Comparison of sprint timing methods on performance, and displacement and velocity at timing initiation.

ABSTRACT

Sprint testing is commonly used to assess speed and acceleration in athletes. However, vastly different outcomes have been reported throughout the literature. These differences are likely due to the sprint timing method rather than differences in athlete ability. Consequently, this study compared different sprint starting methods on sprint time and quantify the velocity and displacement of the athlete at the moment timing is initiated. Starting in a staggered 2-point stance, 12 team sport athletes were required to accelerate 10 meters for 10 repetitions. During each repetition, five independent timing methods were triggered. The methods were: (1) triggering a Move sensor; (2) starting 50cm behind the line; (3) triggering a front-foot switch; (4) triggering a rear-foot switch; and (5) starting with the front foot on the line. Timing for each method was initiated at different points during the acceleration phase and the displacement and velocity of the centroid of the pelvis at the point of timing initiation was assessed under high-speed motion capture. The Move sensor had the smallest displacement and lowest velocity at the point of timing initiation, while the front-foot trigger demonstrated the largest displacement and highest velocities. Trivial to very large effect size differences were observed between all methods in displacement and velocity at the point of timing initiation. Furthermore, small to very large differences in time to 5m were found. These findings emphasize that sprint outcomes should not be compared unless starting methods are identical. Additionally, to detect real change in performance, consistent standardized protocols should be implemented.

Keywords: Velocity, Displacement, Performance, Testing, Speed

INTRODUCTION

Speed and acceleration are desirable physical qualities in sport (6, 13) and are commonly assessed through linear sprint testing (1, 17). This information can be used by practitioners and researchers to compare different athletes and support training prescription. Therefore, the accurate assessment of these qualities is essential. However, despite linear sprint testing being a relatively simple concept, small changes in testing set up may cause substantial differences in testing outcomes (13). For example, previous research has demonstrated that starting in a 2-point *vs* 3-point stance can cause considerable differences in sprint time (~0.2-0.4 seconds over 10 meters) (4). Furthermore, substantial absolute differences in sprint time have been shown to occur when starting method and timing systems are not standardized (7, 8). Therefore, it is important to understand the influence of different testing methods and detail how they alter performance related outcomes.

During sprint testing, athletes often start from a stationary position and accelerate between predetermined points (e.g., 0-5 meters) (9). From this, the time taken for the athlete to sprint between the two points is commonly reported. However, to have an accurate understanding of acceleration, speed, and sprint ability, it is important to initiate timing in a standardized way that captures the entire sprint effort. Specifically, it is necessary to assess the initial propulsive movements that enable an athlete to build up speed (14). Throughout the scientific literature, vastly different sprint performance outcomes have been shown despite similar cohorts being assessed (13). These substantial differences in performance have been attributed to the different starting methods (e.g., on the line *vs.* 50cm behind the line) that were employed and athletes being able to develop varying amounts of velocity prior to triggering the initiation of timing (13). This has made comparisons between cohorts difficult and suggests that unless the method of timing initiation is accounted for, sprint performance may be misleading.

To gain an accurate understanding of an athlete's sprinting ability, it is important to initiate timing as close as possible to the first propulsive movement. A range of methods are commonly used that include starting with the front foot on a mark (15, 22), starting 50cm back from a set of timing gates (17, 18, 20), or using a laser foot switch (5). Additionally, a novel device (Move, Swift Performance, Brisbane, Australia) that claims to measure initial propulsive movements and trigger timing during sprinting has recently been released onto the consumer market. These different methods all initiate sprint timing in different ways and likely have substantial effects on the sprint outcomes observed. Consequently, the aim of this study was to compare different commonly used sprint starting methods on time and quantify the velocity and displacement of the athlete at the moment timing is initiated.

METHODS

Experimental Approach to the Problem

This study simultaneously assessed the effects of five different sprint starting methods on time to five meters, and displacement and velocity at timing initiation. Specifically, the starting methods included: (1) Move sensor trigger, (2) front foot toes 50cm behind dual beam timing gates (50cm behind the line), (3) front foot movement trigger (front foot), (4) rear foot movement trigger (rear foot), and (5) front foot on a set mark (on the line). Timing for each method was initiated at different points during the acceleration phase (e.g., when the rear foot movement trigger was disrupted) and the displacement and velocity of the centroid of the pelvis at the point of timing initiation was assessed under high-speed motion capture.

Five meter sprint performance was assessed by the amount of time the subject took to cover five or 5.5 (50cm behind the line condition) meters.

Subjects

Twelve team sport subjects (10 males and two females; mean ± standard deviation (SD); age: 23.5 ± 3.8 years; stature: 1.79 ± 0.07 m; mass: 80.8 ± 15.6 kg) volunteered to participate in this study. All subjects were familiar with linear sprint testing and confirmed that they did not have any current injuries or diseases that would influence sprint performance before study commencement. All experimental procedures were approved by the institutional ethics committee, and written consent was provided by all subjects before study initiation.

Procedures

To assess the effect of the five different timing initiation methods, all subjects reported to a biomechanics laboratory and completed 10 maximal 10 meter accelerations. Prior to the sprints, all subjects were weighed and stature was measured. Following this, subjects completed a standardized warm up of jogging and dynamic stretching before six (18 mm) individual reflective markers were placed on the left anterior superior iliac spine, right anterior superior iliac spine, right posterior superior iliac spine, left posterior superior iliac spine, clavicle, and sternum, respectively. Once subjects had all markers applied, they were asked to begin the 10 maximal accelerations by crouching into a two-point, staggered, sprint start position. This position was chosen as it is commonly used within the strength and conditioning literature to begin linear speed testing (16, 19, 21). Subjects were allowed to place their feet a comfortable distance apart in a staggered position, with their preferred foot in the front. Approximately two minutes of rest was provided for each participant between sprint efforts.

For each repetition, subjects were required to start with their front foot on a set point that was in line with a reflective marker that was placed on the ground (i.e., on the line) so that multiple timing methods could be assessed in a single sprint. When any of the reflective markers on the body passed this point, timing was initiated through the high-speed motion capture system. This point was set exactly 50cm from a pair of dual beam timing gates (i.e., 50cm behind the line trigger) (Duo, Swift Performance, Brisbane, Australia) which were set at a height of 75cm. Furthermore, two optic laser sensors and reflectors were placed in line with the front and back foot of the subject to initiate timing when the foot left the staggered starting position (i.e., front and rear foot trigger, respectively) (Move, Swift Performance, Brisbane, Australia). Finally, the Move sensor, was positioned directly behind the subject at approximately one meter. Figure 1 provides an outline of the study set up.

Once the subject was ready and in the crouched staggered position, they were required to be as still as possible for approximately five seconds before maximally accelerating 10 meters. Once movement was initiated, all devices were triggered independently (e.g., body through timing gate, foot stopped the breaking of laser sensor) which sent multiple pulse signals that were synchronised with the high-speed motion capture data. Marker trajectories were recorded at 150 Hz by a 12-camera three-dimensional motion analysis system using the Vicon Nexus software package (v2.9; Vicon, Oxford, UK). A centroid of each subject's pelvis was calculated using the four reflective markers on the pelvis and using the processed marker trajectories, data were then exported to MATLAB (MathWorks, Massachusetts, USA) where the resultant displacement from the stationary period and velocity at each timing initiation was calculated. Data were filtered using a low pass Butterworth filter (zero lag) with a cut-off frequency of 6hz.

To calculate five meter sprint performance, a reflective marker was placed five meters from the line that the front foot started on. Timing for the on the line, front and rear foot trigger, and Move device methods was terminated when any of the reflective markers on the subject passed this point. Additionally, a set of timing gates were set at 5.5 meters which were used to terminate timing for the 50cm behind the line method (refer to Figure 1 for study set up). All repetitions were included in the analysis unless an accidental trigger occurred (i.e., if a subject accidentally broke a timing gate beam) or if a reflective marker disconnected from a subject.

Insert Figure 1 here

Statistical Analysis

All statistical analyses were performed in RStudio (version 1.1.463) using the R programming language (version 4.0.5 "Shake and Throw"; R Foundation for Statistical Computing). The sample size required was determined using the *mixedpower* and *simr* packages. A simulated dataset was generated for time to 5 metres, before running a linear mixed model using the *makelmer* function. Statistical power was then estimated using the *mixedpower* function using following the guidelines outlined by Kumle et al. (10). A conservative smallest effect size of interest of -0.20 was set and the sample size was varied across 1000 simulations. The simulated data returned power ranging from 0.86 to 0.87 for each level of the fixed effect (timing initiation method). To determine the difference between the timing initiation methods, linear mixed models were used using the *lmerTest* package. Separate models were built for time to five metres, and displacement and velocity at timing initiation, with timing method used as a fixed effect and participant ID incorporated as a random intercept within each model. The residuals from each model were visually inspected using QQ-plots; subsequently only distance at timing initiation was log transformed. Where significant effects were seen, post hoc analysis was performed using estimated marginal means with a Bonferroni correction to account for multiple comparisons. Statistical significance was set at $p = 0.05$ a priori. The magnitude of differences were assessed using Cohen's (d_z) effect size statistic and 95% confidence intervals (CI) using the *effectsize* package, where the t value from the linear mixed model is divided by the square root of the degrees of freedom error from the same model and interpreted as *trivial*, <0.20; *small*, 0.20-0.49, *moderate*, 0.50-0.79, and *large*, ≥0.80 (11).

RESULTS

The mean ± SD time to five metres, and displacement and velocity at timing initiation for all conditions can be found in Table 1. Additionally, between condition effect sizes and corresponding significance can be found in Table 2. The Move device had the lowest velocity and displacement at the point of timing initiation. This also corresponded with the longest time to five meters. When compared to other starting methods, the Move device had *large* differences in displacement and velocity, apart from foot on the line velocity (*small*). Using a front foot trigger gave the fastest five metre times, displacement, and velocity at point of timing initiation. Differences between starting 50cm behind the line and using a rear foot trigger were the most similar with *trivial*, non-significant differences in outcome measures. However, it should be noted that in all comparisons five metre performance demonstrated *small* to *large* significant differences between conditions (other than for 50cm trigger *vs.* rear foot switch and foot on the line), which reflects differences ranging from 0.04 (50cm trigger *vs.* rear foot switch) to 0.66 seconds (Move device *vs.* front foot switch).

Insert Table 1 here

Insert Table 2 here

DISCUSSION

The aim of this study was to compare the effects of different sprint starting methods on sprint time and quantify the velocity and displacement at the moment timing is initiated. It was found that when compared to other sprint start methods, the Move device demonstrated the smallest amount of displacement from the initial stationary period, lowest velocity when timing started, and consequently, the longest time to five meters. Alternatively, the front foot trigger provided the fastest times but, at the point of timing initiation, athletes on average were moving $>3 m \cdot s^{-1}$ and had travelled close to one meter. Finally, there were significant (*small* to *very large*) differences in overall sprint times between all conditions which indicates that the method of initiating timing can substantially alter performance outcomes. Therefore, practitioners and researchers must be aware of these differences and should standardize the starting method within- and between-testing occasions. Additionally, caution is warranted when interpreting findings from different studies that compare sprint performance without acknowledging these differences.

The Move device demonstrated the smallest displacement from the starting position and lowest velocity at the point of timing initiation. Specifically, using an ultrasonic transceiver, it triggered timing when subjects had a mean displacement of 7.11 (± 4.76) cm. However, due to the smaller displacement and lower velocity, the overall time to five meters when using this method was greater. This suggests that this device may enable practitioners to gather a greater understanding of accelerative ability of an athlete when compared to other sprint testing methods. Recent research has emphasized the need to capture initial propulsive movements during sprinting, not only to gain a better insight into an athlete's capacity, but also for the calculation of horizontal force-velocity-power profiles (12, 14). Contrasting the results from the Move device, substantially faster outcomes were associated with using a front foot trigger. Average sprint performance over five meters was ~0.65 seconds faster than the Move and ~0.2-0.4 seconds faster than using a rear foot trigger, starting 50cm behind a set of timing gates, or starting on the line. This indicates that using a front foot trigger method drastically decreases overall sprint time and may not provide an accurate representation of an athlete's ability to accelerate.

When comparing all methods of sprint start, significant *small* to *very large* differences in sprint time were observed. This is likely influenced by the differences in velocity and change in body displacement prior to the initiation of sprint timing. While differences between using a rear foot trigger and starting 50cm behind the start line did allow for *trivial* differences in starting velocity, this should be tempered by the *small* differences in displacement and *small* significant differences in overall time. Additionally, differences between these methods individuals (i.e., ~0.05s) are equivalent to the between-day reliability typical error observed across short sprint distances (3). Considering these findings, it is strongly recommended that practitioners do not compare testing outcomes within- or between-athletes that have not had the same initiation of sprint start timing used. Additionally, these results support previous calls for greater standardization of sprint testing methods (7, 8).

In conclusion, when compared to other starting methods, the Move device demonstrates the smallest amount of displacement and velocity at the moment of timing initiation. This increases the total sprint time but may allow for an improved understanding of an athlete's accelerative ability. This method is followed by requiring athletes to start with their front foot on a line (e.g., so that the athlete's chest immediately breaks a timing gate beam). Alternatively, the use of foot triggers or starting 50cm behind timing gates can substantially reduce sprint time and may provide an exaggerated impression of an athlete's ability. Therefore, due to substantial differences in sprint times, it is strongly advised that sprint testing is carefully standardized in order to elicit reproducible results, minimise error in measurements, and provide fair comparisons of times between athletes.

PRACTICAL APPLICATIONS

Sprint testing is commonly used by practitioners to measure acceleration and speed. Although, comparison of performance may be misleading if different methods of timing initiation (e.g., starting on the line *vs.* starting 50cm behind the line) have been used. Therefore, it is strongly recommended that testing is standardized within- and between-teams so that improved profiling can occur. Furthermore, to accurately measure an athlete's ability to accelerate, the entire acceleration phase should be assessed from the first propulsive movement. Thus, the Move sensor may provide the most accurate representation of acceleration. Finally, due to the differences in overall sprint time between methods, it is strongly recommended that different sprint testing methods are not compared.

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Figure 1. Outline of study set up.

Table 1. Mean ± SD of sprint time, resultant displacement, and resultant velocity at the point of timing initiation across all measures.

	Time to 5 metres (s)	**Displacement at initiation (cm)**	**Velocity at initiation ($m \cdot s^{-1}$)**
Move device	1.68 ± 0.70	7.11 ± 4.76	0.60 ± 0.44
50 cm foot	1.28 ± 0.10	50.18 ± 16.45	1.98 ± 0.35
Front foot switch	1.03 ± 0.18	86.47 ± 32.97	3.06 ± 1.00
Rear foot switch	1.23 ± 0.12	36.71 ± 8.65	1.91 ± 0.45
Foot on the line	1.41 ± 0.12	13.88 ± 6.10	0.98 ± 0.39

Table 2. Cohen's d_z effect size and 95% confidence limits showing comparisons of velocity, displacement, and time to five metres across all timing initiation methods. A negative effect size reflects less velocity, displacement or time between timing initiation methods.

		Move device	50cm chest	Front Foot Switch	Foot on the line
Velocity	**Rear Foot Switch**	-0.81 [-0.92 to -0.70] *Large*	0.05 [-0.05 to 0.14][*] *Trivial*	0.72 [0.61 to 0.82] *Moderate*	-0.57 [-0.67 to -0.47] *Moderate*
	Foot on the line	-0.24 [-0.33 to -0.14] *Small*	0.62 [0.52 to 0.72] *Moderate*	1.29 [1.16 to 1.41] *Large*	-
	Front Foot Switch	-1.52 [-1.66 to -1.39] *Large*	-0.67 [-0.77 to -0.57] *Moderate*	-	-
	50cm Foot	-0.86 [-0.96 to -0.75] *Large*	-	-	-
Displacement	**Rear Foot Switch**	-0.84 [-1.08 to -0.73] *Large*	0.03 [-0.07 to 0.12][+] *Trivial*	0.71 [0.61 to 0.82] *Moderate*	-0.43 [-0.53 to -0.34] *Small*
	Foot on the line	-0.41 [-0.50 to -0.31] *Small*	0.46 [0.36 to 0.56] *Small*	0.28 [0.19 to 0.38] *Small*	-
	Front Foot Switch	-1.12 [-1.24 to -1.00] *Large*	-0.26 [-0.35 to -0.16] *Small*	-	-
	50cm Foot	-1.12 [-1.24 to -1.00] *Large*	-	-	-
Time to five metres	**Rear Foot Switch**	0.42 [0.32 to 0.51] *Moderate*	0.04 [0.05 to 0.13][ᴪ] *Trivial*	-0.19 [-0.28 to -0.10] *Trivial*	0.16 [0.07 to 0.26] *Trivial*
	Foot on the line	0.25 [0.16 to 0.35] *Small*	-0.12 [-0.21 to -0.03][†] *Trivial*	-0.35 [-0.45 to -0.26] *Small*	-
	Front Foot Switch	0.61 [0.51 to 0.71] *Moderate*	0.23 [0.14 to 0.33] *Small*	-	-
	50cm Foot	0.37 [0.28 to 0.47] *Small*	-	-	-

[*]= *p* value: 0.984; [+] = *p* value: 0.981; [ᴪ] = *p* value: 0.309; [#] = *p* value: 0.002; [†] = *p* value: 0.082; all other *p* values: <0.001. Effect sizes were interpreted as interpreted as *trivial*, <0.20; *small*, 0.20-0.49, *moderate*, 0.50-0.79, and *large*, ≥0.80.