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A PROPOSAL FOR 3D KINEMATICAL ANALYSIS OF THE 100M SPRINT USING A VIDEO-BASED SYSTEM WITH MULTIPLE CAMERAS

Natália de Almeida Rodrigues, Lucas Antônio Monezi, and Milton Shoiti Misuta
Laboratory of Biomechanics and Instrumentation, School of Applied Sciences, University of Campinas;
Email: natalia.rodrigues@fca.unicamp.br, web: www.fca.unicamp.br

INTRODUCTION

The 100m sprint has been divided in four main phases: starting block (reaction time), acceleration, maintenance and deceleration. Each phase shows different features related to specific movements that change with the velocity, acceleration, posture of the body, stride length, stride frequency, etc. The analysis of the 100m sprint is a challenge due to the methodological difficulties involved (camera positioning, a large quantity of cameras needed, high volume for camera calibration, adequate visualization of the markers in the whole image). The aim of this study was to present a proposal for 3D kinematical analysis of the 100m sprint using multiple cameras in the training situation. The analysis comprises: a) describing the movement of the center of mass (COM) during the stance phase and the swing phase, and b) presenting the stride length (SL), stride time (ST), stance phase (SP) and swing phase (SP) of the strides (during phase 1, 2 and 3) of the sprint.

METHODS

This study was authorized by the Research Ethics Committee of UNICAMP (CEP no. 034434/2012). One sprinter (male, national level, with a best time in 2012 of 10,64s, mass: 78,9kg and right handed) was analyzed. The experimental procedure consisted in one maximal sprint of 100m on an outdoor running track, using starting blocks. The body was modeled with 13 rigid segments (forearms, upper arms, head, trunk, pelvis, thighs, shanks and feet). Twenty-one white markers (40mm of diameters) were placed on the parietal eminence, C7 vertebra, acromion, lateral humeral condyles, radial styloid process, between the posterior superior iliac spines, anterior superior iliac spines, greater femoral, lateral femoral condyles, malleolus, calcaneus, 5th metatarsal (right and left respectively). The body center of mass (COM) was calculated based on the anthropometric model proposed in [5] and [2].

The DVideo kinematic analysis system [3] was used to obtain the 3D data. Eight JVC cameras (model GZ-HD620BU) and four Casio cameras (model EXFH25) were fixed on tripods and positioned along the track (Figure 1a). The set of cameras (C1, C2, C5, C6), (C3, C4, C9, C10), (C7, C8, C11, C12) covered the three regions, respectively.

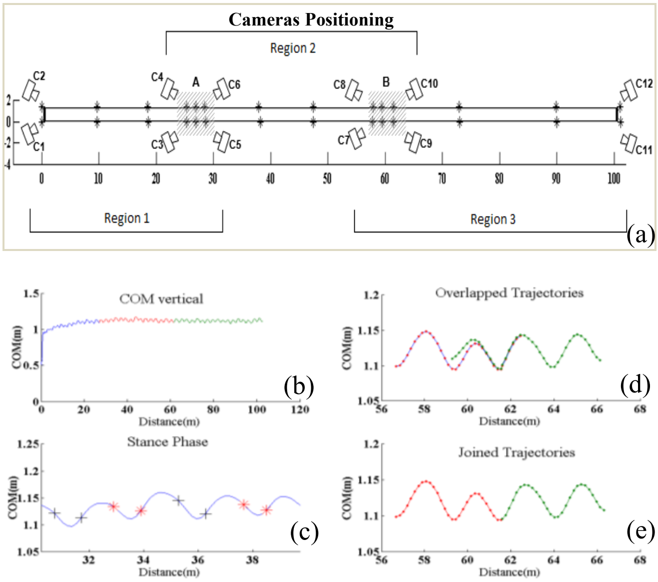

Figure 1: (a) Camera positioning (C_n: n=1, .., 12) to cover each region (1, 2 and 3) throughout the 100m. (b) COM vertical trajectory; (c) COM vertical trajectory, beginning of the right foot stride (+), beginning of the left foot stride (*). Stance phase is indicated by the period between + and * (right and left foot respectively); d) COM vertical trajectories overlapping, relating to region 2 and 3; e) The smoothed COM vertical trajectories from region 2 and 3 were joined, taking into consideration the local minimum.

Camera calibration was performed using the DLT (Direct Linear Transformation) method [1]. The reference system consisted of a volume of 110m (length) x 1,37m (width) x 2,32m (height). Twenty-eight calibration points were placed along the running track. In the transition zone (A: area between the region 1 and 2; B: area between the region 2 and 3) six coincident calibration points were used for the set of cameras (A: C3/C4 and C5/C6; B: C7/C8 and C9/C10), shown in Figure 1a. The 3D data (sampled at 60Hz) were smoothed with a zero-phase forward and a reverse Butterworth digital filter, fourth-order, and cut-off frequency of 10Hz.

The variables used were: a) stride time (ST): time duration of one stride; b) stride length (SL): the distance between 2 successive placements of the same foot (right and left); c) stance phase (SP) in seconds; d) stride frequency was defined as 1/t (t: time duration of one step); e) swing phase (SP) in seconds. The three phases (1, 2 and 3) were defined by considering the stride length (left foot).

RESULTS AND DISCUSSION

The method enabled description of the dynamics of the 100m sprint, using the stride length throughout the 100m distance (Figure 2). The 9th and 16th strides (stride length of left feet) were chosen to define the phases. The average values of stride frequency, respectively for the three phases, were 4.9 Hz, 4.77Hz and 4.38Hz. The transition from phase 1 to phase 2, and from phase 2 to phase 3, occurred respectively at 32.9m and 65.63m (left foot stride).

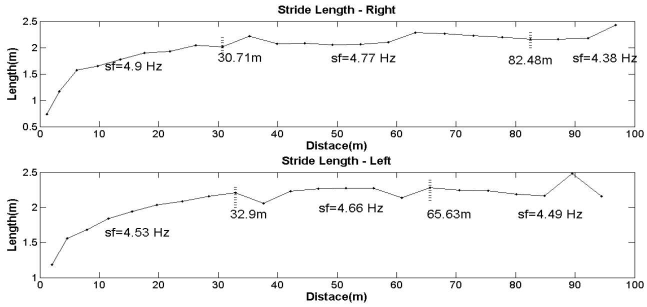

Figure 2: Stride length (right and left foot) throughout 100m.

Mean COM vertical trajectory, normalized to 100% stride length, were presented for right and left feet of the runner (figure 3). The mean standard deviation (SD) for each phase (right and left feet) was 0.056±0.0046m and 0.056±0.0041m (phase 1), 0.011±0.0018m and 0.009±0.0015m (phase 2), 0.008±0.0023m and 0.007±0.002m (phase 3).

The kinematic variables used enabled the quantification of specific aspects in each phase of the sprint. The dynamics used by the sprinter to maintain the speed involved an increase in stride length and stride frequency, or a decrease in ground contact to increase speed (table 1). The stance phase (SP) in the 1st phase was greater than 45.97%. The SP was less than 37% in the 2nd and 3rd phases. This feature is typical for running situations when there is a decreased time in the stance phase and an increased time in the swing phase [4].

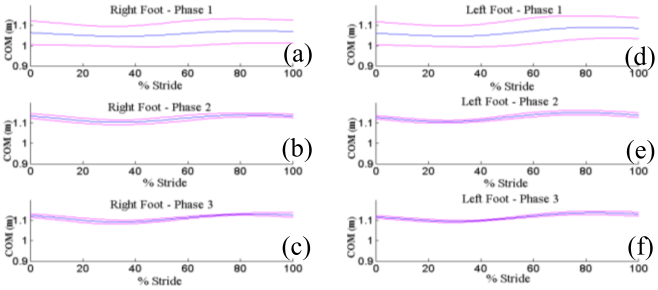

Figure 3: Mean COM vertical trajectory normalized to 100% stride length for each phase of the running. Mean COM vertical trajectory±Standard Deviation (dashed trajectory).

CONCLUSIONS

The method allowed for the obtaining of kinematic variables that represent the dynamics of the 100m sprint in each phase of the running (stride length (SL), stride time (ST), stance phase (SP) and swing phase (SP) of the strides, and movement of COM during the stance phase and the swing phase), throughout 100m. The setup used consisted of: a configuration specifying the positioning of 12 cameras, a reference system consisting of a volume of 110m (length) x 1,37m (width) x 2,32m (height), and 28 calibration points placed along the running track.

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Table 1: Mean and standard deviation of the stride length (SL) in meters, stride time (ST) in seconds, stance phase (SF) in seconds and percentage value and swing phase (SP) in seconds during the three phases (phase 1, 2, 3) of the sprint.

	Phase 1		Phase 2		Phase 3	
	Right	**Left**	**Right**	**Left**	**Right**	**Left**
SL (m)	1.644 ± 0.44	1.855 ± 0.33	2.155 ± 0.08	2.216 ± 0.08	2.256 ± 0.15	2.246 ± 0.12
ST (s)	0.204 ± 0.01	0.221 ± 0.01	0.210 ± 0.008	0.214 ± 0.006	0.228 ± 0.01	0.222 ± 0.01
SF (s)	0.104 ± 0.02 50.14%	0.102 ± 0.02 45.97%	0.077 ± 0.01 37.00%	0.066 ± 0.02 32.40%	0.083 ± 0.00 36.75%	0.077 ± 0.01 35.89%
SP (s)	0.10 ± 0.03	0.12 ±0.02	0.13 ± 0.01	0.14 ± 0.02	0.14 ± 0.02	0.14 ± 0.01