DIFFERENCE IN ACCELERATION PATTERNS IN TWO START TECHNIQUES: CROUCH AND STANDING STARTS

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The purpose of this study was to investigate the difference in the acceleration patterns between the crouch and standing starts. Ten male sprinters performed two maximal effort 60-m sprints from each of two start techniques. Step-to-step spatiotemporal variables and ground reaction forces over the 50-m distance were measured using 54 force platforms. The current results showed that, when compared variables at each step, the crouch start showed shorter block clearing time, higher running speed through higher step frequency during the second half of the acceleration phase, and more horizontally oriented ground reaction force than standing start. These findings suggest that change in start techniques may alter the acceleration pattern through changes in block clearance time, step frequency and force application technique.

KEYWORDS: sprinting, set position, applied force, spatiotemporal variables

INTRODUCTION: Maximum speed in a 100-m running race is a decisive factor for better performance (Volkov and Lapin, 1979). Because the maximum speed is achieved as a result of acceleration, sprint acceleration should be investigated for understanding better sprinting performance. In a sprint race, sprint acceleration has to be initiated from the stationary 'set' position, and an alteration of the position would result in changes in acceleration pattern. In sprint running, there are two start techniques with greatly different "set" positions. One is a crouch start that is used for sprint events up to 400 m, the other is a standing start which is used in a sprint practice and in a relay race (e.g., anchor leg). Salo and Bezodis (2004) found that the centre of mass horizontal velocities after block clearance and at the 1st step push off were significantly higher in the standing start than in the crouch start. They also showed that there was no significant difference in the horizontal velocity between the two start techniques after the 10-m point. Although they provided fundamental knowledge of the difference in the two start techniques, it is still unclear how the acceleration pattern from a set position to maximum running speed differ between the crouch and standing starts. Athletes other than the first runner in a relay race cannot use the starting block, but either start technique can be utilised. Thus, it is important to clarify the detailed differences in acceleration characteristic between two starting techniques for considering a better acceleration strategy in a different situation. The purpose of this study was therefore to investigate the difference in the acceleration pattern between the crouch and standing starts in terms of spatiotemporal and ground reaction force (GRF) variables.

METHODS: Participants were 10 male sprinters (height: 176.7 ± 4.9 cm; body mass: 68.3 ± 6.6 kg; 100-m sprint personal best, 10.91 ± 0.21 s). The content of the experiment was explained to the participants, and written informed consent was obtained. After a warm-up, the participants, wearing their spiked shoes, performed two maximal effort 60-m sprints from each of a crouch start with starting blocks (CS) and a standing start (SS) (in total 4 trials). The trials were separated by 30 min of passive rest. While the participants set the starting blocks at their standard block spacing in CS, they set the foot spacing at their comfortable spacing in SS. A long force platform system, which consisted of 54 force platforms (1.0 × 0.9 m; TF-90100, Tec Gihan, Uji, Japan; 1000 Hz), in National Institute of Fitness and Sports in Kanoya was used to measure GRFs while sprinting from the start to the 50-m mark

(Nagahara et al., 2017). Sprinting time at the 60-m mark was recorded using a photo-cell system (TC Timing System, Brower, Draper, UT, USA).

Based on the 60-m sprint time, the fastest trial in each start technique was selected and used for subsequent data processing. GRF signals were filtered using a Butterworth low-pass digital filter at a cut-off frequency of 50Hz (Nagahara et al., 2017). A block clearance phase and time were determined between the instant of block start (earliest detection in which the first derivative of either the front or rear foot resultant force-time curve > 500 $N \cdot s^{-1}$; Brazil et al., 2016), and the instant in which the front foot was left from the ground (resultant force < 15 N). While SS did not use the blocks, we defined this time as "block clearance time" for SS. Mean applied propulsive force during the block clearance phase was calculated using the anteroposterior force (rear foot + front foot) and normalised to body mass. The applied propulsive impulse during the block clearance phase was calculated by integrating propulsive forces (rear foot + front foot) during the block clearance. After the block clearance phase, step-to-step spatiotemporal variables over the 50-m distance were calculated using the following procedure. Support (ST) and flight times (FT) were determined depending on whether the foot contacted the ground using the threshold set at 10 N of vertical GRF (Morin et al., 2015). Each step duration was determined from the toe-off of one leg to the next toe-off of the other leg. Step frequency (SF) was calculated as the inverse of step duration. Running speed (RS) was calculated by integrating anteroposterior GRFs taking into account the influence of the air resistance (Colyer et al., 2018). RS at each step was calculated by averaging RS from the toe-off of one leg to the next toe-off of the other leg. Moreover, an increment of RS during the block clearance phase was also calculated. Step length (SL) was calculated by dividing RS by SF. The mean net anteroposterior force (MF_{ap}) was calculated by averaging the anteroposterior GRF during the support phase in each step. The mean effective vertical forces (MF_{ev}) was calculated by dividing the effective vertical impulse, which was calculated as the value of vertical impulse subtracting the impulse due to body weight, by the ST (Nagahara et al., 2017). MF_{ap} and MF_{ev} were normalised to body mass.

To cancel bilateral differences, we approximated spatiotemporal and GRF variables against the time axis using a fourth-order polynomial according to a previous study (Nagahara et al., 2017). Because the minimum number of steps of a sprinter in CS and SS for 50-m was 25, the data for 25 steps were extracted for all participants. These 25 steps were defined as the acceleration phase in this study. The means and standard deviations of the approximated spatiotemporal and GRF variables were calculated at each step. The 60-m sprint and block clearance times, as well as GRF variables during the block clearance phase in CS and SS were compared by using the paired t-test. The significance level was set at $p < 0.05$. The spatiotemporal and GRF variables at each step in CS and SS were compared by magnitude-based inference approach (Nagahara et al., 2017). The smallest worthwhile change was determined as an effect size of 0.2 with standardisation of the interpretation between variables in different units.

RESULTS AND DISCUSSION: The 60-m sprint time in CS (7.32 ± 0.13 s) was significantly shorter than that in SS (7.47 ± 0.16 s) ($p < 0.05$). Block clearance time in CS (0.36 ± 0.03 s) was significantly shorter than that in SS (0.48 ± 0.05 s) ($p < 0.05$). These results indicate that the difference in 60-m sprint time between CS and SS resulted from the clearance time. Salo and Bezodis (2004) reported that, although the difference was not statistically significant, time to the 50-m mark in CS was shorter than that of SS. The lack of the statistically significant difference in the previous study was possibly due to small sample size (n = 6), and it can be considered that the results in this study is in line with the previous study.

Figure 1 shows step-to-step changes in spatiotemporal variables and GRF variables for CS and SS and effect size and those 90% confidence intervals between CS and SS. The RS in SS was possibly-most likely (53 - >100%) higher than that in CS from the 1st to 7th step. Moreover, SL in SS was possibly-most likely (50 - >98%) longer than that in CS from the 1st to 10th step. These results demonstrate that the greater RS in SS during the initial acceleration phase was led by longer SL, and this is in line with a previous study (Salo and

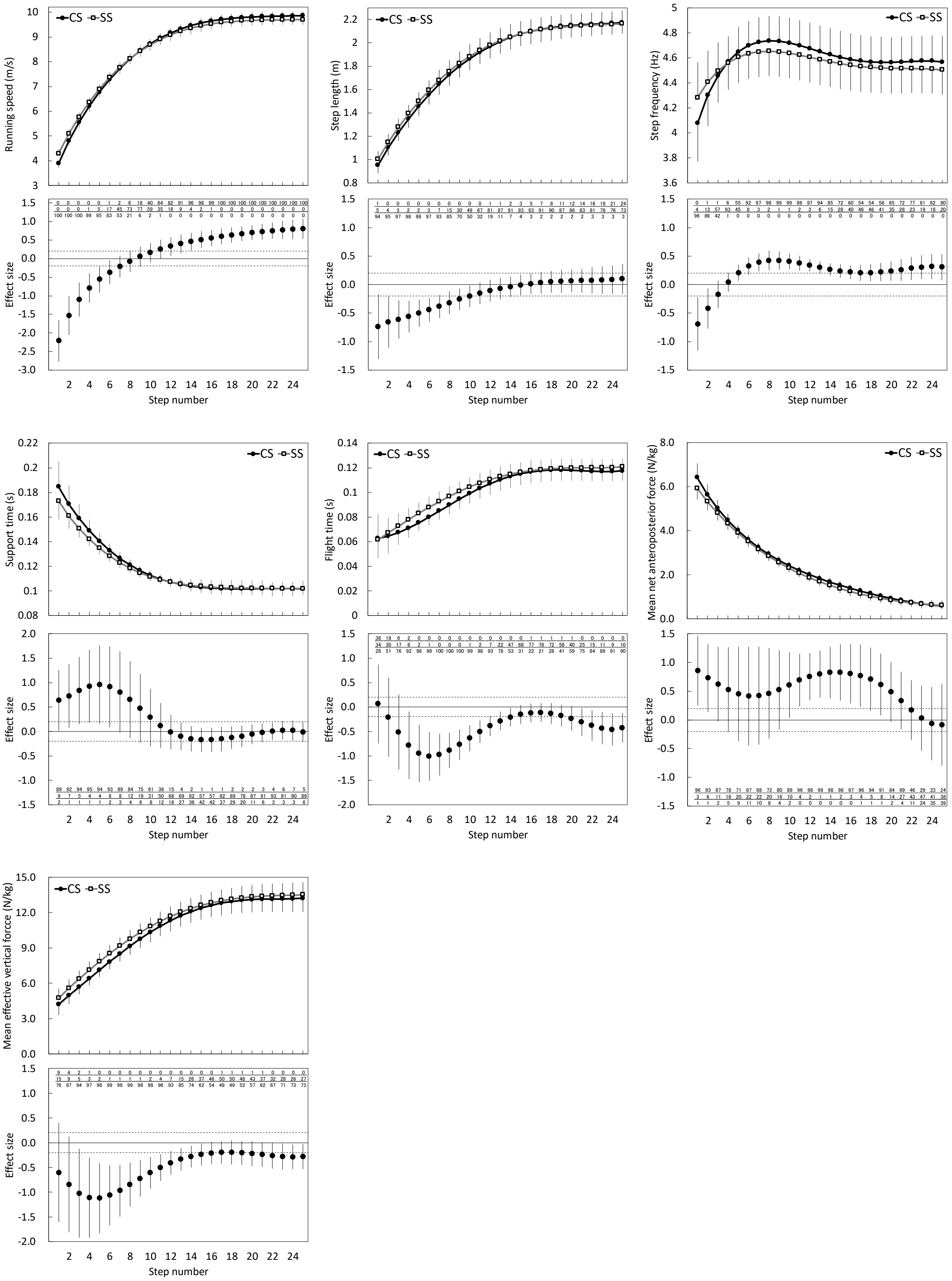

Figure 1. The changes of means and standard deviations of the approximated RS, SL, SF, ST, FT, MF_{ap} and MF_{ev} (above). Effect sizes and those 90% confidence intervals between CS and SS at each step for those variables (below).

Bezodis, 2004). In contrast, from the 11th to 25th step, RS in CS was possibly-most likely (64 - >100%) higher than that in SS. Moreover, SF in CS was possibly-most likely (54 - >99%) higher than that in SS from the 5th to 25th step. Additionally, FT in CS was possibly-most likely (53 - >100%) smaller than that in SS from the 3rd to 14th step and from the 20th to 25th step. Consequently, the greater RS in CS during the second half of the acceleration phase (from the 11th to 25th step) was probably caused by higher SF (from the 5th to 25th step) through shorter FT (from the 3rd to 14th step and from 20th to 25th step).

The MF_{ap} in CS was possibly-most likely (67 - >99%) greater than that in SS from the 1st to 21st step. Moreover, MF_{ev} in CS was possibly-most likely (52 - >99%) smaller than that in SS from the 1st to 16th step and from the 19th to 25th step. These results indicate that the orientation of the force application in CS was closer to the horizontal direction than that in SS during the almost entire acceleration phase. It has been reported that the horizontally oriented force is a determinant of better sprint performance (Morin et al., 2011). Accordingly, it is assumed that CS is a start technique suitable for greater acceleration over the entire acceleration phase for a 50-m distance. While RS was greater in SS than CS during the first half of the acceleration phase, the MF_{ap} in CS was greater than that of SS until the 21st step. This is because of the difference in increment of RS between CS (3.23 ± 0.19 m/s) and SS (3.57 ± 0.26 m/s) ($p < 0.05$) during the block clearance. During the block clearance phase, while the mean propulsive force was greater in CS (8.89 ± 0.51 N/kg) than in SS (7.51 ± 0.94 N/kg) ($p < 0.05$), the force production duration in SS was longer than that of CS, resulting in greater applied propulsive impulse in SS (3.57 ± 0.26 Ns/kg) than in CS (3.23 ± 0.19 Ns/kg) ($p < 0.05$). Therefore, when compared RS at each step, SS shows the greater value during the initial acceleration phase, but the sprinting performance as shown the time taken for a specific distance is likely better in CS at any step. Because the choice of the x-axis (we set the step number in this study) resulted in the aforementioned bias, it should be taken into account the influence of the difference in x-axes (e.g., time, distance).

CONCLUSION: This study investigated the difference in the acceleration pattern between the crouch and standing starts for runners. The current results showed that, when compared variables at each step, crouch start showed shorter block clearing time, higher running speed through higher step frequency during the second half of the acceleration phase, and horizontally oriented ground reaction force than standing start. The finding in this study would be useful for sprinters and coaches to understand the difference between crouch and standing start for manipulating start techniques.

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