KINETICS OF SINGLE SESSION INTRA-INDIVIDUAL DIFFERENCE IN SPRINT ACCELERATION: A CASE STUDY

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This case study aimed to investigate inter-repetition differences in joint kinetics for a single athlete during the acceleration phase of sprinting. One well-trained male sprinter performed three maximal effort 40-m sprints in an indoor experimental site. Using the fastest and slowest trials, spatiotemporal, ground reaction forces, and joint moment variables were calculated step to step for 16 steps. The fastest trial was accompanied by the greater mean net anteroposterior force. Moreover, there were greater hip extension and ankle plantar flexion moments, as well as a smaller knee extension moment, in the fastest trial. Accordingly, producing greater hip extension and ankle plantar flexion moments while suppressing the knee extension moment leads to better sprint acceleration through the greater propulsive force in the initial acceleration section.

KEYWORDS: running, GRF, joint moment, alteration.

INTRODUCTION: In a 100-m race, winner and loser can be separated by as little as 0.001 s. Thus, a small improvement of sprinting performance will result in a better position in the race. Because the maximal speed, which is strongly correlated with the final time in a 100-m race, is achieved by an acceleration phase, differences in acceleration performance can have a substantial effect on the final time. A previous inter-repetition study reported that the fastest trial was achieved with high step frequency and short support time at almost all steps during the acceleration phase, as well as greater propulsive force during the initial acceleration section (Nagahara, Mizutani, Matsuo, Kanehisa, & Fukunaga, 2018). While the previous study investigated the source of single session inter-repetition differences in sprint acceleration in terms of ground reaction forces (GRFs), intra-individual differences in joint kinetics between the fastest and slowest trials have not been investigated. Although analysing external forces provide useful information for better sprint acceleration performance, an investigation of the joint kinetics during the acceleration phase is beneficial for understanding the causes of segment motion that accelerate the body. Moreover, an intra-individual investigation conducted within a single session will bring a better understanding of the variability in performance, because the characteristics of each participant (e.g. morphological features, strength-power capabilities, and psychological state) are almost the same between trials. Therefore, the purpose of this case study was to investigate the inter-repetition differences in joint kinetics for a single athlete during the first half (0-30 m) of acceleration phase of sprinting.

METHODS: One well-trained male sprinter (age, 21 years; stature, 1.67 m; body mass, 59.4 kg; personal best 100-m time, 11.02 s) performed three maximal effort 40-m sprints in an indoor experimental site. The aim and experimental procedures of this study were fully explained before the experiment, and written informed consent was obtained from the participant. The experiment was conducted with approval from the research ethics committee of the institute. The sprint was treated as a 100-m race with starting blocks, and the participant used his own crouched starting position. Fifty force platforms (1000 Hz) connected to a single computer (TF-90100, Tec Gihan, Uji, Japan) measured GRF during sprinting until the 30-m mark. The time at the 30-m mark was recorded with a photocell system (TC Timing System, Brower Timing System, Draper, UT). Recording of the timer was initiated by the starting signal. Thirty-nine infrared cameras (250 Hz) connected to a single computer (Motion Analysis Corporation, Santa Rosa, CA, US) captured three-dimensional coordinates of 47 retro-reflective markers affixed to the participant’s body with a volume of approximately 30 m × 1.5 m × 2 m (length × width × height).

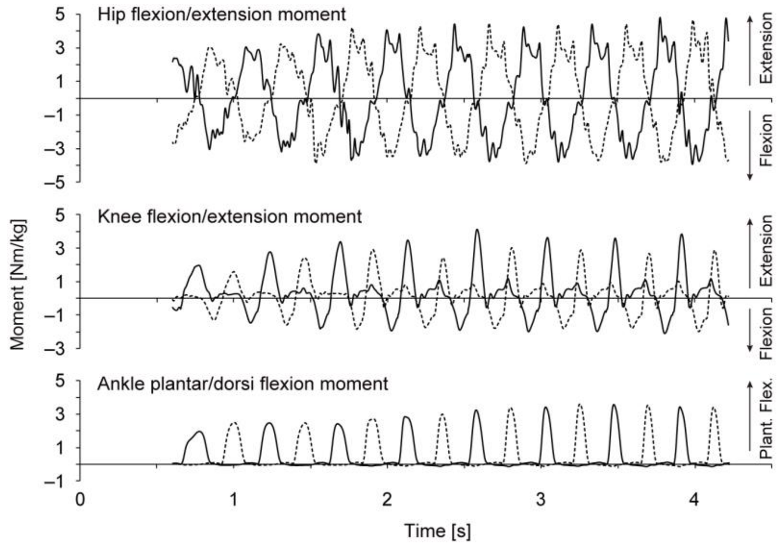

Figure 1: Example of serial changes in hip, knee and ankle extension/flexion (plantar/dorsi-flexion) moments. Solid and dotted lines indicate right and left leg data, respectively.

The fastest and slowest trials were selected according to 30-m sprint time. From the GRF data, step-to-step spatiotemporal and GRF variables were computed. The thresholds to detect foot strike and toe-off were set at 20 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. Step length was calculated as the difference between the positions of the foot (middle of the support phase) for two consecutive steps in the running direction. The running speed was calculated as a product of step length and frequency. The vertical impulse was obtained using a time integration of vertical GRF. Mean braking, propulsive and net anteroposterior forces were computed by averaging these forces during the braking, propulsive and entire support phases. From the marker coordinate data, endpoints of 15 segments of the whole body, consisting of head, upper trunk, lower trunk, hands, forearms, upper arms, feet, shanks, and thighs, were determined in accordance with previous studies (Nagahara, Matsubayashi, Matsuo, & Zushi, 2014a; 2017). The endpoint coordinates were smoothed with a fourth-order Butterworth low-pass digital filter with a cut-off frequency of 20 Hz. Joint moments at the hip, knee and ankle were calculated using a standard inverse-dynamics analysis for both legs (Nagahara et al., 2017) (Figure 1). The location of the centre of mass and the inertia parameters of the respective segments were estimated using the body segment parameters of Japanese athletes (Ae, 1996). Mean lower-extremity joint extension (plantar flexion) moments during each support phase were calculated for step-to-step analysis. Step-to-step spatiotemporal, GRF and joint kinetic variables were approximated using a fourth-order polynomial to cancel bilateral difference and cyclic movement variability (Nagahara, Naito, Morin, & Zushi, 2014b; Nagahara et al., 2018). Before the approximation, we added the mean value of the last two steps for three additional steps after the final step to eliminate the influence of endpoint error. The duration of the last step was used as the time intervals for these added data.

RESULTS and DISCUSSION: The 30-m sprint times were 4.53 and 4.63 s for the fastest and slowest trials. The fastest and slowest trials were recorded at the second and first trials, respectively. Figure 2 shows step-to-step changes in spatiotemporal and GRF variables over a 30-m distance for the fastest and slowest trials. Running speed and step frequency were greater in the fastest trial than the slowest trial, while the step length did not show a difference. The support and flight times in the fastest trial were shorter than that in the slowest trial during the first and second halves of the acceleration phase, respectively. The vertical impulse in the fastest trial was smaller than that of the slowest trial during the entire

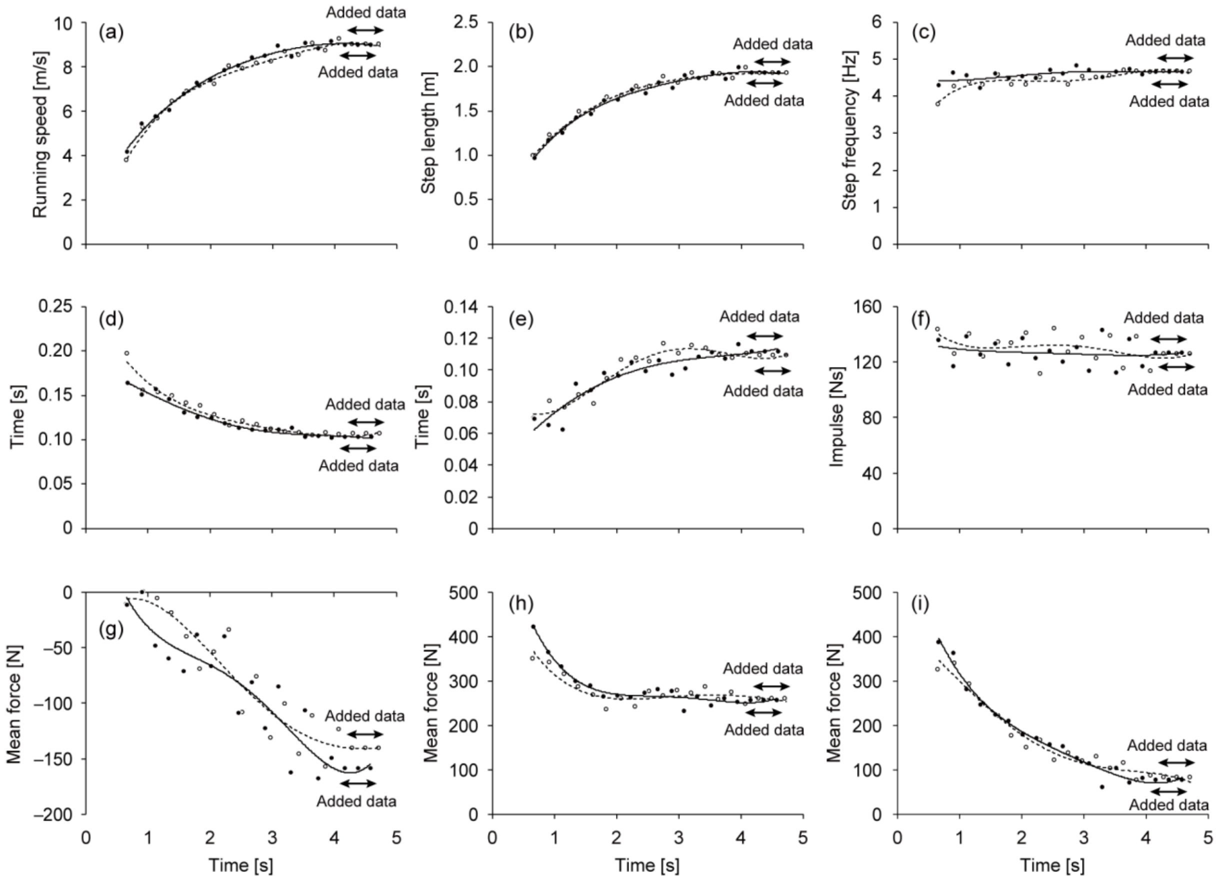

Figure 2: Step-to-step changes in spatiotemporal and GRF variables for 16 steps during sprint acceleration. (a) running speed, (b) step length, (c) step frequency, (d) support time, (e) flight time, (f) vertical impulse, (g) mean braking force, (h) mean propulsive force, (i) mean net anteroposterior force. Closed and open circles show the fastest and slowest trials. Solid and dotted lines are approximated values of the fourth order polynomial for the fastest and slowest trials, respectively. Horizontal two-headed arrows indicate the ranges of added data.

acceleration phase. The mean propulsive and braking forces were greater in the fastest trial than the slowest trial during the first half of the acceleration phase. The mean net anteroposterior force in the fastest trial was greater than that of the slowest trial during the initial section of the acceleration. These results are generally consistent with findings in previous studies which investigated single session intra-individual differences in sprint acceleration performance (Hunter, Marshall, & McNair, 2004; Nagahara et al., 2018). The results show that the better sprint acceleration performance in a single session is accompanied by greater step frequency and shorter support, as well as greater propulsive force, especially during the initial acceleration section. The fact that the results in this study are consistent with the previous study may indicate that the joint kinetics in this study would be able to represent a group with greater participants.

Figure 3 shows step-to-step changes in mean hip, knee and ankle extension (plantar flexion) moments during the support phase in the acceleration phase for the fastest and slowest trials. In the initial acceleration section, there were greater hip extension and ankle plantar flexion moments in the fastest trial than in the slowest trial, while the knee extension moment in the fastest trial was smaller than that in the slowest trial. Taking into account that the greater acceleration was accompanied by the greater propulsive force during the initial acceleration section, producing greater hip extension and ankle plantar flexion moments while suppressing knee extension moment would lead to better sprint acceleration. While the greater hip extension and ankle plantar flexion moments in the fastest trial in this study are consistent with previous studies (Debaere, Delecluse, Aerenhouts, Hagman, & Jonkers, 2015; Johnson & Buckley, 2001), no study has reported that better sprint acceleration performance is accompanied by a smaller knee extension moment. However, Jacobs and

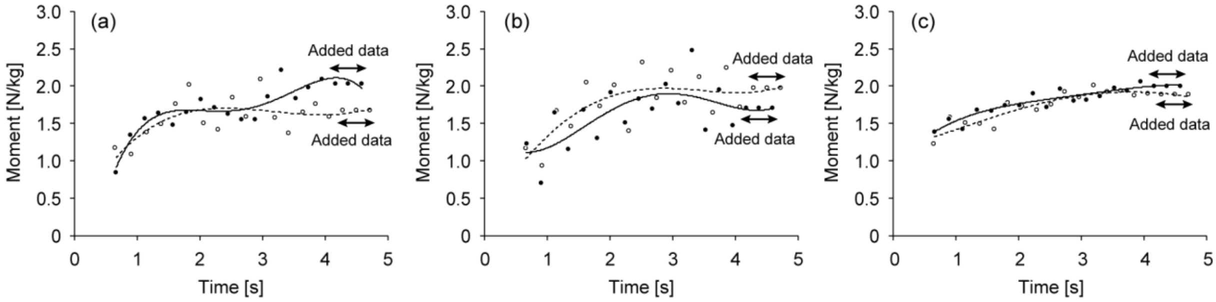

Figure 3: Step-to-step changes in lower-extremity joint moments during the support phase for 16 steps during sprint acceleration. (a) mean hip extension moment, (b) mean knee extension moment, (c) mean plantar flexion moment. Closed and open circles show the fastest and slowest trials. Solid and dotted lines are approximated values the fourth order polynomial for the fastest and slowest trials. Horizontal two-headed arrows indicate the ranges of added data.

van Ingen shenau (1992) indicated that a sprinter's strategy to wait with an extension of leg and rotate first around the support point on the ground during the initial acceleration section is of importance for better acceleration performance. Moreover, they also indicated that premature timing of the knee extension during the support phase will bring an increase in vertical velocity of the body during the initial acceleration section. Although Jacobs and van Ingen shenau (1992) did not investigate joint moments, a smaller knee extension moment in the fastest trial in this study would lead to the aforementioned characteristic feature of the better performance in the initial acceleration section. Consequently, suppression of the knee extensor moment during the support phase would be an effective solution for achieving greater propulsive force in the initial acceleration section of the sprint.
Due to the case study approach, there are several limitations to the generalisation of our findings. Given that this was a single participant study, further studies should attempt to verify whether the same results can be obtained with multiple participants.

CONCLUSION: Using a single session, inter-repetition case study approach, this study demonstrated that greater hip extension and ankle plantar flexion moments and a smaller knee extension moment during the initial acceleration section would contribute to greater sprint acceleration performance.

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