IJREI

International Journal of Research in Engineering and Innovation (IJREI)

journal home page: http://www.ijrei.com

ISSN (Online): 2456-6934

International Journal of Research in Engineering and Innovation Vol-6, Issue-1 ISSN: 2456-6934

REVIEW ARTICLE

Biomechanical model and kinematic analysis of hurdle clearance flight phase: a review

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Article Information

Received: 27 November 2021
Revised: 14 December 2021
Accepted: 26 December 2021
Available online: 02 January 2022

Keywords:

Sagittal Plane
Ground Reaction Force
Technical Guidelines
Biomechanical model
Kinematic analysis

Abstract

The purpose of this study is to identify biomechanical models of the hurdle clearance flight phase that affect the performance of hurdle events. This gives coaches and athlete's important recommendations for identifying performance criteria in a biomechanical model of hurdle clearance. The data in this study are fully original and were gathered from previously published publications in recognized journals on the topic of biomechanics and kinematics of hurdle clearing. Twenty-six articles were assessed, toweled were included in this systematic review. Five articles were recognized in the field of the kinematics of horizontal hurdle flight phase, eight articles were recognized in the field of biomechanics and three books also were included in this systematic review to find out the factors to identify specific criteria of hurdle clearance. As supposed, proper biomechanical model and kinematical variables influence the Minimize air time over the hurdle clearance performance. Important variables are outlined with appropriate evidence. Particular attention should be paid to the take-off phase, flight phase (including sub-phases such as the splitting phase, clearing phase, landing preparation, and landing phase), and landing phase. Specially height of an athlete and stride length, hurdle height, and the hip joint flexibility of the athlete has significantly interacted with the performance.

1. Introduction

The hurdle events are included in the track and field sports program of the Olympic Games and every other major championship. The athletes should cross 10 hurdles at set distances, creating the event extremely technical because the hurdlers try and minimize contact with every hurdle while maintaining forward speed [1]. Hurling could be a complicated technical event that needs high levels of good condition [2]. Sprint speed, inter-segmental coordination, reactive strength, and good technical skills are the primary critical physical fitness characteristics that should be cultivated and consistently reinforced in coaching programs to win in the race [3]. In particular, the approach for passing the obstacle is one of the most important factors influencing the competition outcome [3].suggested that the advancement of the 110-m hurdling technique is a critical component of coaching [2].
Hurdle events will be divided into subsequent phases (Fig. 1). Therefore, a correct hurdle race technique may be a difficult combination of varied running and jumping mechanics [4]. Moreover, the athlete should have exceptional sprinting ability, magnificent flexibility inside the spheroid joint, coordination, balance, dynamic perception, elastic power, and a high degree of technical knowledge [5]. Athletes, coaches, and professionals are always looking for ways to improve their high hurdle performance, specializing in hurdle racing

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https://doi.org/10.36037/IJREI.2022.6104

strategies with a focus on mechanics and dynamics analysis. Over the last three decades, there has been a large amount of research on the study of hurdle racing strategies at all levels to improve performance [6]. According to hurdle clearing assessments, horizontal speed is one of the most important components, therefore losing it should be prevented; otherwise, the period is reduced. In addition to clearing the hurdle as quickly as possible and as biomechanically as possible, the athlete's take-off and landing distances are critical. [7].

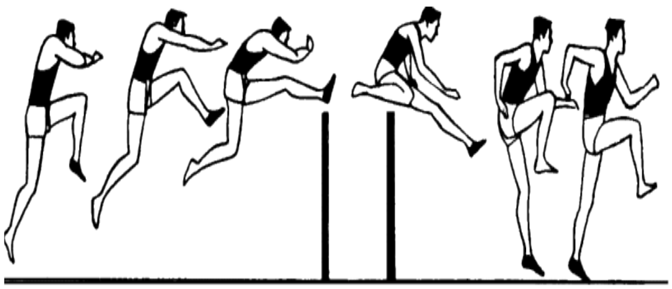


Figure 1: The entire sequence of 110 m hurdle clearing technique-approach runs to the hurdle, hurdle clearance and rhythm between hurdles, and run-out from the last hurdle to the line [8].

Determined the best quantitative relation for associate degree economical hurdle clearance. The quantitative relation The reliance between the take-off of the trial leg and the landing of the lead leg is 60:40 on the wing distance. The clearing of the hurdle is determined by other elements, notably those that define the flight of the center of mass (COM). The correct alignment of these two locations produces the optimal flight of the COM, which is reflected in the flight duration, which should be as short as possible [6].

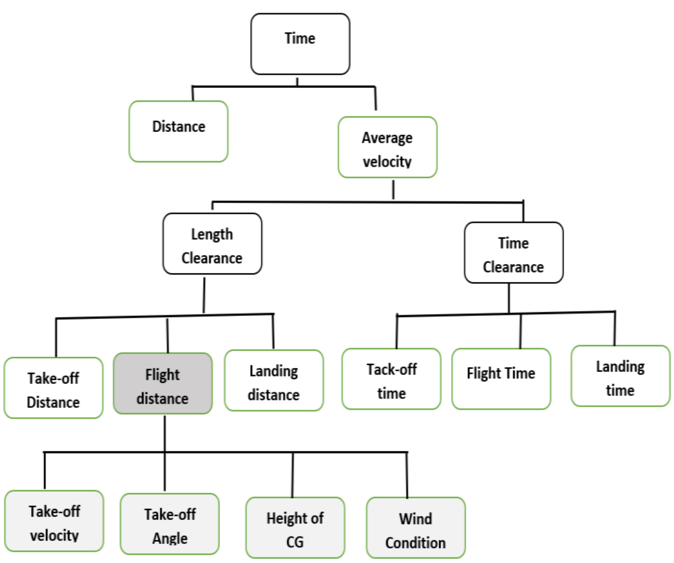


Figure 2: Technical hurdle clearing model. A technical model derived from the stride model utilizing kinematic data for an elite hurdle racer [3].

This instruction may be required for an optimal flight route of the middle of mass (COM). This optimal route results in a lower flying time. Furthermore, the kinematic dynamic structure of the take-off and landings is required for appropriate positioning, since they directly impact the speed of hurdle clearing [9]. According to the updated theoretical technical model, the following kinematic factors have a significant impact on hurdle clearing performance (Fig. 2).
The main criteria of associate degree best horizontal speed, the height of COM at take-off, the pace of the trail-leg, flight duration, the height of COM at landing, and contact time are all factors in the hurdle clearing method [10]. The ability to record contests in track and field has dramatically improved throughout time. Biomechanical data concerning the kinematic analysis of hurdle clearance maximum level of performance [3]. This review research intends to give knowledge about kinematic elements that impact higher hurdle sentence performance to athletes and coaches in order to avoid an important theoretical guideline.

2. Materials and Methodology

The approach for this systematic review was developed based on previously reported recommendations and results. The data in this article are all original and were gathered from articles published in research gate, journal of human kinetics, international journal of biomechanics, journal of sports sciences, journal of sports biomechanics, journal of applied biomechanics, kinematic analysis of Olympic Hurdle performance and research, IAAF, and books. Google scholar, Science Directed Research Gates, and PubMed were used to search for papers on the topics of "Biomechanics of Hurdle Clearance" and "Kinematics of Hurdle." The diagram below divides all the information in this pamphlet by article topics into five paths categorized for convenience (Fig. 3).

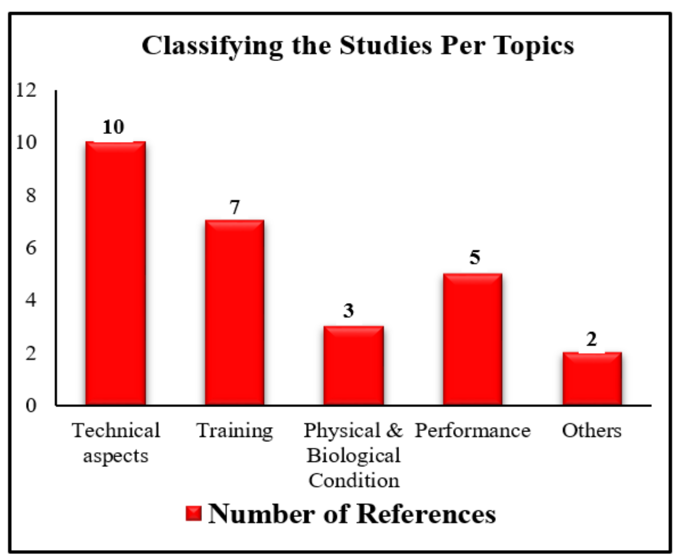


Figure 3: Categorized overall article topics. (Number of Articles 27 Total and Classifying the Using Article per Topics)

The gathered research articles were evaluated, and fake journals and publications that did not fulfill the standards were eliminated. Following a thorough evaluation of the abstracts, introductions, findings, and comments, the acceptable articles were chosen. After evaluating the papers, they were classified according to the phases of hurdle clearing (take-off phase, flying phase, and landing phase). The phases were then subdivided into subgroups based on crucial kinematic factors. (parameters with units) The diagram depicts the important processes in evaluating the athlete's performance level. (Fig. 4).

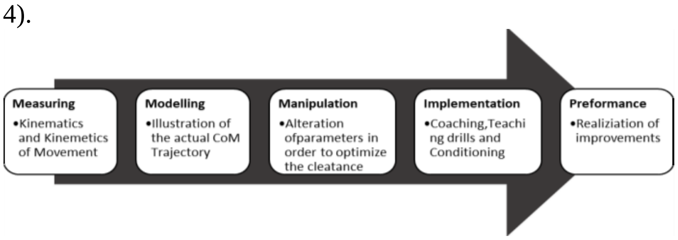


Figure 4: Process evaluates athletes' performance (Using 5 steps-Procedure evaluating performance) [11].

3. Results and discussion

3.1 Statistical analysis

The statistical data illustrate the essential kinematic properties of hurdle clearing as follows (Table 1).

Initially, twenty-six publications were evaluated to see if they met the data criterion or not. Twelve items were chosen from those collections; the remaining articles did not match the criterion. Five of the twelve papers were in the subject of kinematics, eight were in the field of biomechanics, and the rest were books about the biomechanics model of hurdle clearance and kinematic analysis. The findings and results of that twelve art explore phasic lees of obstacle clearing.

The results of body inverse dynamics calculations using Smith's equation are reliable [13] (Table 2).The regression model's equation for performance prediction was calculated as follows (equation 1).

$$\text{Perf. (Performance)} = 17.922 - 0.001 \times F_{\text{y COM at taking off}} + V_{\text{x ankle at landing}} \quad (1)$$

(Perf.) Performance in 110-m hurdles; ($F_{\text{y COM at take-off}}$) vertical reaction force at take-off; (Vx) horizontal velocity of the trail-leg at landing. This equation can identify Hurdler Performance level.

Select Sri Lankan Hurdler R. Dhammika, his personal best timing 14.16s. Mr. H.L.C.Lakmal's research he found V_x, F_y calculated by Mr.Laksara, then predict the performance of National Champion R. Dhammika (14.16 s was set in 2019) [14].

$$\text{Perf. (Performance)} = 17.922 - 0.001 \times F_{\text{y COM at taking off}} + V_{\text{x ankle at landing}}$$

$$\text{Perf. (Performance)} = 17.922 - 0.001 \times 3.5 + 7.46$$

$$\text{Perf. (Performance)} = 17.922 - 3.96$$

$$\text{Perf. (Performance)} = 13.962$$

Table 1: Kinematic characteristics of the sixth hurdle clearing (Sally Pearson, 100-m hurdle race result 12.68) - IAAF World Challenge, Zagreb, 2011 [12]

TAKE – OFF (braking phase)		
Horizontal velocity of CM	8.76	m/s
Vertical velocity of CM	-0.46	m/s
Velocity resultant of CM	8.77	m/s
Height of CM	0.96	m
Take –off distance	2.31	m
TAKE – OFF (propulsion phase)		
Horizontal velocity of CM	8.51	m/s
Vertical velocity of CM	1.45	m/s
Velocity resultant of CM	8.63	m/s
Height of CM	1.03	m
Push-off angle	81.3	°
Contact time	0.10	s
FLIGHT		
Flight time	0.31	s
Height of TT above the hurdle	0.25	m
Maximal height CM	1.16	m
LANDING (breaking phase)		
Horizontal velocity of CM	8.53	m/s
Vertical velocity of CM	-0.93	m/s
Velocity resultant of CM	8.58	m/s
Height of CM	1.08	m
Landing distance	0.86	m
LANDING (propulsion phase)		
Horizontal velocity of CM	8.37	m/s
Vertical velocity of CM	-1.03	m/s
Velocity resultant of CM	8.38	m/s
Height of CM	1.05	m
Contact time	0.09	s

Confirming the above calculations, Roshan will be able to become the national champion of the year 2021 National Athletic Championship, where he will set, R.Dammika Ranathunga Sri Lanka record of 110 Hurdles clocking 13.97 seconds Previous record held by Mahesh Perera of 14.0 set in 1997 Nationals.

A medium-level athlete (13.90 s at 110 m hurdles) had 0.60 s, 0.36 s, 0.21 s, and 0.12 s differences in the above-mentioned parameters (respectively for each variable) [14].

Note; Key factors of hurdle clearance. [13] (COM) center of mass; (Vx) horizontal velocity; (Vy) vertical velocity; (dx) horizontal displacement; (dy) vertical displacement; (Fx) Horizontal reaction force; (Fy) vertical reaction force; (Ft) resultant of reaction force; (Px) horizontal peak power; (Py) vertical peak power; (Pt) resultant of peak power;(*) Significant variation between the ten hurdles at $p < 0.05$;(**) Significant variation between the ten hurdles at $p < 0.001$.

Table 2: Descriptive statistics of the variables studied in take-off, flight, and landing phases

Variables	Take-off phase (Mean ± SD)	CV	Flight phase (Mean ± SD)	CV	Landing phase (Mean ± SD)	CV
Braking Angle (°)	62.02±1.17	0.04	-	-	76.49±1.80	0.04
Propulsion Angle (°)	68.04±2.51	0.04	-	-	63.76±1.32	0.04
Angle Knee Lead Leg (°)	96.05±2.41	0.13**	114.50±2.93	0.12**	143.48±2.44	0.06*
Angle Knee Trail Leg (°)	154.15±1.97	0.06*	30.87±2.26	0.17**	120.61±1.96	0.10**
Angle Hip Lead Angle (°)	93.84±4.20	0.18**	68.01±2.36	0.20**	176.18±3.88	0.07**
Angle Hip Trail Angle (°)	160.94±2.34	0.09**	45.24±2.43	0.23**	110.37±3.61	0.10**
Angle Lead Leg/Trail Leg (°)	-	-	88.49±3.53	0.17**	-	-
Vx COM ($m\text{-}s^{-1}$)	7.41±0.29	0.07**	7.42±0.24	0.07	7.27±0.19	0.07**
Vy COM ($m\text{-}s^{-1}$)	2.08±0.03	0.10**	1.94±0.04	0.10**	1.61±0.08	0.18**
Vx Ankle Lead Leg ($m\text{-}s^{-1}$)	16.64±0.50	0.10**	6.40±0.22	0.08**	0.56±0.09	0.36**
Vy Ankle Lead Leg ($m\text{-}s^{-1}$)	2.94±0.61	0.45**	1.52±0.11	0.20**	3.17±0.30	0.23**
Vx Ankle Trail Leg ($m\text{-}s^{-1}$)	3.73±0.26	0.23**	9.42±0.33	0.07**	13.25±0.37	0.10**
Vy Ankle Trail Leg ($m\text{-}s^{-1}$)	4.75±0.32	0.07**	1.71±0.10	0.17**	3.80±0.24	0.21**
Vx Knee Lead Leg ($m\text{-}s^{-1}$)	7.04±0.29	0.10**	6.50±0.22	0.07**	4.46±0.22	0.14**
Vy Knee Lead Leg ($m\text{-}s^{-1}$)	3.92±0.30	0.29**	2.77±0.14	0.32**	2.59±0.20	0.04**
Vx Knee Trail Leg ($m\text{-}s^{-1}$)	5.10±0.76	0.23**	8.98±0.29	0.07**	9.12±0.36	0.08**
Vy Knee Trail Leg ($m\text{-}s^{-1}$)	2.37±0.46	0.03	1.98±0.07	0.15**	2.19±0.22	0.18**
dx Hurdle (m)	1.87±0.11	0.07**	3.25±0.08	0.08**	1.37±0.14	0.11**
dx COM/Hurdle at Braking (m)	2.29±0.11	0.07**	-	-	1.13±0.15	0.15**
dx COM/Hurdle at Propulsion (m)	1.42±0.10	0.11**	-	-	1.87±0.16	0.09**
dy COM (m)	-	-	1.46±0.01	0.05*	-	-
dy COM at Braking (m)	1.08±0.01	0.07**	-	-	1.26±0.01	0.06**
dy COM at Propulsion (m)	1.25±0.01	0.06*	-	-	1.17±0.01	0.06**
dy Ankle Lead Leg (m)	-	-	1.19±0.02	0.06**	-	-
dy Ankle Trail Leg (m)	-	-	1.22±0.01	0.06**	-	-
dy Knee Lead Leg (m)	1.11±0.02	0.07**	1.34±0.01	0.06**	-	-
dy Knee Trail Leg (m)	-	-	1.42±0.02	0.07**	0.95±.03	0.08**
Contact time (s)	0.12±0.01	0.07**	-	-	0.10±0.01	0.11**

The findings of this study demonstrate unequivocally that the vertical component of COM rate, as well as the lead-leg/trail-leg during take-off and flying phase, are critical determinants in optimal hurdle clearing [15]. The take-off assures associates in the nursing opposite transformation of the horizontal rate of the COM into the vertical rate, and the causal association between these two parameters is due t the change in COM direction of movement during take-off.

Generally, once the enouncing rate will increases all clearance actions happen quicker [16]. Outcomes showed that the horizontal displacement of COM before, during, and when clearing may be the crucial issue for hurdle race performance success [17].

3.2 Take-off phase

To establish a trajectory, a height above the hurdle that reduces the athlete's center of mass (COM) should be increased only as high as necessary for the athlete to clear the hurdle effectively. A high body stance is required for the hurdle attack (Fig. 5). The thrust is forward rather than upward (Run into the hurdle, do not jump). The support leg's ankle joints, knee, and hip are fully extended. In the horizontal posture, the lead leg's thigh swings fast. [18]. The optimum quantitative relationship between take-off and landing objectives is 60:40. We can notice that the individual has a somewhat shorter stride before hurdle clearance and a slightly longer stride after hurdle clearance [19]. The take-off ahead of the hurdle is one of the most critical weather conditions for optimal hurdle clearing since it directly determines the flight of the middle of mass movement [20].

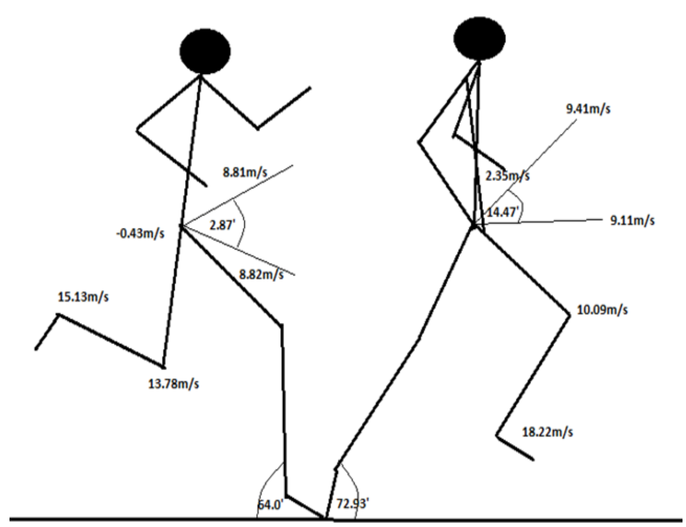


Figure 5: Hurdle Take-off parameters [20].

The topic's take-off time is 100ms, with the take-off comprising of two parts: the braking phase and the propulsion phase.

3.2.1 The braking phases

The breaking component should be as short as possible and is determined by the angle of the position of the take-off leg (64° in the target topic). [19].

3.2.2 The propulsion phases

The propulsion phase concludes with a push-off angle of 22.9° for our subject. The pure purpose II of the take-off leg parameter will be actively put on the ground, with the shoulders forcibly pushed towards the hurdle. [19].

3.2.3 The velocity of hurdle clearance

Hurdle clearance is heavily reliant on the speed with which the hurdle execution of the take-off presents itself inside the horizontal rate of the COM. [19]. The horizontal rate of the COM in the braking section is, however in the propulsion section it will grow to its subject accelerates rate dramatically with efficiency during take-off [20].

3.2.4 Horizontal velocity of the COM

The vertical rate, which in this case is defined by the horizontal and vertical velocities, defines the elevation rate of the COM, which is 9.41m/s1, as well as the elevation angle, which is 14.5°. The relationship between these two rate factors reveals the athlete's ability to shift from the running stride to the take-off stride [20]. The height of the COM during the take-off phase is closely connected to the quality of hurdle clearing [21]. From the standpoint of biomechanics, a track event is one in which vertical oscillations of the COM are as little as possible [22].

3.2.5 COM during take-off

Throughout take-off, the hurdlers maintain a high degree of COM. The peak of the COM at the tip of the propulsion component is 1.08 m, which is 59.3 percent of the athlete's body height (Ex: BH=1.87 m). The COM is raised 13cm from the braking part to the propulsion part. The most COM height on the take-off technique is determined by the obstacle and the flight measurement factors [22], In addition to the previous kinematic characteristics, the speed of hurdle clearing is affected by the speed of the lead leg during the take-off phase [21].

3.3 Flight phase

To less the loss of speed and time in the air. The launch from the ball of the foot is well ahead of the hurdle [23]The lead leg is actively lowered as quickly as doable once the hurdle. The lower part of the lead leg is actively extended forwards within the direction of running, the foot of the lead leg is flexed, the trunk is well bent for higher hurdles, bending is a smaller amount exaggerated for lower hurdles and shoulders stay parallel to the hurdle. The path leg is drawn aboard the body, thigh of the path leg is roughly parallel to the bottom at clearance [18]. The trail leg's ankle is flexed market day, toe the s stilted side, and the trail leg's knee is held high as it pulls through [18]. Reduce the COM's height over the hurdle. Erin-flight light phase is very common. The vertical velocity is too high, and the trail leg is not raised high enough or brought beneath the body [23].

3.3.1 Flight Time

An efficient hurdle clearing strategy is the smallest feasible period of the flight phase (hurdle clearance time) since the hurdle loses velocity theist heehaw length of the flight of the COM other f subject is 3.30 m, the time of the flight phase is 0.38 seconds [24].

3.3.2 Maximal Height of COM above the hurdle

The height of the COM over the hurdle is proportional to the time required to pass the hurdle [20]. The longer the flight phase, the higher the trajectory of the COM's flight. In this situation, the result is 45cm, which does not indicate the most efficient trajectory of COM's flight over the obstacle (Fig. 6). The increase in COM relative to the take-off phase is thus 43cm, which is most likely due to a rather short take-off distance [25].

3.3.3 Body flight trajectory

Depending on the beginning speed of the athlete's center of body mass, take-off-angle air resistance, and distance from barrier to athlete's center of body mass. Determination of rational parameters in hurdling based on initial take-off speed, take-off angle, take-off height, and athlete COM [26].

3.3.4 The height of the trajectory

The upper barrier is also in reverse proportion to these lengths and has minimal values that may be used to push it down. with additional fixed kinematic and geometric properties [26]. Hurdling parameters based on take-off, take, and off-off-angled height It is feasible to use its analysis to adjust athlete actions in the early stages and enhance results while taking physical factors and potentials of a hurdler into account. [25]. The high position of CBM before pushing off, high speed, and relatively far place of pushing off that permit (Fig. 7).

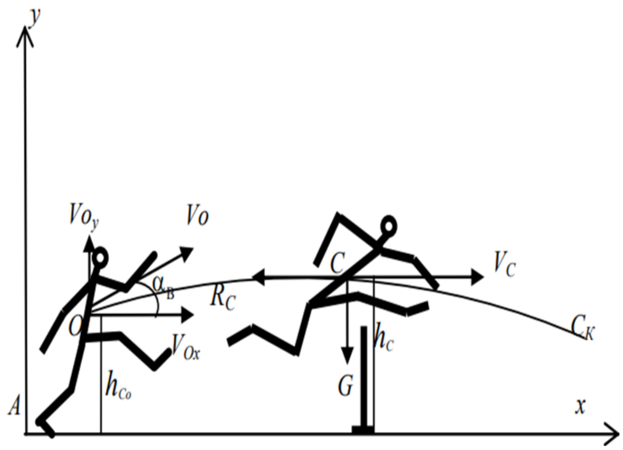
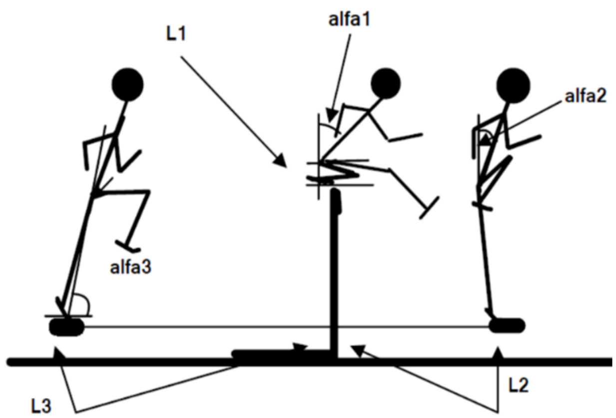


Figure.6: Points for efficiency The trajectory of COM's flight over the hurdle clearance Schema of calculation for determination take-off speed and angle of attack In a hurdle, the CMB take-off height [26].



B

Figure 7: Kinematic characteristics of the hurdler step hurdler step parameters [26]*First, push off at a steeper angle and land faster. Second, complete the entry hurdle in a bent stance, and third, refrain from leaping acting. In the trials of the hurdle step, various portions of the body (arms, legs, and torso) come closer to the CBM trajectory and promote straight and continuous movement.*

3.4 Landing phase

To make a quick transition to running, the landing leg should be active on the ball of the foot (no heel contact at touchdown), the body should not lean backward on landing, the trail leg should remain tucked until touchdown, then it pulls quickly and actively forwards and makes transient contact with the bottom (Fig. 8) The short stride is combative. [18].

The transition from hurdle clearing to sprinting between hurdles must be completed as quickly as possible during the landing phase. This shift from a cyclic movement necessitates extensive technique practice as well as a high level of motor abilities such as speed, strength, coordination, timing, and balance [27].

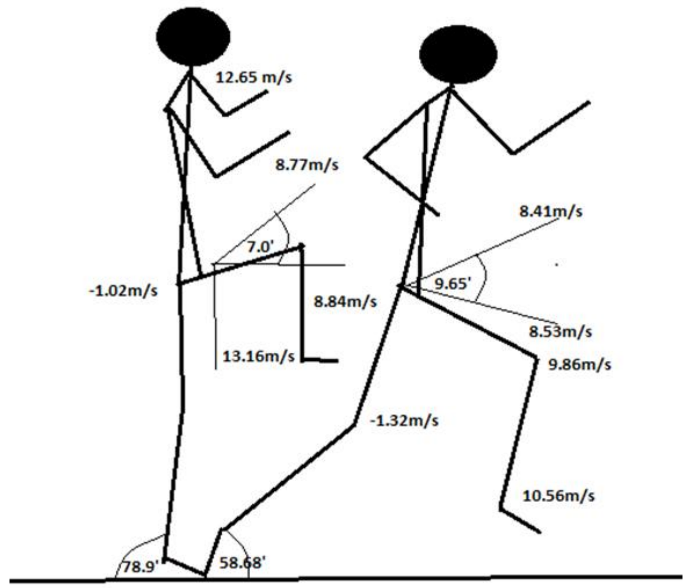


Figure. 8: Hurdle Landing parameters [20].

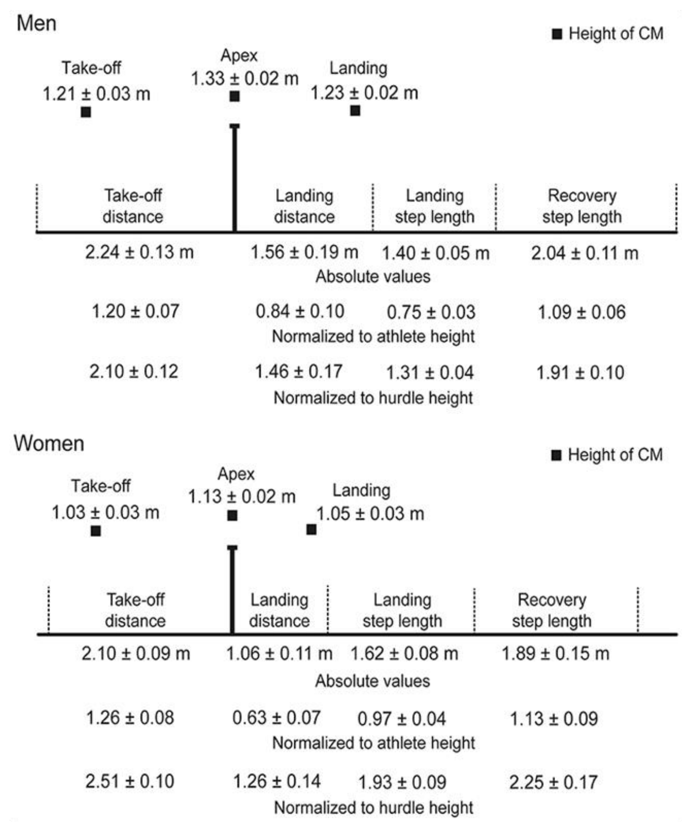


Figure. 9: Suggested approximate step measurement for hurdlers.

3.4.1 Horizontal velocity of COM

The execution of this portion of the record holder Jackson is totally at the prime level. Within the landing portion, the contact time was 0.08second. When landing after clearing the hurdle, the athlete retains a high COM (1.15m), owing to the entire extension of the leg inside the hips and knees [26].

3.4.2 COM-to-foot distance/Knee swing velocity/Ankle swing velocity

The high position of the COM, the direction of the trail leg's knee, the forward bending of the trunk (37° relative to the vertical), the temporal order of the arms relative to the trail leg, and a stable balance are the components that generate the upkeep of the COM's horizontal rate when hurdling clearance. [27]. On the basis of this metric, it is possible to conclude that the topic hurdle clearing technique [26].

Finally, the length of the stride before and after hurdle clearance is used to quantify efficient hurdle clearance (Fig. 9). The overall length of the hurdle stride is 3.67 m. The take-off distance is 2.09 m, accounting for 56.9% of the entire hurdle stride length. The landing distance is 1.58 m, or 43.1 percent of the overall length of the hurdle stride. This particular ratio is dependent on each hurdler, as well as the anthropometric qualities of the hurdler, the rhythm of the hurdle stride, and the push-off angle. [20] 2-dimensional (2D) biomechanical model to measure the ground reaction force which interacts with a long jumping event in takeoff phase. This model can apply to calculate the ground reaction force in terms of the kinematics of body segments. Body segments: calf, thigh, torso, upper arm, forearm, head, and neck ten angle's coordinates were calculated using Kinovea software and those angular displacements, angular velocities, angular accelerations results were used. The 2D biomechanical model was designed with 10 dynamic equations using Langrage equation. Calculated ground reaction force (between 3500-4500N) by the model. [28].

Take-off and landing distances, landing and recovery step lengths, and the height of the COM at take-off and landing are all represented graphically. The barrier is depicted in the manner in which athletes would approach it while sprinting from left to right. The diagram is roughly to size, and there are different diagrams for males and women. The mean values (SD) are provided as absolute values and standardized to athlete and hurdle height for the distances.

*Table 3**:** Structure of selected review articles (Overall sources used for this review are lineup by publication year)*

Year	**Author**	**Topic**
1947	Bernshtejn, N. A. O	On the construction of movements
1981	Schluter, W	Kinematic features of the 110- meter hurdle technique (Kinematische Merkmale der 110-m Hurdentechnik
1983	Smit, J. A	The back somersault take-off: A biomechanics study
1985	Mann, R. &. H. J	Kinematic analysis of Olympic Hurdle Performance:Women's 100 Meters
1986	Mero., &. L. P	Biomechanische Untersuchung des Hurdenlaufs wahrend der Weltmeisterschaften in Helsink
1988	La Fortune, M	Biomechanical analysis of 110 m hurdles
1990	Rash, G. S. V	Kinematic analysis of Top American Female 100-meter Hurdlers
1991	Depena, J	Hurdle clearance technique
1991	McDonald, C. &. D. J	Linear kinematics of the men's 110-m and women's 100-m hurdles races.
1993	Ericsson, K. A. S. H. A	Protocol Analysis
1994	Farlane. B. M	Hurdles: a basic and advanced technical model. Track technique
1994	McLean, B	The biomechanics of hurdling: Force plate analysis to assess hurdling technique.
1995	Iskra, J	The most effective technical training for the 110 meters hurdles
1995	Salo. A., &. G.P	An examination of kinematic variability of motion analysis in sprint hurdles.
1996	Coh, M. &. D. A	Three dimensional kinematic analysis of the hurdle's technique
1997	Ward-Smith, A. J	A mathematical analysis of the bio energetics of hurdling
1997	Salo, A., & Grimshaw, P	3-D biomechanical analysis of sprint hurdles at different competitive level.
1999	Kampmiller, T. S. M. &. V. M	Comparative biomechanical analysis of 110 m hurdles
2000	Coh, M. J. B. &. S. B	Kinematic and dynamic analysis of hurdle clearance technique.
2000	McFarlane, B	The science of hurdling and speed hurde lingInto te 21st century
2000	Rogers, J	Track & Field coaching Manual
2001	Mackenzie, B	Sports Coach, Sprint hurdle technique
2002	Coh M	Kinematic and dynamic analysis of hurdles technique
2002	Salo, A	Technical changes in hurdle clearances at the beginning of 110 m hurdle event
2003	Coh, M	Biomechanical analysis of Colin Jackson's hurdle clearance technique
2004	Coh, M. Z	Kinematical model of hurdle clearance technique
2006	Salo, A., & Scarborough, S	Athletics: Changes in technique within a sprint hurdle run
2008	Mekhrikadze V.V., C.L	Hurdling
2008	Liiu, Y.A	Kinesiological analysis of the hurdling techniques
2008	Bubanj, R. S. R. R. A. B. S. P. V. D	Comparative biomechanical analysis of hurdle clearance technique on 110 m running with hurdles of elite and non-elite athletes.

2008	Bollscweiler, L	A biomechanical analysis of male and female intermediate hurdles and steeplechasers
2010	J, Harrison. A	Biomechanical factors in sprint training.
2010	Kugler, F.L	Body position determines propulsive forces in accelerated running
2011	Lopez, J., Padulles, J. & Olsson	Biomechanical analysis and functional assessment
2012	Coh, M.	Biomechanical studies of 110 m hurdle clearance technique
2019	Anthr, J	Kinematic parameters of the sixth hurdle clearance
2019	Gonzalez-Frutos, P., Veiga, S., Mallo, J. & Navarro, E	Spatiotemporal comparisons between Elite and high level
2019	Amara, S., Mkaouer, B., Chaabene, H., Negra, Y	Key kinetic and kinematic factor of 110-m hurdles performance
2019	Bezodis, I. N	World class male sprinters and high hurdles have similar start and initial acceleration techniques
2019	A.M. G.G Laksara, A.W.S Chandana	Design a D biomechanical model to measure the ground reaction forces of long jumpers
2021	H.L.C. Lakmal, P.C Thotawaththa, & A.W.S Chandana	The kinematics analysis and comparison of foreign and national 110 m hurdling technique in Srilanka

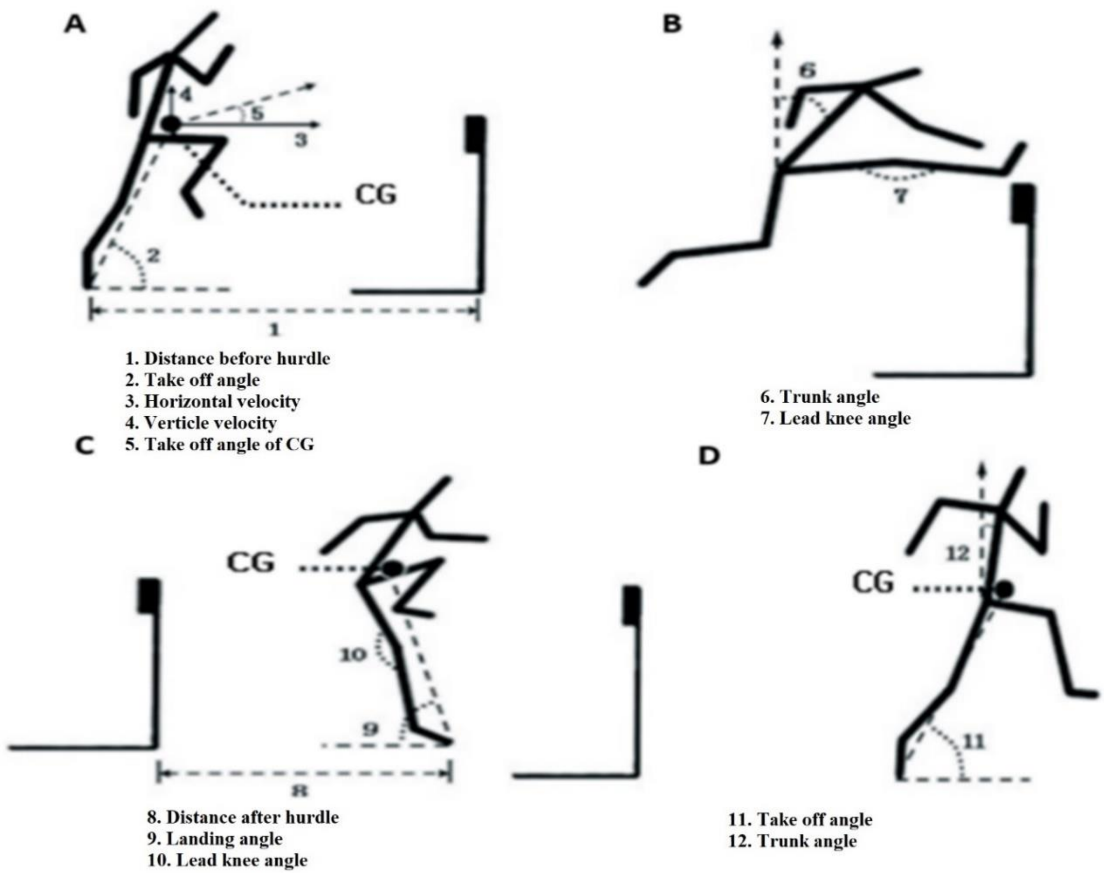


Figure 10: Parameters of hurdle clearance technique [29]. A: variable at the moment of a take-off before e hurdle. B: variables during clearance. C: variables at the moment of landing. D: variables at the moment of take-off after hurdle.

4. Conclusions

Previous research has focused on obstacles, using either kinetic or kinematic analyses. As a result, this study is regarded to be unique in that it analyzed every kinetic and kinematic characteristic of the whole 110-m sprint track event performance. The findings of this study revealed that a larger horizontal velocity, steady with good strength and power, vertical reaction force, an optimal ratio between takeoff and landing distance in horizontal displacement, and a short vertical displacement are more specific factors to achieving maximum level 110 m hurdle clear performance-based on of the results obtained kinematic analysis of the clearance of the hurdles were investigated by many authors to find out the science behavior. Despite the fact that many research has been undertaken, there are still significant limits and crucial issues.

The recommendations and correlations presented by this study have a broad practical applicability, allowing many coaches and athletes to structure their training plans in accordance with scientific beliefs.

Hurdles have been discovered to be some of the most critical characteristics defining a model of hurdle clearing approach (Fig. 10-A to D). The horizontal velocity of the COM during take-off in front of the hurdle, the height of the COM during take-off, and the velocity of the lead leg's knee swing may all be used to define efficient hurdle clearing. the duration of the flying phase the least possible loss in horizontal velocity of the COM during hurdle clearance, a high COM position at landing, a short contact time in the landing phase, and the shortest possible vertical oscillations of the COM, head, shoulders, and hips before, during, and after hurdle clearance Other kinematical parameters, such as segmental location and angle of segments, will be studied in future research to maximize performance. The definitions of kinematic variables are stated as follows.

Those factors define the athlete's performance effectiveness in order for them to improve their performance level. Concerned about the takeoff angle of C.G. and the short horizontal speed during takeoff, which may rely on the body going forward swiftly. Stride length and hence distance before hurdle were both dependent on the runner. The lack of muscular flexibility was demonstrated by the smaller most trunk angle and most lead leg knee angle throughout the flying segment. The following coaching exercises were described.

Calculating the best takeoff point and marking it on the ground before the hurdle while completing stretching exercises for the back thigh muscles. Improving gluteus and hamstring flexibility with dynamic quality workouts, creating the power to separate legs that allows for a quick contraction of the muscles of the trailing leg and quick recovery, increasing hip and pelvic flexibility, since the torso is frequently flexed forward toward the legs over the hurdle, as well as developing ankle explosive strength. After an amount of coaching the techniques of the athlete is considerably improved and centered their variables of momentum of hurdle clearance. This study was useful to coaching observe and improving the athlete's hurdle techniques. Biomechanics study techniques can improve the efficiency of scientific work for coaches and athletes. If the national athlete in the Democratic Socialist Republic of Sri Lanka is in a position to develop their performances by exploiting these biomechanical and kinematic analysis evaluations, it'll be an excellent chance for the Democratic Socialist Republic of Sri Lanka national players for competing internationally. conjointly exploiting that constant quantity analytical conception for his or her coaching planes, Sri Lankan hurdlers can also improve and come through their highest performance level in the future.

Future Scopes

This paper can facilitate the coaches to guide the right biomechanical model in hurdle clearance and its support to reducing air time over the hurdle clearance (to decrease horizontal velocity). It conjointly helps coaches within the preparation of the coaching program for the athletes. it'll be useful in making a general model of hurdle clearance techniques for the help of young hurdlers.

Recommendations

The results of this study show finally, exploitation of this biomechanical model and kinematic analysis are directly confirming for the improve their performance. conjointly get an answer for the decreased air time in the hurdle clearance flight part. exploitation this idea making certain that athlete time and their performance level are often increased. A similar study could also be managed by choosing kinetic and angular mechanics variables, a similar study could also be tried by junior people players, a similar study can even be conducted on feminine players and A Similar study could also be undertaken to research the opposite games and event players

References

[1] I. N. B. A. v. L. u. W. H. C. W. M. P. G. P. H. B. e. a. Bezodis, "World-class male sprinters and high hurdlers have similar start and initial acceleration techniques," Front. Sports Act. Living, p. 1:23. doi: 10.3389/fspor.2019.00023, 2019.

[2] J. Iskra, "The most effective technical training for the 110 metres hurdles," New Studies in Athletics, pp. 10, 3, 51-55. , 1995.

[3] J. López, J. Padullés and H. Olsson, "Biomechanical analysis and functional assessment of D. Robles,," In Proceedings of the 29th , p. 20–23 June; pp. 315–318. , 2011.

[4] L. Bollschweiler, "A biomechanical Analysis of Male and Female Intermediate Hurdles and Steeplechasers," Master's Thesis, Brigham Young University, Brigham, MA, USA, 2008.

[5] A. Salo and S. Scarborough, "Athletics: Changes in technique within a sprint hurdle run," Sport Biomech., pp. 5 ,155–166, 2006.

[6] W. Schluter, "Kinematic features of the 110-meter hurdle technique (Kinematische Merkmale der 110-m Hurdentechnik)," Leistungssport, pp. 2, 118–127, 1981

[7] A. Salo and P. Grimshaw, " 3–D biomechanical analysis of sprint hurdles at different competitive level," Med. Sci.Sports Exerc, pp. 29, 231–237, 1997.

[8] B. Mackenzie, "Sports Coach,Sprint Hurdle technique," Sprint hurdle, 2001.

[9] M. La Fortune, " Biomechanical analysis of 110 m hurdles," Track Field News, pp. 105, 3355–3365, 1988.

[10] S. Amara, B. Mkaouer, H. Chaabene, Y. Negra, S. Hammoudi-Riahi and F. Ben- Salah, "Key kinetic and kinematic factors of 110-m hurdles performance," J. Phys. Educ. Sport, pp. 19, 658–668, 2019.

[11] R. S. R. R. A. B. S. P. V. D. Bubanj, "Comparative biomechanical analysis of hurdle clearance techniques on 110 m running with hurdles of elite and non-elite athletes," Serbian Journal of Sports Sciences,, pp. 2(1-4),37-44., 2008.

[12] J. Anthr, ". Kinematic parameters of the sixth hurdle clearance (Sally Pearson, result of the 100-m hurdle race 12.68) - IAAF World Challenge, Zagreb, 2011.," Sport Phys. Educ, vol. 3, no. 4, 2019.

[13] J. A. Smith, "The back somersault take-off: A biomechanics study," Carnegie Research Paper, pp. 5(1): 31-39, 1983.

[14] H. L. C. Lakmal, P. C. Thotawaththa and A. W. S. Chandana, "The Kinematic Analysis and Comparison of Foreign and National 110 m Hurdling Techniques in Sri Lanka," International Journal of Research in Engineering and Innovation, pp. Vol-5, Issue-4, 1-6, 2021.

[15] M. &. I. J. Coh, "Biomechanical studies of 110 m hurdle clearance technique," Journal of Sport Science,, pp. 5(1), 10-14, 2012.

[16] A. Salo, "Technical changes in hurdle clearances at the beginning of 110m hurdle event," XXth International Symposium on Biomechanics in Sports, pp. (pp. 84-87), 2002.
[17] M. Z. M. &. J. B. Coh, "Kinematical model of hurdle clearance technique.," XXIIIth International Symposium of Biomechanics in Sports , pp. (pp. 311-314), 2004.
[18] J. Rogers, "Track & Field Coaching Manual. Champaign, IL," Human Kinetics, vol. 2, no. 3, 2000.
[19] M. FARLANE.B, "Hurdles: a basic and advanced technical model. Track Technique 1," pp. 128: 1, 4073-4079, 1994.
[20] J. Dapena, "Hurdle clearance technique," Track and Field. Quart. Rev, pp. 116(3), 710-712, 1991.
[21] G. P. SALO. A., "An examination of kinematic variability of motion analysis in sprint hurdles," Journal of Applieid Biomechanics, pp. 14, 211-222, 1995.
[22] T. S. M. &. V. M. KAMPMILLER, ". Comparative biomechanical analysis of 110 m hurdles of Igor Kova_ and Peter Nedelicky," Kinesiologia Slovenica, pp. 1-2, 26-30., 1999.
[23] M. Coh, " Biomechanical Analysis of Colin Jackson’s Hurdle Clearance Technique," New Studies in Athletics, pp. 18, 37-45, 2003.
[24] L. P. Mero A., "Biomechanische Untersuchung des Hurdenlaufs wahrend der Weltmeisterschaften in Helsink," Leistungssport,, pp. 42-43. News 105, 3355-3365, 1986.
[25] N. A. O. Bernshtejn, "On the construction of movements," postroenii dvizhenij, p. 144, 1947.
[26] C. L. Mekhrikadze V.V., "Hurdling," Bar'ernyj beg , p. 78, 2008.
[27] B. McLean, "The biomechanics of hurdling: Force plate analysis to assess hurdling technique," New Studies in Athletics,, vol. 4, pp. 55-58., 1994.
[28] Coh M, "Kinematic and dynamic analysis of hurdles technique," Leistungssport, vol. 4, pp. 43-46, 2002.
[29] K. A. S. H. A. Ericsson, "Protocol Analysis: Verbal Reports as Data. A Bradford Book, London: The MIT," 1993.

Cite this article as: J.A.L.N. Jayathunga, A.W.S. Chandana, Biomechanical model and kinematic analysis of hurdle clearance flight phase: a review, International journal of research in engineering and innovation (IJREI), vol 6, issue 1 (2022), 38-47. *https://doi.org/10.36037/IJREI.2022.6104*