A COMPARISON OF DIFFERENT METHODS FOR IDENTIFYING TRANSITION STEPS IN THE ACCELERATION PHASE OF SPRINT RUNNING

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Transition steps have previously been identified in the acceleration phase of sprinting. To compare transition steps detected using different measures, three sprinters performed maximal 50 m accelerations from blocks. Sagittal plane kinematics were collected using five 50 Hz cameras while touch-down and toe-off events were identified using a 200 Hz panning camera. Centre of mass height, shin angle and trunk angle at touch-down as well as the step where flight time exceeds contact time were used to detect transitions. Comparable transitions were identified based either on centre of mass height or shin and trunk angles at touch-down. These results provide further knowledge to the way in which the acceleration phase is structured and allows athlete specific biomechanical analysis to aid in the coaching of different sections of the acceleration phase in sprinting.

KEY WORDS: athletics, kinematics, coaching knowledge.

INTRODUCTION: The ability to achieve maximal running velocities is dependent on the preceding acceleration phase (Nagahara et al., 2014). Due to the multi-dimensional nature of the 100 m sprint (Delecluse et al., 1995), scientific and coaching literature (Delecluse et al., 1995; Seagrave, 1996; Coh et al., 2006; Nagahara et al., 2014;) has suggested that the acceleration phase can be divided into multiple sections based on kinematic or temporal variables. During initial acceleration the sprinter assumes a forward leaning position of the body with forward acceleration achieved by extension of the joints of the support leg (Debaere et al., 2013). Coaching literature suggests that the initial acceleration ends when shin angles reach about 90° at touch-down (Crick, 2014), while Coh et al. (2006) suggested that the step where flight time exceeds contact time is the end of initial acceleration and the start of the transition phase. During the transition phase, trunk angle relative to the ground continues to increase and support leg mechanics change so that by the end of this phase the sprinter runs with an upright posture (Crick, 2014) and cyclical leg action about the hip joint (Debaere et al., 2013). Recently, Nagahara et al. (2014) identified three sections in the acceleration phase of sprinting based on step-to-step changes in the height of the centre of mass. This supports the multi-phase structure as suggested by Delecluse et al. (1995). However, it is unclear whether using the measures centre of mass height (CM-h), shin angle (SA), trunk angle (TA) and the step where flight time exceeds contact time (FT>CT) to detect transition steps would lead to comparable transitions being detected. Therefore, the aim of this study was to compare the transition steps detected between the different measures. This will provide coaches and sport scientists with valuable knowledge of how sprinters structure their race and the technical changes that take place during the acceleration phase.

METHODS: Data collection: Three well trained male sprinters (22.5 ± 4.4 yrs., 78.5 ± 9.3 kg, 1.82 ± 0.06 m, 100 m PB = 10.74 ± 0.12 s) gave written informed consent to participate in this study after ethical approval was obtained from the university. The participants were injury free throughout the testing. Two testing sessions were conducted at the National Indoor Athletics Centre in Cardiff. On both days, the participants performed their own warm ups followed by five maximal sprints from blocks over 50 m except for participant P03 who only performed three trials on the second day. Five mini DV digital cameras (Sony Z5 x 1, Sony Z1 x 2 and Sony A1E x 2) with a 12 m horizontal and 9 m vertical field of view were set up 19 m from the centre of the lane. The cameras recorded in HD (1440x1080) at 50 Hz with an open iris and a shutter speed of 1/600 s. There was a 2 m overlap between the cameras around the 10 m, 20 m, 30 m and 40 m marks. The cameras were calibrated using 9- 18 control points per camera. This allowed a 10.00 m x 2.17 m volume to be constructed for each camera and a global volume of 50.00 m x 2.17 m with all cameras combined. A sixth camera (Sony Z5) was set up perpendicular to the 30 m mark elevated 5 m above the track and 40 m away from the centre of the lane. This camera served as a panning camera and was used to identify touch-down and toe-off events. It recorded in HD (1440x1080) at 200 Hz with an open iris and a shutter speed of 1/600s. All cameras were synchronised using a series of illuminating LEDs (Wee Beastie, UK).

Data Processing: The videos were extracted from the tapes using Dartfish Team Pro 6.0 (Dartfish) and then converted to .avi format and de-interlaced in VLC 2.1.3 (VideoLan, France). The videos were then digitised in Matlab (The MathWorks Inc., USA, version R2014a) using an open source digitising package (Hedrick, 2008). To assess the accuracy of reconstruction, the root mean square difference (RMSD) between reconstructed and known locations were calculated and represented as a percentage of the field of view. For the panning camera videos, the frames of touch-down and toe-off were digitised with a single point. This process was repeated three times and the frames that showed agreement in at least two of the three re-digitisations were used for further processing. The identified frames were processed in a custom written Matlab function to calculate touch-down event times as well as contact time, flight time and step time. Three frames around touch-down were digitised using an 18 point model of the human body. To assess reliability of digitising, one trial was digitised three times and the RMSD between the transition steps detected using CM-h, shin angles and trunk angles were calculated. Digitised trials were reconstructed in Matlab using an open source 2D DLT camera calibration and point reconstruct function (Meershoek, 1997) which was modified to include lens correction (Walton, 1981). Using a custom written Matlab routine, touchdown event times were synchronised with the reconstructed data from the static cameras to calculate shin and trunk angles at touch-down as well as the centre of mass position at touch-down, based on the inertia data from de Leva (1996), apart from the foot segment for which Winter's data (2005) was used with the added mass of each athlete's running shoe. The data from all five cameras was then combined in Microsoft Excel 2010 and angular data was smoothed using a 3-point moving average. The initial acceleration phase was defined from step one up to the first transition step (T1), while the transition phase was defined as starting with T1 and ending with the start of the second transition step (T2). To detect T1 and T2, the data set for each trial was divided and steps 1 to 10 were used to detect T1 while steps 8 onwards were used to detect T2. T1 was detected by applying a modified straight line approximation (Nagahara et al., 2014) to touch-down CM-h and shin angle data with respect to time. T2 was detected by applying the V-slope method with two straight line approximations (Nagahara et al., 2014) to CM-h and trunk angle data points with respect to time. For both methods, only transition steps where the magnitude of increase was smaller relative to the previous steps were considered. The transition step from the contact time and flight time data was defined as the first step where flight time exceeded contact time (FT>CT). Mean and standard deviations of the detected transition steps were calculated for each participant on each day. Furthermore, a mean RMSD for T1 and T2 between CM-h, shin angle, trunk angle and FT>CT was calculated for each participant on both days.

RESULTS: The average horizontal and vertical accuracy for all five cameras was 0.05% and 0.03% respectively. The RMSD of the repeat digitisation for T1 resulted in 0.0 steps when using CM-h and 0.0 steps when using shin angle as the deciding measure. T2 showed an RMSD of 0.7 steps using CM-h and 0.7 steps when using trunk angles to detect the transition step. Mean and standard deviation of the identified transition steps are displayed in Table 1. The transition steps for T1 based on CM-h ranged from step 3 to step 7 while T1 based of shin angles ranged from step 3 to step 8 for all participants. T2 showed a range between steps 13 and 18 using CM-h and between steps 13 to 20 when using trunk angle to identify the transition steps.

Table 1: Mean and standard deviations for transition steps based on CM-h (T1/T2), shin angles (T1), trunk angles (T2) at touch-down as well FT>CT for all three particpants

	Day 1					Day 2				
Participant	CM-h T1	SA T1	FT>CT	CM-h T2	TA T2	CM-h T1	SA T1	FT>CT	CM-h T2	TA T2
P01	6.2 ±0.8	4.6 ±1.3	15.2 ±1.6	15.4 ±1.1	16.8 ±0.8	4.2 ±1.1	4.8 ±1.9	12.6 ±0.5	15.0 ±1.6	16.8 ±2.6
P02	3.6 ±0.9	3.4 ±0.9	10.0 ±1.0	14.2 ±0.4	14.6 ±0.9	4.4 ±1.1	4.4 ±0.9	10.6 ±1.1	13.4 ±0.9	14.0 ±1.4
P03	3.4 ±0.5	4.6 ±1.7	12.2 ±3.2	16.2 ±1.1	17.2 ±1.1	4.3 ±0.6	3.0 ±0.0	10.7 ±1.2	15.3 ±1.5	15.7 ±2.1

CM-h: CM-height (m); SA: shin angle (º); TA: trunk angle (º); FT>CT: flight time exceeds contact time

Table 2 shows the mean RMSD across five trials for each athlete. The RMSD ranged between 1.4 and 2.5 steps when comparing CM-h (T1) and shin angles (T1) and 0.9 to 2.1 when comparing CM-h (T2) and trunk angle (T2). Comparing FT>CT to CM-h (T1/T2), shin angle (T1) and trunk angles (T2) resulted in the largest range of RMSD. These differences ranged from 6.3 to 10.9 when compared to the other T1 steps and 1.5 to 5.8 steps when compared to the other T2 steps.

Table 2: Mean RMSD between the measures used to detect T1 and T2 for all three particpants

	P01		P02		P03	
	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
T1: CM-h vs. SA	1.9	2.5	1.3	1.7	2.1	1.4
T1: CM-h vs. FT>CT	9.3	8.5	6.5	6.4	9.4	6.5
T1: SA vs. FT>CT	10.9	8.0	6.6	6.3	8.3	7.7
T2: CM-h vs. TA	1.7	2.1	0.9	1.8	2.0	2.1
T2: CM-h vs. FT>CT	1.5	2.6	4.4	3.2	5.1	4.7
T2: TA vs. FT>CT	2.0	4.6	4.8	3.3	5.8	5.4

DISCUSSION: The aim of this study was to compare the transition steps detected using different measures. The results show that the transition step T1 could be detected to within 2.5 steps using either CM-h or shin angle at touch-down, while the transition step T2 could be detected to within 2.1 steps using either CM-h or trunk angle at touchdown. The range of transition steps T1 (range: step 3 to 7) and T2 (range: step 13 to 18) which were identified using CM-h are comparable to the results of Nagahara et al. (2014) who identified T1 between steps 3 to 6 and T2 between steps 10 to 20. These results also agree with a theoretical 100 m race model used for coach education purposes in British athletics (Jones, 2010). This model, which is based on the progression of shin and trunk angles at touch-down suggests that initial acceleration lasts around 7 steps, while the transition phase ends at around step 17. Based on the shin and trunk angle results from this study: T1 occured between steps 3 to 8 while T2 occured between steps 13 to 20. The difference between the transition steps suggested by the model and those identified in this study could be explained by the inter-trial variablity involved when identifying segment angles at touch-down as well as the level of athlete which the race model is based on. While the participants in this study were well-trained to national level sprinters, the theoretical race model was based on elite sprinters. Comparing the step where flight times exceed contact times to the transition identified using the other measures, led to a larger range of RMS differences (see Table 2).

Furthermore, Coh et al. (2006), identified step 9 as the first step when flight time exceeded the contact time. In this study, only P02 (who also had the best 100 m PB) had a comparable step (FT>CT: 10.0 ± 0.9). This could suggest that performance level might influence when this step occurs as the participant from Coh et al. (2006) had a personal best time of 10.14 s while the fastest sprinter in this study had a personal best time of 10.64 s. The results show that two transitions can be identified based either on centre of mass height at touch-down or shin angle and trunk angle at touch-down. Furthermore, comparable transition steps could be identified using these different measures which supports previous work (Nagahara et al., 2014) and adds to a better understanding of these transitions in the acceleration phase of sprinting. Research into this area will help characterise the mechanics of each of these phases in sprint acceleration as well as allowing for athlete specific biomechanical analysis to identify strengths and weaknesses within the different sections of the acceleration phase. Future research is required to futher investigate the specific movement patterns necessary for successful performance in the initial acceleration and transition phases of sprinting.

CONCLUSION: This study identified transitions in a 50 m maximal sprint from blocks using kinematic and temporal variables. Due to the individual nature of transitions in sprint acceleration, this study will inform future coaching practices when designing athlete specific programmes aimed at developing the acceleration phase. Although the transition steps were comparable between the different measures, this is an initial investigation as part of larger study. Further study would be necessary to confirm the consistency of these measures.

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