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BIOMECHANICAL ANALYSIS AND FUNCTIONAL ASSESSMENT OF D. ROBLES, WORLD RECORD HOLDER AND OLYMPIC CHAMPION IN 110 M HURDLES

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ABSTRACT: A biomechanical analysis of the athlete Dayron Robles' hurdle race was carried out using state-of-the-art technology, along with the Spanish record holder Jackson Quiñónez. Robles is a world record holder and an Olympic champion in the 110 metre hurdles. Kinematic data is provided, which offers a detailed analysis of Robles' hurdle race and is related to his performance in strength tests. We reach the conclusion that the high levels of reactive strength, with very short ground contact times, are Robles' main characteristics in comparison with Quiñónez. In addition, an excessive flight time over the hurdle was noted which his trainer, on being made aware of the results of this research, has managed to correct.

KEY WORDS: Athletics, race, kinematics, strength, performance.

INTRODUCTION: The functional assessment and biomechanical analysis of top-level athletes has had a strong impulse in recent years thanks to the use of new technologies. However, it has not always been easy to get access to the great stars of athletics to carry out scientific studies and most of the data published comes from biomechanical studies from competitions, which involves diverse limitations (Brüggemann, Koszewski & Müller, 1997). In our case, we were able to work directly with the Cuban athlete Dayron Robles, world record holder and Olympic champion in the 110 m hurdles. The purposes of this research were to carry out a functional assessment and a technical and biomechanical analysis of Dayron Robles' race, taking the Spanish record holder Jackson Quiñónez as a point of comparison; to compare, analyse and discuss the results of both athletes; to propose research lines in the training of both athletes based on the results obtained from the research; to propose technical models for the 110 m hurdles race that could contribute to improving the performance of athletes who take part in this speciality; to use state-of-the-art technology for the first time in a single piece of research. For this, a case study was carried out, completed however with that of another top-level athlete (n = 2) to be able to better assess the results of the main athlete studied.

METHODS: The athletes Dayron Robles (Cuba), 22 years of age, world record holder in the 110 m hurdles (12"87) and Olympic champion in Beijing in 2008 and Jackson Quiñónez (Spain), 29 years of age, Spanish record holder in the 110 m hurdles (13"33), Olympic finalist in Beijing 2008 and world finalist in Osaka 2007 participated in the research.
The research consisted of carrying out several functional assessment tests and technical and biomechanical analyses in Barcelona on the 24th and 25th of June 2009. The following protocol was used for both athletes: First day: race analysis (four series from starting blocks, the first two with 2 hurdles and the others with 3 hurdles; and a series of 110 m hurdles from starting blocks). In all these series, regulatory distances and heights of hurdles were used and the wind speed was measured. Second day: kinanthropometric assessment (basic measurements, skin folds, perimeters, lengths, diameters and somatocharts); force analysis (deficit and unilateral facilitation calculation by means of force platform; vertical jump tests with the modified Bosco battery of tests - SJ, Rocket Jump, CMJ, CMJas, LJbw, 5" and 15" reactivity; 1/2 squat tests on barbell with four progressive loads - 50%, 100%, 150% and 200% of body weight).

The material used was: 2 MuscleLab ™ (Ergotest, Norway) with force platform, contact platform and linear encoder; 35 m of infrared platforms Optojump Next ™ 1 cm (Microgate S.r.l., Italy), specially designed for hurdle races, synchronised with 11 photoelectric cells and an electronic starting block system Reac Time ™ (Lynx System Developers, USA); 18 high velocity cameras (recording speed: 300 frames per second) Casio ™ exF1 Pro (Casio Computer Co., Ltd., Japan); 1 Stalker radar ™ (Applied Concepts, Inc., USA); 1 anemometer (Gill Instruments, United Kingdom); 1 Chronojump ™ (Chronojump Boscosystem, Spain); kinanthropometric assessment tools; Kinovea 0.8.7. image analysis software.

RESULTS AND DISCUSSION: The results of the kinanthropometric assessment of both athletes show similar characteristics. Some data of Robles and Quiñónez was selected respectively: weight 89.2 kg and 90.2 kg; height 191 cm and 190.5 cm; span 199.5 cm and 199.5 cm; Withers density 1.082 and 1.084; Siri fat percentage 7.3 and 6.5; Lee muscular percentage 53.1 and 51.9; trochanteric height 102.2 cm and 104.8 cm, Rocha bone percentage 15.6 and 16.6. We consider that these circumstances are favourable for our study, in as much as the kinanthropometric characteristics do not condition a difference in the results of the other research tests.

In the results of the race analysis from the start to the first hurdle in the best of the series of 2 and 3 hurdles, we observed that Robles was able to reach the first hurdle in seven strides, one less than Quiñónez, who went for the more usual eight strides. In order to achieve this, Robles places his leading foot (left) in the front block just 30 cm from the starting line and makes more comprehensive pushes, though with short contact times and similar to those of a sprinter, although this obliges him to substantially modify his rhythm after the first hurdle. Robles' contact times in the first supports progressively decrease from 172 to 120 ms, while Quiñónez does so from 194 ms to 142 ms. The distribution of the length of Robles' strides before the first hurdle is 1.22 m, 1.44 m, 1.53 m, 1.84 m, 1.74 m, 2.06 m and 1.87 m.

The distribution of the clearance of the first three hurdles can be seen in Table 1. We can see a total length of the clearance of the hurdle that is clearly greater in the case of Robles, who takes off and lands further from the hurdle. This permits him a broader movement in the leading leg and intense impulsion.

Table 1
Distribution of hurdle clearance (First 3 hurdles)

	Dayron Robles	Jackson Quiñónez
Hurdle 1	2,32 + 1,32 = 3,64 m	2,01 + 1,24 = 3,25 m
Hurdle 2	2,38 + 1,25 = 3,63 m	2,29 + 0,95 = 3,24 m
Hurdle 3	2,42 + 1,07 = 3,49 m	2,35 + 1,01 = 3,36 m

The distribution of the race between hurdles can be seen in Table 2 (first 3 hurdles) and Table 3 (last 4 hurdles). Schmolinsky (1981) proposed a distribution of the race between hurdles of 1.65 m + 2.00 m + 1.94 m, landing 1.35 m from the hurdle and pushing off at 2.20 m from the following hurdle. As you can see, Robles deviates from this model, making the first stride much shorter and compensating it with a huge second stride, which can be seen both at the first hurdles of the race as well as in the last ones.

Table 2
Race distribution Robles/Quiñónez between hurdles (m) (first 3 hurdles)

Hurdle 1	Stride 9/10	Stride 10/11	Stride 11/12	Hurdle 2	Stride 13/14	Stride 14/15	Stride 15/16	Hurdle 3
3,64/3,25	1,37/1,56	2,14/2,09	1,93/2,14	3,63/3,24	1,39/1,55	2,08/2,11	2,00/2,18	3,49/3,36

Table 3
Race distribution Robles/Quiñónez between hurdles (m) (hurdles 7, 8, 9 and 10 in the 110 m hurdles race)

H7	S33/34	S34/35	S35/36	H8	S37/38	S38/39	S39/40	H9	S41/42	S42/43	S43/44	H10	Valla 10
3,80/	1,38/	2,13/	1,96/	3,66/	1,41/	2,05/	2,04/	3,51/	1,51/	2,05/	2,08/	3,65/	
3,25	1,57	2,15	2,09	3,26	1,71	2,15	2,10	3,22	1,60	2,10	2,09	3,32	3,65

The comparison between the times taken by both athletes in the individual 110 m hurdles race (13”51 Robles and 14”11 Quiñónez) shows a difference of 0”60 logical, if we take into account the reference from the last official competition of both athletes before our tests: Robles 13”04 (+2.0) 17/6 Ostrava; Quiñónez 13”53 (+1.3) 21/6 Leiria, in other words 0”49. In our 110 m hurdles test, Robles was faster than Quiñónez in each of the partial stretches between hurdles. It is extremely interesting to analyse the contact times on the push off before the hurdle, the flight time over the hurdle and the contact time on landing after the hurdle. As we can see, one of Robles’ main characteristics is his shorter contact time in the push off before each of the hurdles (0.128 s, ± 0.006 compared to 0.144 s, ± 0.007 for Quiñónez), although he takes off further away from it. The shorter contact time for the foot landing after crossing the hurdle in the case of Robles (0.082 s, ± 0.006, as opposed to 0.107 s, ± 0.005 for Quiñónez) is also significant. Robles is below 100 ms contact for all the landings, whereas Quiñónez does not manage it for any of them. The analysis of the high-speed film recordings do in fact show how Quiñónez’s heel sinks (especially in his right foot) while Robles’ heel remains high and he quickly starts the impulse for the following stride. The remaining contact times between each of the hurdles are also lower in the case of Robles (0.123 ± 0.006; Quiñónez 0.139 ± 0.007). This is an example of Robles' excellent reactive strength, which was confirmed the following day in the continuous reactive 5” and 15” jump tests. For Antúnez (2009), Robles’ coach, the reduction of the support times, not allowing the heel to sink and, therefore, the fact that there are no successive restartings of the race after each ground contact is the fundamental feature of the race. On the other hand, Robles' flight times are excessively long (Robles 0.337 ± 0.009, Quiñónez 0.297 ± 0.010). As are his clearance times (Robles 0.466 ± 0.008, Quiñónez 0.440 ± 0.013). Although part of the explanation can be found in Robles' huge strides, you can also observe that his elevation of centre of mass is greater (12.85 cm against 10.79 cm) and he takes longer to lower his leg after the hurdle. In view of the results of this research, Antúnez, Robles’ coach, particularly worked on this aspect to manage to reduce the flight times and the hurdle clearance times. The results of this improvement were confirmed in the IAAF World Indoor Championships in Doha 2010 where Robles was proclaimed champion in the 60 m hurdles with his personal best: 7”34. In this final, Robles was the second fastest athlete in hurdle clearance (flight time), with an average of 0.320 ± 0.012 (Kuitunen, 2010).

The assessment of the various manifestations of force through the modified battery of Bosco tests does not offer significant differences between both athletes in the SJ, Rocket Jump, CMJ, CMJas and LJbw tests. The height in centimetres of each of the tests for Dayron Robles and Jackson Quiñónez were, respectively: SJ (49.7 and 40.0), Rocket Jump (51.0 and 55.0), CMJ (54.0 and 55.7), CMJas (68.0 and 70.2) and LJbw (12.3 and 8.5). These results are within the average values for top-level sprint athletes (Bosco,1997). On the other hand, significant differences were found in favour of Dayron Robles in the Rebound Jump tests (reactive jumps with knees almost blocked, emphasising the reactive action of the feet and with the help of the arms), both for 5” as well as for 15”. The latter test duration is the closest one to the real duration of a 110 m hurdles race. If the continuous reactive jump test is carried out for five seconds on the front part of the foot, valuable information is obtained about the reactive strength of the ankle extensors, in other words, the reflex-elastic-explosive strength in its maximum expression of reactivity. Of the Bosco battery of tests, this test is the one that has greatest correlation with the results of the speed test in top-level athletes (López

and Padullés, 2000). It is also a good indicator of the predominance of alactic anaerobic power. The average results of the 5" Rebound Jump for Robles and Quiñónez were, respectively: contact time (s): 168 ± 8 and 178 ± 5, heigth (cm): 37,6 ± 3,2 and 26,9 ± 2,3, mechanics power (W/kg): 57,27 ± 4,71 and 41,15 ± 2,65, speed of takeoff ($m \cdot s^{-1}$): 2,71 ± 0,11 and 2,29 ± 0,10. And the average results of the 15" Rebound Jump for Robles and Quiñónez were, respectively: contact time (s): 182 ± 7 and 180 ± 6, heigth (cm): 41,8 ± 3,1 and 28,4 ± 2,8, mechanics power (W/kg): 59,32 ± 4,65 and 42,60 ± 3,61, speed of takeoff ($m \cdot s^{-1}$): 2,85 ± 0,11 and 2,35 ± 0,12. These differences clearly indicate a greater reactive strength in Robles, which is also related to the results of the contact time in races.

CONCLUSION: The race analysis tests and strength assessment of the two athletes in the sample showed that Dayron Robles is faster than Quiñónez in that he has shorter contact time on the race supports, greater reactive strength and the ability to reach the first hurdle in seven strides. This study proposed that Robles could improve his performance by reducing the flight time in the hurdle clearance. The direct transfer of the results of this research to Robles' coach produced technical improvements in the athlete, which were materialised in the IAAF World Indoor Championships in Doha 2010, at which Robles was victorious.

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