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KINEMATICS THAT DIFFERENTIATE THE BEACH FLAGS START BETWEEN ELITE AND NON-ELITE SPRINTERS

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ABSTRACT: This study differentiated the kinematics of the beach flags sprint start between five elite (three males, two females; age = 21.2 ± 2.6 years; height = 1.71 ± 0.04 m; mass = 66.2 ± 5.9 kg) and five non-elite (three males, two females; age = 20.4 ± 1.7 years; height = 1.69 ± 0.08 meters [m]; mass = 61.6 ± 5.7 kilograms) sprinters. A high-speed camera filmed the start. Timing gates recorded the 0-2, 0-5, and 0-20 m intervals. Data included body position during the start and at take-off; start time; first step length; and sprint times. A Mann-Whitney U-test determined significant ($p < 0.05$) between-group differences; effect sizes (ES) were also calculated. Elite sprinters had a greater take-off trajectory angle (p = 0.01; ES = 2.57), and were faster over the 0-2 (p = 0.02; ES = 1.77), 0-5 (p = 0.05; ES = 1.20), and 0-20 m (p = 0.02; ES = 1.83) intervals. Large effects were found for: greater take-off swing leg hip flexion (ES = 1.13) and trunk lean (ES = 1.37); longer duration start time (ES = 1.33); and longer first step length (ES = 1.23) in elite sprinters. A longer start time assists with force generation, which in conjunction with increased hip flexion, could translate to a longer first step. Increased trunk lean shifts the take-off trajectory angle towards the horizontal. A greater trajectory angle at start take-off, which could be advantageous for force production during sprint performance, is likely necessary for beach flags.

KEY WORDS: biomechanics; surf lifesaving; sprint start; acceleration; sprinting; sand surface

INTRODUCTION

Beach flags, which is a popular event within the sport of surf lifesaving, involves a 20 meter (m) sprint from which competitors are required to obtain a flag that is positioned vertically in the sand ahead of their opponents. The beach flags features a unique start when compared to traditional track sprint events. Sprinters begin the event in a prone position with their feet positioned on the start line, facing the opposite direction to where the flags are lined in the sand. Upon hearing the starting whistle, sprinters must turn as quickly as possible to face the flags and begin running. As for track sprinting [13, 15], an effective start is essential for beach flags performance [21]. Given that there are certain start technique variables typical of elite track sprinters [4, 5], it would also be pertinent to ascertain the start technique characteristics for elite beach flags sprinters.

Lockie et al. [21] has analyzed the typical start technique of experienced young adult beach flags sprinters. Following the initiation of the start, sprinters completed an initial posterior movement away from the start line, which helped facilitate the turn. After the turn, the feet were positioned in a manner where the distance was similar to a medium block spacing in the track start [6]. Lockie et al. [21] found that at take-off, the body position adopted by beach flags sprinters was not dissimilar to that of track sprinters following a block start. Some of the kinematic factors from the start that contributed to a faster sprint performance included greater range of motion of the arms, most likely to assist with balance on the unstable sand surface, and a longer first step following the start [21]. While this information is noteworthy, unfortunately there is currently no research that illustrates whether elite-level beach flags sprinters exhibit different start characteristics to their lower-level counterparts.

Due to the paucity of beach flags start research, there is still value in analyzing the athletics sprint start, given that there are particular characteristics of the track start that relate to the beach flags start. Some of the technical kinematic factors that have been related to successful track starts of high-level sprinters include appropriate spacing between the feet in the set position [15,27], greater trunk lean at take-off [2, 3], and an efficient first step following take-off [6]. It is likely that some of these characteristics would also apply to the beach flags start. However, completing movements on a sand surface will cause changes to gait kinematics, especially when compared to more stable surfaces [1,21,25]. The unstable sand surface inherent to the beach flags will in all likelihood cause adjustments to the actions required by beach flags sprinters during the start, especially when compared to typical track sprint start kinematics.

Unstable surfaces have a marked impact on force production. For example, the force generated during a squat jump on sand is reduced when compared to a jump on a rigid surface [12]. Giatsis et al. [12] found that not only did peak force decrease, but the duration of force production was extended on sand. This is also true for maximal sprinting. Alcaraz et al. [1] found that when compared to track sprinting, sand sprinting leads to reduction in step length. This was due to the sand shifting during foot contact, which dissipates some of the force that would otherwise be used to propel the athlete forwards. This is pertinent, as effective force production is also a requirement for a successful track sprint start [4,6]. For beach flags sprinters, there may be compromises between the magnitude and duration of force generation during the start. This can be seen through the time taken to complete the beach flags start. A beach flags start takes approximately 0.72 seconds (s) to complete [21], which is more than twice as long as an athletics track start [3, 23]. This longer start duration may be a function of the need to generate force over a longer time period on the unstable sand surface. However, given that elite track sprinters have faster start times [14], this may also be the case for beach flags sprinters. This must be determined through appropriate research.

Currently, there is no study that has analyzed any differences in the start technique of elite or non-elite beach flags sprinters. Considering that this type of research has been conducted on track sprinters [14], it is pertinent to conduct this on beach flags sprinters as well. This study will identify the characteristics of elite performance in the beach flags start. It is hypothesized that elite beach flags sprinters will possess characteristics that will delineate their performance from that of non-elite sprinters. For example, elite sprinters will have a faster start time, demonstrate a great range of motion in the upper and lower limbs at start take-off, have a longer first step following take-off, and will also be faster over the selected intervals (0-2 m, 0-5 m, and 0-20 m) from this study. The findings of this research will illustrate those kinematic variables that differentiate between elite and non-elite beach flags sprinters, and thus provide pertinent practical information for coaches and sprinters involved with beach flags that could drive their training practices.

MATERIALS AND METHODS

Subjects. Sprinters currently active in beach flags competition at a national (elite group) and regional (non-elite group) level of competition were recruited for this study. Five elite (three males and two females; age = 21.2 ± 2.6 years; height = 1.71 ± 0.04 m; body mass = 66.2 ± 5.9 kilograms), and five non-elite (three males and two females; age = 20.4 ± 1.7 years; height = 1.69 ± 0.08 m; body mass = 61.6 ± 5.7 kilograms) sprinters volunteered for this study. Sprinters from the elite group were all members of the Surf Life Saving Australia (SLSA) national team. Non-elite subjects were recruited from local surf clubs in Newcastle, Australia. Subjects were considered non-elite if they competed in regional competitions, and had not represented at a state or national level. The use of 10 subjects either matches or exceeds previous sprint start research [1,3,6,21,23]. Mixed-gender groups have been used previously to analyze sprint technique [10,13,21,27]. As long as subjects display similar trends in technique during the start [13,21], male and female sprinters can be grouped for analysis. The methodology and procedures used in this study were approved by the University of Newcastle ethics committee, and conformed to the policy statement with respect to the Declaration of Helsinki. All participants received a clear explanation of the study, including the risks and benefits of participation, and written informed consent was obtained prior to testing.

Procedures

Testing was conducted on beaches in Australia. To ensure consistency, testing days of comparable weather conditions and a level section of dry, sandy beach were used. As different sand conditions can affect sprint performance, great care was taken to ensure similar surface conditions were used for all testing sessions. Subjects wore competition attire, which consisted of swimming costumes. Prior to data collection, the subject's age, height, and body mass were recorded. A single session per subject was used for data collection, and, in accordance with and adapted from protocols recommended by SLSA [28], procedures involved sprints over a 20 m distance. An identical warm-up routine was used for each subject, consisting of jogging, dynamic stretches, and acceleration runs. Four successful trials of the sprint protocol detailed in the methodology were obtained for each subject, with three minutes recovery time allocated between trials. For each sprint, subjects were told to complete their typical beach flags start as they would use in competition. Analysis was conducted on the four trials, and the averages were used.

Kinematic Analysis

Figure 1 documents the set-up for the assessment of the beach flags start and sprint time, which has been used in previous research [21]. Sprint time was measured through the use of timing gates (Fusion Sport, Coopers Plains, Australia), which consisted of four reactive data units coupled with reflector units affixed on top of tripods. The reactive data units were synchronized with a handheld computer (Hewlett-Packard, Palo Alto, USA) which collected the data. Time splits were recorded for the 0-2 m, 0-5 m, and 0-20 m intervals. As defined by SLSA protocols, gates were placed at 2 m and 20 m [21,28]. Another gate was placed at 5 m to measure initial acceleration [9,19,21]. The first gate was positioned next to the starter, who initiated timing by passing their hand through the gate's

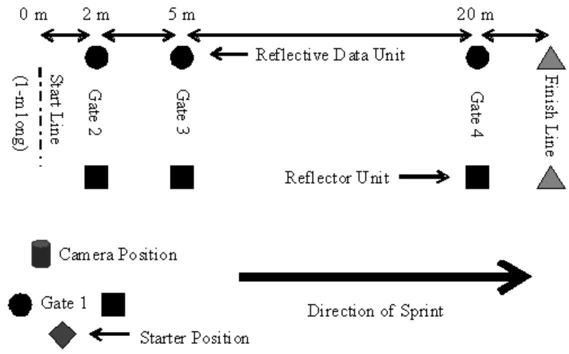

FIG. 1. EQUIPMENT SET-UP FOR THE ASSESSMENT OF THE BEACH FLAGS START AND SPRINT
Note: m = meters

light beam. The reliability of the testing methods used for this study were established by Lockie et al. [21]. The intra-class correlation coefficients (ICC) and Cronbach's alpha (CA) for the 0-2 m interval (ICC = 0.77; CA = 0.93), 0-5 m interval (ICC = 0.81; CA = 0.95), and 0-20 m interval (ICC = 0.93; CA = 0.98) were all considered acceptable.

Each sprint was initiated from the typical prone position used in beach flags. Subjects were given the standard set of commands that are used during beach flags competition. These were: (1) you are in the starter's hands, (2) heads down, and (3) the starter then blew a whistle to start the sprint while simultaneously initiating the timing gate system. Subjects sprinted past the final timing gate and were instructed to not slow down prior to 20 m. This was achieved by placing a target line 5 m beyond the last gate. If participants started prior to the whistle (false start), the trial was disregarded and another attempt was allowed after the recovery period.

A high-speed camera (Basler Vision Technologies, Ahrensburg, Germany), connected to a laptop computer (Dell Inc., Round Rock, USA), recorded kinematic data. The camera frame rate was set at 100 Hertz. Power was supplied by a 300-watt portable invertor (Sinergex Technologies, Orem, USA), connected to a deep-cycle battery. The camera was placed perpendicular to the start line, 5.5 m lateral to the subject (Figure 1). This position recorded sagittal plane movements, and the camera was situated on the side the subject turned towards during their start, and calibrated prior to testing. A limitation of the study is the two-dimensional motion analysis, as there may be a degree of parallax error, especially during the turn. However, the practical nature of this research demanded field testing in competition conditions, and two-dimensional analysis was the only feasible option. Black, hemispherical markers were placed on both sides of the body on the following anatomical landmarks: acromion process (shoulder); lateral epicondyle of the ulna (elbow); midpoint of the styloid process of the radius and ulna (wrist); greater trochanter of the femur (hip); lateral epicondyle of the femur (knee); lateral malleolus of the fibula (ankle); and fifth metatarsal (toe).

The recordings from the camera were analyzed within motion analysis software (Dartfish Video Software Solutions, North Melbourne, Australia). The temporal characteristics calculated were: hand clearance time (period from the initiation of movement until the hands broke contact with the ground); and start time (period from the initiation of movement until the foot of the driving leg broke contact with the ground) [3]. The distance of the posterior movements of the legs behind the start line prior to take-off, and the maximum distance between the feet during the start following the turn, were measured. Kinematic variables analyzed at start take-off included knee, hip, and elbow joint angles, and trunk segment position relative to the vertical angle (Figure 2). Angle of trajectory was the angle between a line passing through the foot in the sand and the trunk segment of the sprinter at the moment of take-off, and the horizontal (i.e. the ground). First step length following the start, which was the distance from the point of take-off of the driving foot until the point of touchdown of the opposing foot, was measured [19,21,24].

Statistical Analysis

Descriptive statistics (mean ± standard deviation) were calculated for each subject. The Levene statistic was used to determine homogeneity of variance of the data. Data was pooled into two groups dependent on the participant's level of competition (elite or non-elite). Due to the sample size, the Mann-Whitney U-test was conducted to determine significant ($p<0.05$) differences between the dependent variables of the elite and non-elite beach flags sprinters. Effect sizes (ES) were used to describe the magnitude of the difference between the two groups for the variables [1]. ES were calculated according to the methods of Cohen [7], where the difference between the means was divided by the pooled standard deviations. Interpretation of ES results were adapted from Rhea [26]. An ES of 0.25-0.50 was considered a small effect; 0.51-1.00 a moderate effect; and ≥1.01 a large effect. All statistical analyses were processed using the Statistics Package for Social Sciences (Version 20.0; IBM Corporation, New York, USA).

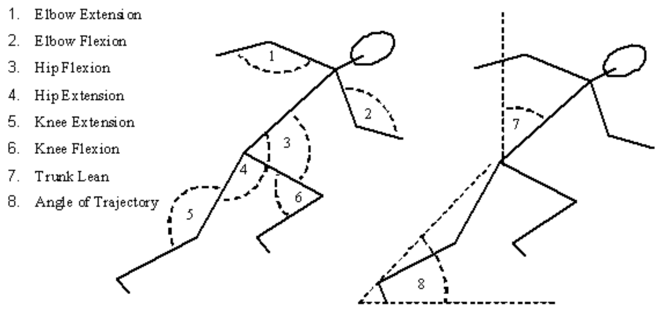

FIG. 2. JOINT KINEMATICS MEASURED DURING THE BEACH FLAGS START
Note: * Significant ($p < 0.05$) difference between elite and non-elite beach flags sprinters

RESULTS

Figure 3 displays the time over the recorded intervals for the elite and non-elite groups. Elite beach flags sprinters had a 19% significantly lower 0-2 m time when compared to the non-elite sprinters ($p = 0.03$; ES = 1.77), and a 12% lower 0-5 m time ($p = 0.05$; ES = 1.20). There was also a significant difference in 0-20 m time, with elite sprinters having an 18% lower time ($p = 0.02$; ES = 1.83). There were no significant differences in the time to clear the hands from the sand, or the start time (Table 1). However, the difference in start time between elite and non-elite sprinters had large ES. There were also no significant differences in the distances specific to the beach flags start (Table 1). Elite sprinters did have a 29% greater first step length, with a large ES.

The joint angles of the body at take-off from the start are illustrated in Table 2. Elite sprinters had an 18% lower hip flexion when compared to the non-elite sprinters, which had a large ES but was not found to be significantly different. Elite sprinters had a 54% greater trunk lean when compared to the non-elite sprinters with a large ES, although a significant difference was not established. There was a significant difference for the angle of trajectory when comparing the two groups. Elite sprinters had a 15% lower angle of trajectory when compared to non-elite sprinters.

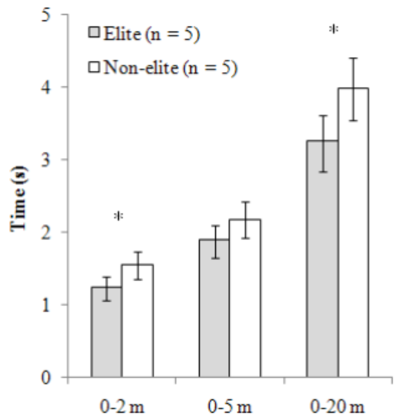

FIG. 3. TIME (MEAN ± STANDARD DEVIATION) DURING THE 0-2 METER (m), 0-5 m, AND 0-20 m INTERVALS FOR ELITE AND NON-ELITE BEACH FLAGS SPRINTERS
Note: s = seconds

DISCUSSION

The beach flags start must allow the sprinter to attain as high a velocity as possible. Speed has been found to be a defining factor between competition levels in track sprinting [5], and field sports [8]. Within the context of the current study, speed was shown to be a defining factor for beach flag sprinters. There were four kinematic variables (angle of trajectory, 0-2 m time, 0-5 m time, and 0-20 m time) that significantly differentiated between elite and non-elite sprinters. There were also several other variables (hip flexion at take-off, start time, and first step length) that had large ES when comparing the elite and non-elite groups. As the movement analyzed within this study was specialized, the subject pool of beach flags sprinters was relatively limited. This may have restricted the number of significant variables that could delineate

TABLE 1. SELECTED START TIMES AND DISTANCES (MEAN ± STANDARD DEVIATION, CORRESPONDING P VALUES AND EFFECT SIZES [ES]) FOR THE ELITE AND NON-ELITE BEACH FLAGS SPRINTERS

	Elite (n = 5)	Non-Elite (n = 5)	p	ES
Times (s)				
Hand Clearance Time	0.43 ± 0.19	0.52 ± 0.15	0.40	0.64
Start Time	0.95 ± 0.31	0.60 ± 0.21	0.08	1.33
Distances (m)				
Posterior Foot Movement	0.11 ± 0.12	0.18 ± 0.03	0.25	0.73
Front and Rear Foot Distance	0.53 ± 0.11	0.48 ± 0.08	0.40	0.55
First Step Length	0.62 ± 0.15	0.48 ± 0.07	0.08	1.23

TABLE 2. JOINT KINEMATICS (MEAN ± STANDARD DEVIATION, CORRESPONDING P VALUES AND EFFECT SIZES [ES]) FOR THE ELITE AND NON-ELITE BEACH FLAGS SPRINTERS

Joint Angle (°)	Elite (n = 5)	Non-Elite (n = 5)	p	ES
Rear Arm Elbow Extension	141.37 ± 10.05	133.07 ± 14.00	0.47	0.68
Front Arm Elbow Flexion	64.88 ± 18.73	69.93 ± 46.87	0.75	0.14
Hip Flexion	71.15 ± 17.57	86.61 ± 7.97	0.12	1.13
Hip Extension	151.90 ± 22.23	160.03 ± 16.48	0.60	0.42
Knee Flexion	93.46 ± 9.94	90.78 ± 9.85	0.92	0.27
Knee Extension	151.07 ± 8.74	146.71 ± 2.83	0.60	0.67
Trunk Lean	55.52 ± 19.62	36.06 ± 4.19	0.12	1.37
Angle of Trajectory	45.93 ± 4.36	54.08 ± 1.07	0.01*	2.57

Note: * Significant ($p < 0.05$) difference between elite and non-elite beach flags sprinters between the groups. Nonetheless, there were still several noteworthy findings.

One of the unique components of the beach flags start is the use of the upper body to push the sprinter from the ground prior to turning and sprinting. The time to clear the hands from the start did not differentiate between elite or non-elite sprinters (Table 1). The push-off from the ground facilitates the elevation of the sprinter's body from the ground prior to the turn. Following this push-off, the beach flags start commonly features an initial posterior movement away from the start line, prior to the sprinter's turn [21]. There were no significant differences between elite and non-elite sprinters when considering this movement (Table 1). Lockie et al. [21] intimates that this is not a negative technique adaptation. This is because the posterior movement may engage the stretch-shortening capacities of the leg muscles [11], while also increasing the kinetic energy involved with the movement [17]. However, an excessive backwards step in beach flags may not be beneficial, as this would essentially lengthen the distance the sprinter would have to cover to attain a flag.

Following the turn in the beach flags start, the sprinter will be in a position where both feet are in contact with the ground. At this point the spacing between the feet is comparable to the block spacing in a track start. Track start research has supported the use of a medium distance (~0.4-0.5 m) [6], and an elongated start position (~0.8 m) [27]. Lockie et al. [21] found that experienced young adult beach flags sprinters adopted a foot spacing closer to that of a medium block spacing distance (0.53 ± 0.09 m). Both elite (0.53 ± 0.11 m) and non-elite (0.48 ± 0.08 m) beach flags sprinters placed their feet in a position close to that of a medium block setting. Lockie et al. [21] also found that a longer distance between the feet during the start correlated with faster times over the 0-2 m and 0-5 m of a 20 m sprint. Nonetheless, beach flags sprinters must choose the most effective foot spacing which increases take-off velocity and optimizes the duration of the start [13,27].

For the most part, the kinematics of the limbs at start take-off did not differentiate between elite and non-elite beach flags sprinters (Table 2), and were similar to those established in the literature [21]. In an analysis of field sport athletes, Murphy et al. [24] ascertained that few joint kinematics delineated between sprinting abilities. Nonetheless, there are some notable distinctions. At the hip joint, a smaller angle for hip flexion of the swing leg (i.e. the leg not in contact with the ground) indicates that the thigh has been brought closer to the trunk (Figure 2). Although the differences were not significant, elite beach flags sprinters had an 18% lower hip angle, which designates more hip flexion for the swing leg (Table 2). An increased degree of swing leg hip flexion may be an adaptation to the sand surface, in that an increased range of motion could allow for a greater increment of internal work for force generation [25]. Lockie et al. [18] suggested a change in hip flexion of the swing leg during acceleration may occur in an attempt to increase step length. This could be an adaptation at start take-off for elite beach flags sprinters.

A greater trunk lean during a track sprint start take-off has a positive influence on running velocity [2,3]. At take-off during a sprint start and through initial acceleration, a position closer to the horizontal is recommended as this is thought to improve the horizontal force generated against the running surface [14,15,18]. In the current study, this was shown to a certain extent. Elite sprinters had a greater trunk lean when compared to the non-elite group ($55.52 \pm 19.62°$ vs. $36.06 \pm 4.19°$) (Table 2). Although the difference was not significant, a large ES was present ($p = 0.12$; ES = 1.37). The smaller participant group may have affected finding a significant result. Nonetheless, these results suggest that elite beach flags sprinters tend to have a greater trunk lean at start take-off. More notably, trunk lean will influence the angle of trajectory at start take-off.

The angle of trajectory was found to be significantly ($p = 0.01$; ES = 2.58) different between elite ($45.93 \pm 4.36°$) and non-elite ($54.08 \pm 0.95°$) beach flags sprinters. The elite sprinters also had a greater angle of trajectory at start take-off when compared to young adult beach flags sprinters ($51.68 \pm 4.39°$) [21]. A more upright body position affects take-off velocity due to a loss of horizontal power [15]. Furthermore, the sand surface will reduce the ability of a sprinter to impart ground reaction force [1]. It is possible that by assuming a body position that encourages a lower angle of trajectory, elite beach flags sprinters may be placed in a more advantageous position to produce force [30]. An angle of trajectory that is closer to the horizontal could then influence a sprinter's ability to generate speed through the initial stages of acceleration [3, 27], which would directly affect the outcome of the beach flags sprint. Coaches for beach flags should focus on lowering the angle of trajectory of their sprinters following the start, as this is a more advantageous body position.

In regards to track sprinting, more skilled sprinters tend to have shorter start times [14,15]. This was not the case for the beach flags start, and was counter to the initial hypothesis for the study. Although the difference in start time between elite (0.95 ± 0.31 s) and non-elite (0.60 ± 0.21 s) sprinters was not significant, it did have a large ES ($p = 0.08$; ES = 1.33) (Table 1). The larger start time found for elite beach flag sprinters may be related to the notion of start impulse. Start impulse is the product of the force generated during a sprint start and the time taken to generate this force [15], and has been suggested as a significant determinant of start performance [22,27]. Potentially, elite beach flags sprinters may allow their start to occur over a longer duration so as to generate more ground reaction force, especially against the unstable sand surface. This is similar to findings made by Giatsis et al. [12] when analyzing elite beach volleyball players. When jumping on a sand surface, elite beach volleyball players will spend more time in contact with the ground, so as to generate more force and increase jump height [12]. Elite beach flags sprinters may take longer to complete their start so as to increase the time in which they can produce force for take-off. The effectiveness of the force generated during the start would be supported by a greater trunk lean and angle of trajectory at take-off. The efficacy of the combination of these kinematic variables could then be seen in the resulting step length following the start.

Elite sprinters had a longer first step length (0.62 ± 0.15 m) when compared to the non-elite sprinters (0.48 ± 0.07 m), and this difference had an ES of 1.23 (Table 1). Although the difference was not significant (p = 0.08), this is still a prominent finding due to the large ES. Increasing the length of the first step of a sprint has been advocated as part of a successful track start [6,27]. Elite track sprinters also tend to have relatively large step lengths [16]. Given the importance of speed generation during the initial stages of a short sprint, generating a longer first step following the start may be an important factor for beach flags sprinters. Indeed, Lockie et al. [21] found a significant correlation between first step length and 0-5 m sprint time, which indicated that a longer step was associated with a shorter time of the initial few meters of a beach flags sprint.

Reducing sprint time is obviously essential for beach flags sprinters. The mean time for all of the 20 m sprint intervals for elite beach flags sprinters was significantly faster than for their non-elite counterparts (Figure 3). This is in line with the studies hypotheses. Speed within the first few meters (i.e. the first 5 m) of a sprint has been found to delineate between faster and slower field sport athletes [24]. Furthermore, in relation to field sports, experienced athletes can achieve high initial speeds and continue this throughout an entire sprint effort over distances up to 20 m [9,20,29]. This is further demonstrated specifically for beach flags by Lockie et al. [21], who found very strong correlations (r = 0.88-0.95) between the 0-2 m, 0-5 m, and 0-20 m intervals of a beach flags sprint. The results from this study signify that following the start, elite beach flags sprinters are faster through all intervals of a beach flags sprint, which ultimately decides the success of the beach flags event.

CONCLUSIONS

The factors that significantly differentiated between elite and non-elite beach flags sprinters were a greater angle of trajectory at start take-off, and faster 0-2 m, 0-5 m, and 0-20 m times. Additionally, large effects were seen for greater swing leg hip flexion and trunk lean at start take-off, a longer duration for start time, and a longer first step following the start. A limitation of this study was the relatively small subject numbers, which may have affected the ability to find statistically significant differences between the groups for some of the analyzed kinematic variables. Nevertheless, within the limitations of the current study, these results suggest that a greater angle of trajectory at take-off following the beach flags start is important for the subsequent sprint performance. This could be facilitated by a longer start time that allows for more force generation, and a greater degree of hip flexion of the swing leg and trunk lean at start take-off. Future research should incorporate more subjects when scientifically analyzing the beach flags start. Three-dimensional motion analysis should also be used to further evaluate the kinematics of the beach flags start, and the analysis of ground kinetics produced during the start should also be a point of emphasis.

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Conflict of Interest Declaration

None of the authors have any conflict of interest.

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