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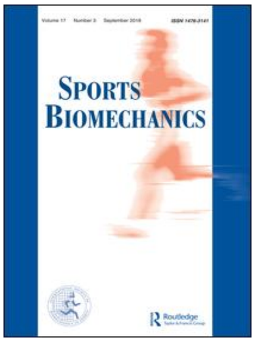

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Effect of hurdling step strategy on the kinematics of the block start

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ABSTRACT

Athletes use either a seven-step or eight-step strategy to reach the first hurdle in the 110 m hurdle event. This study investigated the effect of step strategy on the start position, the block exit and the first four approach steps. Two-dimensional video data were collected in the sagittal plane from 12 male sprinters, grouped as seven-step (n = 6) or eight-step (n = 6) strategists. Mean block spacing was 0.08 m further apart, block contact time 0.06s longer, first step 0.25 m longer and first ground contact 0.03s longer for seven-step athletes compared with eight-step athletes. There was also a greater vertical displacement of the centre of mass (CoM) (0.04 m) for the seven-step athletes compared with the eight-step athletes. Additionally, the front hip mean angular acceleration was 197°/s^2 slower for the seven-step athletes than the eight-step athletes. There was limited difference between groups for mean horizontal velocity at the moment of block exit (0.14 m/s). These technical alterations provide an important first insight into start kinematics. The findings of this study identify the position in the starting blocks, and the key parameters which pertain to the initial phases for a successful seven-step approach strategy to be employed.

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Biomechanics; sprint; acceleration; track and field; athletics

Introduction

The 110 m hurdles event is essentially a sprint, with a series of 10 barriers. While there was no documented use of a seven-step strategy to reach the first hurdle until the 1960 Olympic Games, a seven-step approach has now become the preferred strategy of many elite hurdlers. A seven-step strategy was used by six of the eight finalists at the 2012 Olympic Games, including all three medallists (Pinho et al., 2017). At the 2016 Olympic Games, six of the eight finalists used a seven-step approach, including the silver and bronze medallists. The decision to use either a seven or eight-step approach strategy directly influences the relationship between step length and step frequency. Sprint speed is the product of step length and step frequency and an increase in either (as long as it is not detrimental to the other) or both will result in a greater horizontal velocity (Hunter et al., 2004). There is no absolute consensus on the preferred way to increase sprint speed in individual athletes (Salo et al., 2010), but it is considered to be essential that an optimal relationship between the two is a primary focus when selecting a step strategy. Sprint

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hurdlers are required to maximise step frequency to the first hurdle without compromising the step lengths necessary for successful execution of their selected approach step strategy. Irrespective of step strategy, athletes are required to alter their step lengths and step frequency from those which they would use for a flat sprint. These alterations might influence the positioning of the athlete in the set position and the technique of the block clearance (Tidow, 1991).

The placement of the starting blocks is critical to a successful approach phase and clearance of the first hurdle, and research shows that the distances for the front and rear block from the start line directly influence the position of the CoM in the set position (Čoh et al., 2006). Once movement is initiated from the blocks the trajectory and velocity of the athlete's CoM throughout the first step is dependent upon correct positioning of the CoM in the set position (Schot & Knutzen, 1992). For both flat and hurdle sprint races, a medium start (spacing between the block faces between 0.3 and 0.5 m) is most commonly used and often accepted as the most effective way of developing acceleration as sprint distance increases. Several studies have shown the medium start to result in the quickest performance times at distances of up to 50 yards (45.72 m) (Čoh et al., 1998; Henry, 1952), although, Čoh et al. (1998) identified positive correlations between the 20–30 m phase of acceleration from the blocks and not the initial acceleration phase. Sprint hurdlers have 13.72 m to accelerate before the first hurdle clearance and it is possible that, based upon a chosen step strategy, athletes are adopting start positions that are not optimal to developing horizontal acceleration.

It has previously been identified in both flat (Charalambous et al., 2012; Mero & Luhtanen, 1985; Mero, 1988) and hurdle (Tidow, 1991) sprint races that the success of the start and acceleration phases are decisive to the outcome of the race. When hurdlers leave the starting blocks, they must develop horizontal acceleration via a suitable step strategy, which also positions them correctly for clearance of the first hurdle. Elite hurdlers take-off approximately 2.10–2.40 m from the first hurdle (Mann, 2011; Tidow, 1991). This leaves 11.32–11.62 m from the start line to the point of take-off for the athlete to generate as much horizontal acceleration as possible. Whilst there has been considerable investigation into the biomechanics of the block clearance and start phase of flat sprint races (N. E. Bezodis et al., 2019; Čoh & Žvan, 2015; Čoh et al., 2006; Debaere et al., 2012; Morin et al., 2015; Rabita et al., 2015), there has been little investigation into the seven or eight-step first hurdle approach used by sprint hurdlers.

The first step following the block clearance is the most difficult to execute correctly, yet the most important step of the entire race (Mann, 2011). The first ground contact is critical and particularly the foot's location in relation to the position of the whole-body CoM. If the CoM is behind the ground contact of the first step, then unnecessary braking occurs. Therefore, if seven-step athletes are taking longer steps out of the blocks to cover the same approach distance as eight-step athletes, it essential to ensure the first step ground contact continues to occur posterior of the CoM.

As the athlete approaches the first hurdle, adjustments are made to the technique of each step in preparation for hurdle clearance. It is therefore not possible to compare like-for-like steps throughout the entire acceleration phase. Essentially, there is a functional difference between the strategy used to balance the need for continued acceleration alongside preparation for the hurdle clearance. Previous research (McDonald & Dapena, 1991) has identified a reduction in both step length and flight time prior to take off, rendering like-for-like step parameters throughout the final approach steps, incomparable. Previous research has also identified the initial acceleration to last only four to six steps following block clearance (Nagahara et al., 2014).

The aim of this study was to investigate the effect of first hurdle step strategy on the start position and block clearance phase kinematics, and the spatio-temporal characteristics of seven and eight step approaches throughout the first four steps. It was hypothesised that seven-step athletes position themselves differently in the blocks compared to eight-step athletes to achieve different block exit kinematics. Block contact times and first step lengths are parameters which are likely to differ; however, this is not yet known.

Methods

Participants

Twelve male sprint hurdlers (mean age, 22 ± 2.11 years; body mass, 79.4 ± 11.8 kg; stature, 1.83 ± 0.07 m) volunteered to take part in the study. All were experienced athletes, had a personal best performance time of under 15.00 s in the senior men's 110 m hurdles event (mean: 14.13 ± 0.39 s; range from 13.48 to 14.68 s) and were ranked in the top 35 in Great Britain at the time of data collection. Participants comprised of two groups of six, based on the number of steps taken to the first hurdle during a competitive performance (mean personal best: seven-step; 14.04 ± 0.42 s, eight-step; 14.21 ± 0.42 s). Research study procedures were approved by Sheffield Hallam University Research Ethics Committee. Participants were provided with an information sheet and gave written informed consent before taking part.

Data collection

Data were collected at seven locations, in order to minimise disruption to the athletes' normal training. Standard outdoor athletics tracks were used at the Loughborough University Athletics Centre, Leeds Beckett University Athletics Centre and Brunel University Sports Park. Standard indoor athletics facilities were used at Birmingham Alexander Stadium, University of Bath Sports Training Village, Gateshead International Stadium and Lea Valley Athletics Centre. Each individual athlete's data were collected during a single session. All participants wore their usual running spikes and skin-tight clothing.

Anthropometric data were collected of the participant's mass (BC543, Tanita, Amsterdam, The Netherlands), stature (Marsden Leicester height measure, Rotherham, UK) and leg-length (measured in the anatomical standing position using a tape measure from location of surface markers at ankle joint centre to hip joint centre).

Each participant completed a self-managed warm-up before carrying out three starts from blocks in response to an audible stimulus. Once leaving the blocks participants were required to clear the first two hurdles at their normal race intensity, with hurdle spacings and specifications in-line with 2017–2018 International Association of Athletics Federations (International Association of Athletics Federations [IAAF], 2016) competition rule 168 (hurdle height, 1.067 m; start line to first hurdle distance, 13.72 m; first hurdle to second hurdle distance: 9.14 m). A full recovery was permitted between trials (at least 5 minutes). If participants knocked down the first hurdle, then the trial was not included. Consequently, not all participants were able to complete three successful trials. In total, 16 trials were captured for seven-step athletes and 16 trials for eight-step athletes. The successful trial was selected for those who completed only one trial and the second trial was selected from those who completed either two or three successful trials.

High-speed video footage (200 Hz) of the sprint start and first step from standard starting blocks (set-up to the participants individual race settings) was collected using a single camera aligned with the start line (Table 1). A further high-speed camera was aligned mid-way between the start line and the first hurdle to capture the spatio-temporal parameters of the approach steps (Table 2). All footage was collected with Phantom Miro M110 high-speed cameras (Vision Research, Wayne, New Jersey, USA) which were

Table 1. Description of technique variables calculated from the start camera view.

Parameter	Description
Front block distance (m)	Horizontal distance from the metatarsophalangeal joint (MTP) of the front foot on the starting block to the near edge of the starting line.
Rear block distance (m)	Horizontal distance from the MTP of the rear foot on the starting block to the near edge of the starting line.
Block spacing (m)	Horizontal distance from the MTP of the rear foot on the starting block to the MTP of the front foot on the starting block.
First step length (m)	Horizontal distance from the MTP of the rear foot on the starting block to the MTP of the first step at the first point of ground contact.
Normalised First step length	Non-dimensional normalisation. First step length divided by leg-length.
First ground contact time (s)	Time that the foot can positively be identified as in contact with the ground from the video footage to the first frame of loss of ground contact. This is the first ground contact following block clearance.
Block contact time (s)	Time from frame of first identifiable initiation of movement of the athlete to the frame that the front foot loses contact completely with the front block.
CoM set angle (°)	Angle formed between the vector from the nearest edge of the start line to the position of the centre of mass (CoM) and the horizontal whilst static in the set position.
CoM relative height (%)	Vertical distance of the CoM from the track surface whilst in the set position expressed as a percentage of the athletes standing stature.
CoM vertical displacement (m)	Difference between the vertical height of the CoM at the point of first step ground contact and the height in the set position.
Normalised CoM vertical displacement	Non-dimensional normalisation. CoM vertical displacement divided by leg-length.
CoM touchdown angle (°)	Angle measured from the MTP of the first step at the first frame of ground contact and the position of the CoM.
Front block obliquity (°)	Inside angle of the front foot block face measured from the track surface.
Front knee set angle (°)	Posterior angle of the knee of the front leg whilst static in the set position.
Rear knee set angle (°)	Posterior angle of the knee of the rear leg whilst static in the set position.
Front hip angle change (°)	Change in the anterior angle of the front leg hip from the set position to the end of contact of the front foot on the blocks.
Rear hip angle change (°)	Change in the anterior angle of the rear leg hip from the set position to the end of contact of the front foot on the blocks.
Front hip peak extension (°)	Maximum anterior angle of the front hip throughout the block clearance phase.
Rear hip peak extension (°)	Maximum anterior angle of the rear hip throughout the block clearance phase.
Front hip exit angle (°)	Anterior angle of the front hip at the end of contact of the front foot with the blocks.
Rear hip exit angle (°)	Anterior angle of the rear hip at the end of block contact of the rear foot with the blocks.
Front hip mean angular acceleration (°/s^2)	Mean angular acceleration of the front hip from the first frame of movement in the set position to the end of block contact.
Rear hip mean angular acceleration (°/s^2)	Mean angular acceleration of the rear hip from the first frame of movement in the set position to the end of block contact.
Rear foot block contact time (%)	Time that the rear foot is in block contact expressed as a percentage of the total block contact time.
Block exit horizontal velocity (m/s)	Horizontal velocity of the CoM at the end of front foot block contact.

Table 2. Description of technique variables calculated from the overview camera view.

Parameter	Description
Step length (m)	Horizontal distance between the metatarsophalangeal joint (MTP) of the touchdown step and the MTP of the following contralateral touchdown step.
Step frequency to Step 4 (Hz)	Mean number of steps taken per second from the initiation of motion in the blocks to the end of ground contact of the fourth step. Calculated by dividing the time to end of fourth ground contact by the number of approach steps.
Ground contact time (s)	Time that each step foot can positively be identified as in contact with the ground from the video footage to the first frame of loss of ground contact.
Flight time (s)	Time between steps that neither foot is in contact with the ground.
Approach to Step 4 Take-off (TO) (s)	Time from the initiation of motion to the end of ground contact of the fourth step.
Approach to TO (s)	Time from the initiation of motion to the end of ground contact of the first hurdle take-off step.

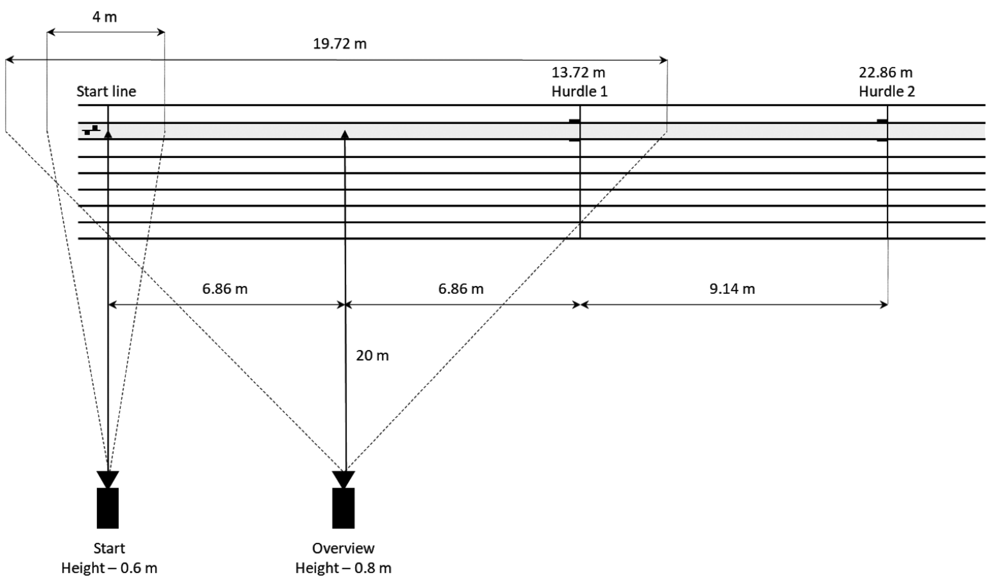

Figure 1. Plan view of camera set-up for hurdle trials (not to scale).

positioned 20 m perpendicular to the centre of the running lane and provided images of the sagittal plane. Cameras were set up in accordance with Figure 1 and identified as either the 'start' or 'overview' camera. Cameras were manually focused, and the field of view was set to 4.00 m wide for the start camera and 19.72 m wide for the overview camera. Shutter-speed was $^{1}/_{500}$ s (exposure of 2000 μs) and aperture was fully open for each camera (Figure 1).

Data processing

Calibration data were collected using a chequerboard method for the start camera and using track markings and hurdle height for linear scaling of the overview camera. To calibrate the start camera a chequerboard (7 x 7 squares each measuring 0.08 m) was manually held in different positions and orientations across the camera image and a series of frames captured. These were used to calibrate the intrinsic and extrinsic camera parameters using Check2D software (V1.5; Centre for Sports Engineering Research, Sheffield Hallam University, UK). Track markings were used to determine the parameters of the overview camera, completed using SimiMotion 9.2.1. (Simi Reality Motion Systems GmbH, Max-Planck-Strasse 11, 85,716 Unterschleissheim, Germany). Footage was manually digitised using SimiMotion 9.2.1 software with an additional ten frames at the start and end of the required start camera footage to allow for end-point errors due to filtering (Smith, 1989).

A total of 18 anatomical landmarks were identified and digitised to create a 16-segment kinematic model based upon DeLeva (1996). Segments were; head, trunk, left and right upper arms, forearms, hands, thighs, shanks, and feet. Trunk data were created from virtual coordinates of mid-hip (mid-point between left and right hip joint centres) and mid-shoulder (mid-point between left and right shoulder joint centres). Gait events were determined by visual inspection of the footage.

Raw image coordinate data were filtered using a second-order low pass Butterworth filter with a cut-off frequency of 7 Hz. The cut-off frequency was identified via residual analysis. For the start camera, raw image coordinate data and camera calibration data were subsequently exported, and planar position data reconstructed (Dunn et al., 2012) using Matlab R2017a (The MathWorks, Natick, MA, USA). Along with the anthropometric data, a total of 32 parameters were determined, 25 from the start camera (Table 1), six from the overview camera (Table 2) and one from the anthropometric data (Table 3). To quantify intra-rater reliability, re-digitisation of markers and gait events was completed by one operator on two of the athletes' trials (one seven-step and one eight-step athlete). A total of eight re-digitisations were completed for each trial. The re-digitised results of the start camera demonstrated low variability with a mean coefficient of variation (CV) of 1.63 ± 1.88 and a maximum of 6.85% (Rear hip angle change) for the seven-step athlete, along with a mean CV of 1.41 ± 1.94 and a maximum of 6.29% (Rear hip angle change) for the eight-step athlete. Similarly, re-digitising of the overview camera yielded a mean CV of 1.19 ± 1.70 and a maximum of 6.58% (Step 1 flight time) for the seven-step athlete, along with a mean CV of 1.42 ± 1.46 and a maximum of 5.35% (Step 1 flight time) for the eight-step athlete. These results were accepted as good intra-rater reliability.

Statistical analysis

Independent-sample *t*-tests (SPSS for Windows, version 24.0; SPSS, Inc., Chicago, IL, USA) were performed to determine differences between the groups for all variables (Tables 4 and 5). Athlete stature, mass, leg-length and leg-length as a percentage of stature were also compared to assess whether there was a difference between groups in anthropometric variables (Table 6).

Table 3. Description of anthropometric variables.

Parameter	Description
Stature (m)	Stature of seven and eight-step athlete groups.
Mass (kg)	Mass of seven and eight-step athlete groups.
Leg-length (m)	Leg-length of seven and eight-step athlete groups measured from the ankle-joint centre to the hip-joint centre.
Leg-length % of stature	Leg-length as a percentage of stature.

To reduce the possibility of type II errors occurring from low participant numbers, the criterion alpha level was set at $p < 0.05$ for statistical significance with $p < 0.1$ accepted as a tendency. This approach has been taken by Alt et al. (2015) when investigating lower extremity kinematics of athlete curve sprinting with low participant numbers (n = 6). Effect size was calculated for each variable using Cohen's *d* (Cohen, 1988). Only large effect size differences ($d \geq 0.80$) were deemed relevant and examined, in-line with Cohen's effect size suggestions.

Results

Seven-step athletes were 0.08 m taller ($p = 0.047$, $d = 1.31$) than eight-step athletes, and tended to be heavier (11.7 kg, $p = 0.100$, $d = 1.05$). There was no real difference in leg-length ($p = 0.290$, $d = 0.65$) between the seven and eight-step athletes (seven-step; 0.91 ± 0.02 m, eight-step; 0.88 ± 0.04 m). There was also no identifiable difference between the groups when considering leg-length as a percentage of stature ($p = 0.360$, $d = 0.61$).

In the set position, the seven-step athletes positioned the front foot and rear foot plates of the starting blocks 0.08 m further apart ($p = 0.043$, $d = 1.34$) compared with the eight-step athletes. Block contact time of the front foot was 0.06 s longer ($p = 0.022$, $d = 1.51$) for the seven-step athletes than the eight-step athletes. The first step length was also 0.25 m longer ($p = 0.008$, $d = 1.91$) for the seven-step athletes than the eight-step athletes. There was a tendency for a longer first ground contact time for the seven-step athletes, contacting the ground for 0.03 s longer ($p = 0.073$, $d = 1.18$) than the eight-step athletes. From the set position to the point of first ground contact, there was also a tendency for seven-step athletes to increase the vertical displacement of the CoM by 0.04 m ($p = 0.081$, $d = 1.12$) compared with eight-step athletes. Additionally, the seven-step athletes showed a tendency of 197°/s^2 slower hip extension acceleration ($p = 0.075$, $d = 1.15$) than the eight-step athletes throughout the block contact phase (Figure 2; Table 4).

Both the second and the fourth steps were 0.30 m ($p = 0.028$ and 0.000, $d = 1.48$ and 4.20, respectively) longer for the seven-step athletes than the eight-step athletes (Figure 3). The first ground contact time showed a tendency to be 0.03 s longer ($p = 0.073$, $d = 1.18$). The

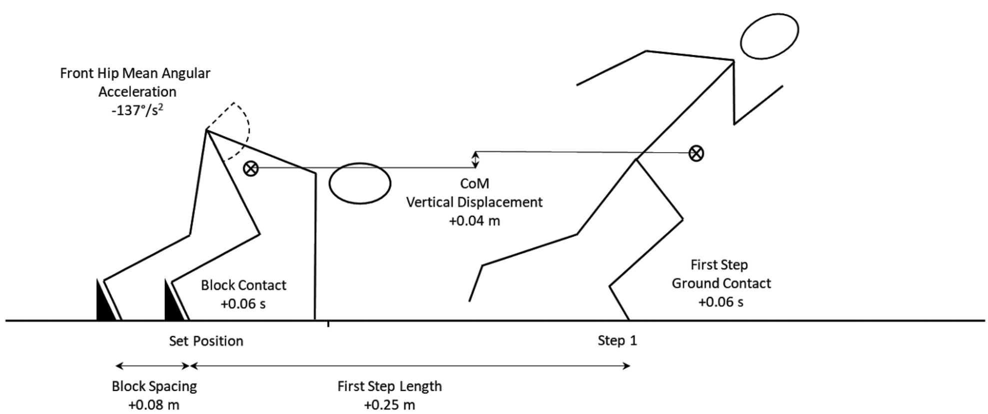

Figure 2. Mean first step differences of seven-step athletes compared with eight-step athletes.

Table 4. Seven and eight-step group mean values (±SD), effect size and *p* values for kinematic variables.

	Seven-step	Eight-step	Cohen's *d*	*p*
Front block distance (m)	0.43 ± 0.11	0.53 ± 0.11	0.93§	0.137
Rear block distance (m)	0.80 ± 0.09	0.83 ± 0.12	0.27	0.652
Block spacing (m)	0.38 ± 0.08	0.30 ± 0.02	1.34§	0.043*
First step length (m)	1.65 ± 0.17	1.40 ± 0.08	1.91§	0.008*
Normalised First step length	1.83 ± 0.20	1.59 ± 0.05	1.65§	0.017*
First step ground contact time (s)	0.23 ± 0.03	0.20 ± 0.02	1.18§	0.073#
Block contact time (s)	0.42 ± 0.05	0.36 ± 0.02	1.51§	0.022*
CoM set angle (°)	72.7 ± 1.9	72.8 ± 4.8	0.05	0.938
CoM relative height (%)	34.5 ± 1.4	35.6 ± 1.3	0.81§	0.193
CoM block contact angle (°)	39.0 ± 2.1	38.7 ± 1.8	0.17	0.771
CoM vertical displacement (m)	0.24 ± 0.04	0.20 ± 0.03	1.12§	0.081#
Normalised CoM vertical displacement	0.27 ± 0.48	0.22 ± 0.31	0.12	0.092#
CoM touchdown angle (°)	84.3 ± 5.8	81.8 ± 2.6	0.56	0.356
Front block obliquity (°)	46.7 ± 6.5	48.3 ± 7.0	0.25	0.678
Front knee set angle (°)	93.0 ± 7.5	94.0 ± 8.2	0.13	0.830
Rear knee set angle (°)	111.2 ± 17.0	121.2 ± 8.9	0.73	0.232
Front hip angle change (°)	129.2 ± 13.5	122.7 ± 10.2	0.54	0.368
Rear hip angle change (°)	49.0 ± 19.6	38.0 ± 12.6	0.67	0.274
Front hip peak extension (°)	165.2 ± 7.5	169.8 ± 7.7	0.61	0.313
Rear hip peak extension (°)	116.3 ± 13.6	116.5 ± 11.2	0.01	0.982
Front hip exit angle (°)	161.8 ± 7.9	166.2 ± 8.9	0.52	0.393
Rear hip exit angle (°)	115.2 ± 13.9	111.3 ± 11.3	0.30	0.611
Front hip mean angular acceleration (°/s^2)	741 ± 220	938 ± 102	1.15§	0.075#
Rear hip mean angular acceleration (°/s^2)	1028 ± 375	1061 ± 306	0.10	0.869
Rear foot block contact time (%)	53.1 ± 4.5	50.7 ± 4.4	0.54	0.370
Block exit horizontal velocity (m/s)	3.66 ± 0.53	3.52 ± 0.23	0.34	0.568

* significant at $p < 0.05$; # tendency at $p < 0.10$; § effect size > ± 0.8.

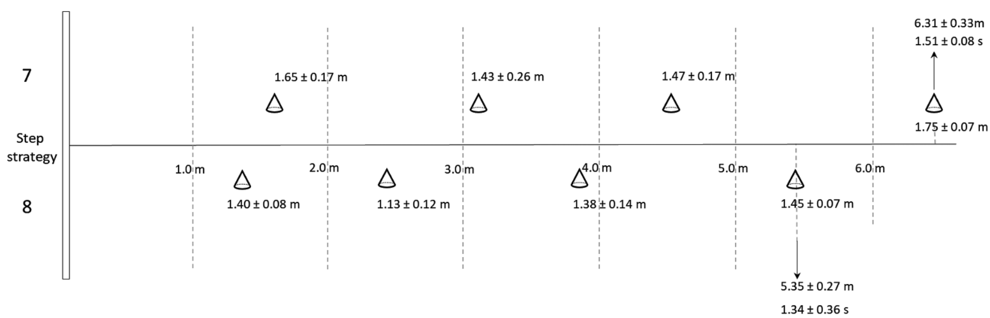

Figure 3. Seven and eight-step strategy mean (±SD) step lengths and time to fourth step (not to scale).

fourth ground contact time also showed a tendency, being 0.02 s longer ($p = 0.055$, $d = 1.25$) for the seven-step athletes compared with the eight-step athletes. The third step ground contact time was also 0.02 s longer ($p = 0.018$, $d = 1.64$). Additionally, the flight time of the fourth step showed a tendency to be 0.02 s longer ($p = 0.052$, $d = 1.52$) for the seven-step athletes. The seven-step athletes also had a 0.34 Hz lower step frequency ($p = 0.001$, $d = 2.59$) and were 0.17 s slower ($p = 0.001$, $d = 2.52$) over the first four steps (Table 5).

There was no reportable difference between the seven and eight-step performance times from the blocks to the take-off for the first hurdle ($p = 0.791$, $d = 0.09$) (Table 5).

Table 5. Seven and eight-step group mean values (±SD), effect size and *p* values for approach step variables.

	Seven-step	Eight-step	Cohen's *d*	*p*
Step length (m)				
Step 1	1.65 ± 0.17	1.40 ± 0.08	1.91§	0.008*
Step 2	1.43 ± 0.26	1.13 ± 0.12	1.48§	0.028*
Step 3	1.47 ± 0.17	1.38 ± 0.14	0.65	0.281
Step 4	1.75 ± 0.07	1.45 ± 0.07	4.20§	0.000*
Step GCT (s)				
Step 1	0.23 ± 0.03	0.20 ± 0.02	1.18§	0.073#
Step 2	0.19 ± 0.02	0.17 ± 0.02	0.90§	0.148
Step 3	0.17 ± 0.02	0.15 ± 0.01	1.64§	0.018*
Step 4	0.16 ± 0.02	0.14 ± 0.01	1.25§	0.055#
Step flight time (s)				
Step 1	0.07 ± 0.03	0.07 ± 0.02	0.24	0.680
Step 2	0.08 ± 0.02	0.06 ± 0.02	1.00§	0.115
Step 3	0.09 ± 0.02	0.09 ± 0.03	0.07	0.905
Step 4	0.11 ± 0.02	0.09 ± 0.01	1.27§	0.052#
Approach to Step 4 Take-off (TO) (s)	1.51 ± 0.08	1.34 ± 0.56	2.52§	0.001*
Step Freq to Step 4 (Hz)	2.66 ± 0.14	3.00 ± 0.13	2.59§	0.001*
Approach to TO (s)	2.29 ± 0.09	2.28 ± 0.10	0.09	0.791

*significant at $p < 0.05$; # tendency at $p < 0.10$; § effect size > ± 0.8.

Table 6. Seven and eight-step group mean anthropometric measurements (±SD), effect size and *p* values.

	Seven-step	Eight-step	Cohen's *d*	*p*
Stature (m)	1.87 ± 0.05	1.79 ± 0.07	1.31§	0.047*
Mass (kg)	85.3 ± 8.6	73.6 ± 13.3	1.05§	0.100
Leg-length (m)	0.91 ± 0.02	0.88 ± 0.04	0.65	0.290
Leg-length % of stature	48.3 ± 0.94	49.3 ± 2.13	0.61	0.366

significant at $p < 0.10$; * significant at $p < 0.05$; § effect size > ± 0.8.

Discussion and implications

The aim of this study was to investigate the effect of first hurdle step strategy on the start position and block clearance phase kinematics, and the spatio-temporal characteristics of the first four steps. The results are in agreement with the hypothesis; that seven-step athletes position themselves differently in the blocks compared to eight-step athletes to achieve different block exit kinematics.

In the set position, the seven-step athletes set up the blocks with the block plates further apart, which appeared primarily due to positioning of the front block plate closer to the start line rather than the rear block further from the start line. Although no tendency was identified for either of these parameters, this finding is in keeping with previous research into initial acceleration between both flat sprinters and hurdlers (I. N. Bezodis et al., 2019). Subsequently, the front foot of the seven-step athletes remained in contact with the block plate for longer than the eight-step athletes. The front hip mean angular acceleration of the seven-step athletes was almost 27% slower than that of the eight-step athletes. It is likely that the lower mean hip extension acceleration identified in the seven-step athletes was linked to an increased block contact time, itself due to the increased distance between the starting blocks in the set position.

The greater spacing between the blocks led to a longer first step for the seven-step athletes. Schot and Knutzen (1992) identified that athletes who set up their blocks with an elongated position (> 0.5 m) took a first step which was 6% longer than athletes using a medium position (0.3–0.5 m). Although seven-step athletes used a medium position, based upon Schot and Knutzen (1992) findings, it is reasonable to conclude that as block spacing increases within the medium start thresholds, first step length also increases. Schot and Knutzen (1992) further suggested that an athlete's physical characteristics can be used to determine the medium block spacing by measuring the athlete's leg-length from the greater trochanter to the lateral malleolus. The front block position suggested was at 60% of the leg-length from the start line, and the inter-block spacing, 45% of the leg-length. Consequently, the longer the athlete's leg-length, the further the feet from the start line and the longer the block spacing. Further to Schot and Knutzen (1992) suggestions, Cavedon et al. (2019) found that using the Cormic Index (ratio of height whilst sitting to stature) to identify block placement led to an improvement in the kinematic and kinetic block start performance, when compared to usual block placement. Despite differences in block positions between the seven and eight-step athletes, calculating the leg-length as a percentage of the stature confirmed that this was not due to any difference in leg-length between the two groups. Further, the normalised first step length identified that the longer step taken by the seven-step athletes was not due to leg-length (Table 4).

To limit the horizontal velocity lost for each step, it is important that the braking phase during foot contact is as short as possible (Čoh & Iskra, 2012; Harland & Steele, 1997). Hunter et al. (2005) identified that better sprinters use an 'active touchdown' (reduced horizontal velocity of the foot and minimised touchdown distance) to minimise horizontal braking force. Due to the longer first step, for a seven-step approach to be successful it is crucial that the first step touchdown remains posterior of the CoM and that an active touchdown can be used to prevent unnecessary braking forces. CoM touchdown angle (Table 4) was not different to the eight-step athletes despite a longer step length. Thus, it is likely seven-step athletes were able to minimise braking by ensuring the CoM touchdown angle was less than 90°.

Seven-step athletes elevated their CoM higher than the eight-step athletes at the point of first ground contact, despite there being no difference in the relative height of the CoM in the set position between groups (Table 4). Čoh et al. (1998) previously reported slightly lower figures for mean relative height of the CoM in the blocks (30% of stature) from a sample of 13 sub-elite (mean 100 m time of 10.73 s) male sprinters. It might be that hurdlers use the blocks differently to flat sprinters due to needing to be more upright in fewer steps to clear the first hurdle. Seven-step athletes took a first step that was almost 18% longer than the eight-step athletes and might have required more space below the CoM to position the foot for the first ground contact. The normalised data for leg-length and the change in height of the CoM identified only a tendency for the difference to be due to leg-length and therefore casts doubt upon leg-length being a decisive factor. It must be considered though that the seven-step athletes were taller than the eight-step athletes and the longer step length might be a result of increased stature despite there being no identifiable difference in leg-length (Hunter et al., 2004).

Despite the first four like-for-like step lengths being longer for the seven-step athletes than the eight-step athletes, step three does not satisfy the criteria as defined by the statistical analysis. It does though appear that the third step behaved as a recovery step for the seven-step athletes following the longer first two steps (Figure 3). In agreement with findings from previous sprint-based literature (Salo et al., 2005), there was a regular progression of increasing step lengths following the first step from the eight-step athletes, but the third step of the seven-step athletes was only slightly longer than the second step. The step frequency of the seven-step athletes was, as expected, lower than the eight-step athletes. Likewise, the seven-step athletes took 0.17 s longer to reach the end of the fourth ground contact. For seven-step athletes, this event occurred almost 1 m further from the front block plate, or 1 m closer to the first hurdle.

All like-for-like ground contact times were longer for the seven-step athletes although, only the first, third and fourth ground contact times satisfied the criteria as defined by the statistical analysis. As the seven-step athletes completed longer steps, it is possible that this was achieved from generating greater impulse. Previous findings have shown that as sprinters move through the acceleration phase to maximum velocity, the time of each flight phase increases and the time of each ground contact decreases (Salo et al., 2005). This occurred, step-by-step for both seven and eight-step athletes in this study. Only the flight time of the fourth step was longer for the seven-step athletes. Compared with the eight-step athletes, the fourth step length of the seven-step athletes was longer, which accounts for the increase in flight time. Despite the seven-step athletes taking longer steps out of the blocks, there was no real increase in equivalent flight times compared with the eight-step athletes. This is consistent with current maximal velocity sprint literature whereby the ability to exert mass-specific forces during ground contact, in the shortest possible time and not the ability to reposition the limbs, is a limiting performance factor (Weyand et al., 2000).

The findings of this study identify that seven-step athletes are positioning the block plates further apart in the set position, front block contact was maintained for longer and the CoM was raised. This led to a longer first step and a longer first ground contact time. Despite reducing angular acceleration of the front hip, the increased block contact time of the seven-step athletes may have led to an increase in impulse. Although horizontal velocity of the CoM at the point of block exit was not different, it is not yet known whether there is a difference at the point of first hurdle take-off or where any difference might occur throughout the approach phase. There was no discernible difference between the time taken from the blocks to the take-off for the first hurdle but, this parameter must be interpreted with caution as the position of the take-off event in relation to the hurdle position is not considered. It is not possible to favour either step strategy from the findings of this study alone. The research does though, provide an important insight into the sprint hurdle start performances of seven and eight-step athletes. Compared with the eight-step approach, seven-step athletes position the block plates further apart, maintain contact with the front block for longer, elevate the CoM to a greater extent and take a longer first step.

There are a number of limitations associated with this study. The use of two-dimensional analysis of footage with manual digitisation as a research method has accuracy limitations when compared to more favourable methods such as three-dimensional analysis or motion capture. As well as the first hurdle clearance, future research should look closely at the steps prior to the hurdle clearance and identify whether the step differences seen in this study continue throughout the entire acceleration phase.

Additionally, future studies should consider the kinetics of each of the approach steps to achieve a more comprehensive understanding of the seven-step strategy. There is a lack of research into the influence of anthropometric characteristics on the sprint start, therefore, research is needed into the physical characteristics of the athlete and the optimum block settings.

Conclusion

The effect of step strategy to the first hurdle on the block start was investigated in this study. Seven-step athletes position their blocks with a greater distance between the front and rear block plates. This allows seven-step athletes to maintain contact with the front foot for longer and results in displacing of the CoM to a greater extent during a longer first step. Presented technical alterations to the block positioning and the execution of the first steps are useful considerations for coaches and athletes who may be experimenting with the transition between seven or eight-step strategies. By ensuring the athlete trains with a block spacing which is increased from their normal eight-step block spacing, and takes a longer first step, the capacity to perform a seven-step approach is increased. However, care should be taken to ensure increases in block spacing and first step length do not lead to subsequent increases in approach step time parameters. To gain a clearer understanding of the seven and eight step strategies, further studies must investigate the kinematics of the steps prior to the first hurdle and the hurdle clearance, as well as the individual step kinetics of the entire phase.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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