GROUND REACTION FORCE OF THE FIRST TRANSITION DURING ACCELERATED SPRINTING: A PILOT STUDY

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This study aimed to show changes in step-to-step ground reaction forces around the first transition during maximal accelerated sprinting with a typical sprinter. One male sprinter performed five 60-m maximal accelerated sprints, during which ground reaction forces through 50 m were recorded with 54 force platforms. There were sudden shifts of values for step frequency, support time, vertical impulse and braking and propulsive mean forces at around the 5th step as the first sprint transition. These sudden shift of variables support the concept of sprint transition during acceleration phase. The findings of this study would be interesting for the future study of locomotor control and practically useful for considering the strategy of accelerated sprinting.

KEY WORDS: locomotion, running, kinetics, acceleration.

INTRODUCTION: Accelerated sprinting ability to reach high speed is critical to short distance sprint running events and also to ball games (Slawinski et al., in press; Faude et al., 2012). Recently, Nagahara et al. (2014) have verified that there are two breakpoints at around the 4th and 14th step during the entire acceleration phase of sprinting, called "sprint transition." Around the first transition, it abruptly happens as a phenomenon of the first sprint transition that the magnitude of elevation of body center of gravity (CG) became small. Moreover, at the next step of the transition, it can be seen that increase in step frequency terminates, the foot starts contacting on the ground in front of the CG, and the knee joint starts to flex during the support phase. Although the kinematic features of the first sprint transition have been clarified, kinetic feature of it has never been investigated. Indeed, it would be interesting to explore what is happening around the first sprint transition in terms of step-to-step ground reaction force. The study of ground reaction force during the entire acceleration phase of maximal sprinting clarifies the function of the human bipedal locomotor system, and it could provide basic knowledge to improve accelerated sprinting performance. This study aimed to show changes in step-to-step ground reaction forces around the first transition during maximal accelerated sprinting with a typical sprinter.

METHODS: One well-trained male sprinter (age, 19 years; stature, 1.74 m; body mass, 68.0 kg; personal best 100-m time, 10.88 s) performed five maximal effort 60-m sprints in an indoor experimental site. The sprint was treated as a 100-m race with starting blocks, and the participant used his own crouched starting position. The surface of the running lane was the same as that of an official outdoor athletics track field. Fifty-four force platforms (1000 Hz) connected to a single computer (TF-90100, TF-3055, TF-32120, Tec Gihan, Uji, Japan) meausured ground reaction force during sprinting through 52-m from 1.5-m behind of the starting line to 50.5-m mark. The time of the 60-m sprint was recorded with a photocell system (TC Timing System, Brower Timing System, Draper, UT). The photocell system was set at sides of starting line, so that it was initiated by sprinter's hand when the movement started, and the 60-m mark. From the ground reaction force data, spatiotemporal variables, ground reaction impulses and mean ground reaction force were computed. The thresholds to detect foot strike and toe-off were set at 10 N of vertical force. Each step duration was determined from the foot strike of one leg to the next foot strike of the other leg. Step frequency was calculated as the inverse of step duration. Support time was defined as the duration of the foot touching the ground, and flight time was defined as the duration of neither foot touching the ground. Duty factor was calculated as a ratio of flight time in relation to support time. Position of the ground contact foot was determined as the center of pressure of ground reaction force on the ground during support phase at each step. Step length was calculated as the difference between the positions of the foot for two consecutive steps in the running direction. The running speed was calculated as a product of step length and frequency, in order to eliminate an influence of air resistance. Although changes in a CG height was calculated through the double integration of acceleration, which was deduced from vertical ground reaction force, with respect to time in this study, the computation did not provide reliable changes in value, because it was possibly affected by the noise of ground reaction force data, errors of data collection, and air resistance. The aforementioned all possible errors accumulate when computing the positional data for many steps, and the accumulation of the errors showed deviation of CG height from expected one, although this influence of the errors is normally ignored when investigating a locomotion with force platforms at one or two steps. Thus, the changes in the CG height was eliminated, whereas that was a key variable in a previous study to detect the transition (Nagahara et al. 2014).

RESULTS and DISCUSSION: This study firstly illustrated the changes in ground reaction force variables through the first sprint transition step, and this would provide deeper understanding of human locomotor system during accelerated sprinting. The time of 60-m sprint was 7.10 ± 0.07 s. Figure 1 shows ground reaction forces of a typical trial during the entire acceleration phase of maximal sprinting. The vertical and propulsive maximum forces increased and decreased to approximately the 17th step and then maintained, while the braking peak force gradually increased through the entire acceleration phase. Figure 2 shows the step-to-step changes in spatiotemporal variables during the acceleration phase. In line with a previous study (Nagahara et al., 2014), there were specific features of changes in values around the 5th step as the first sprint transition: increment of step frequency and great reduction of support time until the transition step, and the termination of increase in step frequency and the suspension of decrease in support time at the next step. These characteristic changes were found for all five trials of the participant. This demonstrates that the phenomenon of the first transition during maximal accelerated sprinting is highly repeatable and inevitable in so far as the sprinter in this study. Thus, the future study investigating whether similar results are obtained with other participants is suggested.

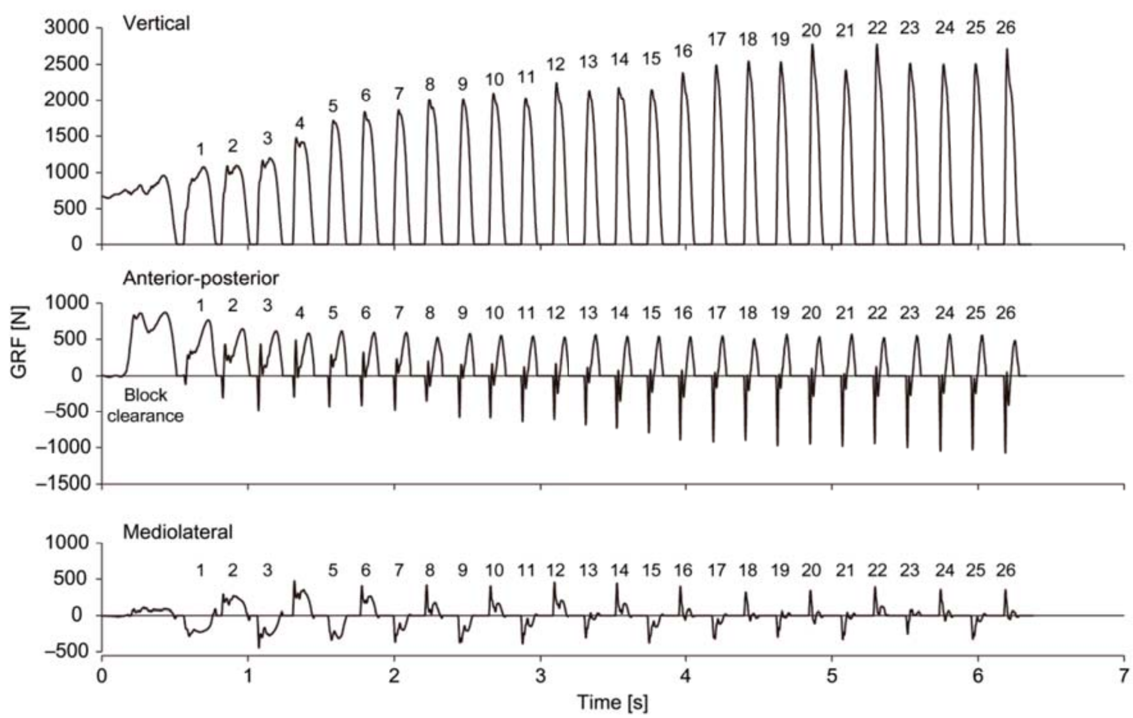

Figure 1: Ground reaction forces of a typical trial during the entire acceleration phase of maximal sprinting.

Figure 3 shows the step-to-step changes in ground reaction impulses and mean ground reaction forces during the entire acceleration phase of maximal sprinting. At the first transition (5th) step, the vertical impulse became small and the mean braking and propulsive forces were temporarily large. Integrating the aforementioned changes in spatiotemporal and ground reaction force variables, running speed acutely increased with increase in step frequency, decrease in support time, increase in mean braking force until the transition step, and the mean propulsive force temporarily increased at the transition step. At the next step of the transition, increase in step frequency terminated and decrease in support time temporarily suspended. Based on the context of these changes, it seems that the accelerated sprinting is disturbed by some sort of restriction of human locomotor system at the transition step, because of its irrational sudden changes. It is difficult at this time to conclude the reason of the sudden shift in ground reaction force at the first sprint transition. However, on the basis of the hypothesis that there are two different cyclic movement patterns before and after the first transition step, the fact that there are different features of ground reaction force at the transition in contrast to those before and after the transition step would be the proof of that the adjustment between two running patterns does not smoothly proceed around the transition step during the maximal accelerated sprinting. The deviances of kinetic variables at the transition step were also found in human walk-to-run transition (Segers et al., 2006). This similarity shows the possibility of that there is a transition of human locomotion under the maximal effort accelerated sprinting condition which caused by some constraints of human bipedal locomotor system.

Although our primary focus was to demonstrate the changes in variables around the first sprint transition, increasing braking impulse and mean force and, in contrast, maintaining propulsive impulse and mean force were found after the 15th step during accelerated sprinting. These results indicate that the acceleration strategy of sprinting changed at around the 15th step. That is, whereas increase in running speed became small with both decrease in propulsive impulse and increase in braking impulse until the 15th step, it became small only by increasing braking impulse after the 15th step. The step where the specific alteration was found during the acceleration phase in this study was similar to previously proposed

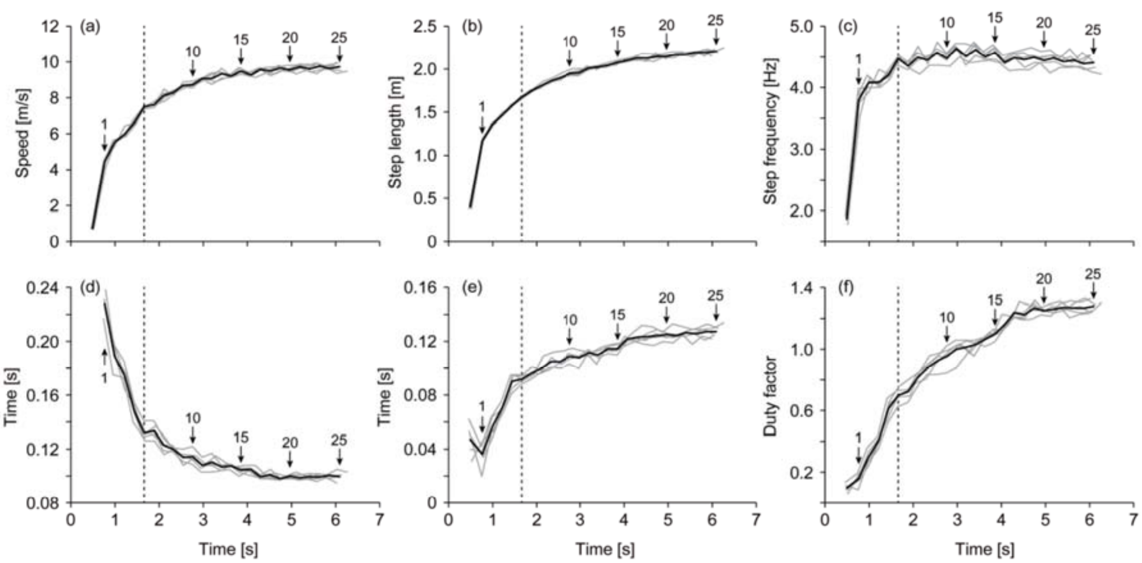

Figure 1: Step-to-step changes in spatiotemporal variables during accelerated sprinting. (a) running speed, (b) step length, (c) step frequency, (d) support time, (e) flight time, (f) duty factor. Gray and black solid lines are individual trials and mean value. Numbers with arrows indicates step number. Dotted vertical line at the 5th step shows the step of the first sprint transition. Block clearing phase was treated as step 0 and, for the support time, the data at the block clearance was excluded in order to prioritize a visibility of data from the 1st step.

second sprint transition at around the 14th step (Nagahara et al., 2014), and this supports the concept of dividing the acceleration phase at around the 14th or 15th step.

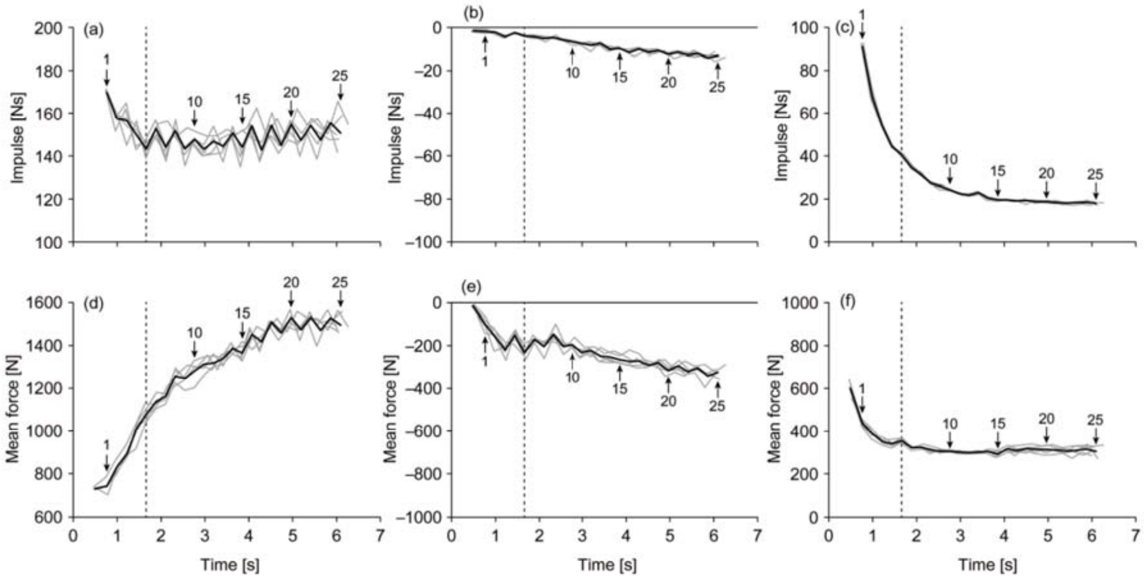

Figure 2: Step-to-step changes in ground reaction force impulses and mean ground reaction forces during accelerated sprinting. (a) vertical impulse, (b) braking impulse, (c) propulsive impulse, (d) mean vertical force, (e) mean braking force, (f) mean propulsive force. Gray and black solid lines are individual trials and mean value. The symbols have the same meaning as those in Figure 2. Block clearing phase was treated as step 0 and, for the vertical and propulsive impulses, the data at the block clearance was excluded in order to prioritize a visibility of data from the 1st step.

CONCLUSION: This study aimed to show changes in step-to-step ground reaction forces around the first transition during maximal accelerated sprinting with a typical sprinter. There was abrupt temporal increase in propulsive impulse at the 5th step as well as the termination of increase in step frequency and the temporal suspension of decrease in support time at the next step. These sudden shift of variables support the concept of sprint transition. Whereas further studies should verify whether similar results are obtained with other participants due to the pilot feature of this study, the findings of this study would be interesting for the future study of locomotor control and practically useful for considering the strategy of accelerated sprinting.

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