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ORIGNAL ARTICLE

The kinematic analysis and comparison of foreign and national 110 m hurdling techniques in Srilanka

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Abstract

The purpose of the study was to compare the biomechanical parameters of the hurdle clearance technique of the fifth hurdle in the 110 m hurdle race of National Champion (R. Dammika) in Sri Lanka (14.16 s was set in 2019) and D. Robles of Cuba (12.87 s world record was set in 2008). Despite the athletes having performed at different times, we used comparable biomechanical diagnostic technology for both hurdlers. Roshan's clearance techniques the researchers have settled cameras in order to get the clear views of the hurdles of the 4th and the 5th. Subject performance was recorded with a sample of approximately 100 Hz motion cameras. Robles's Data were collected by the previous analysis. The results of R. Dhammika's hurdle clearance was not effective, as it was characterized by a maximal loss of horizontal center of mass (COM) velocity. R. Dhammika completed the hurdle clearance slightly slower, as it took him 0.59 s. Roshan's take-off phase also lasted 0.13 s, his flight phase 0.37 s, and his landing 0.09 s. Robles's hurdle clearance took 0.50 s: 0.10 s for the take-off, 0.33 s for the flight phase, and 0.07 s for the landing phase. Dhammika's Sprint height also included in a lower value under the recommend of COM height. Hurdle clearance landing velocity drop and COM drop Significantly high and Landing phase distance value also higher than stranded value. All the coaches should have to obtain a great knowledge about biomechanical training methods to improve the hurdle technique from minimizing the biomechanical errors.

1. Introduction

Hurdles race has a long history; its original basis is human race gradually formed life technology as overcoming obstacles in fast running during fighting process with nature and animals to achieve 1830; In 1864, it started 109.72 m hurdles race; in 1888, Frenchman made supplement by adding 28 cm let it become 110m hurdles race. In 1896 Olympic Games, it has already had 110m hurdles race event, but as hurdle techniques were not perfect at that time, performance was only 17.6 s, which is not ideal. Since the second Olympic Games, it started 110m hurdles race and listed as formal competition event in international games [15].

Hurdling can be classified as a very complex technical event that requires high levels of physical fitness [11] In fact, sprint speed, inter-segmental coordination, reactive strength, and great technical skills are the most key physical fitness aspects that should regularly be developed and routinely implemented in training programs to succeed terrace [8]. In particular, the technique of clearing the hurdle represents one of the most determinant elements defining the competitive result [16, 21]. In this context, [11] indicated that the improvement of the 110

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m hurdle race technique represents one the central component of training [2]
Efficient hurdle clearance technique is generated by the following factors: Contact time of take-off, an optimal ratio of the braking phase to propulsion phase of take-off, The ratio of the point of take-off to landing relative to the hurdle, Flight time, short braking phase in landing, High position of the center of gravity (CG) at landing, Minimal reduction in the horizontal force of the CG at landing [19]. The horizontal velocity of the hurdler between the fourth and the fifth hurdle is highly correlated with the end result in the 110 m hurdle race [5].

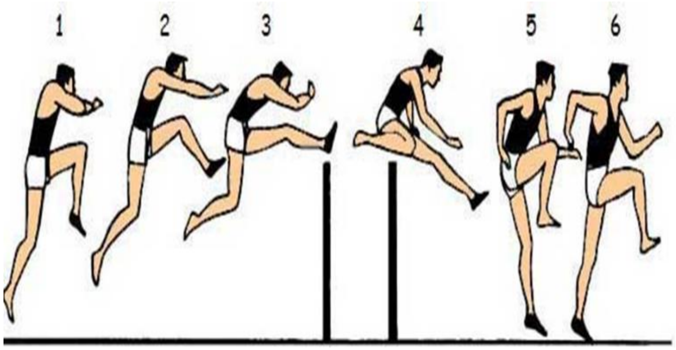


Figure 1: Whole sequence of 110 m hurdle clearance technique

Biomechanics in sport incorporates a detailed analysis of sport movements in order to minimize the risk of being injured and improve sports performances. Sport and exercise biomechanics encompass the area of science which is concerned with the analysis of the mechanics of human movements. It is a discipline that applies to all the laws of mechanics to study body movements and help in gaining a greater understanding of performance in athletic events through modeling and measurements.
R. Dhammika has renewed the Sri Lankan number one spot with a timing of 14.16 s at the 2019 National trials and he is chasing the Sri Lankan record of 13.97 s which was set previously. In order to win a world class medal at the world 110m hurdle event, he must exceed runs under 13.60 s at least. In order to reach this timing, athletes must practice the proper techniques and finesses for this posture. Further, paying more attention on the new athletic methods, keeping a good physical health and focusing on the skills one can sharpen up their performance skills in order to take his or her capabilities to a higher version which can be listed as several techniques that one can follow in this sporting area. We can achieve a global victory in triple 110m hurdle event in Sri Lanka by identifying those errors by the guidance of well-trained coachers and internationally appreciated, accepted skills and by creating a corrective method in an arch and every position.
These studies were conducted to analyze comparable data held by Department of Sport Science and Physical Education Biomechanical measurements of both athletes (Sri Lankan National Number one athlete R. Dhammika and D. Robles were performed at different times with different measurement technologies within under comparable conditions. In both cases, a kinematic analysis of the fifth hurdle clearance technique was used. High standards of biomechanical measurements were taken into account, indicating that the observed results were impartial. We realize that the study would have been more beneficial if we had been able to analyze a greater amount of obstacle clearances, but due to organizational and technological restrictions, this was not possible. The study's key objective was to identify, examine, and analyze the essential kinematic characteristics of two athletes' hurdle clearance technique at hurdle 5 who have set the highest standards of biomechanical rationality in 110 m high hurdle races.

2. Materials and Methods

2.1 Participants

Two hurdlers, National number one R. Dhammika (body mass 70 kg, height 178 cm) from the Sri Lanka and World record holder D. Robles from Cuba, took part in this experiment (body mass 79 kg and height 191 cm). Both competitors specialized in the 110-meter hurdle and were or are world champions in the event. Table 1 shows more personalized and anthropometric data for both athletes. Prior to the official video recording, the respondents received their informed consent and were informed of the study's protocol and procedures. The athletes recruited for the experiment were specific and reliant on the ability to make a video recording with its comprehensive procedure during an international conference, and above all, dependent on the level of competition. The experiment can be classified as a case study because it includes the analysis of the hurdle technique for only two competitors. The work reports scientifically sound experiments and provides a considerable amount of new information.

Table 1: Basic anthropometric and biographical data of R. Dhammika (Sri Lanka) and D. Robles (Cuba).

Parameters	R. Dhammika	D. Robles
Date of birth	1998	1986
Body height (m)	1.78	1.92
Body mass (kg)	63	79
Body Mass Index (BMI)	19.8	21.43
Best result (s)	14.16	12.87
Experimental result (s)	14.37	13.00

2.2 Experimental Design

No any method yet was detected in measuring the kinematic and dynamic parameters of 110 m hurdle event and other athletic events in Sri Lanka. This study is based on the researcher's innovative and experimental methods in data complication and in person interviews which were conducted aligned with the National Level Training Coaches in Sri Lanka in defining the detected problematic conditions in this field. Majority of coaches were borne up the opinion of that new strategies should be made in upgrading Sri Lanka's athletes' performances in the Event of Hurdling. Though the Hurdle clearance techniques are already being used, it is needed much attention for an Asian country like Sri Lanka where it has the potential of producing productive athletes to the world. The factors that are notified through this study will systematically be beneficial for both the coaches as well as athletes.

The experiment design used was a comparison of dynamic and kinematic variables between two 110 m hurdles races at the segment between hurdles 4 and 5 and hurdle clearance of world record holder and National number one. D. Robles recordings of hurdles took place during regular international athletics competitions and R. Dhammika recordings took place Domestic National Competition, although in two different places and two different years. These two conditions forced the experiment to match two different race recording methodologies. The hurdle races of Dhammika and Robles were both recorded using two cameras each, although of different resolutions of 50 Hz frames per second and 100 Hz per second, respectively. From a methodological point of view, this may be a significant difference, but the conditions of variability were respected when processing data. In order to avoid the errors involved in analysis, real measurements were recalculated, taking into account the measurement error, which actually means that they corresponded (e.g., 50 Hz means 0.04 s between frames, so a hurdle clearance time of 0.5 s vs. 0.54 s represents a single frame). In both analyses the model of Dempster [8] was used for the calculation of the body's COM and the kinematic program ARIEL (Ariel Dynamics Inc., Trabuco Canyon, CA, USA) for the digitization was applied.

2.3 Procedure of Measurements–National Number one

The researcher has used two high-speed cameras for the video analysis which is occurred in two sagittal planes [4]. This video frame was to focus on during the Hurdle take off and Clearance and landing phase, as the hurdle clearance phase was the most important phase in this study. Furthermore, the researchers have used cameras to capture the clear view of the hurdle clearance techniques for an analysis. In the clearance techniques the researchers have settled cameras in order to get the clear views of the hurdles of the 4^{th} and the $5^{th.}$ Anthropometric measurements (height & weight) of athlete was taken before the test begun. Subject performance was recorded with a sample of approximately 100 Hz motion cameras. All cameras were placed 10m away from the player's performance sagittal plane and Camera height 1.20 m and camera rage left 3 m and right 3 m and also focus length 35 mm [13]. Coordination of Center of gravity trajectory was observed. Before take the videos calibrated vertical axis using pole in performance sagittal plane. All video data was collected in Sugathadasa Outdoor Stadium, Colombo. All analyzes were performed using the Kinovea software and Microsoft Excel 2016 and all kinematics variables were calculated. Two-dimensional coordinates of Center of Gravity were used to find the relevant kinematic variables.

2.4 Foreign Player Measurement – Dayron Robles

Biomechanical analyses of Robles's 5th hurdle clearing technique was performed at the 2011 IAAF World Challenge - Zagreb International Race. Weather conditions were optimal; the outside temperature was 23 °C, and the wind speed was 0.2 m/s. Authorization to perform biomechanical measurements was obtained from the Technical Delegate of the European Athletics Federation and the Organizing Committee of the competition. The running track lane in the zone of the 5th hurdle was covered by two Casio high-frequency digital Casio EX-F1 512 × 384 (300 fps) sampled down to 100 fps cameras (Casio Computer Co., Ltd., Tokyo, Japan), which were interconnected and synchronized. The shutter speed of the Casio cameras was 1/300 s. The cameras were set perpendicular to the zone of the 5th hurdle (running hurdler) at an angle of 90◦. The zone of the 5th hurdle was calibrated with a 2 m × 2 m × 2 m reference frame, within which eight points were measured. Data processing utilized an APAS computer system for 3D kinematic analysis (Ariel Performance Analysis System). Digitization of a 15-segment athlete body model was carried out, defined by 15 reference points [8] The point coordinates were smoothed with a 14 Hz digital filter. The center of mass (COM) was calculated from the digitized points based on Dempster's (1955) model of determination of COM via the ARIEL kinematic program (Ariel Dynamics Inc., Trabuco Canyon, CA, USA).

3. Results

The difference in body weight between competitors was only 16 kg. An even greater difference was in body height and was 13 cm in favor of Robles. Both measurements significantly differentiated hurdlers in terms of a measure of body fat (the ratio of the weight of the body in kilograms to the square of its height in meters), which was 1.63 in favor of Robles (Table 1). The time difference between those two records is 1.32 s. Dhammika set his Sri Lankan record at the age of 21 and Robles at the age of 22. Based on biomechanical analyses (Table 2), the following results were obtained: Robles's total stride length was 3.66 m, and the stride was completed in 0.33 s, while Dhammika's stride length was 3.70 m, and it was slightly slower, lasting 0.37 s. During hurdle clearance, D. Robles reached the highest COM point at 1.38 m (0.32 m above the height of the hurdle), which corresponded to 72.2 % of his body height. R. Dhammika reached the COM trajectory point at 1.35 m (0.28 m above the hurdle height), which was 75.8 % of his height. The difference between the lowest COM point in the eccentric phase of the take-off was 1.11 m for Robles and 0.92 m for Dhammika; and the highest COM point during the flight phase was 1.387 m for Robles and 1.347 m for Dhammika. The height of the COM at the end of the concentric phase of take-off for Robles was 1.23 m and 0.97 m for Dhammika.

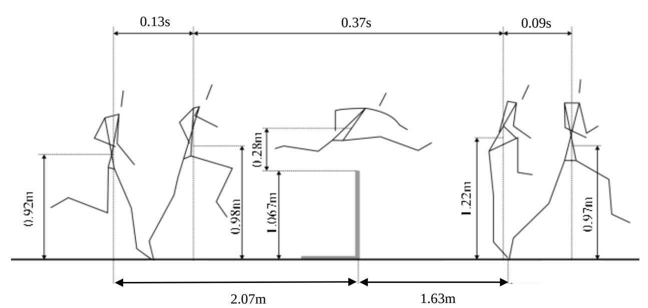
Table 2: Biomechanical variables of the clearance of the fifth hurdle.

Variables	D. Robles	R. Dhammika	Difference	Δ (%)
Horizontal velocity 4H-5H (m/s)	9.18	8.94	0.24	2.68
Take-off (breaking phase)				
Horizontal velocity of COM (m/s)	8.70	7.31	1.39	19.02
Vertical velocity of COM (m/s)	-0.70	-0.35	0.35	100
Velocity resultant of COM (m/s)	8.73	7.32	1.41	19.26
Height of COM (m)	1.11	0.92	0.19	20.65
Foot to hurdle distance (m)	2.43	2.07	0.36	17.39
Take-off (propulsion phase)				
Horizontal velocity of COM (m/s)	9.00	7.88	1.12	14.21
Vertical velocity of COM (m/s)	1.80	1.45	0.35	24.13
Velocity resultant of COM (m/s)	9.18	8.01	1.17	14.60
Height of COM (m)	1.24	0.98	0.26	26.53
Push-off angle (◦)	78.7	72	6.7	9.31
Contact time (s)	0.10	0.13	0.03	23.08
Flight				
Flight time (s)	0.33	0.37	0.04	12.12
Height of COM above the hurdle (m)	0.32	0.28	0.04	14.28
Maximal height COM (m)	1.52	1.18	0.34	28.81
Landing (braking phase)				
Horizontal velocity of COM (m/s)	8.80	7.46	1.34	17.96
Vertical velocity of COM (m/s)	-1.00	-0.89	0.11	12.35
Velocity resultant of COM (m/s)	8.86	7.51	1.35	17.98
Height of COM (m)	1.30	1.22	0.08	6.56
Foot to hurdle distance (m)	1.23	1.63	0.4	32.52
Landing (propulsion phase)				
Horizontal velocity of COM (m/s)	9.35	7.31	2.04	27.91
Vertical velocity of COM (m/s)	-1.00	-1.01	0.01	1
Velocity resultant of COM (m/s)	9.40	7.38	2.02	27.37
Height of COM (m)	1.23	0.97	0.26	26.81
Contact time (s)	0.07	0.09	0.02	28.57

4. Discussion

Robles took 0.50 s to complete the hurdle clearance process, which included 0.10 s for take-off, 0.33 s for flying, and 0.07 s for landing phase. Meanwhile, R. Dhammika completed the hurdle clearance a little more slowly, as it took him 0.59 s. Roshan spent 0.13 s for take-off, 0.37 s for the flight phase, and 0.09 s for the landing phase. For comparison, the measurement of Amara [1]—a medium level athlete (13.90 s at 110 m hurdles) showed differences in the abovementioned parameters of 0.60 s, 0.36 s, 0.21 s, and 0.12 s (respectively for each variable). Dhammika's slower clearance of the hurdle is associated with a longer landing distance over the hurdle, extending both the flight phase and the shock absorption phase. A slower hurdler [8] had a similar problem; his excessive height of the vertical COM displacement together with a high take-off angle had a negative impact on the time to clear the hurdle. The difference in the flight parabola between the two athletes can be attributed mainly to the difference in their height and the difference in their functional abilities. Based on the kinematic parameters of the parabola, we can, therefore, conclude that D. Robles has a more rational hurdle clearance technique (Fig. 2). The take-off distance for Robles was 2.43 m, which was 66.4 % of the total clearance length over the hurdle. We could conclude that D. Robles utilizes a more realistic hurdle clearing strategy based on the kinematic properties of the parabola (Fig. 2).

R. Dhammika



D. Robles

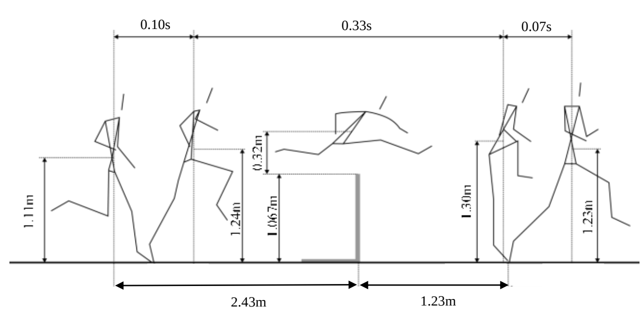


Figure 2: Comparison of the biomechanical parameters of the landing

Robles' take-off distance was 2.43 m, accounting for 66.4 % clearance length across the hurdle. For Dhammika, the take-off distance was 2.07 m, which was 55.9% of the total length of clearance. Dhammika's landing distance was 1.63 m (44.0% of his total stride length), while Robles's was 1.23 m (33.6% of his total stride length). It can be compared with some other studies [8,19], which indicate that the optimal ratio between take-off spot and landing place should be 40–60 %, which is comparable with Amara's [2] findings (i.e., 58:42). This ratio was confirmed by previous researchers [6,7,8,10,19,23], which indicated that take-off distance should range from 2.04 cm to 2.31 cm. In turn, the landing distance was shorter. We can identify two different hurdle clearance strategies.

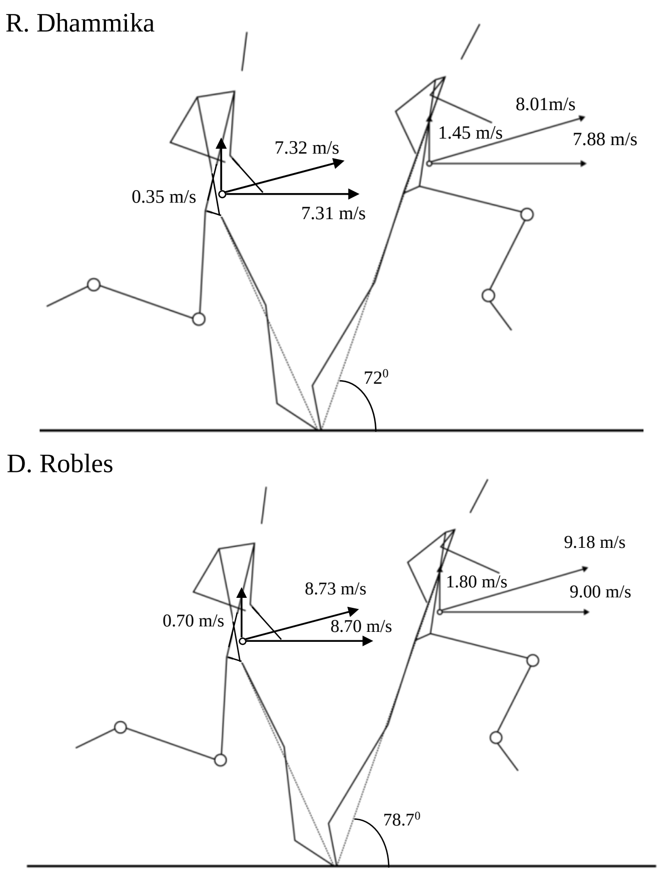


Figure 3: Comparison of the biomechanical parameters of take-off before the hurdle.

Robles clears the hurdles faster, with a longer take-off and a nearer landing. The duration of Robles's flight phase is 0.33 s, and that of Dhammika is 0.37 s. A technical model of When [29] indicated that the optimal over the hurdle time should range between 0.30 and 0.33 s for a world class hurdler. This confirms the importance of the take-off (the angle between the top of the foot and the hip) and landing distances in high hurdler races, as was previously mentioned by Coh and Iskra [7] and Lopez [21]. In the concentric phase, Robles had a take-off angle of 78.7^0, and Dhammika's was 72^0. The COM velocity resultant during the braking phase of the take-off was 8.73 m/s for Robles and 7.32 m/s for Dhammika. This velocity resultant of COM is defined as the vector sum of the vertical COM velocity (0.70 m/s for Robles, –0.35 m/s for Dhammika) and horizontal COM velocity (8.70 m/s for Robles and 7.31 m/s for Dhammika). It changes until the last contact of the take-off when it measured 9.18 m/s for Robles and 8.01 m/s for Dhammika. Robles's vertical COM velocity at that time was 1.80 m/s, and Dhammika's was 1.45 m/s; their horizontal COM velocities were 9.00 m/s and 7.88 m/s, respectively.

The COM horizontal velocity during take-off thus increased by 0.30 m/s for Robles and Dhammika. The relative increase in the horizontal velocity of COM for Robles was 3.30 % and 7.7 % for Dhammika (Fig. 3). The take-off duration was the same for both athletes. But Dhammika's take-off time little more

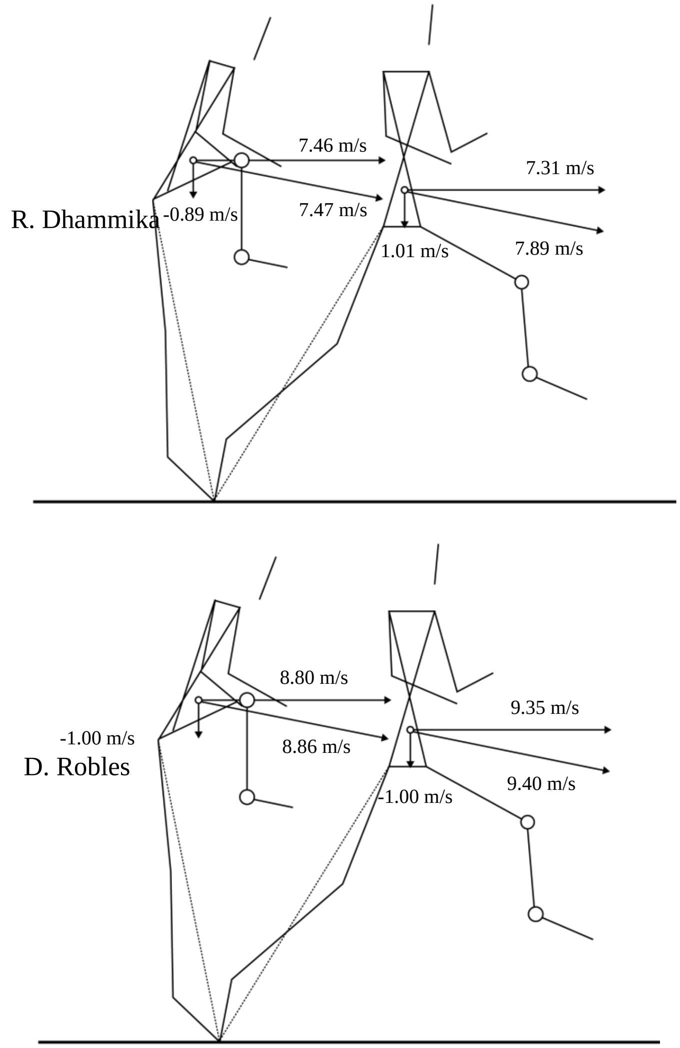


Figure 4: Comparison of biomechanical parameters of hurdle clearance

(0.13 s). Robles's COM height during take-off increased by 0.13 m, but Dhammika COM height during take-off increase 0.06 m (Fig. 2). It is more significantly different between these two players. Dhammika was not extended the joints of the body perfectly and that was affected less of COM height to that above hurdle. In that case he has struggled to clear the hurdle correctly. And also, Dhammika's hurdles velocity was more less than Roble's hurdles velocity. All velocity parameters were in a low level. But takeoff angle and clearance distance nearly same values. It is comparable with data of Amara [2], Li and Fu [16], and Lopez. [19], who claimed that during take-off (propulsion phase), the average height of the COM should be around 1.12 m.

The transition between hurdle clearance and the sprint between hurdles is dependent on the landing phase. For Robles, the horizontal velocity at landing was 8.80 m/s, which means that the horizontal velocity decreased by 0.20 m/s (2.2 %). For Dhammika, the horizontal velocity decreased by 0.42 m/s (5.6 %). During the landing phase, Robles's height of COM decreased by 0.07 m (5.4%) and 0.25 m (25.7%) for Dhammika. The short duration of the landing phase (0.07 s for Robles and 0.09 s for Dhammika) indicated a high level of reactive power [10] for both athletes (Fig. 3), and an efficient transition to sprinting between hurdles [12,14]. But Dhammika's sprinting of transition was very weak because COM landing decreased 25 %. He couldn't be able to control COM in this period that affect to the velocity drop in to his sprinting. He was given more energy to clear the hurdles and sprint.

For Dhammika, the reduction in the horizontal velocity of COM was greater than that of Robles, and the height of his center of mass (COM) was lower at landing, so it can be concluded that Robles has a slightly more biomechanically rational hurdle clearance technique. In addition, our results do not contradict the research of Amara [1], who claimed that the vertical component of COM velocity and the lead-leg/trail-leg at take-off and at flight phase constituted key factors of optimum hurdle clearance. According to Amara [1,2] and Shibayama. [22], in addition to the take-off angle, the knee and the hip angles are very important in high hurdles clearance, as also found in previous studies done by Coh [5,6], Xi. [17], Bubaj [3] and Sidhu [26]. Liu [15] just confirmed this statement and additionally indicated that the flight-phase duration is also defined by the takeoff angle, which should be lower

5. Conclusions

In the present study, that analyzed the rationality of the 110 m hurdle clearance techniques of R. Dhammika and D. Robles, using diagnostic technology for kinematic analysis. Both athletes have different personal records in the 110 m hurdle races (Dhammika 14.16 s, Robles 12.87 s). The two hurdlers are quite different in morphological constitution, with Dayron Robles being 14 cm taller than R. Dhammika. Based on the results obtained, it can be concluded that D. Robles has a more effective hurdle clearance technique. It is characterized by a smaller loss of horizontal velocity of COM during clearance, a better COM flight parabola over the hurdle, and a smaller difference between the hurdle height and the height of the highest COM point, compared to Dhammika's achievement. It proves that their hurdle clearance efficiencies differ but depend on the same kinematic parameters. Therefore, the hurdle clearance technique of the Dhammika has to more improve. The huge drop velocity value showed that, he couldn't be able to maintain the horizontal velocity. Dhammika's Sprint heigh also included in a lower value under the recommend of COM height. Hurdle clearance landing velocity drop and COM drop Significantly high and Landing phase distance value also higher than stranded value. According to this study Sri Lankan athletes have to develop the Horizontal velocity between two hurdles and clearance of the velocity effectively. We can acknowledge a great idea about hurdle techniques difference of the Natal Sri Lankan athletes and international athletes. All the coaches should have to obtain a great knowledge about biomechanical training methods to improve the hurdle technique from minimizing the biomechanical errors, can achieve the high-performance levels of the athletes in International Competitions.

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