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ORIGINAL ARTICLE

Kinematic and kinetic differences in block and split-stance standing starts during 30 m sprint-running

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Abstract
This study aimed to understand the kinematic and kinetic differences between two sprint starts: block and split-stance standing. Fourteen sub-elite male sprinters (100 m time: 11.40 ± 0.39 s) performed block and split-stance standing starts sprints over 30 m of in-ground force platforms in a randomised order. Independent t-tests and repeated measures mixed model analysis of variance were used to analyse the between-condition variables across conditions, and over four step phases. Block start sprints resulted in significantly ($p < .05$) faster 5 m (5.0%, effect size [ES] = 0.89) and 10 m (3.5%, ES = 0.82) times, but no significant differences were found at 20 and 30 m. No significant differences were found in any kinematic measure between starting positions. However, block starts resulted in significantly ($p < .001$) greater propulsive impulses (6.8%, ES = 1.35) and net anterior-posterior impulses (6.5%, ES = 1.12) during steps 1–4, compared to the standing start. Block starts enable athletes to produce a greater amount of net anterior-posterior impulse during early accelerated sprinting, resulting in faster times up to 10 m. When seeking to improve initial acceleration performance, practitioners may wish to train athletes from a block start to improve horizontal force production.

Keywords: *Acceleration, technique, velocity, impulse, sprint-training*

Highlights

- Block starts results in significantly faster times to 10 m compared to standing starts.
- Block starts enable athletes to produce significantly greater propulsive impulses and net anterior-posterior impulses over the early phases of sprint acceleration.
- Beyond 10 m, small differences in kinematics and kinetics were found between starting positions resulting in statistically comparable sprint times at 20 and 30 m.

Introduction

The start and initial acceleration phases are crucial components to the outcome of sprint-running performance (Bezodis, Salo, & Trewartha, 2015; Willwacher et al., 2016). In sporting events, different starting positions are adopted to optimise sprint performance, for example, a crouch start (American football, track and field sprint events) or a standing start (soccer, rugby, and basketball) (Macadam, Cronin, Uthoff, Johnston, & Knicker, 2018; Slawinski et al., 2017). For a crouched start, athletes can use starting blocks in a four-point stance (track and field) or a three-point contact position without blocks (American football), while standing starts are often performed from a spilt-stance or parallel stance position. In a crouched start, the athlete's centre of mass is positioned lower down and further back from the starting line than in the standing position (Salo & Bezodis, 2004). When using starting blocks, the crouched position enables an athlete to maximise the forward-directed component of ground reaction force (GRF), leading to

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greater forward horizontal acceleration, which is vital for the start and acceleration phases of a sprint (Cusick, Lund, & Ficklin, 2014). Though a block start is compulsory for all sprint-running events up to 400 m, for athletes in relay races only the first athlete uses starting blocks, while athletes running the subsequent sections of the event must decide whether to adopt a three-point start, or a standing start (Salo & Bezodis, 2004). Moreover, though information from block starts provides important understanding for track sprint performance, it is less relevant to team-sport athletes who accelerate from a standing position.

The standing start position has not been subjected to the same analysis as the crouched start. Ostarello (2001) summarised earlier research, which suggested that some practitioners have noted the standing start is easier to teach than the crouched start, results in quicker attainment of an upright position and full running stride; and can be faster over short distances up to 30 m. Comparisons between different crouch and standing starts have led to mixed findings. During the initial phase of accelerated sprinting, the block start was shown to be significantly faster (2.5 m = 14.2–23.4%, 5 m = 9.4–16.6%) than a standing start position in male Division I collegiate American football players (Cusick et al., 2014). Similarly, results from physical educational students with mixed sporting backgrounds, found that 5 m sprint times were significantly faster (4.4–11.7%) following a crouched three-point start position compared to three different standing starts (parallel, jump, and false start positions) (Slawinski et al., 2017). Moreover, the crouched start resulted in significantly greater maximal power and mean horizontal force with a more forward orientation of the resultant force at take-off (Slawinski et al., 2017). Over greater distances (40 m), Haugen, Tønnessen, and Seiler (2012) found standing starts were faster than crouched starts (three-point contact and block) in track and field male and female athletes during a reliability study. Of note, block start performance depends on specific technical skills (Debaere, Delecluse, Aerenhouts, Hagman, & Jonkers, 2013), therefore, for athletes with a lack of experience in this start, the results can vary. Finally, no significant difference between block and standing starts for the times to reach either the 25 or 50 m marks were found in trained male and female university track sprinters (Salo & Bezodis, 2004). Thus, it is not clear whether a crouched or standing start is more advantageous for track and field athletes, and whether differences in the GRF and its orientation could explain the differences found between starting positions. As only one study has compared starting positions with a single force plate for kinetic analysis (Slawinski et al., 2017), and kinematic analysis is lacking beyond 5 m, further research is required. Moreover, as step kinematics and kinetics are thought to be key determinants of sprinting performance (Hunter, Marshall, & McNair, 2005; Morin et al., 2012), and are a result of a combination of complex interactions through the human system (Nagahara, Takai, Kanehisa, & Fukunaga, 2018), investigating differences in these variables between starting positions is required to further our understanding.

Therefore, the aim of this study was to investigate 30 m over ground sprint-running performance between two starting styles: four-point block and split-stance standing, and the associated kinematic and kinetic characteristics with each start position. Insights into this area may provide a greater understanding of starting technique and knowledge on how different start positions can lead to mechanically-enhanced sprint start performance. It was hypothesised that block starts of sub-elite sprinters would result in faster sprint times due to greater propulsive forces generated from block take-off, compared to standing starts.

Methods

Subjects

Fourteen well-trained Japanese male sprinters (age: 20.6 ± 1.16 years; body mass: 65.3 ± 4.9 kg; height: 172.8 ± 3.9 cm; personal best 100 m race time: 11.40 ± 0.39 s) volunteered to participate in this study. All participants were informed about the objective and potential risks and benefits of the study prior to giving their written consent. None of the participants reported any musculo-skeletal injuries prior to or during the study.

Experimental design

A cross-sectional design was used to investigate the kinematic and kinetic characteristics of sprinting between two starting styles: four-point block and split-stance standing over an entire 30 m distance. Approval for the experiment was obtained from the local ethics committee. This study was conducted in accordance with the Declaration of Helsinki.

Procedures

The testing was conducted on an indoor track with athletic track surface. Each athlete completed his own individual warm-up comprising of progressive running drills interspersed with dynamic stretching and submaximal runs (30 m) ranging from 50% to

Figure 1. Examples of block (A), and split stance standing (B) start positions.

90% of maximal effort. Thereafter, participants, performed two maximal effort sprints over 30 m for two different start positions: (1) block and (2) split-stance standing (Figure 1) in a randomised order.

Subjects chose their own preferred block spacing and angles for the block start. The split-stance standing start was completed with the toes of one foot positioned just behind the start line and the other foot placed at a self-selected distance behind the front foot (no blocks or hand contact). Subjects were instructed not to use rocking or swinging motions before the start. Trials were separated by five to ten-minutes of passive recovery, dependent on individual requirements. Athletes performed all trials wearing track spike shoes and tight-fitting clothing. For both starts, one experimenter provided a start signal using an electronic starting gun (Digi Pistol, Molten, Hiroshima, Japan), in the same manner used in official 100-m races. The fastest trial based on 30 m sprint time (explained below) from each condition was used for subsequent data processing and analysis.

Step kinematics and kinetics were quantified using thirty in-ground force platforms (TF-90100, Tec Gihan, Uji, Japan; 1000 Hz) which quantified GRF data (Nagahara et al., 2018; Nagahara, Mizutani, Matsuo, Kanehisa, & Fukunaga, 2017b). The electronic starting gun connected to an operating computer provided the synchronisation for the timer and force platforms. The electronic starting system also started a laser distance measurement system (301, Jenoptik, Jena, Germany; 100 Hz), which quantified 5, 10, 20, and 30 m sprint times. Raw distance data was used to quantify the sprint times and no filter or model was applied. The laser device was positioned on a tripod at a height of 1 m and placed at a distance of 5.5 m behind the start line.

Step-to-step kinematic variables over 30 m were generated from GRF data using MATLAB (V2018a, Mathworks, Natick, Massachusetts, USA). In order to eliminate the influence of random noise and accurately detect the ground contact and flight phases of the step cycle, GRF signals were filtered using a Butterworth low-pass digital filter at a cut-off frequency of 50 Hz (Nagahara et al., 2017b; Nagahara et al., 2018). Contact time and flight time were considered when vertical GRF rose above and fell below 20 N. Using inverse step duration, step frequency was calculated from the foot strike of one leg to the foot strike of the other leg. The anterior-posterior distance between two contralateral foot positions determined step length. The centre of pressure in the anterior-posterior direction during the middle of the contact phase determined foot position at each step (Nagahara, Mizutani, Matsuo, Kanehisa, & Fukunaga, 2017a). Time integration of three-dimensional GRFs were used to calculate impulses as per previous studies (Nagahara et al., 2017a; Nagahara et al., 2017b). Therefore, vertical impulse, net medial-lateral impulse (medial forces were treated as positive and lateral forces as negative, thus net medial-lateral equals the sum of medial and lateral) (Nagahara et al., 2017b), propulsive impulse (positive values), braking impulse (negative values), and net horizontal impulse (sum of propulsive and braking) were calculated over the 30 m distance. The kinetic variables were normalised to the corresponding athlete's body mass to determine how much impulse was produced per kg body mass.

To understand how start positions affect different phases of accelerated sprinting, average values for every four steps from the 1st to the 16th were determined similarly to Girard, Brocherie, Morin, Degache, and Millet (2015) and Nagahara et al.

(2018). Due to 16 steps being the smallest number taken over the 30 m sprint for all participants, we standardised the analysis number of steps to be 16. Accordingly, representing each variable up to 16 steps was quantified over four step phases (1st–4th, 5th–8th, 9th–12th and 13th–16th) and the average of 16 steps. Due to the specific muscular and technical demands represented during the block-clearing phase of sprinting (Debaere et al., 2013), we did not include the block-clearing phase. Nor did we include the initial push-off steps from behind the start line form the standing start. Therefore, an equal number of steps were analysed from both starts as the first step after the start line was used for as the first step in both trials.

Statistical analyses

Descriptive statistics (means and standard deviations) were calculated for all statistical comparisons. All variables were found to be normally distributed as the Shapiro–Wilk's test had an alpha level >0.05. Independent t-tests were used to compare sprint times, and the average of all step values between groups. An analysis of variance (ANOVA) using repeated measures was used to analyse step kinematic and kinetic variables across the two start conditions over the four-step phases. Pairwise comparisons were carried out with Bonferroni post hoc correction. An alpha level of $p < 0.05$ was selected. Effect sizes (ES) between conditions were evaluated using Cohen's d (Cohen, 1988) and 90% confidence intervals (CI) were used. Practical interpretation of ES was evaluated as follows: < 0.2 (trivial); 0.2–0.6 (small); 0.6–1.2 (moderate); 1.2–2.0 (large); > 2.0 (very large) (Hopkins, 2002).

Results

Block start sprints resulted in significantly faster 5 m (5.0%, $p = .026$, ES = 0.89) and 10 m (3.5%, $p = .040$, ES = 0.82) times compared to the standing start (Table I). Although block starts were found to facilitate a moderate effect on sprint performance over the standing start at the 20 m (2.2%, ES = 0.65) and 30 m (1.7%, ES = 0.54) mark, these differences did not reach statistical significance. No significant differences were found between block and standing starts during the 10–20 m (−0.1%, ES = 0.03) and 20–30 m (0.1%, ES = 0.06) split times.

For the step kinematics, no significant between-group/start differences were found in average step kinematic variables, and over the four-step phases (Table I). For the within-group/start analysis, however, significant differences in all step kinematics were found for all step phases. In both conditions throughout the four-step phases, measures of step length and flight time increased, while step width and contact time decreased. Step frequency was found to increase up to steps 9–12, and then decrease at steps 13–16, for both conditions.

For kinetics, the only significant differences between group/start conditions were observed over steps 1–4, with block starts resulting in significantly ($p < .001$) greater propulsive impulse (6.8%, ES = 1.35) and net anterior-posterior impulse (6.5%, ES = 1.12) (Table II). For the within-group/start analysis, significant differences between step phases were found in both conditions for all kinetic measures. Throughout the four-step phases for both types of starts, braking impulse increased, while propulsive, net anterior-posterior and net medial-lateral impulses all decreased. For the block start, after the initial 4 steps, vertical impulse decreased during steps 5–8, but then increased during steps 9–12 onwards. While from the standing start, vertical impulse decreased during steps 5–8 and steps 9–12.

Discussion

This study determined how different start positions affected 30 m sprint performance and the associated kinematics and kinetics as quantified using 30 m of in-ground force plates. The main findings of this study were (1) block start sprints result in significantly faster 5 m (5.0%, ES = 0.89) and 10 m (3.5%, ES = 0.82) times, but not at the 20 and 30 m mark; (2) no significant between-group / start differences were found in any step kinematic measures; and, (3) block starts resulted in a significantly ($p < .001$) greater amount of propulsive impulse (6.8%, ES = 1.35) and net anterior-posterior impulse (6.5%, ES = 1.12) during steps 1–4. These findings provide previously unknown insights into the kinematic and kinetic characteristics associated with four-point block and split-stance standing starts position over an entire 30 m over-ground accelerated sprint. Although we hypothesised that block starts would result in faster sprint times, the current study demonstrates that block starts were only significantly faster than standing starts up to 10 m, most likely due to the greater propulsive forces found during early acceleration.

Performing sprints from a block start position resulted in significantly faster 5 and 10 m times, compared to a split-stance standing start position. Previous studies (Cusick et al., 2014; Slawinski et al., 2017) have found 5 m sprint times were significantly faster from a three-point crouched and block start compared to a standing start, though this is the first

Table I. Sprint times and step kinematic changes (% and effect sizes) for block and standing start sprint-running over multiple phases of steps

Variable	Step phases	Block	Standing	Difference (%)	Effect size (90% confidence intervals)
5 m time (s)	-	1.46 ± 0.05	1.54 ± 0.11*	5.0	0.89 (−0.03: 1.82)
10 m time (s)	-	2.17 ± 0.07	2.23 ± 0.11*	3.5	0.82 (−0.09: 1.74)
20 m time (s)	-	3.39 ± 0.09	3.47 ± 0.13	2.2	0.65 (−0.25: 1.55)
30 m time (s)	-	4.53 ± 0.12	4.60 ± 0.16	1.7	0.54 (−0.36: 1.43)
10–20 m (s)	-	1.22 ± 0.04	1.22 ± 0.03	−0.1	−0.03 (−0.91: 0.85)
20–30 m (s)	-	1.13 ± 0.03	1.14 ± 0.03	0.1	0.06 (−0.82: 0.94)
	1–4	1.29 ± 0.11^{bcde}	1.34 ± 0.11^{bcde}	4.2	0.46 (−0.44: 1.35)
	5–8	1.69 ± 0.11^{acde}	1.72 ± 0.12^{acde}	1.6	0.26 (−0.62: 1.14)
	9–12	1.90 ± 0.12^{abde}	1.91 ± 0.12^{abde}	0.5	0.08 (−0.80: 0.96)
	13–16	2.03 ± 0.13^{abce}	2.04 ± 0.15^{abce}	0.8	0.07 (−0.81: 0.95)
Step length (m)	Average	1.73 ± 0.11^{abcd}	1.75 ± 0.12^{abcd}	1.6	0.17 (−0.71: 1.06)
	1–4	0.30 ± 0.07^{bcde}	0.30 ± 0.06^{bcde}	0.0	0.00 (−0.88: 0.88)
	5–8	0.22 ± 0.06^{acde}	0.22 ± 0.07^{acd}	0.0	0.00 (−0.88: 0.88)
	9–12	0.15 ± 0.05^{abde}	0.14 ± 0.07^{abde}	−4.4	−0.16 (−1.05: 0.72)
	13–16	0.11 ± 0.05^{abce}	0.11 ± 0.06^{abce}	0.0	0.00 (−0.88: 0.88)
Step width (m)	Average	0.19 ± 0.05^{abcd}	0.19 ± 0.06^{abcd}	0.0	0.00 (−0.88: 0.88)
	1–4	4.20 ± 0.31^{bcde}	4.21 ± 0.24^{bcde}	0.2	0.04 (−0.84: 0.91)
	5–8	4.39 ± 0.21^{a}	4.39 ± 0.18^{a}	0.0	0.00 (−0.88: 0.88)
	9–12	4.43 ± 0.23^{ae}	4.44 ± 0.19^{ade}	0.1	0.05 (−0.83: 0.93)
	13–16	4.37 ± 0.23^{a}	4.35 ± 0.24^{ac}	−0.4	−0.09 (−0.97: 0.80)
Step frequency (Hz)	Average	4.35 ± 0.23^{ac}	4.35 ± 0.21^{ac}	−0.1	0.00 (−0.88: 0.88)
	1–4	0.078 ± 0.012^{bcde}	0.083 ± 0.011^{bcde}	6.7	0.42 (−0.47: 1.30)
	5–8	0.102 ± 0.009^{acd}	0.104 ± 0.011^{acd}	1.3	0.20 (−0.68: 1.08)
	9–12	0.112 ± 0.010^{abde}	0.113 ± 0.011^{abde}	0.8	0.10 (−0.79: 0.98)
	13–16	0.123 ± 0.011^{abce}	0.123 ± 0.013^{abce}	0.0	0.00 (−0.88: 0.88)
Flight time (s)	Average	0.104 ± 0.010^{acd}	0.106 ± 0.011^{acd}	1.9	0.19 (−0.69: 1.07)
Contact time (s)	1–4	0.163 ± 0.014^{bcde}	0.156 ± 0.013^{bcde}	−3.9	−0.52 (−1.41: 0.38)
	5–8	0.126 ± 0.006^{acd}	0.125 ± 0.007^{acd}	−0.9	−0.15 (−1.03: 0.73)
	9–12	0.114 ± 0.006^{abde}	0.113 ± 0.007^{abde}	−1.1	−0.15 (−1.03: 0.73)
	13–16	0.107 ± 0.005^{abce}	0.108 ± 0.006^{abce}	0.4	0.18 (−0.70: 1.06)
	Average	0.127 ± 0.007^{acd}	0.125 ± 0.008^{acd}	−1.6	−0.27 (−1.15: 0.62)

*Significant difference between block and standing start positions at $p < 0.05$.
^{a}Represents significantly different from step phase 1–4 at $p < 0.05$.
^{b}Represents significantly different from step phase 5–8 at $p < 0.05$.
^{c}Represents significantly different from step phase 9–12 at $p < 0.05$.
^{d}Represents significantly different from step phase 13–16 at $p < 0.05$.
^{e}Represents significantly different from average step phase at $p < 0.05$. Data presented as mean ± SD.

study to compare times at 10 m. Although sprint times for the block start were 2.2% and 1.7% faster than the standing start times at the 20 and 30 m marks, respectively, the differences were non-significant. Moreover, split times at 10–20 m and 20–30 m were similar between conditions (−0.1% to 0.1%). These findings are comparable to the results of Salo and Bezodis (2004) who found no significant difference in sprint times at 25 and 50 m between block and standing starts using trained university track sprinters. Therefore, from the small body of evidence it appears that block starts provide an initial advantage over the early phase of an accelerated sprint (0–10 m), though as the sprint distance increases, the difference is mitigated, with statistically comparable sprint times >10 m being achieved with either start position. However, as block start take-off is dependent on specific technical skills, greater sprint differences may be found between conditions with elite sprinters, thus further research within this cohort is warranted.

Trivial to small differences were found in force plate derived step kinematics between start positions, these differences were statistically non-significant. Starting conditions were found to have similar trivial changes in step frequency (−0.4% to 0.2%) and step width (−4.4% to 0%) in all step phases. While comparisons between starts resulted in small changes between conditions (−1.6% to 1.6%) for step length, flight times and contact times for all step phases, except steps 1–4. Step length (−3.7%) and flight times (−6.0%) were shorter, and contact times (4.3%) were longer in the block start compared to the standing start during these initial four steps. Though non-significant in this study, these finding shows differences in kinematic variables during the

Table II. Relative step kinetic changes (% and effect sizes) for block and standing start sprint-running over multiple phases of steps

Variable	Step phases	Block	Standing	% Difference	Effect size (90% confidence intervals)
	1–4	0.858 ± 0.045[bcde]	0.800 ± 0.041*[bcde]	−6.8	−1.35 (−2.32: −0.37)
	5–8	0.479 ± 0.029[acd]	0.459 ± 0.022[acd]	−4.2	−0.78 (−1.70: 0.14)
	9–12	0.347 ± 0.025[abde]	0.341 ± 0.026[abde]	−1.6	−0.24 (−1.12: 0.65)
	13–16	0.296 ± 0.026[abce]	0.294 ± 0.026[abce]	−0.8	−0.08 (−0.96: 0.80)
Propulsive impulse (N·s/kg)	Average	0.495 ± 0.024[acd]	0.473 ± 0.022[acd]	−4.4	−0.08 (−0.96: 0.80)
		−0.039 ±	−0.034 ±		
		0.019[bcde]	0.013[bcde]		
		−0.065 ±	−0.073 ±		
		0.016[acde]	0.019[acde]		
		−0.114 ±	−0.121 ±		
	1–4	0.024[abde]	0.020[abde]	−13.4	0.31 (−0.58: 1.19)
	5–8	−0.161 ±	−0.171 ±	12.4	−0.46 (−1.34: 0.44)
	9–12	0.027[abce]	0.030[abce]	6.0	−0.32 (−1.20: 0.57)
	13–16	−0.095 ±	−0.100 ±	5.9	−0.35 (−1.24: 0.54)
Breaking impulse (N·s/kg)	Average	0.016[abcd]	0.017[abcd]	4.9	−0.30 (−1.19: 0.58)
	1–4	0.819 ± 0.053[bcde]	0.766 ± 0.041*[bcde]	−6.5	−1.12 (−2.06: −0.17)
	5–8	0.414 ± 0.028[acd]	0.386 ± 0.018[acd]	−6.8	−1.19 (−2.14: −0.24)
	9–12	0.233 ± 0.020[abde]	0.220 ± 0.017[abde]	−5.3	−0.70 (−1.61: 0.21)
Net anterior-posterior impulse (N·s/kg)	13–16	0.135 ± 0.028[abce]	0.123 ± 0.032[abce]	−8.8	−0.40 (−1.29: 0.49)
	Average	0.400 ± 0.019[acd]	0.374 ± 0.015[acd]	−6.6	−1.52 (−2.52: −0.52)
Net medial-lateral impulse (N·s/kg)	1–4	0.283 ± 0.101[bcde]	0.290 ± 0.094[bcde]	2.5	0.07 (−0.81: 0.95)
	5–8	0.165 ± 0.104[acd]	0.171 ± 0.099[acd]	3.8	0.06 (−0.82: 0.94)
	9–12	0.070 ± 0.086[abde]	0.073 ± 0.083[abde]	5.2	0.04 (−0.84: 0.92)
	13–16	0.016 ± 0.061[abce]	0.031 ± 0.065[abce]	92	0.24 (−0.64: 1.12)
	Average	0.134 ± 0.078[acd]	0.142 ± 0.080[acd]	5.8	0.10 (−0.78: 0.98)
Vertical impulse (N·s/kg)	1–4	2.301 ± 0.165[bc]	2.284 ± 0.140[bc]	−0.7	−0.11 (−0.99: 0.77)
	5–8	2.221 ± 0.109[ad]	2.235 ± 0.086[a]	0.6	0.14 (−0.74: 1.02)
	9–12	2.235 ± 0.111[a]	2.230 ± 0.104[a]	−0.2	−0.05 (−0.93: 0.83)
	13–16	2.272 ± 0.112[b]	2.277 ± 0.109	0.2	0.05 (−0.83: 0.93)
	Average	2.257 ± 0.117	2.256 ± 0.105	0.0	−0.01 (−089: 0.87)

*Significant difference between block and standing start positions at $p < 0.05$.
[a]Represents significantly different from step phase 1–4 at $p < 0.05$.
[b]Represents significantly different from step phase 5–8 at $p < 0.05$.
[c]Represents significantly different from step phase 9–12 at $p < 0.05$.
[d]Represents significantly different from step phase 13–16 at $p < 0.05$.
[e]Represents significantly different from average step phase at $p < 0.05$. Data presented as mean ± SD.

initial start take-off steps between starting positions. Moreover, these findings in step length are comparable to Salo and Bezodis (2004) who found significant differences between starting positions during the initial two steps, with the block start resulting in a decreased step length compared to the standing start. The greater differences found in the initial four steps between starting conditions are most likely related to the differences in body positions. Given the more upright position and higher centre of gravity in the standing start, athletes are able to achieve a longer step and transition to the next step faster (i.e. less contact time), compared to the block start position. This was highlighted in the data, as the sprint distance increased, the difference between start position kinematics decreased and showed less variance (≤ 1.9%) for all variables after the first four steps. This potentially corresponds to the initial effects of the two starting positions reducing, that is, it could be speculated that by step 5 and beyond, the centre of mass position and angles are largely similar as the athlete is now upright. Given the lack of research into kinematic changes between starting positions, comparable findings are limited, and thus future research is required to further our understanding, particularly regarding body and joint angle kinematics.

Regarding the kinetic comparisons, block starts resulted in greater propulsive impulses over all phases, with a significant increase (6.8%) and large ES found between steps 1–4. Differences between conditions in propulsive impulse decreased as the sprint distance increased. For braking impulse, no significant differences were found overall between conditions with small magnitudes of ES found during all step phases. Therefore, greater net anterior-posterior impulses were found from the block start with larger effect sizes found between the first two step phases, and a large effect size found in average values. Only Slawinski et al. (2017) has compared kinetics between starting positions, finding that maximum power output, and vertical and horizontal GRF were significantly greater in a 3-point crouched start compared to standing starts over the initial 5 m. Block starts enable athletes to extend both legs from a bent position, enabling high amounts of power generation from the hip joint, thus providing greater block-induced power for push-off (Otsuka, Kurihara, & Isaka, 2015). Therefore, it can be proposed that block starts enable athletes to extend both legs from a greater bent position than standing starts, which would result in a greater amount of horizontal force of front and rear legs. Moreover, the more forward leaning body position, relative to the horizontal vector, coupled with the longer contact times from a block start over the initial step phases contributing to horizontally oriented forces. These factors may have enabled a greater amount of propulsive impulse to be achieved earlier than a standing start, contributing to greater horizontal velocity. Additionally, the large ES difference in net anterior-posterior impulse favouring the block start likely contributed to the significantly faster 5 and 10 m sprint times. As net anterior-posterior impulse has been found to be an important factor in acceleration performance (Nagahara et al., 2017a; Rabita et al., 2015), results from this study indicate that underlying kinetic determinants of accelerated sprinting are optimised when athletes use 4-point block starts compared to standing split-stance starts. However, after the initial two acceleration step phases, no significant differences in kinetics were found with similar split times at 10–20 m and 20–30 m. This could be explained as in both conditions, the athletes are most likely in similar upright positions and horizontal forces attained from the block start are no longer significantly greater. Moreover, it would seem that start positions have minimal effects on medial-lateral and vertical impulse. It appears that starting with blocks has the largest influence on horizontal kinetics and allows for greater horizontal propulsion during the initial phases of accelerated sprinting.

Conclusions

In conclusion, block starts enable athletes to produce significantly greater propulsive impulses and net anterior-posterior impulses over the early phases of sprint acceleration, resulting in significantly faster sprint times up to 10 m. Subsequently, as the sprint distance increases beyond 10 m, small differences in kinematics and kinetics were found between starting positions resulting in statistically comparable sprint times at 20 and 30 m. These findings suggest that block starts enable a greater amount of horizontal force to be applied, possibly due to the body's forward leaning position from the low crouched position, resulting in faster initial acceleration. Therefore, when the goal is to improve initial acceleration performance, practitioners may wish to train athletes from a block start position to improve horizontal force production.

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