STEP-TO-STEP SPATIOTEMPORAL DETERMINANTS OF FEMALE SPRINT PERFORMANCE DURING THE ENTIRE ACCELERATION PHASE

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The purpose of this study was to clarify the kinematic determinants of maximal effort female sprint performance during the entire acceleration phase of a single sprint. Fifteen sub-elite female sprinters completed a 60 m maximal effort sprint from starting blocks over a long force platform system. Ground reaction force data was used to calculate step length, step frequency, support time and flight time. Pearson's product moment correlation coefficient was used to clarify the association between the rate of changes in these spatiotemporal variables and acceleration at every step. Peformance determinants elucidated included the rate of changes in step length (1st to 10th steps), step frequency (2nd to 7th steps), support time (1st to 5th steps) and flight time (4th to 7th steps). Results were considered similar to past research on male sprinters, although showed slightly different correlations.

KEYWORDS: ground reaction force, kinematics, force platform.

INTRODUCTION: Achieving higher maximal speed via acceleration is of great importance for faster 100-m sprint times (Slawinski et al, 2010). Clarifying relationships of running acceleration with rate of changes in spatiotemporal variables may provide an understanding of spatiotemporal variables contribution to acceleration at different acceleration phases. Previous research clarified the rate of changes in spatiotemporal variables step-to-step for male sprinters during the acceleration phase, suggesting that increasing step length (SL) from the 5th to 15th steps and step frequency (SF) for the 1st to 3rd steps may relate to greater acceleration (Nagahara et al, 2014). However, these findings were elucidated with male sprinters and minimal research exists that focuses solely on female athletes.
Further research suggests that sprint determinants may be linked with sex due to running performance differences (Abe et al, 2019; Cheuvront et al, 2005). Paruzel-Dyja et al (2006) reported that male sprint times are SL dominant and female times are SF dominant, which may be influenced by strength characteristics, body composition, mass and height differences (Abe et al, 2001; Abe et al, 2019; Aerenhouts et al, 2012). Male sprint times may be faster due to greater SL, similar SF and shorter support times (ST), even when leg length is normalised (Debaere et al, 2013; Slawinski et al, 2010). These spatiotemporal differences between sexes suggests that performance determinants may differ during acceleration. The purpose of this research was to elucidate step-to-step kinematic determinants of female sprint performance over the entire acceleration phase. Clarifying performance determinants may provide greater specificity into considering race strategies and coaching methods for female sprinters.

METHODS: Fifteen sub-elite female sprinters participated (mean±SD: age 20.1±1.6 years; height 162±5 cm; body mass 52.9±5.1 kg; 100 m race personal best time 12.70±0.52 s). This research was approved by the institutes ethics committee. A 60 m maximal effort sprint from starting blocks was completed after a self-selected warm up. Self-selected athletic attire and spiked race shoes were worn. Step-to-step ground reaction force (GRF) was measured with 54 force plates (1000 Hz) embedded in a tartan track from approximately 1.5 m behind the start line to the 50.5 m mark, from a single computer (TF-90100, TF-3055, TF-32120, Tec Gihan, Uji, Japan). Running speed was computed integrating the mass-specific anteroposterior GRF subtracting the influence of aerodynamic drag in accordance with previous studies (Colyer et al, 2018; Nagahara et al, 2019). Foot strike detection was set at exceeding 20 N of vertical GRF. Step durations were defined as the time between foot strikes of the contralateral foot and SF calculated as the inverse of step durations. Average running speed for each step duration was obtained and SL calculated by dividing average running speed by SF at each step. Flight time (FT) was analysed when no feet were contacting the ground and ST defined as ground contact duration for each step.

A fourth order polynomial for approximation of running speed and spatiotemporal variables was used to reduce bilateral differences and cyclic movement variability (Nagahara et al, 2014; Nagahara et al, 2018). Three separate mean values were added (mean of the last two steps recorded) to eliminate the influence of the polynomial endpoint. These three extra padded values were excluded from statistical analysis. Acceleration and rate of changes in spatiotemporal variables were computed as the first derivative of approximated data. Group means of every step until the 27th step (last step before the participant with the smallest total number of recorded steps ran off force platforms) was used for statistical analysis and block clearance was excluded. Pearson's product moment correlation coefficient was implemented to compare step-to-step relationships between running acceleration and the rate of changes in spatiotemporal variables. The significance level was set at P>0.05. The step-to-step rate of changes in spatiotemporal variables were used in accordance with previous research (Nagahara, 2014). Independent spatiotemporal variables included the rate of changes in SL, SF, ST and FT respectively. Correlation coefficient interpretations as an effect size were set to 0.1-0.3 (small), 0.3-0.5 (moderate), 0.5-0.7 (large), 0.7-0.9 (very large) and >0.9 (extremely large) (Hopkins et al, 2009).

RESULTS: Running speed, SL and FT increased rapidly during initial acceleration and gradually thereafter toward the maximal speed (Figure 1). The inverse of this trend was present for ST. The SF increased acutely during the initial acceleration phase, reached maximum at the 14th step, and decreased subsequently. Significant positive correlations against running acceleration were found for SL rate of change from 1st to 10th steps (large–extremely large) and 15th to 22nd steps (large–very large), SF rate of change at the 26th to 27th steps (large), ST rate of change from the 1st to 5th steps (large–very large) and FT rate of change from the 4th to 7th steps (large) (Figure 2). Significant negative correlations against running acceleration were found for SF rate of change from the 2nd to 7th steps (large–very large) and FT rate of change at the 26th to 27th steps (large).

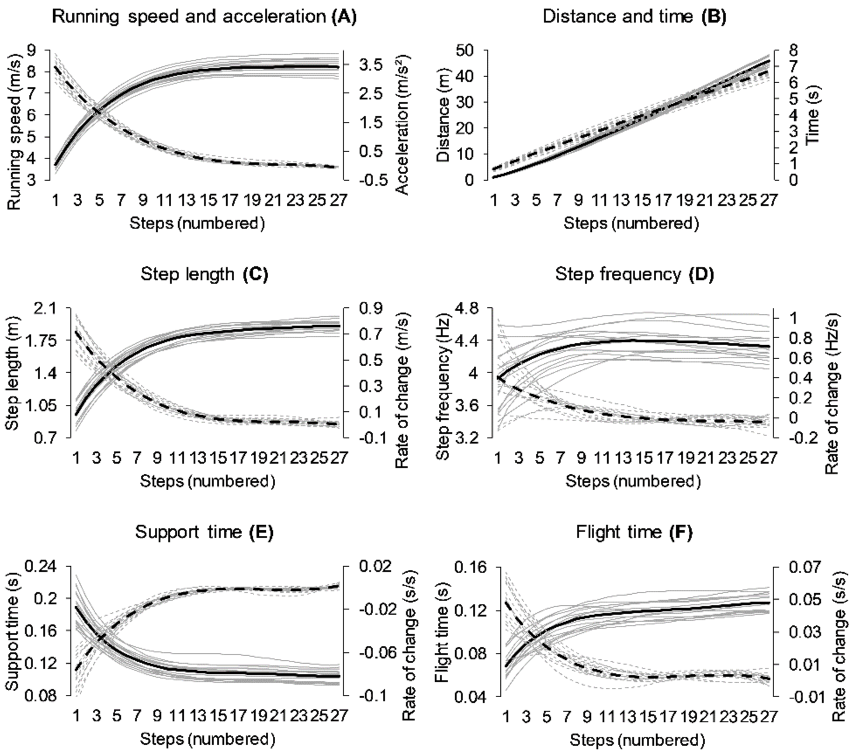

Figure 1. Step-to-step group means (black) and individual results (grey) for running speed and acceleration (A), distance and time (B), SL and SL rate of change (C), SF and SF rate of change (D), ST and ST rate of change (E), and FT and FT rate of change (F). Solid lines are labelled on the left axis and dashed lines labelled on the right axis.

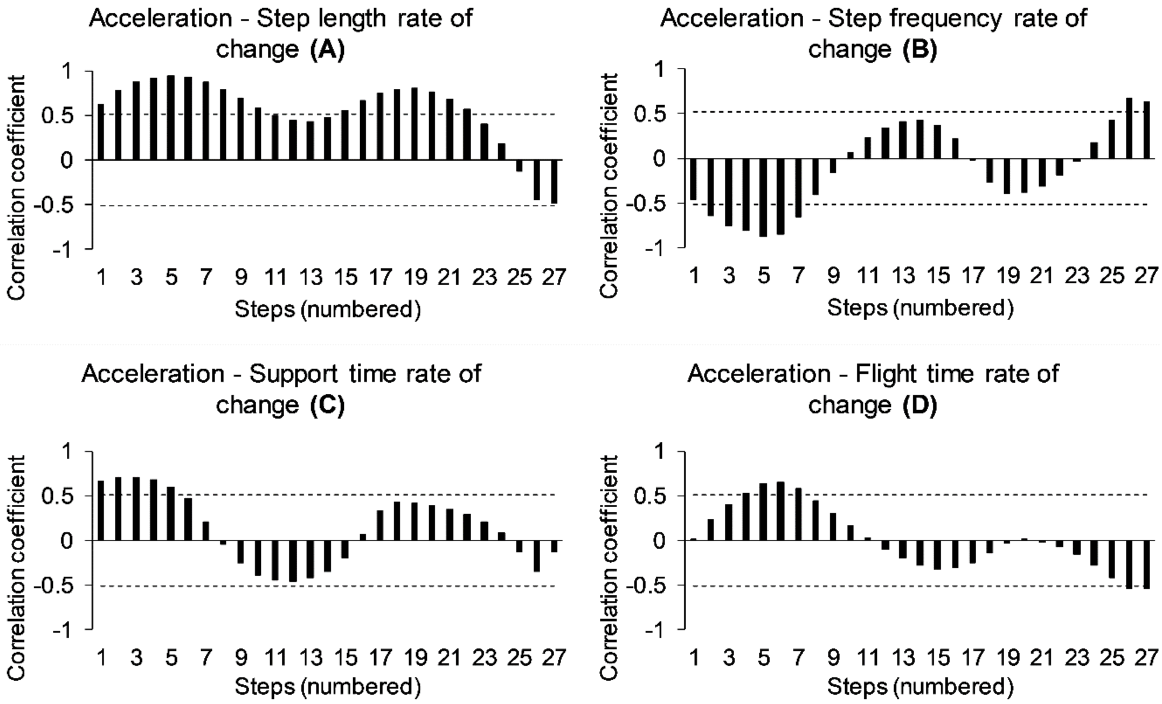

Figure 2. Correlation coefficients between acceleration and rate of changes in SL (A), SF (B), ST (C) and FT (D). Significance (P>±0.05) is represented by the black dashed lines (r= ±0.514).

DISCUSSION: This is the first research focused solely on female sprinters, specifically clarification of spatiotemporal determinants of performance over the entire acceleration phase. It was assumed that independent variables with significant correlations at specified steps (Figure 2) may be considered determinants of performance in terms of acceleration. The SL rate of change was considered a performance determinant, suggesting that increasing SL from the 1st step is likely important for greater acceleration during the entire acceleration phase, except for the middle acceleration section. Furthermore, initial acceleration correlation results for the rate of changes in SF, ST and FT demonstrates that suppressing acute increases in SF through suppressing rapid decreases in ST and greater increases in FT may be an important indicator of better performance during the initial acceleration phase. In addition, there was a correlation of running acceleration with SF rate of change positively and FT rate of change negatively for the 26th and 27th steps. This result may be due to running speed decreases after the 24th step peak, attributed to suppressing this decrease in running speed during deceleration by suppressing decreases in SF, through suppressing increases in FT.

Female sprinters had much earlier SL rate of change significant associations (from 1st step) with running acceleration compared to male sprinters in previous research (Nagahara et al., 2014), suggesting that increasing SL during the initial acceleration section may be more important for female sprinters. Earlier importance of SL increase may have contributed to the coupled earlier importance of FT increases for females (4th to 7th steps) compared to males (8th to 10th steps) (Nagahara et al., 2014). Further differences were found with previous research on males in terms of SF rate of change, with females demonstrating negative correlations until the 10th step and males showing positive correlations for the first five steps (Nagahara et al, 2014). Therefore, during initial acceleration male sprinters may need to focus on faster SF changes while the opposite may be true for female sprinters. This may be attributed to muscle mass and GRF capability differences between males and females (Debaere et al., 2013; Slawinski et al., 2010). For female sprinters, this inverse relationship between SF rate of change and acceleration suggests that rapidly increasing SF rate of change may decrease acceleration, thus female sprinters should not focus on quickening steps after block clearance. However, only SF had large participant variability (Figure 1), suggesting that it may be beneficial for coaches to examine SF characteristics individually and group means should be interpreted with caution. The ST results are in accordance with past research suggesting longer ST during initial acceleration is important for greater force production

(Murata et al., 2018), however this research differs by providing greater specificity for how long female sprinters should prioritise suppressing decreases in ST during initial acceleration.
The time and distance of each step varies among athletes, thus GRF and spatiotemporal determinants may differ between individuals at specific time or distance points. Alternatively, using step number may increase the specificity of group GRF and spatiotemporal characteristics and are easily identified and understood by athletes and coaches. Therefore, step number was considered an appropriate standardisation for the x axis. Furthermore, significance may not always be practically relevant and results should be analysed with sprint context in mind to determine relative importance. Between participant differences may have influenced results due to the small sample size and single trial analysis. Future research with multiple repeated trials may be needed to cross examine results on female sprinters with this study to determine the reliability of results.

CONCLUSION: Spatiotemporal performance determinants for female sprinters was elucidated step-to-step for the entire acceleration phase. The main findings included greater increases in SL from the 1st step with suppressing SF increases, suppressing ST decreases and greater FT increases may be factors of better performance during the initial acceleration phase. These findings contradict past research on male sprinters by demonstrating earlier step correlations between acceleration and SL rate of change and opposite correlations between acceleration and SF rate of change during the initial acceleration section, thus provided greater specificity for female sprinters training targets. Results may have practical implications for coaches and athletes to consider beneficial race strategies and training prescription to increase female specific sprint performance.

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