ANALYSIS OF ANGULAR MOMENTUM IN HURDLING BY WORLD AND JAPANESE ELITE SPRINT HURDLERS

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The purpose of this study was to investigate the characteristics of the angular momentum of the limbs during the airborne phase of sprint hurdling. Twenty-nine male hurdlers participated in this study. Their hurdling motions at the seventh hurdle were videotaped using two high-speed cameras. During the first half of the airborne phase, the faster hurdlers required a large angular momentum of the lead leg, which they compensated for by a large counter direction of angular momentum in the trail leg. During the second half of the airborne phase, faster hurdlers swung the lead leg for a shorter duration by adjusting the head and trunk. However, if hurdlers overemphasise the downward motion of the lead leg, this can result in excessive backward and left leaning of the trunk upon landing.

KEY WORDS: motion analysis, lead-leg, shorter duration.

INTRODUCTION: The hurdling motion can be separated into three phases: the take-off phase, the airborne phase, and the landing phase. As no external forces except for gravity act on the body during the airborne phase, the total angular momentum of the entire body is conserved during the airborne phase. This means that we can quantify the kinetic function of the trunk and each limb by using the law of conservation of angular momentum during the airborne phase. McDonald and Dapena (1991) studied the angular momentum of the entire body during hurdling. They observed that the fast downward motion of the lead leg just before touchdown was produced primarily by the transfer of angular momentum from the trail leg. However, as La Fortune (1991) and Coh (2004) reported, a faster hurdler spends less time airborne during a race. Therefore, it is important to analyse the characteristics of the angular momenta of the entire body, trunk and each limb based on the law of conservation of angular momentum in order to obtain suggestions for improving hurdling performance. The purpose of this study was to investigate the characteristics of angular momentum of each limb during the airborne phase in sprint hurdling.

METHODS: Twenty-nine male hurdlers (Height: 1.84 ±0.05 m, Mass: 74.6 ±6.9 kg, Time in analysed race: 13.77 ±0.45 s) participated in this study. The motions from the touchdown of the takeoff leg (i.e. trail leg) at the seventh hurdle to the takeoff of the lead leg at the seventh hurdle during official competitions (including the IAAF World Championships in Athletics) were videotaped using two high-speed VTR cameras (200, 250 or 300 Hz). Much such data have been videotaped by the Scientific Committee of the Japan Association of Athletics Federations. The positions of 25 body landmarks and calibration marks in the projected images were digitised by using a motion analyser (Frame-DIASII, DKH, Japan). Then we calculated the three-dimensional coordinates by using the Direct Linear Transformation method (Abdel-Aziz & Karara, 1971). The coordinate data were smoothed using a Butterworth low-pass filter with optimal cut-off frequencies, which were determined by the residual error method proposed by Wells & Winter (1980). Figure 1 shows the classification of the movement phases. LN is the point of zero of the X component of the angular momentum of the lead leg (McDonald & Dapena, 1991). The angular momentum of each segment in the global coordinate system was calculated by using the method proposed by Dapena (1978). The calculated values were normalised by the square of body height and body weight (the unit of angular momentum was s^{-1}). To take into consideration the kinetic function of the body segments, we divided the body into five groups: head and trunk (HT); arm on the side of the lead leg (AL); arm on the side of the trail leg (AT); lead leg (LL); and trail-leg (TL). The amount of change in the angular momentum of each group during each phase and the duration of each phase were calculated. Correlation coefficients between the calculated values and average running velocity were calculated using Pearson's Product - Moment correlation coefficient (r).

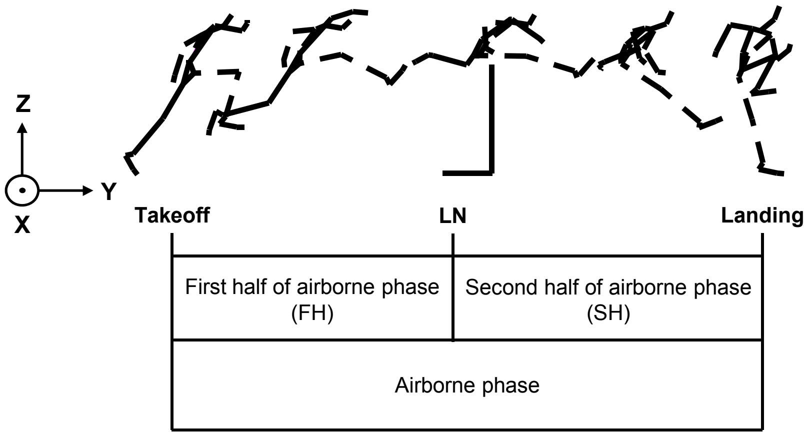

Figure 1: Classification of the movements.

RESULTS: Figure 2 shows the relation between the average horizontal velocity and the duration of each phase. There was a significant negative correlation between the running velocity and the duration of the second half of the airborne phase (SH; r = -0.687, p<0.001). However, there was no significant correlation between the running velocity and the duration of the first half of the airborne phase (FH). Figure 3 shows the amount of change in angular momentum during the FH and the SH for all body groups. There was a significant positive correlation between the running velocity and the amount of change in angular momentum of the HT about the Y-axis (SH: r = .511, p <0.01). There were significant negative correlations between the running velocity and the amount of change in the angular momentum of the LL about the X-axis (FH: r = -.457, p <0.05, SH: r = -.482, p <0.01) and the Y-axis (SH: r = -.576, p <0.01). Finally, there was a significant positive correlation between the running velocity and the amount of change in the angular momentum of the TL about the X-axis (FH: r = .409, p <0.05).

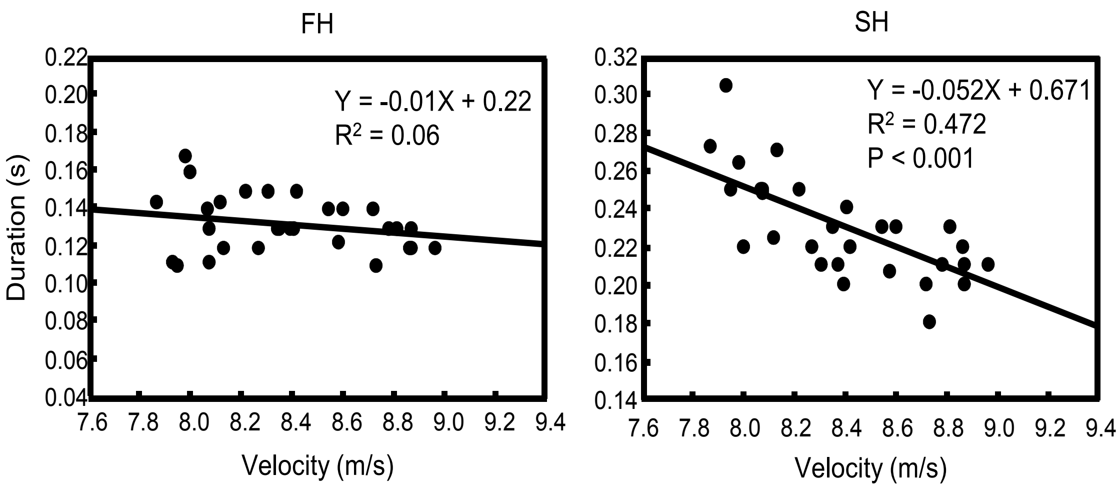

Figure 2: Relationship between average horizontal velocity and duration of each phase.

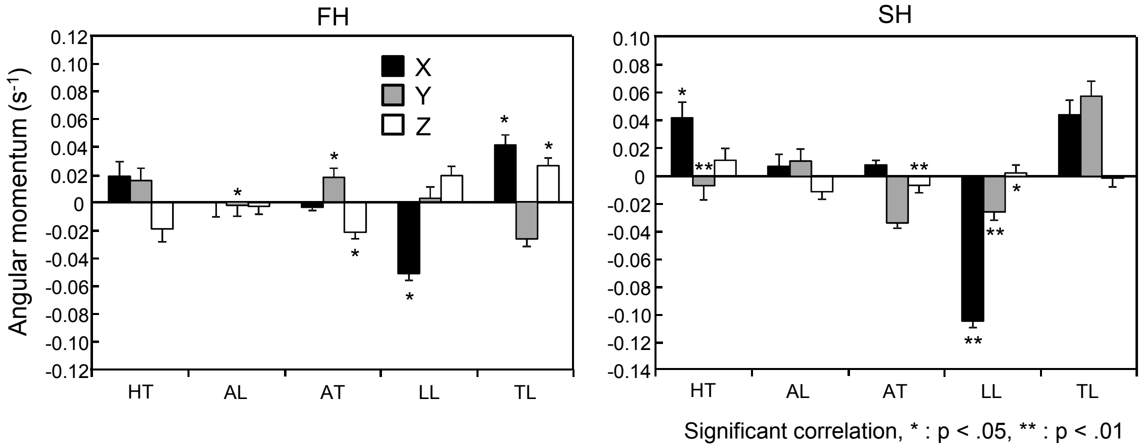

Figure 3: The amount of change in angular momentum during FH (left) and SF (right) of body groups.

DISCUSSION: Faster hurdlers exhibit a larger decrease in angular momentum in the LL and a larger increase in angular momentum in the TL about the X-axis during FH. Shibayama et al. (2011) reported that faster hurdlers positioned the thigh of the LL near the perpendicular axis at takeoff. Therefore, faster hurdlers have a large distance from the body CG (centre of gravity) to the CG of the LL. This means that faster hurdlers need a large positive angular momentum of the LL at takeoff, which they compensate for with a large counter direction of angular momentum in the TL. Also, faster hurdlers have a large decrement in angular momentum of the LL about the X-axis and the Y-axis during SH. In addition, they have a large increment in the angular momentum about the X-axis and a small decrement in angular momentum about the Y-axis of the TL. Also, they exhibit a shorter SH. Therefore, faster hurdlers swing their LL for a shorter duration by compensating with the HT. McDonald and Dapena (1991) reported that the downward motion of the LL was produced mainly by a transfer of angular momentum from the TL. However, the results of this study indicate that the large positive change in the angular momentum of the TL about the X-axis during FH did not influence the downward motion of the LL during SH but the upward motion of the LL during the FH. However, if hurdlers overemphasise the downward motion of the LL, this can result in excessive backward and left leaning of the trunk upon landing. Consequently, this study suggests that hurdlers need to change their LL downward motion depending on their running velocity.

CONCLUSION: The results of this study revealed that faster hurdlers had a large decrement in the angular momentum of the lead leg, which they compensate using their trail leg during the first half of the airborne phase, and with the head and trunk during the second half of the airborne phase. It is important for shorter-duration hurdling motions to associate lead leg motion with head and trunk motion.

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