
STEPPING BACK TO IMPROVE SPRINT PERFORMANCE: A KINETIC ANALYSIS OF THE FIRST STEP FORWARDS

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ABSTRACT

Frost DM and Cronin, JB. Stepping back to improve sprint performance: A kinetic analysis of the first step forwards. *J Strength Cond Res* 25(10): 2721–2728, 2011—Using a step backward to initiate forward movement can increase force and power at push-off and improve sprint performance over short distances. However, it is not clear whether the benefit provided by this paradoxical step influences the mechanics of the first step forwards. Twenty-seven men of an athletic background performed maximal effort 5-m sprints from a standing start and employed a step forwards (parallel and split stance) or backwards (false) to initiate movement. Each sprint was started with an audio cue that also activated the timing gates. Three trials of each starting style were performed and movement (0 m), 2.5-, and 5-m times were recorded. An in-ground force plate placed at the 0-m mark measured the kinetic and temporal characteristics of the first step. Sprint times to 2.5 and 5 m were slower ($p < 0.05$) when a parallel start was used. No differences were seen in the normalized peak forces (vertical and horizontal) or the vertical impulse between starts, but the vertical mean force was 11 and 12% higher for the false and split starts, respectively. Surprisingly, the parallel start's impulse was significantly greater than that of the false (24%) and split (22%) styles, a consequence of the additional time spent in contact with the ground. The ground contact time, time to peak force, and time from peak force to toe-off (vertical and horizontal) were significantly longer for the parallel start. These temporal variables were also better correlated with sprint performance than any kinetic measure ($0.42 \leq r \leq 0.75$). The false start appears to be advantageous over short distances by improving push-off and the temporal characteristics of the first step.

KEY WORDS force, impulse, standing start, temporal

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INTRODUCTION

The ability to accelerate over short distances is of paramount importance to the success of many athletes participating in field- and court-based sports. Whether chasing down a fly ball, evading a defender, or charging the net to pick up a drop shot, acceleration is critical. In a 100-m sprint, 64% of the athlete's total time can be accounted for by the block start and acceleration phase alone (15); therefore, when the distance to be covered is only 10- to 20-m, performance is most dependent on the first few steps. Consequently, coaches should be placing most of their efforts on acceleration mechanics and first step quickness to maximize the efficiency of training (17). But how should a coach be instructing these skills for field- and court-based sports when their chaotic nature rarely allows an athlete to set his or her position before the initiation of forward movement? The guiding principles that have been developed for track sprinters and blocks starts are likely very similar to those needed for court athletes; however, there is still much to learn in regard to the mechanics specific to standing starts and the instances when athletes are unable to set themselves with a staggered stance and crouched position.

Kraan et al. (8) offered one of the first mechanical arguments in favor of one standing start technique over another in 2001. The researchers compared the force and power at push-off between 3 starting styles that varied in foot position only, namely, a staggered stance, a parallel stance, and a parallel stance whereby movement was initiated with a “false” step backwards. Although counterintuitive, it was concluded that using a backwards step to accelerate forwards could be advantageous, in large part because of additional benefit from the stretch shortening cycle at push-off. Before this finding, the “false” step had been viewed by many as wasted time and counterproductive, which then led to a belief that an athlete should eliminate this unnecessary movement to produce a more time-efficient start (1). However, this was despite the fact that most athletes inherently adopt the backwards stepping strategy when asked to sprint forwards from an athletic ready position (8).

To initiate forward movement from a stationary standing position, the center of mass must be positioned anterior to the

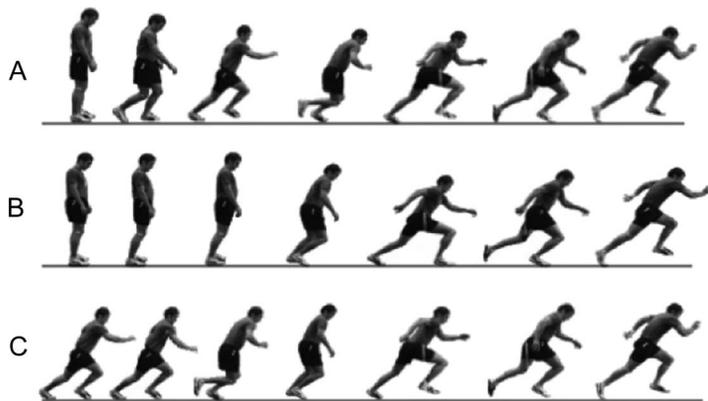


Figure 1. The false (A), parallel (B), and split (C) starting styles. The false and parallel starts were initiated with a backward step and forward lean, respectively.

base of support (feet) (1). This is achieved in one of 2 ways: a rotation of the body about the ankle joint (i.e., leaning forwards), thereby shifting the center of mass forward, or by displacing the support area behind the center of mass (i.e., placing one foot backward) (1). However, if the time taken to achieve the backward step does not exceed the time required to shift the center of mass forward, the false step could elicit performance improvements over short distances. This is precisely what the evidence now shows (4,6). Using a step backwards to cover only 0.5 m, takes no more time than to rotate the body about the ankle joint and travel the same distance (6), and it improves sprint performance over 2.5, 5, and 10 m (4,6).

However, should it be assumed that the superiority of the false step is a consequence of the enhanced force and power at push-off alone? The means chosen to shift the center of mass and initiate forward movement may also impact the manner in which the athlete contacts the ground on the ensuing step

mechanics of standing starts is needed because it may provide coaches and researchers with valuable insight to further custom their acceleration training for field- and court-based athletes.

In a previous paper (6), the authors' reported sprint times for 3 standing starts, including the parallel and false starts discussed above; however, no mention was made to the execution of the first step. Therefore, the objective of this investigation was to evaluate the kinetic and temporal characteristics of the first forward step for 3 standing start techniques (parallel, false, and split). Participants were subsequently categorized as fast and slow, and the data were reexamined to determine whether sprint performance could be differentiated based on the characteristics of the first step forwards.

METHODS

Experimental Approach to the Problem

To assess the effect that either starting strategy had on the first step forwards and, thus sprinting performance, athletic men from various sporting backgrounds performed 3 5-m sprints employing 3 different standing starts: (a) a parallel start—movement was initiated with a step forwards; (b) a false start—movement was initiated with a step back; and (c) a split start—movement was initiated from a split stance. An audio cue was used to initiate movement and trigger a timing system that captured sprint times at the 0-, 2.5-, and 5-m marks. A force plate was placed 0.5 m in front of the starting line

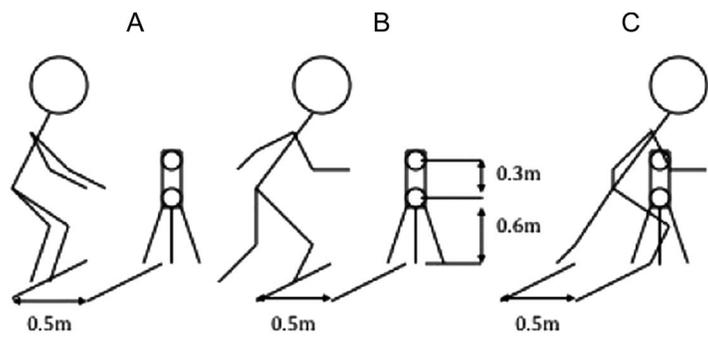
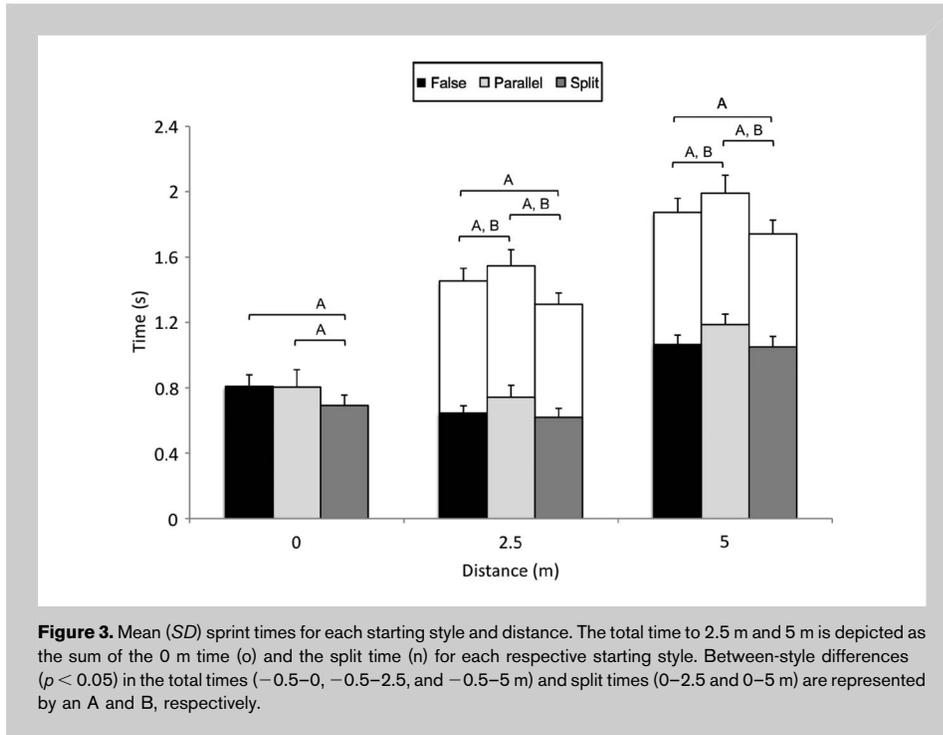


Figure 2. A) Starting position of parallel and false start. B) Starting position of split start and representative of the backward step for the false start. C) First forward step for all each start.



(0-m mark) to measure the ground reaction force of the first step forwards. A between-start comparison was conducted for each distance recorded and the temporal and kinetic characteristics of the first step. Participants were subsequently divided into 3 groups (fast, average, and slow) for each starting style, and a between-group analysis was performed to differentiate slow and fast participants.

Subjects

Twenty-seven men of an athletic background volunteered to participate in this study. Each individual cited previous involvement in an organized running-related sport (e.g., rugby, Australian Rules Football); however, no one competed at the national level. Their age, height and body mass were 22.1 ± 2.9 years, 1.80 ± 0.7 m, and 76.1 ± 7.7 kg, respectively. The Human Ethics Committee of the University approved

the investigation, and all participants gave their informed consent before the data collection began.

Starting Styles

Three standing starts were compared in this investigation. Two began with the feet in parallel (parallel and false) and one was initiated from a staggered, or split foot position (Figure 1). The false start began with participants placing both feet directly behind the starting line. On the audio command, the first movement was a step backward with the right foot. Subjects were permitted to raise their left foot as the right went back, as long as the first step forward was also with the right foot. This protocol was used to maintain consistency between all starting styles. The

parallel start began in the same manner as the false start (both feet directly behind the starting line), but on the audio command, participants initiated movement by stepping forwards with the right foot. No backward movement with either foot was permitted. A split stance starting posture was used as a control condition to allow comparisons with the false start to be made because it involved a similar foot position before the commencement of forward movement. The split start was also initiated by stepping forwards with the right foot. Subjects were instructed to remain still until hearing the audio buzzer.

Equipment

Three pairs of dual-beam infrared timing lights (Swift Performance Equipment, Lismore, NSW, Australia) with a beam height of 0.6 and 0.9 m from the ground were

TABLE 1. Mean (SD) first step kinetics for each starting style (all participants).*

Start	Vertical			Horizontal		
	Impulse (m·s ⁻¹)	Peak force (% BW)	Mean force (% BW)	Impulse (m·s ⁻¹)	Peak force (% BW)	Mean force (% BW)
False	0.85 (0.32)	1.92 (0.28)	1.21 (0.19)†	1.07 (0.19)†	0.89 (0.16)	0.51 (0.11)
Parallel	0.82 (0.37)	1.82 (0.29)	1.09 (0.20)	1.41 (0.28)	0.93 (0.15)	0.50 (0.10)
Split	0.83 (0.31)	1.88 (0.29)	1.22 (0.19)†	1.10 (0.17)†	0.91 (0.16)	0.51 (0.10)

*BW = body weight.
†Significantly different than the parallel start ($p < 0.05$).

TABLE 2. Mean (SD) temporal characteristics of the first step for each starting style (all participants).*

Start	GCT (ms)	Vertical		Horizontal	
		TPF (ms)	TPF-TO (ms)	TPF (ms)	TPF-TO (ms)
False	213 (19)†	122 (18)†	91 (9)†	147 (16)†	67 (8)†
Parallel	287 (37)	187 (31)	100 (13)	203 (38)	84 (23)
Split	218 (22)†	126 (20)†	92 (18)†	148 (24)†	70 (21)†

*GCT = ground contact time, TPF = time to peak force, TPF-TO = time from peak force to take-off.
 †Significantly different than the parallel start ($p < 0.05$).

positioned 0, 2.5, and 5 m from the start line (Figure 2). The starting line was located 0.5 m behind the first timing light to prevent any extraneous movement from prematurely breaking the beams (5). Ground reaction forces of the first step were measured with an in-ground 0.8×0.6 -m triaxial force plate (Kistler, model 9287B, Switzerland), positioned directly in front of the start line, and sampled at 1,000 Hz.

Testing Procedures

Participants completed a general warm-up comprising 10 minutes of light jogging and dynamic stretching. They were then familiarized with the 3 starting styles that were to be used during the investigation and asked to perform 5 submaximal 5-m sprints progressing in intensity from 50 to

90% of maximal effort with a self-selected starting style. Participants wore athletic running shoes and performed all sprints indoors on a rubberized surface. Kraan et al. (8) stated that initiating forward movement with a backward step is instinctive for up to 95% of individuals; therefore, to ensure that participants reacted naturally to the audio cue and to avoid any influence of the parallel start, the false start was performed first. The order of the 2 remaining starting styles (parallel and split) was randomized for all participants. Each subject was required to perform a minimum of 3 5-m maximal sprint efforts for each starting style with the last 2 being recorded for analyses. Approximately 90-second rest was given between trials and 3 minutes rest between starting styles. If the trial was not completed according to the

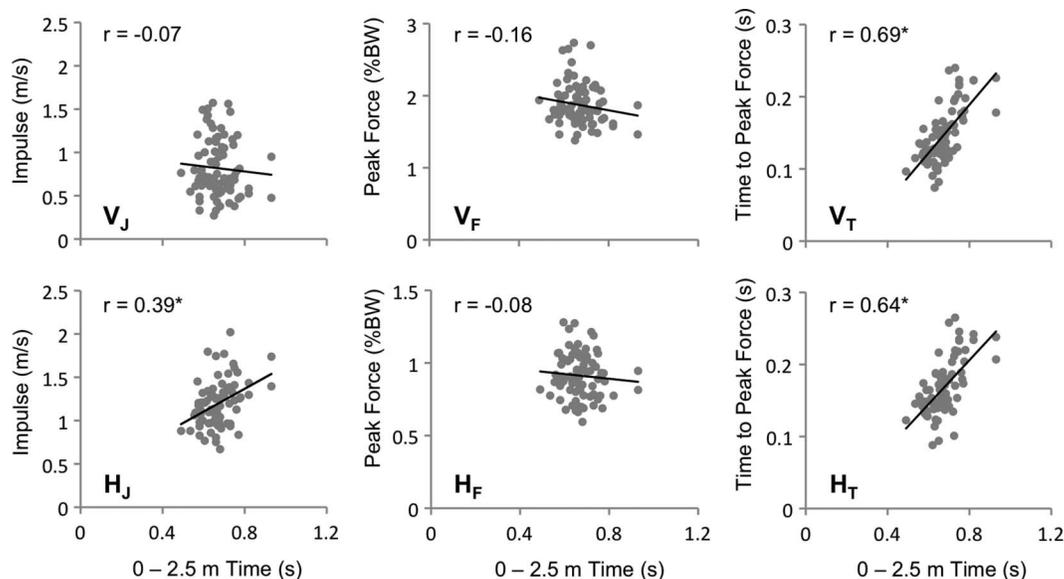


Figure 4. Correlations between the 0- to 2.5-m sprint times and the vertical (V) and horizontal (H) impulse (J), peak force (F) and time to peak force (T). The impulse and peak force are normalized to body mass and body weight respectively (*significant correlation; $p < 0.05$).

TABLE 3. Mean (SD) sprint times for the fastest ($n = 9$) and slowest ($n = 9$) participants of each starting style.

Group	0- to 2.5-m Time (s)						0- to 5-m Time (s)					
	False		Parallel		Split		False		Parallel		Split	
Fast	0.60	0.02*†	0.67	0.03†	0.56	0.03†‡	1.01	0.03†‡	1.14	0.02†	1.00	0.04†‡
Slow	0.69	0.03‡	0.82	0.07	0.68	0.02‡	1.12	0.05‡	1.24	0.06	1.11	0.04‡

*Significantly different than the parallel and split start ($p < 0.05$).
 †Significantly different than the slow group ($p < 0.05$).
 ‡Significantly different than the parallel start ($p < 0.05$).

descriptions outlined above or the participant attempted to anticipate the starting buzzer, then an additional trial was completed after another 90 seconds of rest. All trials were initiated with a buzzer (Swift Performance Equipment) that also triggered the timing gates. This was used as a means of capturing the reaction and movement times before crossing the first timing gate.

Statistical Analyses

The start (touchdown) and end (takeoff) of the first ground contact were defined by the instants in time at which the vertical force rose above 10 N and fell below 25 N, respectively (7). The vertical and horizontal ground reaction forces (peak and mean) were expressed relative to body weight (%BW), and the horizontal impulse (force \times time) was normalized to body mass (meters per second), thereby reflecting the change in the horizontal velocity of the center of mass during stance (7). The vertical impulse was also expressed in relation to body mass; however, the impulse because of body weight was removed before normalization (7). The total ground contact time (GCT) was separated into 2 phases: the time to peak force (TPF) and the time from peak force to take-off (TPF-TO). All 3 temporal variables were used as descriptors

for each standing start. The results are represented by the mean of 2 trials. After the initial analyses, participants were separated into 3 groups (fast, average, slow) based on their 0- 2.5-m times for each specific starting style. Only the data of the fast and slow groups are presented in detail.

Sprint performance over 2.5 and 5 m and ground contact characteristics (force, impulse, and time) were described with means and SDs. Pearson correlation coefficients were used to identify relationships between the sprint times and the metrics of the first step. Participants were subsequently categorized based on their 0- to 2.5-m sprint times; thus, main effects and group interactions were assessed with a 2-factor (start \times speed) analyses of variance (SigmatStat 3.5, Systat Software Inc, Richmond, CA, USA). For all significant interactions, Holm-Sidak post hoc comparisons were used to investigate the differences. Statistical significance was set at $p \leq 0.05$.

RESULTS

The coefficients of variation, describing within-subject intertribal reliability, were $<15\%$ for all reported variables.

All Participants

No significant differences were noted in the time taken to the first gate between the false and parallel starts, although both

TABLE 4. Mean (SD) first step kinetics for the fastest ($n = 9$) and slowest ($n = 9$) participants of each starting style.*

Start	Group	Vertical			Horizontal		
		Impulse (m·s ⁻¹)	Peak force (% BW)	Mean force (% BW)	Impulse (m·s ⁻¹)	Peak force (% BW)	Mean force (% BW)
False	Fast	0.79 (0.32)	1.85 (0.22)	1.19 (0.18)	1.05 (0.18)†	0.88 (0.12)	0.51 (0.09)
	Slow	0.76 (0.28)	1.81 (0.21)	1.13 (0.17)	1.05 (0.21)†	0.83 (0.15)	0.46 (0.11)
Parallel	Fast	0.90 (0.41)	1.85 (0.27)	1.16 (0.21)	1.46 (0.27)	0.99 (0.12)	0.56 (0.10)
	Slow	0.71 (0.26)	1.75 (0.20)	1.01 (0.11)	1.32 (0.26)	0.83 (0.09)	0.43 (0.07)
Split	Fast	0.75 (0.25)	1.82 (0.19)	1.17 (0.14)	1.08 (0.19)†	0.89 (0.89)	0.51 (0.08)
	Slow	0.82 (0.33)	1.84 (0.24)	1.21 (0.19)	1.10 (0.18)	0.90 (0.14)	0.51 (0.10)

*BW = body weight.
 †Significantly different than the parallel start ($p < 0.05$).
 ‡Significantly different than the slow group ($p < 0.05$).

TABLE 5. Mean (SD) temporal characteristics of the first step for the fastest ($n = 9$) and slowest ($n = 9$) participants of each starting style.*

Start	Group	GCT (ms)	Vertical		Horizontal	
			TPF (ms)	TPF-TO (ms)	TPF (ms)	TPF-TO (ms)
False	Fast	206 (13) [†]	119 (9) [†]	87 (7)	143 (11) [†]	63 (8)
	Slow	230 (16) [†]	132 (17) [†]	98 (6)	157 (15) [†]	73 (6) [†]
Parallel	Fast	265 (33) [‡]	170 (30)	95 (11) [‡]	191 (32)	74 (14) [‡]
	Slow	305 (33)	194 (24)	111 (13)	210 (26)	96 (17)
Split	Fast	213 (21) [†]	123 (17) [†]	90 (11)	146 (14) [†]	67 (9)
	Slow	218 (17) [†]	131 (13) [†]	88 (6) [†]	154 (14) [†]	64 (5) [†]

*GCT = ground contact time; TPF = time to peak force; TPF-TO = time from peak force to take-off.

[†]Significantly different than the parallel start ($p < 0.05$). Please cite footnote [‡] in table 4.

[‡]Significantly different than the slow group ($p < 0.05$).

styles took significantly longer than the split start (Figure 3). At 2.5 and 5 m, there were significant differences between all 3 starts (parallel was slowest). When the movement time was removed (time to the first gate) and only the time between each successive gate was examined, the false and split starts were not significantly different at any distance. Both however were significantly faster than the parallel start (15.0% for 0–2.5 m and 9.5% for 0–5 m). There were no significant differences among any of the starts in the time taken to sprint from 2.5 to 5 m.

Despite slower sprint times for the parallel start, there were no significant differences in the vertical impulse or vertical peak force (PF), in comparison to the 2 other starting styles. The vertical mean force (MF), however, was 11 and 12% higher for the false and split starts, respectively (Table 1). With regard to the horizontal kinetics of the first step forwards, there were no significant changes in MF and PF, but the parallel start's impulse was significantly greater than that of the false (24%) and split (22%) starting styles (Table 1).

The GCT, TPF, and time from peak force to toe-off, for both the vertical and horizontal components of the ground reaction force were significantly shorter when participants adopted a split or false start to initiate forward movement (Table 2).

Correlations

When the data for the 3 starting styles were collapsed and correlated with the 0- to 2.5-m sprint times (no movement time included), similar results were obtained to those reported above; significant correlations were noted with the vertical MF ($r = -0.33$), horizontal impulse ($r = 0.39$), and all temporal variables associated with the ground contact of the first step ($0.42 \leq r \leq 0.75$). The relationships for the vertical and horizontal impulse, peak force, and TPF are illustrated in Figure 4.

Fast and Slow Participants

The 0- to 2.5-m times for the fast and slow sprint groups were significantly different for each starting style (Table 3); on

average, the faster subjects completed the 2.5-m distance in 16.2% less time (119 milliseconds). As was found with the group data, using a forward step to initiate movement resulted in significantly slower sprint times to 2.5 m (fast and slow groups) than when a false step or split stance was used (mean of 101 and 126 milliseconds for the false and split starts, respectively; Table 3).

Fast and slow participants for each starting style could not be differentiated based on any kinetic variable investigated (Table 4). In fact, the only differences found to be statistically significant were those noted for the GCT and vertical and horizontal TPF-TO within the parallel starting style (Table 5). Like the sprint times, the between-style differences were similar to those reported for the group data (Table 4); the horizontal impulse, GCT, TPF, and TPF-TO were significantly lower when participants were allowed to step back or use a split start to initiate forward movement (Table 5).

DISCUSSION

Stepping backwards to initiate forward movement can improve sprint performance over short distances (4,6). Partly because of the increased force and power production at push-off (8), the current findings provide evidence to suggest that the paradoxical starting style also provides direct mechanical benefits to the acceleration phase of the sprint. The characteristics of the first step forwards were found to be dependent on the start technique used, particularly with regards to the temporal variables associated with ground contact (Tables 1 and 2). The total time spent on the ground, the TPF, and the TPF-TO were all significantly greater when the parallel starting stance was used. Generally, additional time spent in stance during the acceleration phase is expected, because of changing biomechanical conditions and increasing velocity (3), and advantageous in terms of force production (12); the extended length of time spent on the ground often leads to a greater impulse and thus change

in velocity (12). However, in this case, it appears that the additional contact time was not an efficient means to improve performance as the parallel split time for 0–2.5 m was significantly slower than both other starts. In fact, when compared to existing data from elite (3,9,13) and well-trained (12) track athletes coming out of the blocks, the GCT for the parallel start was 29–66% higher. In comparison, the false and split start contact times were within the range reported by Schot and Knutzen (12) for competitive university sprinters (i.e., 208–222 milliseconds).

It is plausible that the increased support time associated with the parallel starting style is simply an indication of a lower horizontal velocity at contact. Having to lean forwards to position the center of mass ahead of the feet to initiate movement could alter the segment mechanics and change the *manner* in which the athletes contact the ground, particularly during the first step when execution or efficiency is crucial (13). Making use of the backwards step alters the *way* an athlete produces force at push-off by changing their segment mechanics and facilitating use of the stretch-shortening cycle (8); therefore, it would not be surprising to also observe a higher horizontal velocity at the first ground contact. Although measuring the segment kinematics was beyond the scope of this investigation, the mean vertical force, another possible gauge of changes to velocity (16), was also significantly higher for the false and split conditions. Although there were no differences in the peak vertical or horizontal forces, the temporal characteristics of the ground contact phase highlight definitive changes to the rate of force development (i.e., peak force and time to peak force), another performance parameter that has been linked to better sprint times (13).

Previous research has identified the horizontal and block impulses as strong predictors of sprint performance (7,12) and first step efficiency (2,3), respectively. However, to the authors' knowledge, there had been little work done to establish similar relationships for short sprints initiated from standing. Nonetheless, it was hypothesized that the inferior performance associated with the parallel stance would be related in part to an attenuated impulse of the ground reaction force of the first step forwards. Surprisingly, this was not found to be the case. The normalized vertical impulse was comparable across starting styles, despite differences in mean force and contact time, and the horizontal impulse for the parallel start was *higher* than the false and split by 32 and 28%, respectively. Because the mean horizontal forces were not different between styles the larger impulse was a product of the additional time spent on the ground, and as stated previously, contact duration might be directly related to poor performance. Therefore, when comparing standing starts that change the way athletes make contact with the ground (e.g., backwards step), it might be more important to consider the composition of the impulse (force and time) than the magnitude alone.

When the 0- to 2.5-m sprint times for all 3 starts were correlated with the various temporal and kinetic characteristics

of the first step, the mean vertical force and the horizontal impulse were the only kinetic variables to demonstrate a significant relationship, although only moderate at best (i.e., $r \sim 0.3$). Also, as stated previously, the impulse–performance relationship was positive, implying that a lower impulse was related to a faster split time. This finding is contrary to existing literature for both block (7) and standing starts (14) but logical when considering the time component to the impulse. In fact, all 3 temporal variables of the support phase were better correlated with the split times than were the kinetics. The impulse of the ground reaction force is an important aspect of acceleration, but so too is minimizing the amount of time spent in stance (3). After only 2 strides out of the blocks the GCT can decrease by as much as 23% because of the increase in the horizontal velocity. Therefore, if stepping backward can augment the horizontal velocity immediately after push-off, it is conceivable that there are also changes to the mechanics of the first steps forward, which are manifested as differences in the GCTs. The rationale given as to why the false step is inefficient has been that it is time spent moving in the wrong direction (1); however, the results of this investigation are evidence to the contrary. Mechanical differences in the 2 techniques might make the parallel start least efficient over shorter distances.

The secondary objective of this investigation was to examine whether the fast and slow participants could be differentiated based on the temporal and kinetic characteristics of the first step. Surprisingly, the answer was no. Despite an average increase of 16.2% in the 0- to 2.5-m split times, the only variables found to be significantly different were the GCT and the TPF-TO for the parallel start. Metrics such as impulse, peak and mean force and the rate of force development, shown previously to impact sprint performance (2,7,13, 14), failed to distinguish the 2 subgroups. Slawinski et al. (13) found that the resultant impulse of the first step was greater for elite sprinters than well-trained athletes, but the impulse was not normalized to body weight or body mass, despite there being a 13-kg difference in the 2 groups; the elite sprinters were the heavier group. Therefore, had the data been expressed relative to the size of the athletes the results may have been consistent with the current findings. Nonetheless, the fact that fast and slow participants in this study could not be differentiated was intriguing and warrants an investigation of the segmental kinematics, particularly in light of the between-start differences.

The split stance starting style was used as a control condition because it allowed each participant to position their right foot behind the center of mass before the initiation of forward movement. A horizontal impulse could be generated immediately after the starting cue, without having to displace the center of mass or take a step backward, thereby reducing the time taken to reach the first gate. However, with the exception of a stoppage in play, athletes will rarely find themselves with an opportunity to adopt this starting posture (6), consequently reducing its practical significance. That

said, in comparison to the false start, there were no differences found between any temporal or kinetic characteristic of the first step, and previous research has shown that the split start is less effective than stepping backwards in terms of generating horizontal force and power at push-off. Therefore, to maximize sprint performance over short distances, the false step might be most advantageous, although an examination of the kinematics is needed to fully understand the implications for training.

PRACTICAL APPLICATIONS

The results from this study provide further support for the use of a backward step to improve sprint performance over short distances (e.g., 2.5 m). The mechanical advantage provided at push-off also influences the temporal characteristics of the first step, possibly making the initial acceleration phase more efficient and effective. With a parallel start, the center of mass must be repositioned in front of the feet before a horizontal force can be developed. Consequently, there is a delay in the development of horizontal velocity; greater time is spent in contact with the ground and the acceleration over short distances is compromised. If athletes were able to stop play and set their position, a staggered stance might afford the greatest performance, but when this is not the case, the best way to initiate forward movement is with a step in the opposite direction.

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