ASYMMETRY IN THE APPLICATION OF INWARD GROUND REACTION FORCE DURING CURVED SPRINTING ON ATHLETIC TRACK

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We assessed the factors influencing the application of inward GRF during the left and right contact phases in curved sprinting. This study resulted no significant differences in inward impulse and mean inward GRF between the two contact phases. The symmetry index in inward GRF depended on the magnitude of both inward GRFs during the left and right contact phases. Based on the significant correlation between mean inward GRF and hip abduction torque, we propose that large inward GRF is influenced by the absence of inward pushing during the left contact phase, whereas it is influenced by outward pushing during the right contact phase. The left contact phase seems to involve a shift in the action direction of ankle plantarflexion, as mean inward GRF exhibited a significant correlation with ankle plantarflexion.

KEYWORDS: centripetal impulse, inward inclination, body rotation, movement selection.

INTRODUCTION: Curved sprinting requires the generation of inward impulse during the contact phase to facilitate a change of sprinting direction. Previous studies (Churchill et al., 2016; Ishimura & Sakurai, 2016) have observed asymmetry in the inward impulse, with a larger impulse during the left contact phase than the right contact phase. However, we have noted that the ratio of the left/right contact phases to bending is uneven between individuals during 200 m race (unpublished data). Technical notes for curved sprinting would be derived based on the varying contribution of the left/right contact phases. The purpose of this study was to identify the factors affecting the amount of inward ground reaction force (GRF) for each left and right contact phase.

To apply inward GRF, there are two methods: pushing the ground outward (Figure 1a) and shifting the action direction of flection torque inward by inward inclination (Figure 1b) and/or inward turning (Figure 1c). Because both methods involve asymmetrical movement, such as the left leg needing to shift the action direction of joint flexion while the right leg needs to push outward, we hypothesize asymmetrical behaviour in applying inward GRF. We challenge to assess the factors influencing the application of inward GRF during the left and right contact phases.

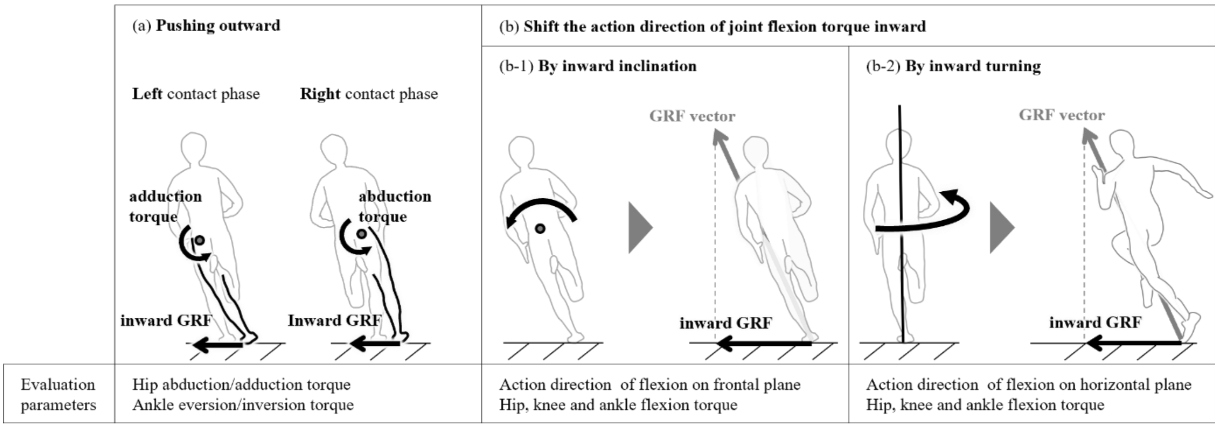

Figure 1: Methods to generate inward GRF.

METHODS: Fourteen male sprinters (mass, 67.07±4.70 kg; 200 m personal best, 21.61± 0.61 s), wearing spiked shoes, conducted submaximal runs along a curved path with a radius of 42 m. This radius corresponds to the curvature of 5-6 lanes on a standard outdoor track, with the first lane having a radius of 36.5 m. Approximately 35 meters after the standing start, three-dimensional marker trajectories on their bodies and GRFs were measured using a motion capture system at 250 Hz with 27 infrared cameras (Vicon-MX, Oxford Metrics Ltd., Oxford, UK) and four force plates at 1000 Hz (8981A, 9287B and 9287C, Kistler Instruments Ltd, Winterhur, Switzerland). A forward direction was defined as the mean velocity of the center of mass at 10 frames before touchdown. Then, the inward direction was defined as the cross product of the vertical and the forward directions. Considering application of GRF, we calculated the impulse normalized by body mass

$$Impulse = \int_{touchdown}^{toe\ off} GRF \big/ body\ mass, \tag{1}$$

and mean GRF during the contact phase by dividing the impulse by the contact duration

$$Mean\ GRF = Impulse / \Delta T_{contact}. \tag{2}$$

To investigate the factors influencing the application of inward GRF, we calculated following parameters, including joint torques at the hip, knee, and ankle, the action direction of the hip extension/flexion axis on frontal and horizontal planes (inward inclination and turning), and foot orientation on the horizontal plane (inward turning) at touchdown. These parameters present the shift in the action direction of hip flexion. Joint torques were integrated in time, and then divided by body mass and contact duration. To examine asymmetry, corresponding t-test were conducted between the left and right sides. The degree of asymmetry was assessed using the "Asymmetry Index" proposed by Robinson et al. (1987). Impulse for asymmetry in inward GRF and magnitude in inward GRF for the left/right contact phases were evaluated using Pearson product-moment correlation coefficient. The significance level was set at 5%.

RESULTS: We can confirm there is no difference in speed between left and right contact phases (Figure 2a). Contact time only had significant difference; left contact time was longer than right (Figure 2c), however, inward impulse and mean inward GRF did not have significant differences (Figure 2b&d). We conform a significant correlation between asymmetry in inward GRF and mean inward GRF during the left (r=-0.78) and right (r=0.68) contact phase (Figure 3).

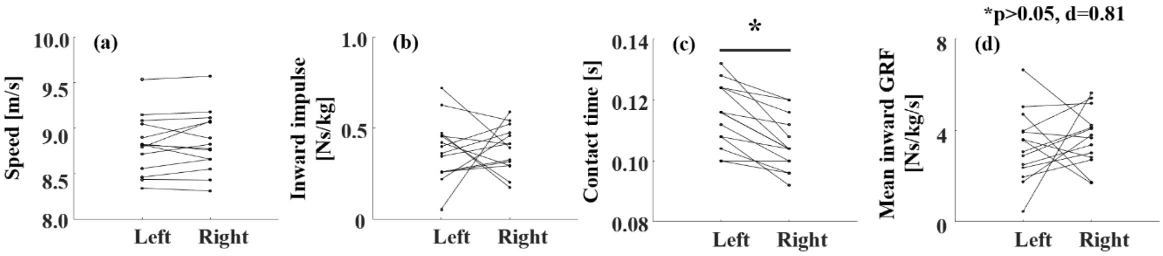

Figure 2: Differences between left and right contact phases in speed (a), inward impulse (b), ground contact time (c) and mean inward GRF (d).

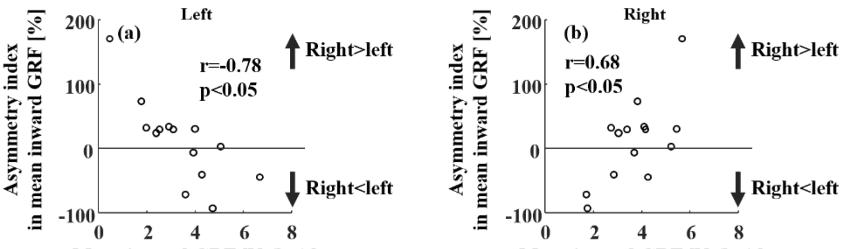

Figure 3: The correlation between asymmetry index in mean inward GRF and the magnitude of mean inward GRF for left (a) and right (b) contact phases.

In the correlation between mean inward GRF and lower joint torques, there were significantly negative correlations in hip abduction torque (r=-0.56) and ankle dorsiflexion torque (r=-0.61) during the left contact phase. Since all sprinters exhibited plantarflexion torque, the greater mean inward GRF is led to greater plantarflexion torque during the left contact phase. Conversely, a significant positive correlation was found in hip abduction torque (r=0.62) during the right contact phase (Figure 4). In the correlation between mean inward GRF and inward inclination and inward tuning of the hip extension/flexion axis, and foot inward turning at touchdown, there was no significant correlation in all parameters for both left and right contact phases (Figure 5).

DISCUSSION: In fourteen male sprinters having no difference in speed between left and right contact phases, this study resulted no significant differences in inward impulse and mean inward GRF between left and right contact phase (Figure 2). In addition, the symmetry index was depending on the among of both inward GRF (Figure 3). These results suggest that

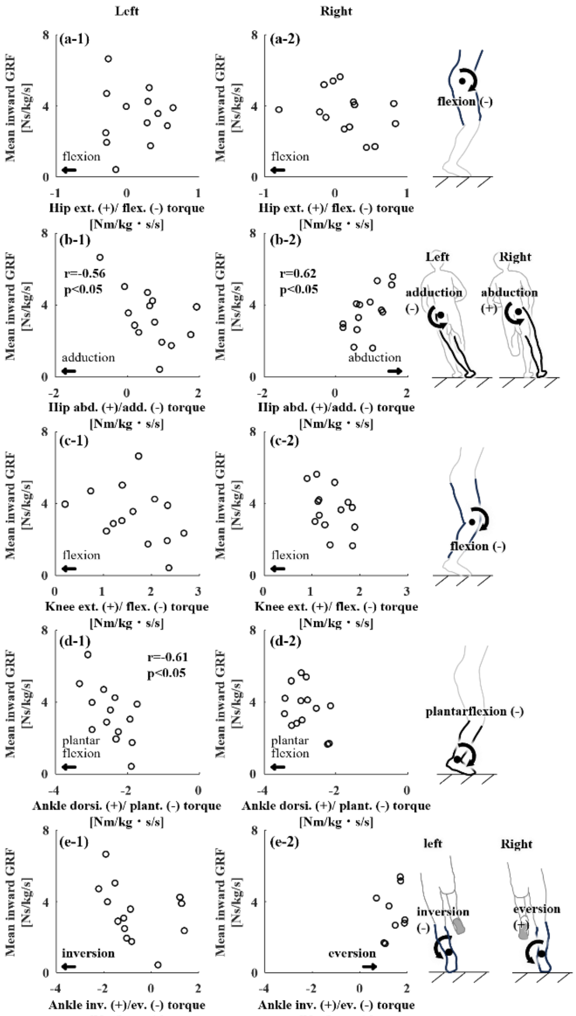

Figure 4:
The correlation between mean inward GRF and mean joint torque.

The left and right columns represent data for the left and right contact phase, respectively.

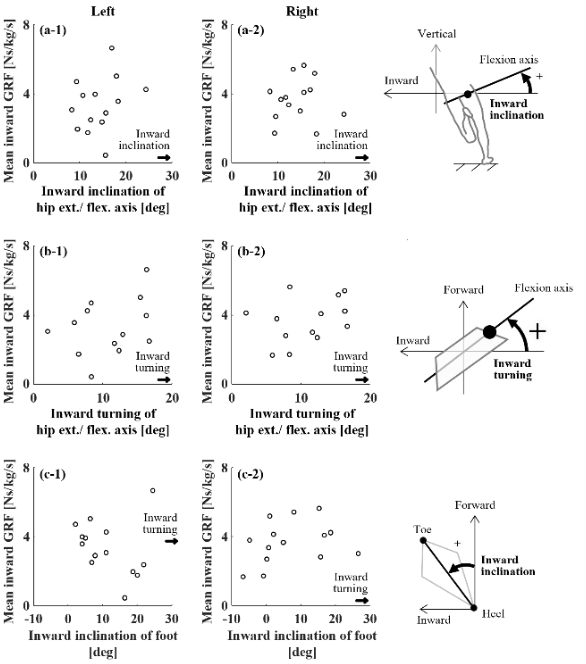

Figure5:
The correlation between mean inward GRF and inward inclination (a), inward turning (b) angles in the axis of hip extension/flexion, and foot inward turning angle (c).

The left and right columns represent data for the left and right contact phase, respectively.

asymmetries in inward GRF may not necessarily be evident, contradicting previous studies that reported a larger impulse during the left contact phase compared to the right contact phase (Churchill et al., 2016; Ishimura & Sakurai, 2016). To further identify the factors influencing the amount of inward GRF during each contact phase, we assessed the correlation between mean inward GRF and joint torque as well as the relationship between joint torque and the action direction of joint flexion torque at touchdown. Significant correlations were observed between mean inward GRF and hip abduction torque, with negative correlation during the left contact phase and with positive correlation during the right contact phase (Figure 4b). These results suggests that large inward GRF is influenced by the absence of inward pushing during the left contact phase, whereas it is influenced by outward pushing during the right contact phase. The left contact phase seemed to involve a shift in the action direction of ankle plantarflexion, as mean inward GRF exhibited a significant correlation with ankle plantarflexion torque (Figure 4e-1). However, the inward turning of the left foot did not result a significant positive correlation with the mean inward GRF. Conversely, there was a trend towards greater mean inward GRF when the foot was facing in the forward direction (Figure 5c-1). A significant inward GRF during the left contact phase can also be generated by shifting the ankle plantarflexion axis. Luo & Stefanyshyn (2012) demonstrated that in wedged footwear, the average eversion angle of the inside leg (left leg in this study) ankle reduced, resulting in a significant increase in plantarflexion torque generation. They suggested that inward inclination associated with curved sprinting positions the ankle joints in extreme internal/eversion, potentially hindering ankle moment generation. These findings suggest that ankle torque generation during ankle plantarflexion also influences inward GRF.

The limitations of this study include our inability to determine the reasons for the variations in the degree of asymmetry among sprinters. If sprinters adjust the degree of asymmetry to match their own motion, there may be optimal techniques for each sprinting motion to run faster on a curved path. We aim to address these limitations though further studies that incorporate sprinting motion data on a straight path.

CONCLUSION: We challenged to assess the factors influencing the application of inward GRF during left and right contact phases in curved sprinting. Based on the significant correlation between mean inward GRF and hip abduction torque, we suggest that large inward GRF is influenced by the absence of inward pushing during the left contact phase, whereas it is influenced by outward pushing during the right contact phase. Furthermore, the left contact phase seems to involve a shift in the action direction of ankle plantarflexion, as mean inward GRF showed a significant correlation with ankle plantarflexion.

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