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COMPARATIVE BIOMECHANICAL ANALYSIS OF HURDLE CLEARANCE TECHNIQUES ON 110 M RUNNING WITH HURDLES OF ELITE AND NON-ELITE ATHLETES

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Abstract The purpose of this scientific work was to compare the differences in the hurdle clearance techniques and speed between elite athletes achieving top results and physical education students. The comparison of the hurdle clearance technique was made on the basis of the biomechanical models of Colin Jackson and Darko Mladenović. Biomechanical model of Colin Jackson was taken from “Application of biomechanics in track and field” [11]. Analysis of the biomechanical model of Darko Mladenović was made at the Faculty of Physical Education in Niš. By comparing those results we could conclude that there were considerable differences in the speed of hurdle clearance while the difference in the technique of hurdle clearance was significantly smaller. This research could also conclude that for the top results to be achieved a great speed of hurdle clearance is essential.

Key words: hurdles, speed, technique, differences

INTRODUCTION

Biomechanics of sports is a young scientific discipline which studies human movements and ascertains the laws of mechanics which influence sports results.

Modern biomechanics in sports is the product of high technology and a high level of knowledge in the domain of kinesiology, mathematics, physics, functional anatomy, physiology and computer technologies.

In hurdling, the loss of horizontal speed needs to be the least possible, but agility depends on several factors, especially those which describe the launching phase in front of hurdle, the path line of the body gravity centre and the landing after the flight over the hurdle. For an efficacious hurdling technique the points of launching and landing are the most important. The adequate position of these two points is a condition for optimal flying path of the body gravity centre and reduces the flight time which needs to be as short as possible.

Besides the adequate position, the kinematic and dynamic structure of launching and landing influences directly the speed of hurdling. Therefore, our kinematic analyses were done in order to establish the content of an ideal hurdling technique.

According to previous researche hurdle clearance technique is one of the fundamental elements which directly influence the competing result [4, 5, 6, 7, 8].

The agility of running over hurdles is one of few basic factors which contribute in achieving better results. Over the years flying over hurdles has been replaced by running over hurdles, which decreases the vertical oscillation of the body gravity centre. It has been found that the technique of running over hurdles is better if the vertical oscillation of the body gravity centre is lower. That is why runners try to place the angular point of body gravity centre path as low as possible in the flying phase, closer to the hurdle (Figure 1), in order to reduce the path of the ballistic curve [1].

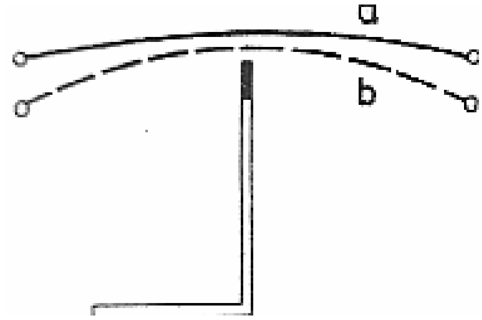

Figure 1. The angular point of the runner's body gravity centre path

But the fact is that the oscillations of body gravity centre path are higher with shorter runners: The maximal running speed in 110 m with hurdles is usually achieved between the 3rd and 4th hurdle, and in races in 100 m between the 1st and 2nd hurdle.

The frequency of movements, as one of the indicators of the technique level, in 110 m and 100 m hurdles is about 3.6-3.7 cycle/sec and in 400m hurdle it is about 3.3 cycle/sec. The rhythm of running between the hurdles needs to be matched with the technique and agility of the runner. In hurdling at 100 m and 110 m the rhythm is always the same (3 strides), and changes in rhythm occur at 400 m because of insufficient physical preparation (the first 5 hurdles in 13 strides and the next 5 hurdles in 14 - 15 strides).

In athletics there are several possibilities of changing and keeping the rhythm on the track:

- free start with acceleration at the end of the track;
- fast acceleration until the 3rd or 4th hurdle, speed maintenance until the 7th or 8th hurdle, and maximal acceleration at the last 2-3 hurdles; and
- achieving the maximal speed at the first hurdle and maintaining the speed until the end of the race.

The running technique between hurdles, especially at 110m hurdles, involves complete extension of articulatio talocruralis and articulatio genus while it is not complete in hip articulation, with the consequence of a higher position of the body gravity centre during the course of the race. In the case of extension in the three articulations mentioned, running over hurdles is more difficult.

The duration of the launch phase in front of the hurdle is longer (about 0.18-0.25 sec) than that of the landing phase behind the hurdle (about 0.9 - 0.12 sec), whereas the whole hurdling action lasts about 0.34-0.40 sec and thedistance passed is 3.30 - 3.50 m for men and 3.00 - 3.20 m for women.

In the launch phase at the moment when the trunk is in continuation of the lead leg, the launch angle is 60° - 70°. In the flying phase of the stride (with legs spread in the direction forward-backward), the angle of bended legs is 117º - 123º.

While running in a lane, runners with high speed should acquire the centrifugal force and keep the technique and the rhythm of running. It is more accurate to launch with the right foot, because it is then possible to run along the interior of the lane, taking the hurdle from its left. The left leg with the pendulum effect does not obstruct the activity of the body.

Runners' body height of both sexes is a big advantage, more pronounced in case of small body weight, especially at running at 400 m hurdles.

MATERIALS AND METHODS

SAMPLES

This study aimed to establish the differences in hurdling techniques between elite runners (Colin Jackson – C.J.) and non-elite athletes (Darko Mladenović – D.M., a student of Faculty of Sports and Physical Education), so as to establish what is needed to achieve the proper hurdling technique and high scores. An attempt to answer the posed questions was made by examining the differences in the phases of launch and flight.

TESTING PROCEDURE

The biomechanical analyses related to C.J. were made at «Velenje-Slovenija 2002», a track-and-field event, during his preparations for the European Championship in athletics which was to be held in Munich in 2002. Biomechanical measurements were performed by a group of experts of Biomechanical laboratory of the Department for Sport in Ljubljana. The main task was to establish the kinematic model of the technique of running over the 4th hurdle. The measurements were performed by 3-D video analysis. The recording included two synchronized cameras with the frequency of 50 Hz. A 15-segment model and the kinematic program ARIEL were used to calculate the body gravity centre (BGC).

The biomechanical analyses related to D.M. were performed at the Faculty of Sports and Physical Education of Niš. The recording was divided into 34 frames and data were obtained by following an arrangement. Measurement was performed using KA Video and KA2-D programs which enabled 2-D analyses of the recording, Stanković [9]. The analyses of D.M.'s recording and techniques by the KA2-D program are shown in Figures 2 and 3.

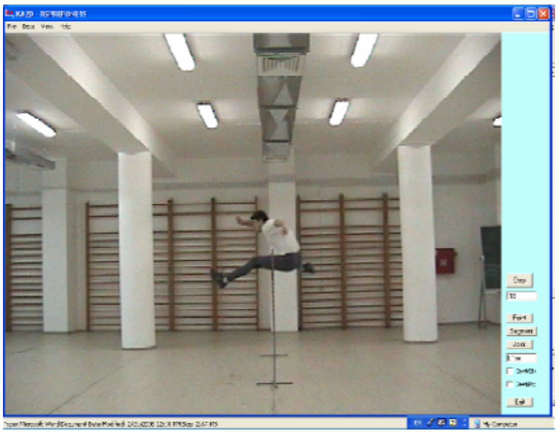

Figure 2. A photo of D.M. at Faculty of Sports and Physical Education of Niš

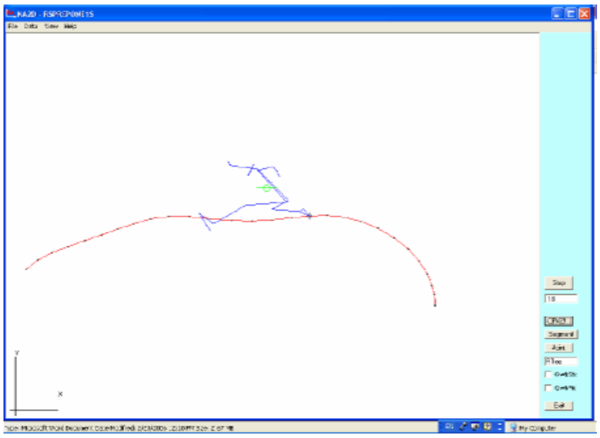

Figure 3. Program KA2-D enabled 2-D analyses of D.M.'s hurdling performance

RESULTS

BIOMECHANICAL ANALYSIS OF 110M HURDLES BY COLIN JACKSON

In 2002, C.J. was age 35, he had body height of 185 cm and body weight of 75 kg. The racing time which he achieved during testing was 13.47 sec. Based on the kinematic model of C.J.'s, the conclusion is that the hurdling efficacy is defined by the launch path distance in front of the hurdle and the path distance until landing. The total length of the flight was 3.67 m. The distance path of the launch in front of the hurdle was 2.09 m and represented 56.9 % of the total flight length. The distance path of landing was 1.58 m behind the hurdle and represented 43.1 % of the total flight length. Previous studies affirmed that the optimal ratio between the points of launch and landing is 65 % : 35 %. Therefore, the conclusion is that C.J. had a shorter launch in front of the hurdle and a longer landing behind the hurdle [3, 4, 6].

The launching point is one of the vital elements for optimal hurdling. The launch length in front of the hurdle defines the path of the BGC. The launch time was 100 msec and it consisted of two phases: the detachments of the rear and the front of the foot. The frontfoot detachment phase should be as short as possible and depends on the angle between the lead foot and the track surface. The rearfoot detachment phase ended at an angle of 72.90º between the lead foot and the track surface. These parameters show that the lead leg rested on the track during the launch, while the shoulders were in the position forward to hurdle.

The speed of hurdling depends on the rebound efficiency which is manifested through the horizontal velocity of the BGC. In the phase of the frontfoot detachment it was 8.81 m/sec while in the phase of rearfoot detachment it increased until 9.11 m/sec (the increase was 3.3%). So, C.J. had a high capacity of acceleration during the launch. Besides the horizontal velocity of the BGC, another important launch parameter was the vertical velocity which was 9.41m/sec and the angle of elevation was 14.5°. The connection between these two velocity parameters showed that C.J. had a high capacity of changing from running into hurdling (Figure 4).

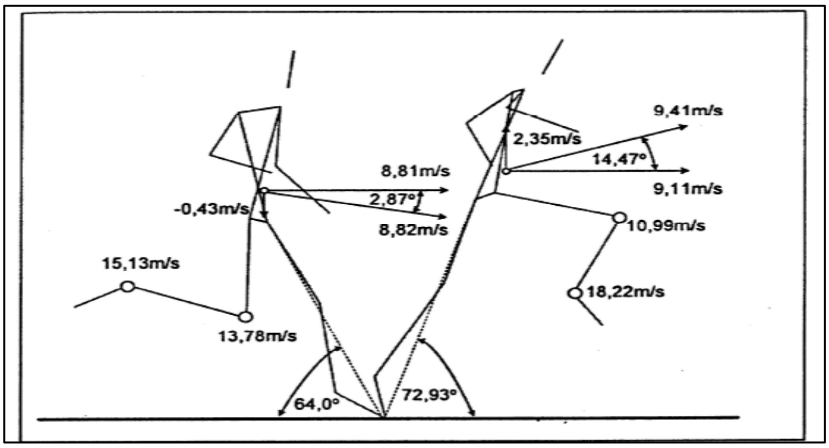

Figure 4. C.J. – the launch

The quality of hurdling is in direct connection with the height of the BGC in the flight phase. From the aspect of biomechanics, a successful hurdle race considers the least vertical oscillations of the BGC. The runner should keep a high position of the BGC in the moment of the frontfoot detachment. At the moment of rearfoot detachment, C.J. had the BGC height of 1.08 m from the track surface, which was 59.3 % of his body height. The elevation of the BGC from the phase of frontfoot launch to the phase of rearfoot detachment was 13 cm. Maximal height of the BGC depends on the launching technique in front of the hurdle as well as on the runner's morphologic characteristics.

Together with the previously mentioned kinematics parameters, hurdling velocity depends on the speed of the trailing leg during the launch. C.J. attacks hurdles aggressively, and velocity of articulatio genus of his trailing leg was more than 13 m/sec, while his foot velocity was 18.22 m/sec, which was twice as fast as the horizontal velocity of the BGC during the launch.

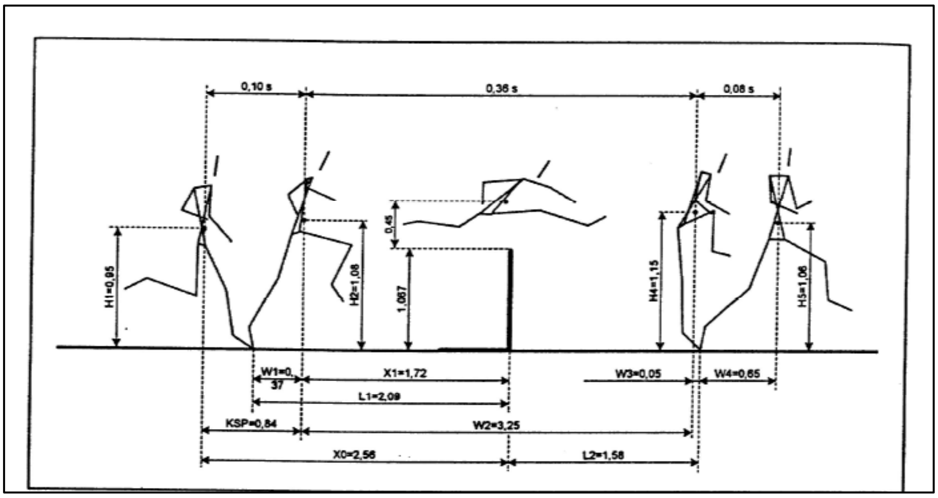

Figure 5. C.J. – the flight

The criterion for an efficient hurdling technique is the shortest flight time because sprinters lose velocity while they are in the air. The flight length of C.J.´s BGC was 3.30 m and his flight time was 0.36 sec. The higher the flying path of the BGC is, the longer the flight takes. C.J.'s BGC height above the hurdle was 45 cm, which shows that the path was not the most efficient. The elevation of the BGC from the launch phase of 44.3 cm shows that it was the result of a relatively short distance between the launch spot and the hurdle. The flight phase is also an important element of hurdling. This phase contains the most potential for the improvement of competition results. In the landing phase fast change from flying to running is necessary. This transformation from acyclic to cyclic locomotion demands a high level of technical knowledge and high motor capacities such as speed, power, coordination, timing and balance.

The landing contact time was 0.08 sec. During the landing phase which followed the flight phase, C.J. kept a high BGC position, which was the result of full extension of the leg in the articulatio genus and hip articulation (Figure 5). Soft landing after the flight is connected with the vertical BGC velocity, which is negative (-1.02 m/sec). The horizontal BGC velocity in the phase of landing was 8.77 m/sec, which means that C.J. lost velocity of 0.34 m/sec or 3.7 % during the flight phase of rebound (Figure 6). Based on these parameters, the conclusion is that C.J. had great hurdling efficiency, which permitted him to create optimal speed between the hurdles.

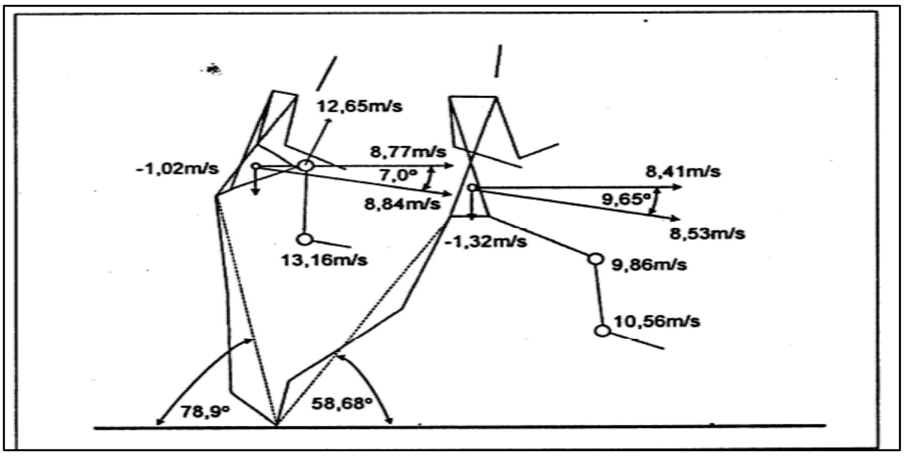

Figure 6. C.J. – the landing

BIOMECHANICAL ANALYSIS OF 110M HURDLES BY DARKO MLADENOVIĆ

Darko Mladenović (D.M.) is a student of Faculty of Sports and Physical Education in Niš. During the testing he was 21 years old, he had body height of 175 cm, body weight of 80 kg and the best racing result of 20 sec in a 110 m hurdle.

D.M.'s total flight length during the testing was 3.35 m. The length of the path in the phase of frontfoot detachment in front of the hurdle was 1.92 cm which consisted 52.8 % of the total flight length. The landing length ehind the hurdle was 1.70m which consisted 47.2 % of the total flight length.

The contact time at the launch phase was 0.10 sec. For easier analysis the launch was divided in two phases: the frontfoot and rearfoot detachment phases. The launch has importance in hurdling because the characteristics of the launch impact the path of the BGC over the hurdle. At the moment of rearfoot detachment, D.M.'s angle between the body and the surface was wider (76°). Horizontal velocity of the BGC in the phase of frontfoot detachment was 7.24 m/sec while in the phase of rearfoot detachment it decelerated to 6.37 m/sec. This deceleration of the horizontal BGC velocity points to an insufficient transformation capacity of acyclic to cyclic locomotion (from running into launch). An important parameter is vertical velocity, which together with horizontal velocity gives the resultant velocity of the BGC. The angle between horizontal and resultant velocity was 22°. Such a wide angle which appeared during the launch phase shows a worse hurdling technique and the reason was the deceleration of horizontal velocity (Figure 7).

Also, besides the parameters mentioned, the velocity of the flight over hurdle is influenced by the velocity of the trailing leg. The velocity of articulatio genus of the trailing leg was 13.41 m/sec, while the trailing foot impulsion of in the phase of rearfoot detachment was 14.10 m/sec, which was twice as high velocity as the horizontal velocity of the BGC.

The quality of the flight over a hurdle depends on the height of the BGC during the flight phase. In search of a more efficient hurdling technique, the least possible vertical oscillations are needed. The height of the BGC during the launch phase with D.M. was 1.21 m, which points to the high position in the phase of the rear launch. In order to lose as little speed as possible during the flight phase, the length and the launch time are important. D.M.'s flight length was 3.35 m and his flight time was 0.5 sec. This flight time points to a great height of the BGC above hurdle during the flight phase (0.42 cm). The height of the BGC above the surface was 148.7 cm. Such vertical distance shows growth of the BGC height of 0.25 m with regard to the launch phase (Figure 8).

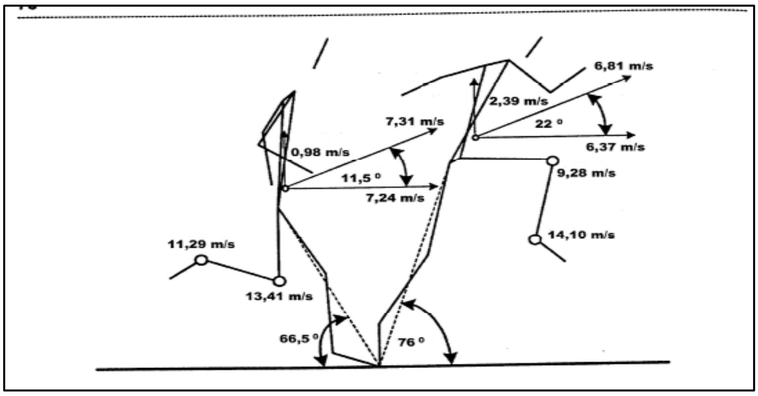

Figure 7. D.M. – the launch

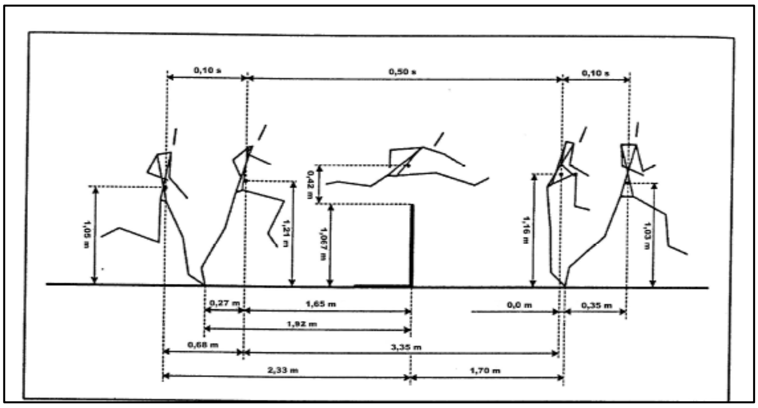

Figure 8. D.M. – the flight

In the landing phase, which is an important element of the technique, the capacity to change from flying over a hurdle to running between hurdles was analyzed. The landing contact time with D.M. was 0.10 sec. Also, during the phase of landing it was obvious that the landing was not good enough because vertical velocity was -2.80 m/sec. During the change from the phases of frontfoot to rearfoot detachment, the horizontal velocity did not increase but it decelerated, which points to inadequate balance, power and technical preparation (Figure 9).

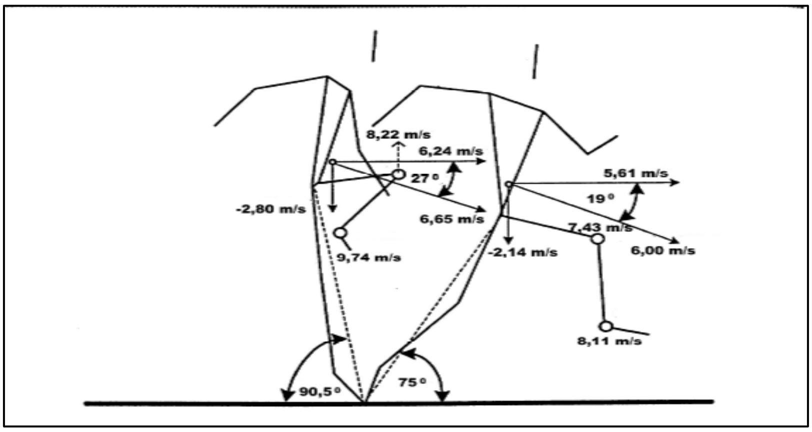

Figure 9. D.M. – the landing

Comparative Results

Table 1. Comparative parametres with C.J. and D.M.

PARAMETRES	AD MEASUREMENTS	C. J.	D. M.	Absolute differences	Relative differences (%)
Velocity	m/sec	8.83	6.90	1.93	21.86
Frontfoot detachment ph.					
Horizontal vel. of BGC	m/sec	8.81	7.24	1.57	17.82
Vertical vel. of BGC	m/sec	-0.43	0.98	1.41	327.90
Resultant vel. of BGC	m/sec	8.82	7.31	1.51	17.12
Height of BGC	m	0.95	1.05	0.10	10.53
Vel. of art. genus	m/sec	13.78	13.41	0.37	2.69
Vel. of art. talocruralis	m/sec	15.13	11.29	3.84	25.38
Rearfoot detachment ph.					
Horizontal vel. of BGC	m/sec	9.11	6.37	2.74	30.08
Vertical vel. of BGC	m/sec	2.35	2.39	0.04	1.70
Resultant vel. of BGC	m/sec	9.41	6.81	2.60	27.63
Height of BGC	m	1.08	1.21	0.13	12.04
Vel. of art. genus	m/sec	10.99	9.27	1.72	15.65
Vel. of art. talocruralis	m/sec	18.22	14.10	4.12	22.61
Launch length in front of hurd.	m	2.09	1.92	0.17	8.13
Contact time in det. phase	sec	0.08	0.12	0.04	50.00
Flight time	sec	0.36	0.50	0.14	38.89
Height of BGC above hur.	m	0.45	0.42	0.03	6.67
Maximal height of BGC	m	1.52	1.49	0.04	2.78
Landing ph. (frontfoot)					
Horizontal vel. of BGC	m/sec	8.77	6.24	2.53	28.85
Vertical vel. of BGC	m/sec	-1.02	-2.80	1.78	174.51
Resultant vel. of BGC	m/sec	8.84	6.65	2.19	24.77
Height of BGC	m	1.15	1.16	0.01	0.87
Vel. of art. genus	m/sec	12.65	8.22	4.43	35.02
Vel. of art. talocruralis	m/sec	13.16	9.74	3.42	25.99
Lenght of reb.after hurd.	m	1.58	1.70	0.12	7.59
Landing ph. (rearfoot)					
Horizontal vel. of BGC	m/sec	8.41	5.61	2.80	33.29
Vertical vel. of BGC	m/sec	-1.32	-2.14	0.82	62.12
Resultant vel. of BGC	m/sec	8.53	6.00	2.53	29.66
Vel. of art. genus	m/sec	9.86	7.43	2.43	24.65
Vel. of art. talocruralis	m/sec	10.56	8.11	2.45	23.20
Contact time in land.ph.	sec	0.10	0.14	0.04	40.00

CONCLUSIONS

Based on previous biomechanical studies, the conclusion is that the launch and landing phases define the technique level of hurdling, which is an important factor in running in 110m hurdle races and in the final result. The function of the launch is to ensure the satisfactory transformation of horizontal into vertical velocity of the BGC. Horizontal velocity decelerates while vertical velocity increases which is the consequence of the BGC changing direction. In the landing phase, which is important in the domain of techniques, the contact time with the track surface in the phase of frontfoot detachment needs to be as short as possible in order to maintain the BGC horizontal velocity during the phase of flying over the hurdle.

Hurdling efficiency could be defined by the horizontal velocity of BGC during the phase of the launch in front of the hurdle, the height of the BGC during the phase of the flight, the velocity of the articulatio genus of the trailing leg, flight time and the least possible loss of horizontal velocity during the flight over the hurdle.

C.J. had a better hurdling technique,which was confirmed by his previous results. This analysis established that although C.J. had slight aberrations from the ideal path during the launch phase, he had a better flight time due to his capacities to increase the speed during the flight phase.

By analyzing D.M.'s performance there were established shortcomings which could be removed in further practice, by better physical and technical preparation.

PRACTICAL APPLICATION

Practical application of this research is in precisely established differences in kinematic parameters of the hurdle clearance technique. Thereby, the established differences will be helpful to coaches in the correction of the training process and achieving top results, which directly depends on the variables researched in this work.

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