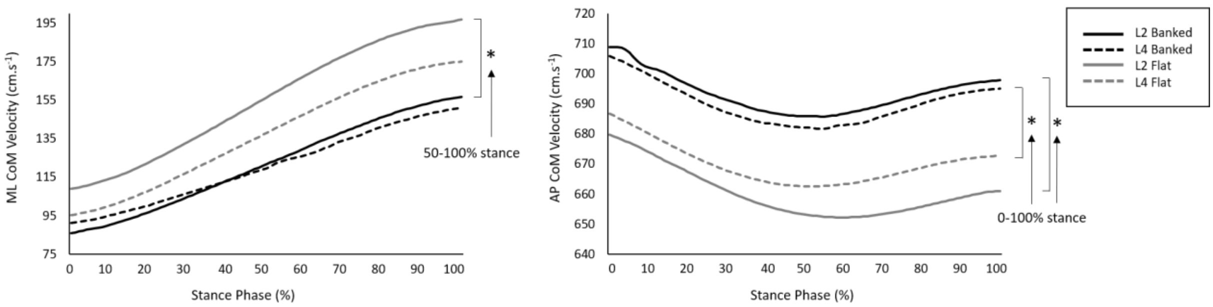

Figure 2: Medio-lateral (ML) and anterior-posterior (AP) whole-body CoM velocity throughout the stance phase. ***Note: * indicates p<0.05; % of stance indicates the phase of statistical significance.***

Table 1: Stance phase mean ± SD for anterior-posterior (AP) and medio-lateral (ML) measures of CoM displacement from BoS and CoM velocity within the four curved track conditions.

		CoM displacement from BoS	CoM velocity
Banked lane 2	AP	-1.40 ± 3.53	693.33 ± 47.22
	ML	-15.30 ± 8.91	121.61 ± 40.56
Banked lane 4	AP	-1.11 ± 5.02	689.80 ± 49.87
	ML	-10.41 ± 8.61	120.57 ± 42.21
Flat lane 2	AP	-4.11 ± 6.24	660.27 ± 39.70
	ML	-26.92 ± 8.07	155.01 ± 36.79
Flat lane 4	AP	-2.49 ± 4.84	669.71 ± 39.39
	ML	-26.20 ± 7.76	137.00 ± 39.56

DISCUSSION: Athletes employed different dynamic postural control strategies when running around a bend on a banked versus a flat track. Specifically, the introduction of banking resulted in athletes reducing the lateral distance of their CoM in relation to their BoS, in comparison with flat track conditions. Within flat track conditions, athletes likely increased trunk lean towards the inside of the curve (Churchill et al., 2015) which was evidenced in the more lateral positioning of CoM in relation to the inside leg. When running on a banked track, athletes demonstrated the ability to better counteract the torque which acts to rotate the body away from the centre of the curve, in comparison with the flat track trials and enabled runners to achieve increased anterior CoM velocity. The findings support previous evidence that banked track facilitates the maintenance of speed (Greene, 1987), highlighting the value of the use of a banked track in indoor athletics.

To overcome environmental constraints and efficiently orient their bodies towards the desired direction of travel, individuals may be expected to employ different strategies of postural control when running about different radii, however, our comparison of lane 2 versus lane 4 CoMdisp and CoMvel revealed no significant differences between the conditions. Further investigation of individual differences is warranted, however the group findings indicate whole-body postural dynamics were maintained irrespective of curve radii which provides some support for athletes to compete in inside and outside lanes without substantial decrement in performance compared to their competitors.

It is possible that a reduced familiarity with running on a banked track may account for the CoMdisp differences found in the current study to some extent. Investigation of intra-individual differences in relation to banked track experience and running speed may offer further understanding of the differences observed. It is possible that athletes may respond differently to the environmental constraints in accordance with familiarity due to their perceived safety and ability to resist leaning into the curve.

In addition to local biomechanical analyses (e.g. joint angles), understanding the global characteristics of how these athletes respond to the changes in running condition provides important information that could be used to enhance the decomposition of the task, providing coaches with useful conceptual understanding of the skill. Based on the training principles of specificity and overload, these finding can support the development of drills and physical preparation to facilitate effective control strategies for maintaining whole body posture during the challenging task of sprinting around a curve.

CONCLUSION: With an increased ability to maintain anterior CoM velocity, running on a banked track was found to be favourable to flat curve running from a whole-body postural control perspective. Group analysis revealed inside and outside lanes did not have a substantial influence on whole-body dynamics, however further exploration at an individual level is required. In addition, understanding of the intricate coordination responses to both banking and lane conditions will further our appreciation of how athletes maintain preferred CoM dynamics and how coaching strategies can facilitate these.

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