SPATIAL, TEMPORAL, AND KINETIC VARIABLES DURING THE EARLY ACCELERATION PHASE OF SPRINTING

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INTRODUCTION

A variety of biomechanical factors determine sprinting performance. Sex, experience level, and training specificity may also influence how speed is manifested. In the process of further understanding these issues, research has sought to identify the relationships between a variety of kinetic and kinematic variables and sprinting speed.

Sex-based differences in horizontal plyometric (Kossow & Ebben, 2017) and sprint (Devismes et al., 2019; Jimenez-Reyes et al., 2018) performance have been studied. In some cases, no sex-based differences were found (Kossow & Ebben, 2017), whereas others demonstrated select differences in sprinting biomechanics (Devismes et al., 2019; Jimenez-Reyes et al., 2018).

Propulsive anterior-posterior (A-P) impulse may be more valuable than vertical impulse in the development of sprint velocity (Hunter et al., 2005). However, studies examining the relationship between variables such as force, impulse, and power, and their relationship to speed have produced equivocal results. For shorter duration sprints such as 10 meters, horizontal impulse at eight meters was correlated with sprint time, whereas impulse during the first step was not (Kawamori et al., 2013). Variables such stride length, frequency, contact time, and flight time have been studied, with some of these variables correlated to short distance sprint performance (Lockie et al., 2013). Stride length is correlated with short sprint speed (Lockie et al., 2013). However, it is unknown how short and progressively increasing strides during acceleration, as has been recommended with devices such speed ladders (White, 2007), influence sprint kinetics and kinematics. The purpose of this study was to determine the kinetic and kinematic variables that are related to acceleration speed of men and women subjects who used short strides during the early acceleration phase of sprinting.

METHODS

Ten women (mean ± SD, age = 19.3 ± 1.06 yr) and ten men (mean ± SD, age = 20.01 ± 0.99 yr) served as subjects in this study. The subjects were informed of the risks associated with the study and provided written consent. The study was approved by the institution's Internal Review Board.

Subjects were tested in the sprinter start and standing start conditions. Each began with the subject within 2 cm behind the first of two force platforms. During each sprint condition, the first and second steps occurred on the first platform and the third and fourth steps struck the second platform. Subjects accelerated throughout the entire 10 meter sprint. The countermovement jump was also tested with a manual vertical jump testing device (Vertec, North Easton, MA, USA). Two trials of each sprint condition and the countermovement jump were performed. The order of the sprinter start and standing start conditions was counterbalanced.

The test exercises were performed on two force platforms (Accupower, Advanced Mechanical Technologies Incorporated, Watertown, MA, USA), oriented in series, countersunk, and mounted flush to the floor. The force platforms were calibrated prior to each testing session. Data were acquired at 1000 Hz and analyzed in real time with proprietary software (Accupower, Advanced Mechanical Technologies Incorporated, Watertown, MA, USA).

Peak vertical and A-P plane horizontal GRF data were obtained for each sprint start based on the analysis of the force-time record. Subject's horizontal to vertical force ratio, time between steps, stride frequency, and duration of vertical ground reaction force were calculated from these data.

Data were analyzed with the SPSS 26.0 statistical package (International Business Machines Corporation, Armonk, New York). Assumptions for linearity of statistics were tested and met. The trial-to-trial reliability of the dependent variables were assessed using average measures Intraclass correlation coefficients (ICC) and coefficients of variation. ICC were found to be > .60 and CV less than 10.0; thus, variables were considered reliable and the average values were used for further analyses. Pearson's correlation coefficients were used to assess the relationship between start condition velocities for the four steps (individually and overall) to years of sport participation, subject weight, subject height, countermovement jump height, horizontal and vertical forces, horizontal to vertical force ratio (H:V), time between steps, average stride frequency, duration of foot contact, and stride distance between steps and for all four steps. Partial correlations were used to remove the effect of sex, as there were significant differences between men and women for height and weight. The alpha level was set at $p \leq 0.05$.

RESULTS

For the two types of sprint starts, significant correlations were found between the overall velocity of the four steps to subject height, countermovement jump, average horizontal force, average vertical force, average H:V, average stride frequency, average foot contact duration, and step distances (see Table 1). No other bivariate and/or partial correlations were found between the overall velocity of the four steps and any other variable, or for individual step velocities to any variable ($p > 0.05$; $r < .44$).

Table 1. Significant bivariate and partial correlation coefficients (bivariate/partial) for sprint and standing start velocities across steps 1-4 (N=20). Partial correlation removed the effect of sex.

	HT (cm)	CMJ (cm)	HF (N)	VF (N)	H:V	SF (steps/sec)	FC (sec)	SD 3-4 (m)	SD 1-4 (m)
SP	-.05/-.54 [a]	.54 [a]/.31	-.09/-.46 [a]	-.26/-.71 [b]	.31/46 [a]	-.14/-.01	-.15/-.18	.68 [a]/.65 [a]	.51 [a]/.40
ST	-.01/-.28	.50 [a]/.30	.10/-.28	-.11-.51 [a]	.38/.39	-.93 [b]/-.92 [b]	.48 [a]/-.56 [a]	.08/.04	.28/.30

SP = sprint start four step velocity; ST = standing start four step velocity; HT = subject height; CMJ = counter movement jump height; HF = horizontal force averaged for the four steps; VF = vertical force averaged for the four steps; H:V = ratio of horizontal to vertical force averaged for the four steps; SF = stride frequency for the four steps; FC = average duration of foot contact; SD 3-4 = step distance of steps 3 to 4 for the corresponding start; SD 1-4 = total step distance for the four steps in the corresponding start.

[a] Significantly correlated ($p \leq 0.05$).

[b] Significantly correlated ($p \leq 0.001$).

DISCUSSION/CONCLUSION

This study showed that for the sprinter start condition, step distance is positively correlated with sprint velocity. This finding raises questions about the use of acceleration ladders with adjustable and relatively short distances between rungs, as used in acceleration training (White, 2007), in order to increase stride frequency.

Results of the current study suggests that increasing stride length after the first two steps may be important for short duration sprinting speed. Previous research showed that step distance is positively correlated with velocity (Lockie, et al., 2013). Thus, there may be some limits to how short steps should be during acceleration training.

Across the four steps assessed, subjects in the current study had an average step distance of approximately 0.6 meters, a step frequency of over 5 Hz, and a mean ground contact time of 0.25 seconds per step. These values are different than previous research which found a mean step distance of 1.18 meters, a step frequency of 4.13 Hz, and a mean ground contact time of 0.15 seconds per step (Lockie et al., 2013). National team track athletes produced mean step distances of 0.98 to 1.30 meters and ground contact times ranging from 0.15 to 0.17 seconds at the beginning of the sprint (Coh et al., 2017). Thus, subjects in the current study took shorter strides, had a higher stride frequency, and spent more time with the foot in contact with the ground, which may explain why stride frequency and duration of the foot contact were negatively correlated with velocity in some of the analyses.

The current study demonstrated that average horizontal force was either not related or negatively correlated to sprint velocity. No other study found force to be negatively correlated with velocity. Average vertical force was either not correlated, or negatively correlated with velocity in the current study. Some evidence indicates that vertical force is important for lower ability athletes (Jimenez-Perez et al., 2018). In the current study, the average H:V was either unrelated, or positively related, to sprinting velocity. This ratio is believed to be important for speed development (Duffin et al., 2019), since propulsive force is thought to be more important than vertical force (Hunter et al., 2005).

During the acceleration phase of sprint training, it may be important to liberalize step length after the first two steps if using acceleration ladders. There appears to be no disadvantage to shorter initial steps. Athletes should produce short foot contact durations and achieve foot contact as fast as possible. Lengthy foot contact duration may result in the creation of more force, but at the expense of the sprint velocity.

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