STEP-TO-STEP ANALYSIS OF ANTEROPOSTERIOR GROUND REACTION FORCE DURING 110 M HURDLE

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The purpose of this study was to examine acceleration and deceleration profiles throughout the hurdle sprint until the 5th hurdle in terms of step-to-step ground reaction force. Four male collegiate hurdlers (performance range: 13.73–14.27 s) performed two maximal effort 60 m hurdle sprint. Ground reaction forces from the start to the 50 m mark was measured using 54 force platforms. The braking and propulsive impulse, the running speed and the amount of change of the speed at each step were calculated. The results demonstrate that the force application profiles were different among four steps in one interval of a hurdle sprint, indicating a different role of each step in the interval. Moreover, the role of steps in each interval likely does not change across the four intervals.

KEYWORDS*:* braking impulse, propulsive impulse, running speed.

INTRODUCTION: Sprinting and jumping abilities are of great importance for better performance in many sports. A 110 m hurdle sprint requires both abilities for accomplishing better performance. In a 110 m hurdle race, ten 1.067 m hurdles are arranged regularly (the distance from starting line to the 1st-hurdle is 13.72 m, and that between two consecutive hurdles is 9.14 m). Hurdlers take 7 or 8 steps from the start to the 1st-hurdle and four steps (take-off and landing step and two interval sprint steps) between the hurdles regardless of performance levels. To clear the hurdles and to run the intervals, hurdlers perform asymmetrical leg movements. Thus, each of four steps between two consecutive hurdles will have different characteristics. Accordingly, it would be interesting to investigate how hurdlers increase or decrease running speed for each step between hurdles. Running speed is changed by the force applied onto the ground. It has been reported that the horizontal ground reaction force (GRF) acting on the centre of mass was largest during the sprint acceleration phase and decreased as the speed increased (Morin et al., 2012; Nagahara et al. 2017). Previous studies of the hurdle sprint that investigated step-to-step changes have only reported kinematic features. For example, Hay (1986) and Ito and Togashi (1997) demonstrated that by the instant of take-off the horizontal velocity decreases while the vertical velocity increases for changing the direction of the movement of the whole body to clear the hurdle. Moreover, they also showed that, a hurdler must accelerate between the hurdles. Although their studies provided useful information for understanding the characteristics of the hurdle sprint, step-to-step changes in GRF during the hurdle sprint will bring deeper understanding of the role of each step during one interval and the changes of running speed in each interval. The purpose of this study was to examine acceleration and deceleration profiles throughout the hurdle sprint until the 5th hurdle in terms of step-to-step ground reaction forces.

METHODS: Four male collegiate hurdlers (Mean ± SD: 1.78 ± 0.07 m, 78.5 ± 3.2 kg, age: 23 ± 2.2 y) participated in this study. Their personal 110 m hurdle official best time was 14.02 ± 0.23 s (range: 13.73–14.27 s). Written informed consent was obtained after explaining this study.
The hurdlers performed two maximal effort 60 m hurdle sprints from starting blocks. GRFs from the start to the 50 m mark was measured using 54 force platforms (TF-90100, TF-3055, TF-32120, Tec Gihan, Uji; 1000 Hz). Four of the 54 force platforms, placed under the starting location, measured GRFs produced by both hands and feet at the crouch start. A photocell

system (TC Timing System; Brower Timing Systems, Draper, UT, USA) measured the hurdle sprint time.
The noise in the GRF signal was reduced using a 4th-order Butterworth low-pass filter at 80 Hz. The cut-off frequency was decided based on a residual analysis. Foot strike and toe-off instants during sprinting were determined using a filtered vertical GRF at threshold of 30 N. Foot placement was determined as the centre of pressure (COP) position at the middle of the support phase. The filtered anterior–posterior force at each step was integrated using the trapezoid formula to obtain the propulsive and braking impulses. The propulsive and braking impulses were normalized by dividing by body mass. Because the sum of propulsive and braking impulses does not take into account the influence of aerodynamic drag, serial changes in running speed was calculated integrating the mass-specific anteroposterior GRF with taking into account the aerodynamic drag, which was calculated with body height and mass, along with the aerodynamic friction coefficient (Colyer, Nagahara, & Salo, 2018) (Figure. 1). Step-to-step changes in running speed were calculated as the difference in serial running speed from the toe-off instant to the next toe-off instant of the other leg. An example of the changes in running speed is shown in Figure 2. Moreover, four steps in each interval was defined as follows: take-off step (TS), landing step (LS), first interval step (1st-IS), and second interval step (2nd-IS).

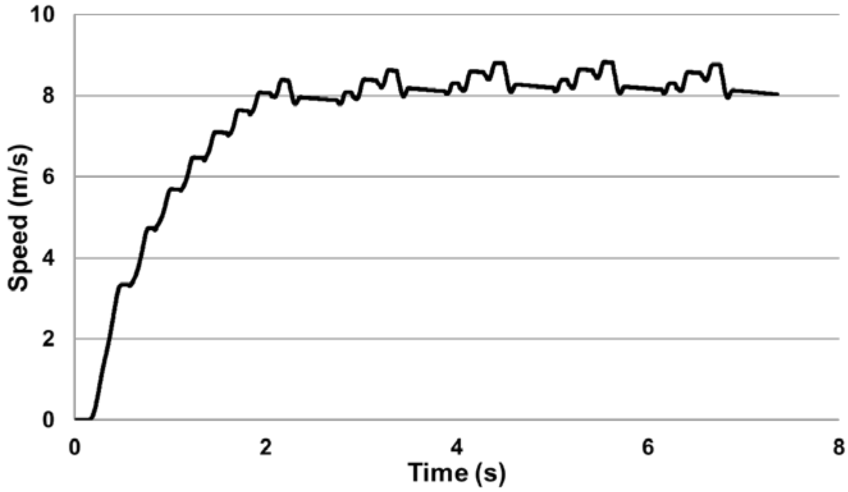

Figure 1: Changes in running speed in the hurdle sprint.

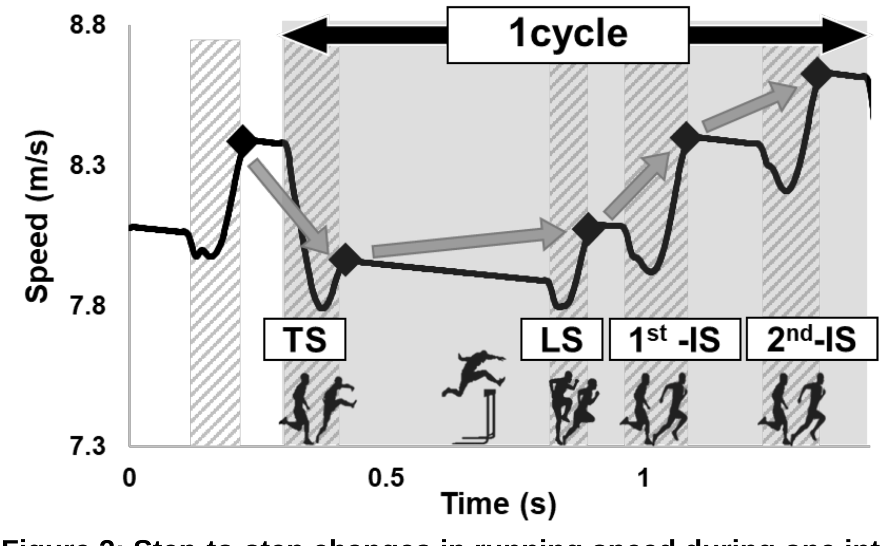

Figure 2: Step-to-step changes in running speed during one interval. The instants of toe-off are shown using diamonds. The areas filled with a stripe pattern show the support phases.

RESULTS: The propulsive and braking impulses change during the support phase in the hurdle sprint (Figure 3). The braking impulse was the largest at the TS (-0.62 ± 0.09 Ns/kg), and the value decreased to LS (-0.10 ± 0.01 Ns/kg), increased to 1st-IS (-0.15 ± 0.01 Ns/kg), and decreased to 2nd-IS (-0.14 ± 0.01 Ns/kg). The propulsive impulse increased from TS (0.21 ± 0.02 Ns/kg) to 1st-IS (0.47 ± 0.03 Ns/kg) and then decreased to the next TS (0.22 ± 0.02 Ns/kg).

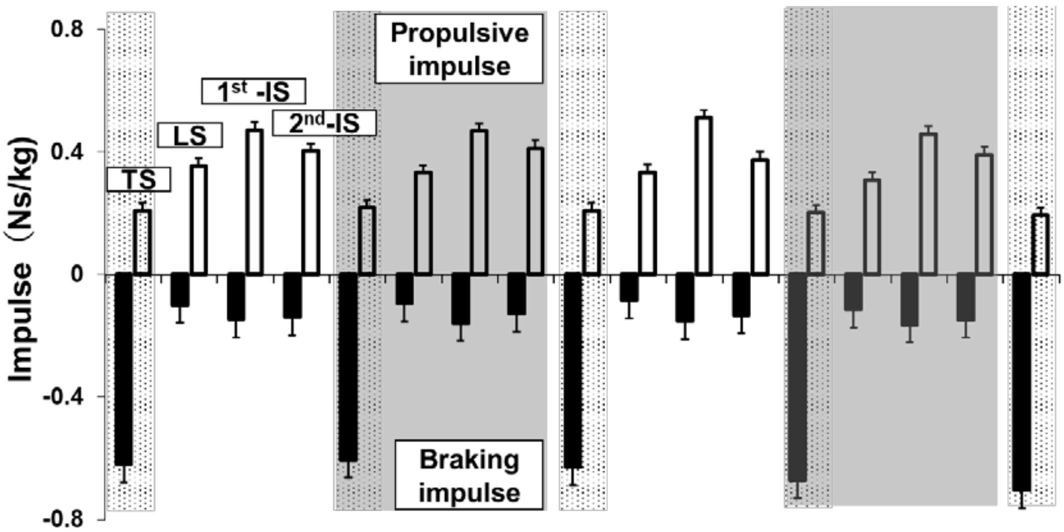

Figure 3: Step-to-step changes in the propulsive and braking impulses during the support phase for four intervals. The TS were shown with dotted background.

Figure 4 shows comparisons of changes in running speed at each step between the hurdle sprint. The TS showed the largest decrease in running speed (-0.48 ± 0.07 m/s), while 1st-IS produced the greatest increment of running speed (0.28 ± 0.05 m/s). The amount of changes in running speed at each step in each interval nearly unchanged through the four intervals along with the large fluctuation of running speed within one interval.

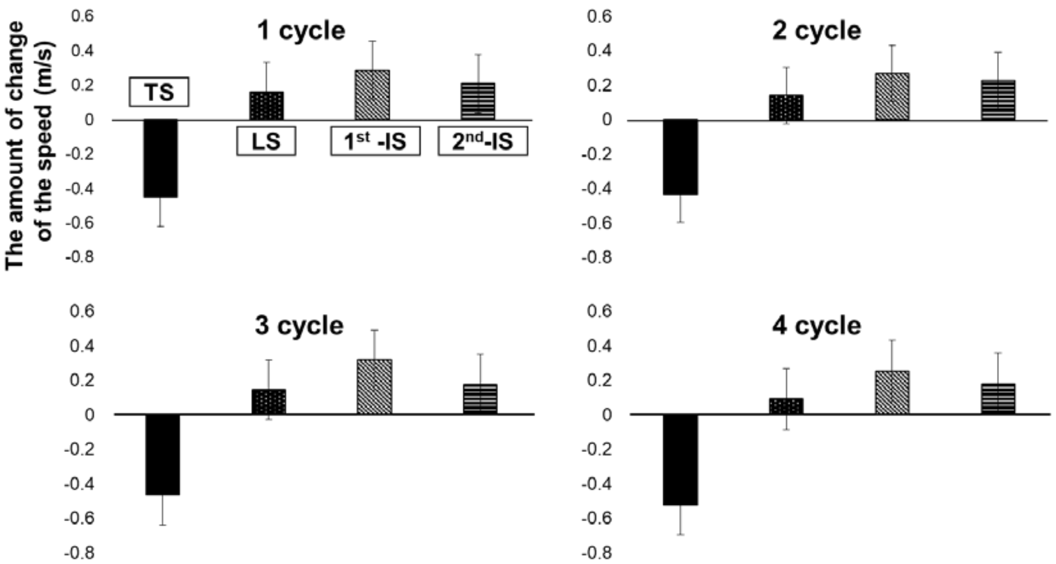

Figure 4: The amount of changes in running speed at each step in the hurdle sprint for four intervals.

DISCUSSION: To the best of our knowledge, this study is the first to investigate the step-to-step changes in GRFs during the hurdle sprint until the 5th hurdle. The results demonstrate, based on the observational approach, that the force application profiles were different among four steps in one interval of hurdle sprint. Specifically, the hurdlers accelerated for three steps before TS, and decelerated greatly at TS (Figure 4). This large deceleration at TS is probably generated to produce vertical force for elevating the body to clear the hurdle as indicated in previous studies (Hay, 1986; Ito & Togashi, 1997). Among the three steps before TS, 1st-IS showed the largest increment of speed, even though the running speed at the foot strike of LS was smallest (Figure. 2). These results indicate that the role of LS is likely to shift from jumping to running. When considering the braking and propulsive impulses, the smaller increment of running speed in 2nd-IS than in 1st-IS is probably led by not the greater braking impulse but the smaller propulsive impulse (Figures 3 and 4). These results demonstrate that the hurdlers would produce smaller propulsive force during the latter half of the support phase in 2nd-IS to prepare for the next TS.

Focusing on the cycle (from TS to 2nd -IS) -to-cycle difference, the changes in running speed at each step during the hurdle sprint were nearly unchanged through the four intervals (Figure 4). This indicates that the role of each step likely does not change across the four intervals. The fact that the profile of changes in running speed in each interval did not differ may suggest that the improvement of steps in one interval will improve the entire performance greatly.

CONCLUSION: The present study demonstrates that the force application profiles were different among four steps in one interval of hurdle sprint, indicating that the role of each step in one interval during the hurdle sprint is different. Moreover, the roles of steps in each interval likely does not change across the four intervals. The findings in the current study would be useful for hurdlers and coaches to consider training modalities and programs.

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