HOW HITTING THE HURDLE AFFECTS PERFORMANCE IN THE 110 M HURDLES

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This study aimed to clarify the kinematic factors of hurdle hitting and its effect on the performance in 110-m Hurdles. Three male hurdlers volunteered. The trial which from start to the second hurdle was conducted about 20 times and these trials were recorded by motion capture system with 240 Hz. From all trials, 19 Non-Hitting Trials (NHT) and 33 Hitting Trials (HT) were classified. Kinematic variables and hitting grade, which is a value obtained by root mean square of the acceleration of hurdle's bar, were calculated. As a result, the cause of hitting the hurdle was the low height of centre of mass (CoM) of the body at the take-off. Moreover, hitting grade was correlated with decrease in velocity by hurdle hitting during the hurdle clearance phase (r = 0.43). Furthermore, a decrease in running speed after landing at the first hurdle was also confirmed in HT trials.

KEYWORDS: failure motion, athletics, performance deterioration

INTRODUCTION: The 110-m hurdles is a specific track event that is combining sprint and hurdle clearance. In particular, hurdle clearance technique is an important element to improve performance (Coh & Iskra, 2012). Therefore, many researchers have been analyzing the hurdle clearance technique (1991; McLean, 1994; McDonald, 2002; Coh & Iskra, 2012). These researches mostly analyzed the motion without hitting the hurdle, however, hurdle hitting occurs frequently during the 110-m hurdles race.
In the race, hurdler decelerates after reaching the maximum speed in the middle. Decrease in speed should be influenced by hitting the hurdle. Pollitt et al. (2018) reported a case that the hurdler greatly decelerated such as race rank fell by hitting the hurdle. In contrast, Graubner & Nixdorf (2011) reported a case that the hurdler broke a record and won the race despite great hit that fall the first hurdle. From this literature, hurdle hitting may not necessarily be negative. It is pointed out that the 110-m hurdles have the highest rate of hurdle hitting because its hurdle is the highest in all hurdle events (Pollitt et al., 2018). Analyzing the rate of hitting the hurdles using Pollitt et al. (2018) data, it was found that the rate of hitting the hurdle is 35 – 40%. However, previous studies did not mention the kinematic factor of hitting the hurdle. In general, the cause of hitting the hurdle has been thought of as short take-off distance and low take-off angle, however, these conjectures have not been verified scientifically.
This study aimed to clarify the kinematic factors of the cause and effect of hitting the hurdle. We form two hypotheses: 1) the cause of hitting the hurdle are shortening the distance between take-off horizontal position and hurdle and decreasing the take-off angle, and 2) the effect of hitting the hurdle is decrease in velocity during hurdle clearance and after landing by disordered posture, and this effect is large as increasing hitting grade.

METHODS: Three male hurdler (20.3 ± 0.5 years, 1.78 ± 0.03m, 70.8 ± 3.8 kg, personal best = 14.82 ± 0.41 sec) participated in this study. In all participants, lead leg was right and trail leg was left. After a warm-up, participants were asked to perform trial from the start to the second hurdle with maximum effort. This trial was repeated about 20 times with enough rest. Through the experiment, data of 33 Hitting trials (HT) and 19 Non-Hitting trials (NHT) were collected.
A motion capture system consisting of 16 cameras (Vicon bonita3, Oxford, UK) were used to record the hurdle clearance phase with 240 Hz. Furthermore, the section from the start to the

first hurdle (approach) and the section from the first hurdle to the second hurdle (interval) was recorded by the high-speed camera with 120Hz and 240Hz respectively. We used the whole body marker set with 43 makers and a hurdle marker attached centre of the other side of the bar. The position coordinates of the markers were smoothed using a Butterworth low-pass digital filter with a cut of frequency of 8 – 19 Hz. The whole body kinematic model was used for the following analysis included 15 rigid segments (head, upper trunk, lower trunk, upper arms, forearms, hands, thighs, shanks and feet). The centre of mass (CoM) of each segment and the whole body were calculated using the body partial inertia coefficient (Ae et al., 1992). The hip joint centre was estimated according to Harrington et al. (2007). Lower limb kinematic variables were global angle were calculated as follows: angle of hip joint, knee joint and leg which was defined as the vector pointing from the hip to the ankle (Figure 1). The take-off parameters which are the distance between the toe of lead leg and hurdle's bar, angle and horizontal and vertical velocity were calculated. Step parameters which are step length (SL) and step frequency (SF) during interval and running speed which is the product of SL and SF were calculated. The degree of hitting the hurdle was defined as the value obtained by root mean squares (RMS) processing the acceleration of the hurdle marker. The RMS processing time was from release on take-off leg to contact on landing leg. Decrease in velocity during hurdle clearance phase was defined as the difference of CoM horizontal velocity between take-off and landing.
The Mann-Whitney U test was used to compare the parameters between NHT and HT. Furthermore, The Spearman's rank correlation coefficient was used to analyze the relationship between the degree of hitting the hurdle and decrease in velocity. The statistical significance level was set at $p < 0.05$.

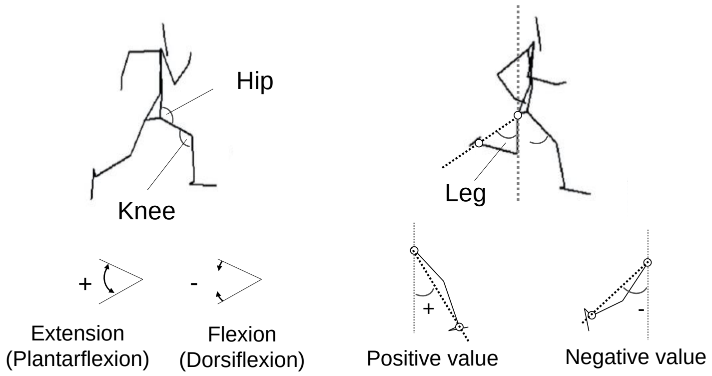

Figure 1: Definition of lower limb joint and segment angles

RESULTS: In the take-off parameters, there was no significant difference. Table 1 shows that the height of the CoM of the whole body, lower trunk, lead leg thigh, shank, foot and trail leg thigh at the take-off were significantly lower in HT than those in NHT. Table 2 shows that the lower limb joint and segment angle of lead leg at the take-off and landing. At the take-off, leg segment of the lead leg was significantly more swinging up in NHT than that in HT and knee joint of the lead leg was significantly more extension in NHT than that in HT. The CoM horizontal velocity and leg angle of the lead leg at the one step before the take-off were significantly lower in HT than those in NHT. (HT: velocity = 7.59 ± 0.18 m/s, leg angle = -54.5 ± 5.9 deg; NHT: velocity = 7.70 ± 0.19 m/s, leg angle = -50.1 ± 6.8 deg, $p < 0.05$). In the lower limb motion at the landing, lead leg angle was significantly larger in HT than that in NHT and hip joint angle was significantly flexion in HT than that in NHT.
Figure 2 shows that there was a positive correlation between the degree of hitting the hurdle and decrease in velocity during hurdle clearance ($r = 0.43$, $p < 0.05$). This relationship tended to differ depending on the body part of hitting the hurdle. At the landing, CoM horizontal velocity was slightly lower in HT than that in NHT (HT: 6.88 ± 0.22 m/s; NHT: 6.98 ± 0.20 m/s, p =

0.05), then CoM horizontal velocity at the following release of the landing step was significantly lower in HT than that in NHT (HT: 7.10 ± 0.18 m/s; NHT: 7.23 ± 0.20 m/s, $p < 0.05$). Regarding the interval running, average running speed and average SF were significantly lower in HT than those in NHT(HT: running speed = 7.90 ± 0.22 m/s, SF =4.71 ± 0.14 Hz; NHT: running speed = 8.15 ± 0.22 m/s, SF = 4.86 ± 0.11 Hz, $p < 0.05$).

Table 1: The height of CoM of whole body, upper body and lower limb

	NHT	HT	
Whole body (m)	1.18 ± 0.03	1.16 ± 0.03	*
Head (m)	1.61 ± 0.03	1.60 ± 0.03	
Upper trunk (m)	1.43 ± 0.02	1.42 ± 0.02	
Lower trunk (m)	1.13 ± 0.03	1.11 ± 0.03	*
Lead leg thigh (m)	1.02 ± 0.05	0.99 ± 0.05	*
Lead leg shank (m)	0.90 ± 0.06	0.86 ± 0.05	*
Lead leg foot (m)	0.65 ± 0.07	0.60 ± 0.06	*
Trail leg thigh (m)	0.76 ± 0.02	0.75 ± 0.02	*
Trail leg shank (m)	0.46 ± 0.01	0.46 ± 0.01	
Trail leg foot (m)	0.23 ± 0.01	0.22 ± 0.01	

Values are expressed mean ± SD.
*: Significance difference between NHT and HT ($p < 0.05$).

Table 2: Lower limb joint and segment angle of lead leg at the take-off and the landing

	Take-off			Landing		
	NHT	HT		NHT	HT	
Lead leg						
Hip joint (deg)	76.7 ± 5.8	78.3 ± 5.6		119.0 ± 1.9	113.9 ± 2.9	*
Knee joint (deg)	84.4 ± 8.7	77.3 ± 7.7	*	146.6 ± 2.2	147.6 ± 3.1	
Leg (deg)	53.1 ± 7.1	48.5 ± 7.6	*	16.6 ± 2.1	19.0 ± 2.5	*

Values are expressed mean ± SD.
*: Significance difference between NHT and HT ($p < 0.05$).

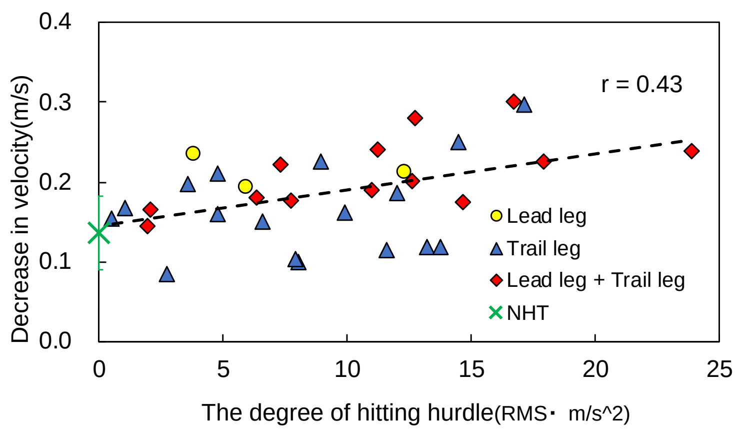

Figure 2: Relationship between the degree of hitting hurdle and decrease in velocity

DISCUSSION: This novel study succeeded to reveal the kinematic factors of hitting the hurdle. As regards the cause of hitting the hurdle, our hypotheses that take-off position is close to the hurdle and take-off angle is low were not supported. The height of CoM was only 2.0 cm lower in HT than in NHT. This is only a 2.0 cm difference, but a difference of 2 cm was also found

just above the hurdle. This 2.0cm would be a major factor in deciding whether or not to hit the hurdle. In the case of HT, the hurdler entered the take-off phase with low CoM horizontal velocity and the lead leg was more kicked backwards during the same phase. This motion may indicate that hurdlers were kicking more backwards to compensate for the lower running speed. These may be the reason for the delay of leg recovery, and consequently swing up of lead leg at the take-off was insufficient. Due to these lead leg motions, it can be assumed that the CoM of the whole body at the take-off became low in HT.
As for the effect of hitting the hurdle, it was confirmed that a distinct decrease in velocity during hurdle clearance phase occurred by hitting the hurdle. This result supported our hypotheses. In addition, although case example, it seems that the decrease in velocity of hurdle hitting with lead leg (Figure 2, circle dots) was larger than that with trail leg (triangle dots) regardless of the degree of hurdle hitting. The reason why is because the hit with lead leg occurs in the first half of hurdle clearance phase, and consequent the duration in decrease in velocity becomes longer. Coh (2003) also reported that the horizontal velocity of hurdle clearance depends on the horizontal velocity of swing up of the lead leg. Thus, it is considered that the hit with lead leg directly leads to the large decrease in velocity during the hurdle clearance. Furthermore, leg angle of the lead leg at the landing was larger in HT than that in NHT. This motion may increase the breaking phase. Coh & Iskra (2012) reported that one of the most essential factors in hurdle clearance techniques is shortening the breaking phase at the landing. In the case of HT, CoM horizontal position was located more backward at the landing, so that the breaking phase probably became longer and the subsequent interval running speed decreased. From the above, it was found that hitting the hurdle not only directly decreased hurdle clearance velocity, but also had a negative effect on the sprinting just after landing.

CONCLUSION: This study aimed to clarify the kinematic factors of the cause and effect of hurdle hitting in 110-m hurdle. We newly found that the cause of hitting the hurdle was the low vertical position of CoM at the take-off. This posture may have been caused by lead leg motion. Regarding the effect of hitting the hurdle, direct decrease in velocity during hurdle clearance phase by hurdle hitting was confirmed, and it tended to increase especially for the hit with lead leg. In addition, inefficient landing motion derived from the hurdle hitting caused a decrease in the running speed thereafter.

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