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# Three Dimensional Kinematic Analysis of Hurdle Clearance Technique

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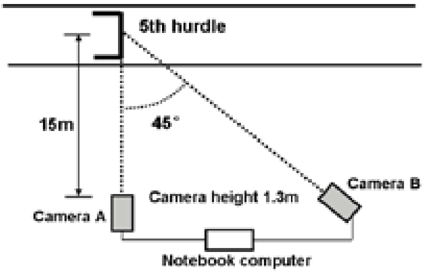
**ABSTRACT**

*On the basis of the results obtained by 3 - D kinematic analysis of the 110m hurdles of the subject, important parameters defining a model of hurdle clearance technique have been found. Analysis was made of subject technique over the 4th hurdles. According to the author, efficient hurdle clearance can be defined by the horizontal velocity of the CM during the take-off in front of the hurdle, the height of the CM during the take-off, the velocity of the knee swing of the swinging leg, the flight phase time, the smallest possible loss in the horizontal velocity of the CM during clearing the hurdle, a high position of the CM at landing, a short contact time in the landing phase and the smallest possible vertical oscillations of the CM, head, shoulders, and hip before, during and after clearing the hurdle. Values for these parameters of subject technique are given and discussed.*

**KEYWORDS : hurdles, technique, kinematics**

**INTRODUCTION:** Technically, the high hurdles are among the most demanding track and field events. According to some of the research carried out to date (Schluter, 1981; Mero and Luhtanen, 1986; La Fortune, 1988; McDonald and Dapena, 1991; Dapena, 1991; McLean, 1994; Kampmiller, Slamka and Vanderka, 1999), the hurdle clearance technique is one of the key elements defining the competitive result. From the aspect of biomechanics, hurdles are a combination of cyclic sprinting and acyclic clearance of ten 1.067m hurdles. Therefore, the athlete must possess a high level of sprinting abilities, special flexibility at the hip joint, fast strength, and a high level of technical knowledge. While clearing the hurdle, the loss of horizontal velocity must be as small as possible. However, this depends on numerous factors, especially those, that define the take-off before hurdle clearance, the trajectory of the movement of the CG, and the landing after hurdle clearance. For efficient hurdle clearance, the point of the take-off and the point of landing of hurdle clearance are important. The correct position of these two points is a prerequisite for an optimal CG flight trajectory and reflects in the flight time, which must be as short as possible (Schluter, 1981; Dapena, 1991). In addition to the correct position, the kinematic-dynamic structure of take-off and landing, which directly affects the velocity of hurdle clearance (La Fortune, 1988; McLean, 1994) is also important. Therefore the objective of the present study was to determine which parameters generate the most efficient hurdle clearance technique on 4th hurdle in 110 meter race by combining a 3D kinematic analysis.

**PROCEDURE AND METHODS:** The measurements were carried out on a War hero's track-and-field stadium Sangrur Punjab with a synthetic surface. According to the protocol, athlete performed five runs from starting blocks with the clearance of ten hurdles, set at standard distances from the start. The kinematic and dynamic analysis of the technique was performed at the fourth hurdle . A 3D kinematic system Quintic Software (sports and coaching v-17) and motion-pro with two mutually synchronized digital cameras SONY DSR operating at a frequency of 50 Hz and placed at an angle of 90° and 45° with respect to the object filmed, were used to establish the kinematic parameters.




**Set-up of cameras**

**SELECTION OF SUBJECT:** Biomechanical analysis was performed on a single male athlete, gold medalist in junior level national championships in India, with an age of 20 years, body height 189 cm, and weight 73 kg. The mean result in the 110m hurdles was 14.63 s. and the best result was 14.50 s.

**CRITERION MEASURES:** The following will be the criterion measures for this study with the help of advanced 3D software Quintic Software (sports and coaching v-17) and Motion Pro.

**Take – off ( braking phase)**
1. Horizontal velocity of CM
2. Vertical velocity of CM
3. Height of CM
4. CM to foot distance
5. Knee swing velocity
6. Ankle swig velocity

**Take – off (propulsion phase)**
1. Horizontal velocity of CM
2. Vertical velocity of CM
3. Height of CM
4. CM to foot distance
5. Knee swing velocity
6. Ankle swig velocity
7. Take-off distance
8. Contact time
9. Take-off angle

**Flight**
1. Flight time
2. Height of CM above the hurdle
3. Maximal height CM
4. Maximal velocity over the hurdle

**Landing (braking phase)**
1. Horizontal velocity of CM
2. Vertical velocity of CM
3. Height of CM
4. CM to foot distance
5. Knee swing velocity
6. Ankle swig velocity
7. Landing distance
8. Landing angle

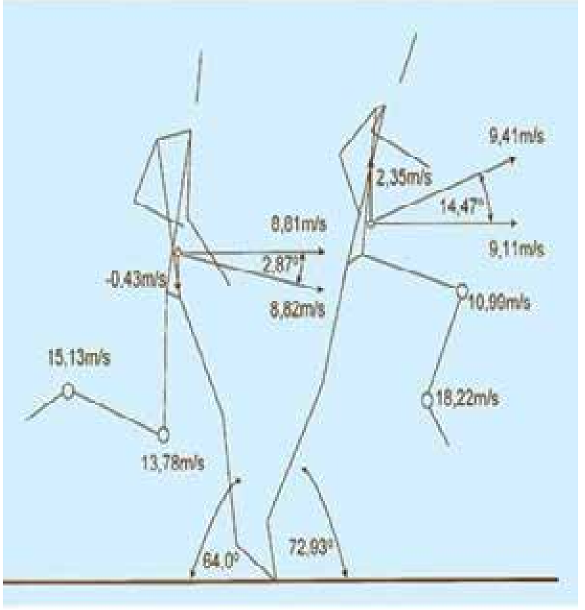
**Landing (propulsion phase)**
1. Horizontal velocity of CM
2. Vertical velocity of CM
3. CM to foot distance
4. Knee swing velocity
5. Ankle swing velocity
6. Contact time

**STATISTICAL ANALYSIS:** The statistical data show the following basic kinematic characteristics of hurdle clearance.

**Table 1 Kinematic Parameters of Hurdle Clearance**

| Sr. No. | Parameter | Unit | Subject |
|---|---|---|---|
| | **Take – off (Breaking Phase)** | | |
| 1) | Horizontal velocity of CM | $m.s^{-1}$ | 8.81 |
| 2) | Vertical velocity of CM | $m.s^{-1}$ | 0.43 |
| 3) | Height of CM | M | 0.95 |
| 4) | Centre of mass to foot distance | M | .46 |
| 5) | Ankle swing velocity | $m.s^{-1}$ | 15.13 |
| 6) | Knee swing velocity | $m.s^{-1}$ | 13.78 |
| | **Take –off (Propulsion Phase)** | | |
| 7) | Horizontal velocity of CM | $m.s^{-1}$ | 9.11 |
| 8) | Vertical velocity of CM | $m.s^{-1}$ | 2.35 |
| 9) | Height of CM | M | 1.08 |
| 10) | Centre of mass to foot distance | M | 0.38 |
| 11) | Ankle swig velocity | $m.s^{-1}$ | 18.22 |
| 12) | Knee swing velocity | $m.s^{-1}$ | 10.99 |
| 13) | Foot to hurdle distance | M | 2.09 |
| 14) | Contact time | S | 0.100 |
| 15) | Take off angle | $0^0$ | 72.9 |
| | **Flight** | | |
| 16) | Flight time | S | 0.38 |
| 17) | Height of CM above the hurdle | M | 0.45 |
| 18) | Maximal height CM | M | 1.44 |
| 19) | Maximal velocity over the hurdle | $m.s^{-1}$ | 19.05 |
| | **Landing (Braking Phase)** | | |
| 20) | Horizontal velocity of CM | $m.s^{-1}$ | 8.77 |
| 21) | Vertical velocity of CM | $m.s^{-1}$ | -1.02 |
| 22) | Height of CM | M | 1.15 |
| 23) | CM to foot distance | M | 0.50 |
| 24) | Ankle swig velocity | $m.s^{-1}$ | 13.16 |
| 25) | Knee swing velocity | $m.s^{-1}$ | 12.65 |
| 26) | Landing distance | M | 1.58 |
| 27) | Landing angle | $0^0$ | 78.9 |
| | **Landing (Propulsion Phase)** | | |
| 28) | Horizontal velocity of CM | $m.s^{-1}$ | 8.41 |
| 29) | Vertical velocity of CM | m.s-1 | -1.32 |
| 30) | Height of CM | M | |
| 31) | CM to foot distance | M | 0.65 |
| 32) | Ankle swig velocity | m.s-1 | -10.56 |
| 33) | Knee swing velocity | m.s-1 | -9.86 |
| 34) | Contact time | S | 0.08 |

**Figure 1 Take-off position graphical representation**



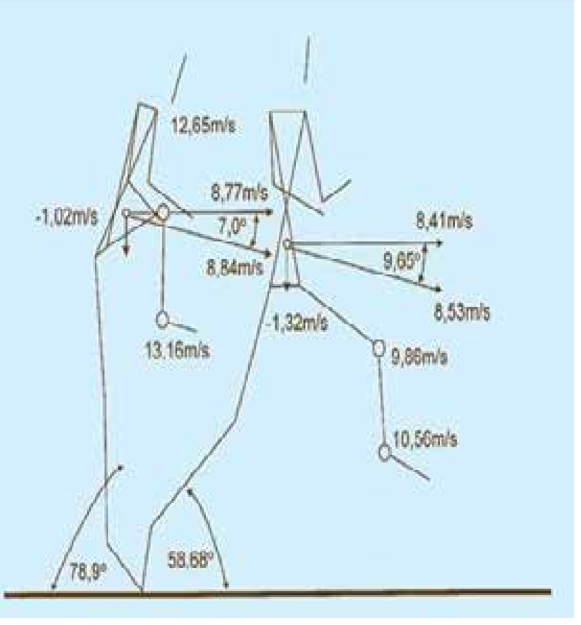




**Figure 2 landing position graphical representation**

## DISCUSSION AND FINDING

On the basis of the results in Table 1, the following characteristics of a kinematic model of the clearance technique of subject at the 4th hurdle by can be established: Efficient hurdle clearance is defined by the length of the stride before hurdle clear ance and after hurdle clearance. The total hurdle stride length is 3.67 metres. The take-off distance is 2.09 metres , which represents 56.9% of the total hurdle stride length. The landing distance is 1.58 metres, which is 43.1% of the total hurdle stride length. This ratio is specific for each hurdler and depends, above all, on the anthropometric characteristics of the hurdler; on the stride rhythm between the hurdles, and on the push-off angle. According to the studies (La Fortune, 1991; McLean, 1994; Jarver, 1997; Salo and Grimshaw, 1998; Kampmiller et al., 1999), the optimal ratio between the take-off point and landing point is 60:40. We can see that subject has a slightly shorter stride before hurdle clearance and a slightly longer after hurdle clearance. The take-off in front of the hurdle (Figure 1) is one of the elements of vital importance to optimal hurdle clearance, since it directly defines the trajectory of the movement of the centre of mass (CM). The take-off time of the subject amounts to 100ms, with the take-off consisting of two phases: the braking phase and the propulsion phase. The braking phase must be as short as possible and depends on the angle of the placement of the take-off leg (in target subject this angle is 64°). The propulsion phase ends with a push-off angle, which in our subject is 72.9°. These parameters point to the take-off leg being actively placed on the ground and the shoulders aggressively pushed towards the hurdle. The velocity of hurdle clearance depends to a large extent on the execution of the take-off, which manifests in the horizontal velocity of the CM. The horizontal velocity of the CM in the braking phase is 8.81m/s-1, while in the propulsion phase it increases to 9.11m/s-1, i.e. by 3.3%. We can see that subject accelerates his velocity during take-off extremely efficiently. In addition to the horizontal velocity of the CM, an important parameter of take-off is the vertical velocity, which in this case is 2.35m/s-1. The horizontal and vertical velocities define the elevation velocity of the CM, which is in this case 9.41m/s-1 and the elevation angle, which amounts to 14.5°. The relationship between these two parameters of velocity shows the athlete's ability for an efficient transition from the running stride into the take-off stride. The quality of hurdle clearance is directly correlated with the height of the CM in the take-off phase. From the aspect of biomechanics, an efficient hurdle race is the one in which vertical oscillations of the CM are as small as possible (Schluter, 1981; Dapena, 1991; McFarlene, 1994; Salo and Grimshaw, 1997; Kampmiller et al., 1999).The athlete must maintain a high position of the CM during take-off. In sbject, the height of the CM at the end of the propulsion phase is 1.08 metres, which represents 59.3% of his body height (BH=1.87 m). The raising of the CM from the braking phase to the propulsion phase amounts to 13cm.The maximum CM height thus depends on the technique of take-off in front of a hurdle and on the anthropometric characteristics of the flight. In addition to the above mentioned kinematic parameters, the velocity of hurdle clearance depends also on the velocity of the lead leg during the take-off phase. Subject attacks the hurdle with his lead leg extremely aggressively. The velocity of the knee swing of the lead leg amounts to more than 13m/s-1, while the velocity of the foot of the lead leg is 18.2m/s-1, which is more than double horizontal velocity of the CM during take-off. The criterion of an efficient hurdle clearance technique is the shortest possible time of the flight phase (hurdle clearance time) since the hurdler loses velocity in air (Mero and Luhtanen, 1986; McDonald and Dapena, 1991; Arnold, 1995). The length of the flight of the CM of subject is 3.30 metres, the time of the flight phase is 0.38 seconds. In the finalists of the 110 metres Hurdles at the 1997 IAAF World Championship in Athletics in Athens, the average hurdle clearance time at the fourth hurdle was 0.34 s (Johnson 0.32s, Jackson - 0.34s, Kovac - 0.34s, Schwarthoff -0.30s, Philibert - 0.34s, Reese - 0.38s, Crear - 0.36s). The height of the CM above the hurdle is in direct correlation with the hurdle clearance times (Dapena, 1991). As a rule, the higher the trajectory of the flight of the CM, the longer the flight phase. In subject, this value is 45cm, which in this case does not point to the most efficient trajectory of the flight of CM over the hurdle. The raising of CM relative to the take-off phase is thus 43cm, which is probably the result of a relatively short take-off distance.

The landing phase (Figure 2 ) is one of the most important elements of the hurdling technique. This phase has the largest reserve potential for improving the competition result (McLean, 1994; Arnold, 1995). In the landing phase it is necessary to carry out as efficiently as possible the transition from hurdle clearance to running between hurdles. This transition from acyclic movement into cyclic movement requires a high degree of technical knowledge, a high level of motor abilities, such as speed, strength, co-ordination, timing, and balance. In the World Record holder, Jackson, the execution of this element is really at the very top level. The contact time in the landing phase lasts only 0.08 of a second. At landing after clearing the hurdle, he maintains a high position of the CM (1.15m), which is above all due to the full extension of the leg in the hips and knee. The CM is exactly above the foot. The foot is in complete plantar flexion, thereby neutralizing the ground reaction force that occurs at landing after clearing the hurdle. The high position of the CM, the direction of the knee of the trail leg, the bending of the trunk forward (37° relative to the vertical), the timing of the arms relative to the trail leg, and a stable balance are those elements which generate the maintenance of the horizontal velocity of the CM after hurdle clearance, which is a prerequisite for an efficient model of running to the next hurdle. The horizontal velocity of the CM in the landing phase is 8.77m/s-1, which means that in the hurdle clearance phase a reduction in velocity by 0.34m/s-1, i.e.3.7% occurred in the athlete. On the basis of this parameter it can be established that subject has efficient hurdle clearance technique, enabling him to develop optimal velocities between the hurdles. The efficiency of the technique used by subject can also be assessed from the aspect of vertical oscillations of the head and shoulders during clearing the hurdle. These oscillations are in the order of magnitude of + 18cm. When clearing the hurdle, the athlete thus lowers the trajectory of the flight of the CM by strongly bending the trunk forward, creating thereby favorable conditions for an active landing after clearing the hurdle.

**Conclusion:**

On the basis of the results obtained by the 3 - D kinematic analysis of the clearance of the 4th hurdles in the 110 metres Hurdles, some of the most important parameters defining a model of hurdle clearance technique have been found. Efficient hurdle clearance can be defined by the horizontal velocity of the CM during the take-off in front of the hurdle, the height of the CM during the take-off, the velocity of the knee swing of the lead leg the flight phase time the smallest possible loss in the horizontal velocity of the CM during clearing the hurdle, a high position of the CM at landing, a short contact time in the landing phase and the smallest possible vertical oscillations of the CM, head, shoulders, and hips before, during and after clearing the hurdle.

## REFERENCES

Dapena, J. (1991). Hurdle clearance technique. Track and Field. Quart. Rev., 116(3), 710-712. | DEMPSTER, W. T. (1955). Space requirements of the seated operator. WADC Technical Report, Wright-Petterson Air Force Base, Ohaio: 55 - 159. | Gollhofer, A., & Kyrolainen, H. (1991). Neuromuscular control of the human leg extensor muscles in jump exercises under various stretch-load conditions. IJSM,12, 34-40. | GRIMSHAW, P.( 1995). A kinematic analysis of sprint hurdles training strategies ( isolation drills) Athletic Coach 29 : 4, 24-28. | HOMMEL, H. & ARNOLD M. (1995). NSA photosequences 33 & 34 110 m hurdles : Colin Jackson. New Studies in Athletics 3, 57- 65 | ISKRA, J. (1995). The most effective technical training for the110 m hurdlers. New Studies in Athletics, 3, 51-55. | JARVER, J. (1997). The hurdles - Contemporary theory, technique and training. El Camino Real: Tafnews Press p.131. | KAMPMILLER, T., SLAMKA, M. & VANDERKA, M. (1999). Comparative biomechanical analysis of 110 m hurdles of Igor Kova_ and Peter Nedelicky. Kinesiologia Slovenica 1-2, 26-30. | LA FORTUNE, M.A. (1988). Biomechanical analysis of 110 m hurdles. Track and Field | Mc FARLANE B. (1994): Hurdles: a basic and advanced technical model. Track Technique 128: 1, 4073-4079. | McDonald, C., & Dapena, J. (1991). Linear kinematics of the men's and woman's hurdles races. Medicine and Science in Sports Exercise, 23(12), 1382-1402. | McLean, B. (1994). The biomechanics of hurdling: Force plate analysis to assess hurdling technique. New Studies in Athletics, 4, 55-58. | Mero, A., & Luhtanen, P. (1986). Biomechanische Untersuchung des Hurdenlaufs wahrend der Weltmeisterschaften in Helsinki. Leistungssport, 1, 42-43. News 105, 3355-3365. | SALO, A. & GIMSHAW P. (1997). 3 - D biomechanical analysis of sprint hurdles at differ- | ent competitive level MSS 29 : 2, 231-237 SCHLUTER, W. (1981). Kinematische Merk- | male der 110-m | SALO, A., & GRIMSHAW P. (1995). An examination of kinematic variability of motion analysis in sprint hurdles. Journal of Applieid Biomechanics 14, 211-222. | SALO, A., PELTOLA, E., VIITASALO, T. (1993). Eninge Biomechanische Merkmale des Zwischenhurdenlaufs im 110 m Hurdenlauf. Leistungssport, 2, 59-62. | Schluter, W. (1981). Kinematische Merkmale der 110-m Hurdentechnik. Leistungssport, 2, 118-1 |