SEX-BASED ANALYSIS OF SPRINT ACCELERATION

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INTRODUCTION

Sprinting speed is important for many sports. The role of vertical and anterior-posterior (A-P) force has been studied during sprinting (Coh et al., 2017; Duffin et al., 2019; Nagahari, 2018). Some of this work assessed the role of force production on velocity, acceleration, or sprinting times (Coh et al., 2017; Coyler et al., 2018; Kawamori et al., 2014; Nagahara et al., 2018).

Studies revealed vertical and A-P kinetic data, which could be used to calculate or specifically identified horizontal to vertical force ratios (Duffin et al., 2019; Kawamori et al., 2014). Horizontal force is important for maximizing sprinter speed during the early acceleration phase (Duffin et al., 2019; Kawamori et al., 2014). Only one study assessed the force-velocity profile of men and women, showing that women have a more force-oriented profile, whereas men developed more power (Devismes et al., 2019).

The purpose of this study was to assess the magnitude of horizontal and vertical force production, the horizontal to vertical force production ratio (H:V), and its effect on a variety of kinetic and kinematic variables during the early acceleration phase of sprinting. Sex-based differences were also assessed.

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 and provided informed written consent. The study was approved by the institution's Internal Review Board.

Subjects performed 10 meter sprints from sprinter and standing starts across two force platforms oriented in series. During each sprint, the first and second steps occurred on the first platform and the third and fourth steps occurred on the second platform. The force platforms (Accupower, Advanced Mechanical Technologies Incorporated, Watertown, MA, USA) were calibrated prior to testing. Data were acquired at 1000 Hz and analyzed in real time with proprietary software. Horizontal to vertical force ratio, time between steps, average stride frequency, and duration of vertical ground reaction force were calculated. Data were analyzed with a statistical package (SPSS 26.0, 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 > .60 and CV less than 10.0; thus, the average values were used. Since there were significant differences in the height and mass of the men and women, a 3-Way mixed measures ANCOVA (start * steps * sex) removing the effect of body mass, was used to determine differences for horizontal and vertical forces, as well as the H:V. A 3-Way mixed measures ANCOVA (start * sex) removing the effect of height, was used to determine differences for distance and velocity between steps. A 2-Way Mixed ANCOVA (starts * sex) removing the effect of height, was used to compare time and velocity from steps 1 to 4. Bonferroni adjusted pairwise comparisons were used when significant main effects were found. When data were non-spherical, a Greenhouse-Geisser correction was used. Data are expressed as means ± SD. Partial Eta Squared (η_p^2) with thresholds of: small = 0.1, moderate = 0.3, large = 0.5, very large = 0.7, and extremely large = 0.9 were used to interpret effect size (Hopkins, et al., 2009).

RESULTS

The Two-Way ANCOVA revealed main effects for start and sex (p = 0.037; ηp2 = 0.231 and p = 0.002; ηp2 = 0.440 respectively) as well as a significant interaction (p = 0.028; see Figure 1) for velocity from steps 1 to 4. There were no main effects for time from steps 1 to 4 (start p = 0.072; ηp2 = 0.178 and sex p = 0.354; ηp2 = 0.051; see Table 1), but there was a significant interaction (p = 0.041; see Figure 1). Results of the 3-Way ANCOVAs revealed significant main effects only for steps 1 to 4 of velocity (p = 0.029; ηp2 = 0.187); step 1 to 2 (Mean ± SE = 2.76 ± 0.10 m/sec) was less than steps 2 to 3 and 3 to 4, which did not differ (3.52 ± 0.09 and 3.63 ± 0.10 m/sec respectively). There were no other main effects (p > 0.05; ηp2 < 0.205; see Table 1). There were significant interactions of Sex * Start in the 3-Way ANCOVAs for horizontal force and H:V (p = 0.018 and 0.013 respectively; see Figure 2). See all data in Table 2.

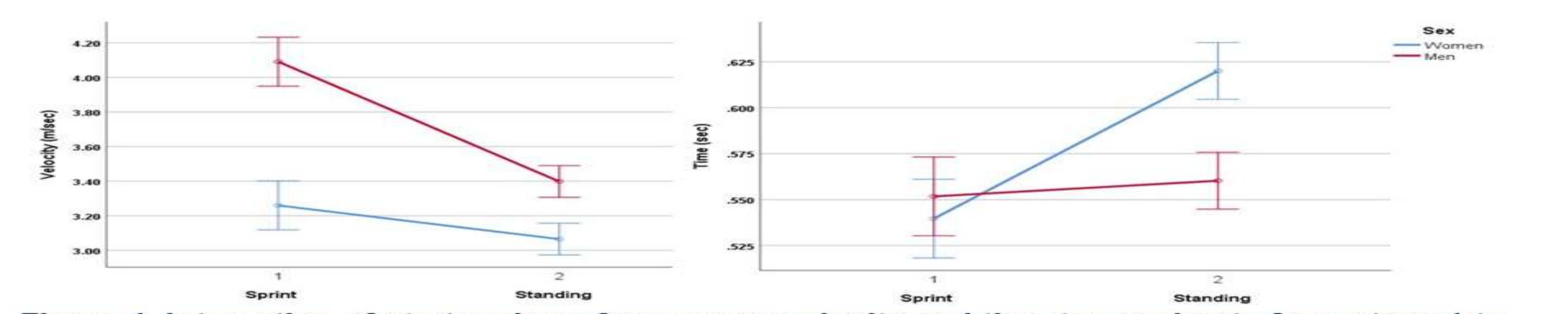

Figure 1. Interaction of start and sex for average velocity and time to accelerate from steps 1 to 4 during sprint and standing starts for men and women (variability illustrated by Standard Error).

Table 1. Time and average velocity for steps 1-4 of sprint and standing starts (Mean ± SD; n = 10 of each sex).

	Women		Men	
	Sprint	Standing	Sprint	Standing
Time (sec)	0.551 ± 0.060	0.610 ± 0.047	0.540 ± 0.056	0.571 ± 0.038
Velocity (m/sec)	3.45 ± 0.46	3.12 ± 0.23	3.90 ± 0.41	3.34 ± 0.27

[a] Sprint significantly faster than Standing start (p = 0.037).
[b] Men significantly faster than women (p = 0.002).

Table 2. Sprint and standing start variables for each step (Mean ± SD; n = 10 of each sex).

	SP1	SP2	SP3	SP4	ST1	ST2	ST3	ST4
Women								
H Force	334.6 ± 49.4	331.2 ± 51.8	308.0 ± 52.5	374.4 ± 58.3	371.5 ± 41.9	307.1 ± 39.3	304.7 ± 48.6	346.0 ± 50.0
V Force	956.6 ± 188.5	1037.2 ± 214.6	1016.7 ± 230.0	1169.9 ± 238.1	1077.5 ± 203.7	1054.5 ± 244.3	1084.5 ± 262.8	1088.7± 206.1
H:V	0.36 ± 0.05	0.33 ± 0.06	0.31 ± 0.04	0.33 ± 0.05	0.35 ± 0.04	0.30 ± 0.07	0.29 ± 0.06	0.33 ± 0.05
Time	0.184 ± 0.009	0.190 ± 0.016	0.193 ± 0.021		0.205 ± 0.016	0.206 ± 0.021	0.189 ± 0.19	
Distance	0.52 ± 0.09	0.69 ± 0.06	0.66 ± 0.09		0.52 ± 0.06	0.71 ± 0.11	0.67 ± 0.10	
Velocity [a]	2.81 ± 0.43	3.58 ± 0.23	3.45 ± 0.46		2.55 ± 0.40	3.48 ± 0.67	3.39 ± 0.60	
Men								
H Force	385.5 ± 66.1	426.3 ± 77.2	375.6 ± 103.4	490.0 ± 158.8	475.6 ± 65.9	398.0 ± 74.5	411.2 ± 74.8	489.2 ± 147.1
V Force	1210.4 ± 184.9	1376.3 ± 198.1	1220.2 ± 179.5	1489.5 ± 294.3	1381.4 ± 145.4	1351.2 ± 184.6	1273.0 ± 167.3	1523.7 ± 315.4
H:V	0.32 ± 0.04	0.31 ± 0.04	0.31 ± 0.07	0.33 ± 0.10	0.34 ± 0.02	0.30 ± 0.03	0.33 ± 0.05	0.32 ± 0.08
Time	0.185 ± 0.020	0.180 ± 0.020	0.182 ± 0.016		0.190 ± 0.017	0.206 ± 0.039	0.183 ± 0.019	
Distance	0.56 ± 0.04	0.66 ± 0.05	0.71 ± 0.09		0.55 ± 0.06	0.67 ± 0.06	0.69 ± 0.09	
Velocity [a]	2.80 ± 0.80	3.68 ± 0.48	3.90 ± 0.41		2.90 ± 0.35	3.33 ± 0.62	3.77 ± 0.52	

SP = sprint condition; ST = standing start condition; Numbers after SP and ST = step in sequence; H Force = horizontal force (N); V Force = vertical force (N); H:V = Ratio of horizontal to vertical force; Time (sec); Distance (m); Velocity ($m\text{-}sec^{-1}$). Steps are foot contacts 1 to 2, 2 to 3, and 3 to 4 for Time, Distance, and Velocity variables.
[a] Step 1 to 2 significantly different than steps 2 to 3 and 3 to 4 ($p \leq 0.05$).

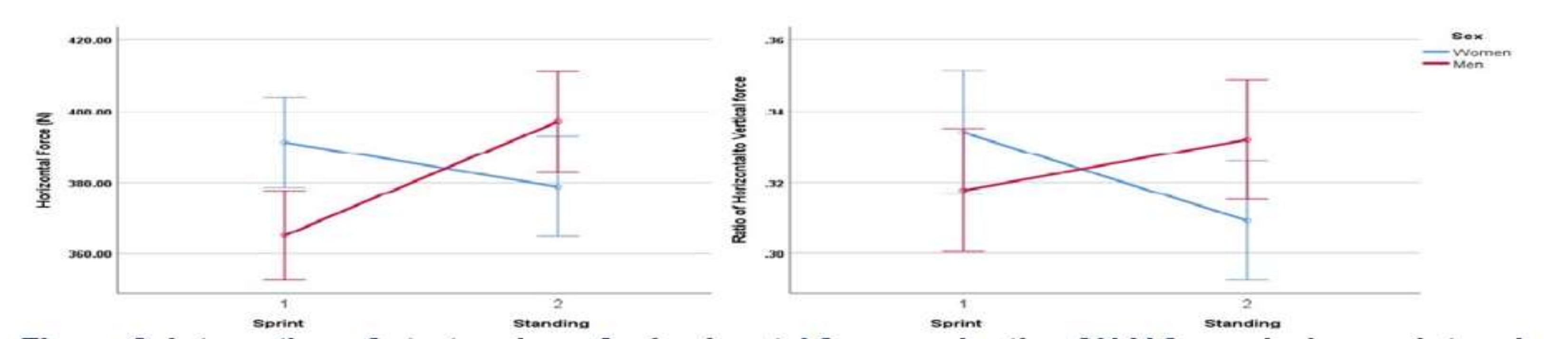

Figure 2. Interaction of start and sex for horizontal force and ratio of H:V force during sprint and standing starts for men and women (variability illustrated by Standard Error).

DISCUSSION/CONCLUSION

This study analyzed how men and women accelerate at the start of a sprint. During the sprinter start, women develop more force and a higher H:V than men. The opposite is true for the standing start. Research shows that women may have a more force oriented profile than men, though men develop greater force during standing starts (Devismes et al., 2019). In the current study, men developed greater force and velocity than women, as previously shown (Devismes et al., 2019).

The current study demonstrates that step distance increased from the first to second step. Others demonstrated a decreased distance between these steps, and a substantially longer first step than found in the current study (Coh, et al., 2017).

In the current study, velocity increased after the first step, which is consistent with previous research (Coyler et al., 2018). The current study demonstrated that both men and women developed greater velocity from the sprinter compared to the standing start positon and a greater mean H:V ratio during the sprinter condition. Some evidence suggests greater horizontal, and not vertical force may be most important for sprinting performance (Kawamori et al., 2013). However, in the current study, men generated more mean horizontal ground reaction force in the standing compared to the sprinter condition, yet produced lower velocity.

The H:V in the present study ranged from 0.29 to 0.36:1 for all steps and subjects. These values are slightly lower than previously found (Duffin et al., 2019), and lower than the H:V of approximately 0.53:1 during block start sprints (Coh et al., 2017).

This study found that while both sexes produced lower velocity and higher time to complete the four steps when using the standing start; men tended to be more negatively affected than women. This occurred despite men apparently increasing horizontal force and H:V, while women did not. However, the analyses demonstrated relatively few sex-based differences, suggesting that speed development training need not differ significantly between men and women.

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