

ORIGINAL SCIENTIFIC PAPER

Biomechanical Model of Hurdle Clearance in 100m Hurdle Races: A Case Study

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Abstract

The purpose of the study was to identify and analyze the biomechanical structure of the hurdle clearance of the sixth hurdle in the 100-m hurdle race of Sally Pearson, the Olympic and world champion. An analysis of the hurdle clearance technique was carried out at the IAAF World Challenge - Zagreb 2011 international competition. 3-D kinematical analysis was utilized along with Ariel Performance Analysis System (APAS) for data processing. Digitization of the 15-segment model of the athlete's body, which was defined with 17 reference points, was performed. The results of the study show the extreme rationality of the hurdle clearance technique, which is demonstrated in the time interval between takeoff and landing (0.31 seconds), in the short contact times of the takeoff phase (0.10 seconds) before the hurdle and landing following the hurdle clearance (0.09 seconds), in the low flight parabola of the central TT (0.25 m), in the minimal decrease in horizontal velocity (1.5%), and in the efficient transition between the hurdle clearance and the sprint between hurdles. The obtained parameters can serve as orientational model values in the 100-m hurdle running technique training process for athletes.

Key words: Hurdle Race, Technique, Biomechanics, Kinematics, Case Study

Introduction

The biomechanical model of hurdle clearance for the 100-m hurdle race is based on the technique of the Australian athlete Sally Pearson, one of the world's greatest runners of 100-m hurdle events. The greatest achievement of her career thus far has been winning the gold medal in the 100-m hurdle race at the London Olympic Games in 2012. She holds many other top achievements such as the gold medal at the Daegu World Championship in 2011, the gold medal at the 2017 World Championships in London, the silver medal at the 2008 Beijing Olympics, and the silver medal at the 2013 World Championship in Moscow. Her personal record for the 100-m hurdle event is 12.28 seconds, which is the sixth fastest time in the history of the event. All these achievements rank Sally Pearson among the most elite athletes of modern athletics.

High hurdle races are among the most technically demanding athletic disciplines. According to previous studies (Schluter, 1981; Mero & Luhtanen, 1986; La Fortune, 1988;

Bruggemann & Glad, 1990; McDonald & Dapena, 1991; Dapena, 1991; McLean, 1994; Iskra, 1998; Kampmiller, Slamka, & Vanderka, 1999; Čoh, 2001; Blazevidh, 2013) the hurdle clearance technique is one of the key elements that determines a competitive result. From a biomechanics standpoint, the 100-m hurdle race combines the cyclic sprint and the acyclic clearance of 10 hurdles with a height of 0.838 m. The athlete must, therefore, have a high level of sprinting skills, exceptional hip joint mobility (flexibility), fast power, and a high level of technical knowledge. During the hurdle clearance, the loss of horizontal velocity must be kept to a minimum. This ability depends on a number of factors, especially those that define the takeoff before the hurdle, the trajectory of the movement of the CM (CM = center of mass) and the landing after the barrier (Kampmiller, Slamka, & Vanderka, 1999; Amritpal & Shamsher, 2015). In order to achieve rational hurdle clearance, the takeoff point before the hurdle and the landing point following the barrier are essential. The correct position of

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these two points determines the optimal flight trajectory of the CM, which is reflected in the time duration of the airborne phase, which should be as short as possible (Schluter, 1981; Dapena, 1991). In addition to the correct position of the points, the kinematic-dynamic structure of the takeoff and landing also directly influence the velocity of the hurdle clearance (La Fortune, 1988; McLean, 1994).

The aim of the study was to identify and analyze the biomechanical model of the hurdle clearance of the sixth hurdle in an athlete of the highest quality based on 3-D video analysis of kinematic parameters.

Methods

Biomechanical analysis of the hurdle clearance technique of the sixth hurdle by Sally Pearson (25 years old, body height 1.67 m, body weight 60 kg, P.R. 100 hurdles 12.28) was performed at the Mladost track-and-field stadium for the IAAF World Challenge international competition - Zagreb 2011, Croatia. The weather conditions were optimal; the outside temperature was 23 °C, the wind velocity was - 0.4 m.s.⁻¹. Permission to carry out biomechanical measurements was obtained from the Technical Delegate of the European Athletics Federation and the organizing committee of the competition. The lane in the zone of the sixth hurdle was covered by two high-frequency cameras CASIO-DIGITAL CAMERA EX-F1 (Casio Computer Co., Ltd.,

Tokyo, Japan), which were interconnected and synchronized. The cameras had a frequency of 300 Hz with a resolution of 720 x 576 pixels. The zone of the sixth hurdle was calibrated with a reference measuring frame of 2 m x 2 m x 2 m, and eight points of the calibration frame were considered for analysis. The APAS (Ariel Performance Analysis System) computer system for 3-D kinematic analysis was used for data processing. Digitization of the 15 - segment model of the athlete's body, which was defined using 17 reference points (Winter, 2005), was performed. Point coordinates were smoothed using a digital filter with a frequency of 14 Hz. Recording was performed at a frequency of 300 Hz, and point digitization was performed at 100 Hz. The center of mass (CM) was calculated based on anthropometric tables from the digitized points (Winter, 2005).

Results

According to the results of the biomechanical analysis (Table 1, Figure 1), the athlete had an average velocity of 8.58 m/s at the clearance of the sixth hurdle. The total stride length was 3.17 m. The takeoff distance was 2.31 m or 72.9% of the total step length over the barrier. The landing distance was 0.86 m from the hurdle, which represented 27.1% of the total step length over the barrier. The points of takeoff and landing determine an extremely rational flight parabola of the CM in relation to the hurdle position.

Table 1. Kinematic parameters of the sixth hurdle clearance (Sally Pearson, result of the 100-m hurdle race 12.68) - IAAF World Challenge, Zagreb, 2011.

PARAMETERS	UNIT	R
Rhythmic Units (Hurdle 5- 6)	m/s	8,58
TAKE – OFF (braking phase)		
Horizontal velocity of CM	m/s	8,76
Vertical velocity of CM	m/s	-0,46
Velocity resultant of CM	m/s	8,77
Height of CM	m	0,96
Take –off distance	m	2,31
TAKE – OFF (propulsion phase)		
Horizontal velocity of CM	m/s	8,51
Vertical velocity of CM	m/s	1,45
Velocity resultant of CM	m/s	8,63
Height of CM	m	1,03
Push-off angle	°	81,3
Contact time	s	0,10
FLIGHT		
Flight time	s	0,31
Height of TT above the hurdle	m	0,25
Maximal height CM	m	1,16
LANDING (breaking phase)		
Horizontal velocity of CM	m/s	8,53
Vertical velocity of CM	m/s	-0,93
Velocity resultant of CM	m/s	8,58
Height of CM	m	1,08
Landing distance	m	0,86
LANDING (propulsion phase)		
Horizontal velocity of CM	m/s	8,37
Vertical velocity of CM	m/s	-1,03
Velocity resultant of CM	m/s	8,38
Height of CM	m	1,05
Contact time	s	0,09

Note: m/s - meters per second; s - seconds; ° - degree

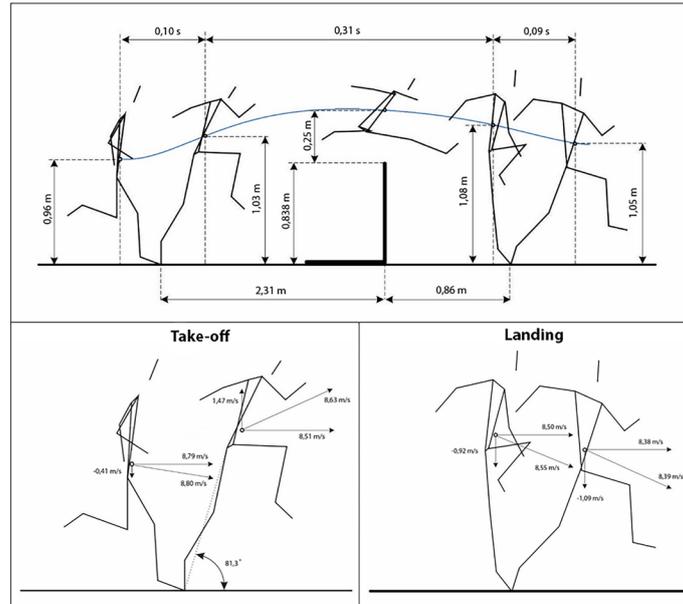


Figure 1. Biomechanical analysis of the sixth hurdle clearance (Sally Pearson, R: 12.68 s).

The highest point of the body's center of mass (CM) was 0.25 m during the hurdle step, while the highest point of the flight parabola was 1.16 m. The difference between the lowest TT point, in the eccentric phase of the takeoff (0.96 m), before the hurdle and the highest CM point, in the flight phase (1.16 m), was 0.20 m. The rationality of the hurdle clearance was also evident in the short flight time, which was 0.31 s.

The push-off angle in the concentric phase of takeoff was 81.3 degrees. The height of the CM at the braking phase was 0.96 m, and 1.03 m at the end of the propulsion phase of the push-off. The path length of CM in the Y - vertical axis was

0.07 m. These parameters provided optimal conditions for the development of velocity of the CM during takeoff.

The horizontal velocity of the TT at the preparatory step of the push-off was 8.79 m / s, and 8.51 m / s at the end of takeoff (Figure 2). The horizontal velocity of the CM was therefore decreased by 0.28 m / s (3.2%) during takeoff. An important parameter was also the vertical velocity of the CM during takeoff, which was 1.47 m / s. The horizontal and vertical velocities of the CM determine the propulsion phase resultant velocity at the hurdle, which was measured at 8.63 m / s and was directed at an angle of 9.6 degrees.

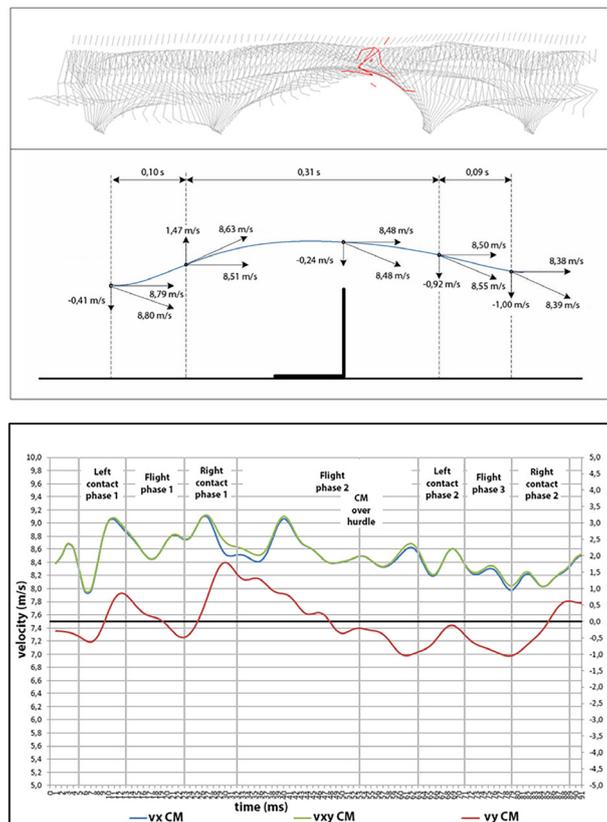


Figure 2. Analysis of the velocity of the central point of the body's center of gravity (TT) during the clearance of the sixth hurdle (Sally Pearson, R: 12.68 s).

Discussion

The transition from the hurdle clearance to the sprint between hurdles depends on the landing phase. In the case of Sally Pearson, the horizontal velocity of the CM after hurdle clearance was 8.38 m/s, which means that when the hurdle was cleared, the velocity was decreased by 0.13 m / s (1.5%). According to previous studies (Mero & Luhtanen, 1986), this represents a very small decrease in velocity at hurdle clearance and is one of the decisive technical factors that determines this elite athlete.

At the moment of initial contact, following the hurdle clearance, the height of the CM was 1.08 m. During the landing phase, the height of the CM was decreased by 0.03 m, and at the moment of push-off this height value was 1.05 m. The small decrease in the height of the CM (2.8%) during the landing phase and the short duration of this phase (0.09 s) indicates an efficient and rational transition into the sprint between hurdles. To maintain horizontal velocity after the hurdle clearance, the contact time of the landing is very crucial, and must last less than 100 milliseconds (La Fortune, 1988; McLean, 1994).

In addition to the correct landing technique following the hurdle clearance, the ability of the muscular system to resist rapid stretching or stiffness is important. Stiffness, as a neural mechanism of muscle activity, depends primarily on muscle preactivation and reflexes: the myotatic and Golgi tendon reflexes (Gollhofer & Kyrolainen, 1991). Depending on the biomechanical characteristics of the landing step, it is characterized by short-range elastic stiffness, where an immediate mechanical response of the activated muscle to eccentric contraction at landing takes place. The parameters mentioned above, in particular, the short contact time of the landing step (90 milliseconds) after hurdle clearance and the extremely small decrease in horizontal velocity after clearing the barrier, indicate an efficient and biomechanically rational hurdling technique.

The present study examined the rationality of the hurdle clearance technique of Sally Pearson, the Olympic winner of the 100-m hurdle race, by using modern diagnostic technology for biomechanical analysis. Technique analysis highlighted the small difference between the height of the CM and the height of the hurdle at the moment of hurdle clearance and the exceptionally small decrease in velocity at the transition from hurdle clearance to the sprint between barriers. The contact phases before and after the hurdle clearance were extremely short, indicating the athlete's high capacity for reactive power. This reactive power makes it possible for the competitor to maintain a high sprint velocity between hurdles, which contributes to her top achievements in running 100-meter hurdle races and has established her as one of the best competitors in this discipline in the history of track-and-field.

Acknowledgements

Pictorial and graphics software is the copyrighted work of Stanko Štuhec.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Received: 7 June 2019 | **Accepted:** 4 July 2019 | **Published:** 11 October 2019

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