Colin Jackson's Hurdle Clearance Technique

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INTRODUCTION

Colin Jackson is, uncontestedly, one of the greatest athletes in the history of British track & field. He holds the world record in the 110m hurdles (12.91-Stuttgart, 1993) and in the 60m hurdles (7.30 -Sindelfingen, 1994). He has established 10 European records and eight Commonwealth records.

The 2002 season, in which he became European Champion (13.11-Munich), is probably his last season in the international arena. In his long, extremely successful career Colin Jackson has set high standards in the 110m hurdles. In the opinion of many experts he has developed hurdles technique virtually to perfection. Within the scope of preparation for the 2002 European Track & Field Championships, he also took part in he international meeting "Velenje- Slovenia 2002," where he won in the hurdles with the time of 13.47. Thus, an opportunity for us to analyze the hurdles technique of this extraordinary hurdler presented itself.

Biomechanical measurements were carried out by a team of experts from the Biomechanics Laboratory at the Faculty of Sport in Ljubljana.

The main objective of the study was to establish a kinematic model of hurdling technique over the fourth hurdle and a model of rhythm of running from the fourth to the fifth hurdle by means of a 3-dimensional video analysis.

Kinematic parameters in the section between the fourth and the fifth hurdle were measured with two synchronized cameras (Sony-DSR-300 PK) placed at an angle of 120° (Fig. 1). The frequency of the cameras was 50 Hz.

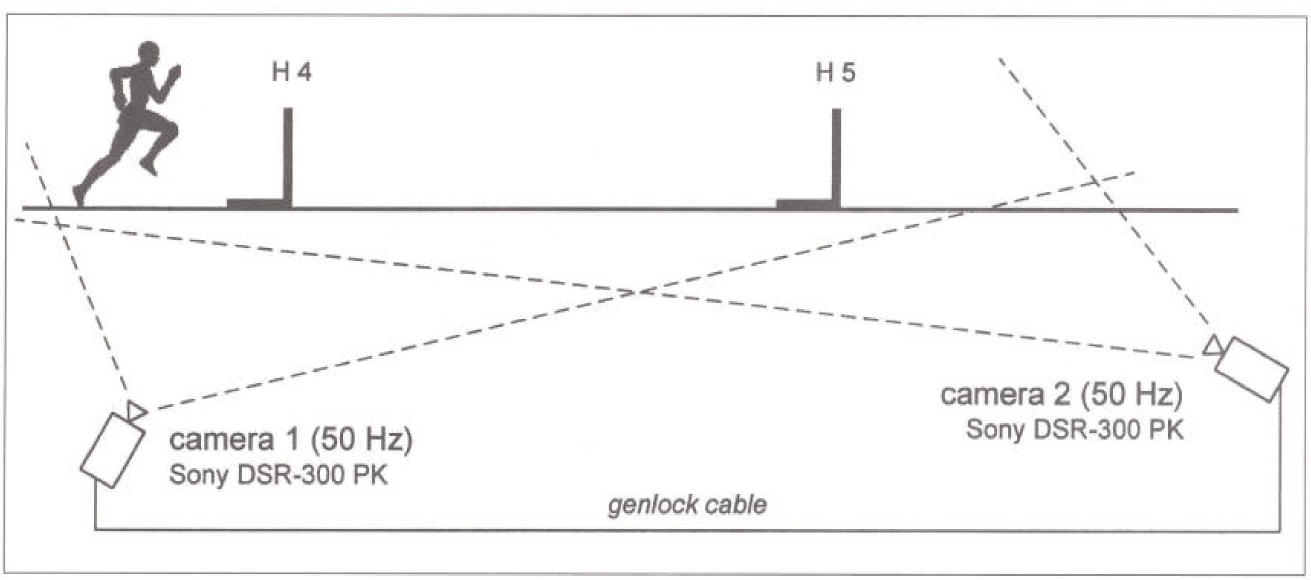

Figure 1: Measurement procedure

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For the calculation of the body's center of gravity, a 15-segment model (Dempster, 1955) and the kinematic program ARIEL (Ariel Dynamics Inc., USA) were used.

The competition conditions were optimal: the ambient temperature was 27°, and the wind velocity w=0.0m.s-1.

Why did we decide to analyze these two hurdles? Some studies (Lafortune, 1988; Salo, Peltola and Viitasalo, 1993; Grimshaw, 1995; Iskra, 1995) show that the horizontal velocity of the hurdler between the fourth and the fifth hurdle is highly correlated with the end result in the 110m hurdle race.

RESULTS OF THE BIOMECHANICAL STUDY

On the basis of the results in Table 1, the following characteristics of a kinematic model of the technique of clearing the 4th hurdle by Colin Jackson (C. J.) can be established:

- Efficient hurdle clearance is defined by the length of the stride before hurdle clearance and after hurdle clearance. The total hurdle stride length for C.J. is 3.67m. The takeoff distance is 2.09m, which represents 56.9% of the total hurdle stride length. The landing distance is 1.58m, 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 C. J. has a slightly shorter stride before-hurdle clearance and a slightly longer after-hurdle clearance.

- The takeoff in front of the hurdle (Fig. 2) is one of the elements having vital importance for optimal hurdle clearance since it directly defines the trajectory of the movement of the center of mass (CM). The takeoff time of the subject amounts to 100ms, with the takeoff 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 C. J. this angle is 64°). The propulsion phase ends with a push-off angle, which is in our subject 72.9°. These parameters point to the fact that the take-off leg is 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 takeoff, which manifests itself in the horizontal velocity of the CM. The horizontal velocity of the CM in the braking phase is 8.81 m.s-1, while in the propulsion phase it increases to 9.11 m.s-1, i.e., by 3.3%. We can see that the competitor very efficiently accelerates the velocity during takeoff. In addition to the horizontal velocity of the CM, an important parameter of the takeoff is the vertical velocity, which is 2.35 m.s-1. The horizontal and vertical velocity define the elevation velocity of the CM, which is 9.41 m.s-1, and the elevation angle, which amounts to 14.5°. The relationship between these two parameters of velocity shows that the athlete has the ability to perform an efficient transition from the running stride into the takeoff stride.

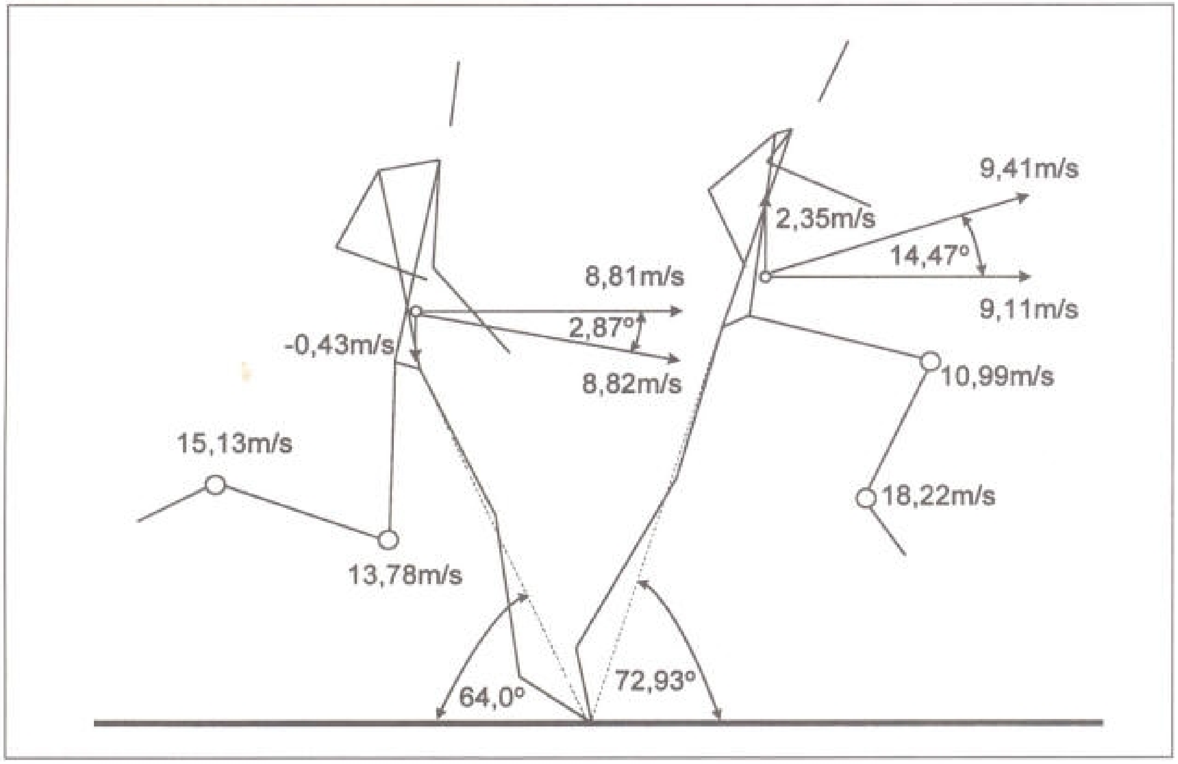

Figure 2: Takeoff phase (Colin Jackson - 13.47s)

- The velocity of hurdle clearance depends to a large extent on the execution of the takeoff, which manifests itself in the horizontal velocity of the CM. The horizontal velocity of the CM in the braking phase is 8.81 m.s-1, while in the propulsion phase it increases to 9.11 m.s-1, i.e., by 3.3%. We can see that the competitor very efficiently accelerates the velocity during takeoff. In addition to the horizontal velocity of the CM, an important parameter of the takeoff is the vertical velocity, which is 2.35 m.s-1. The horizontal and vertical velocity define the elevation velocity of the CM, which is 9.41 m.s-1, and the elevation angle, which amounts to 14.5°. The relationship between these two parameters of velocity shows that the athlete has the ability to perform an efficient transition from the running stride into the takeoff stride.

- The quality of hurdle clearance is directly correlated with the height of the CM in the takeoff phase. Biomechanically, an efficient hurdle race is the one in which vertical oscillations of the CM are as small as possible (Schluter, 1981; Dapena, 1991; McFarlane, 1994; Salo and Grimshaw, 1997; Kampmiller, et al., 1999). The athlete must maintain a high position of the CM during takeoff. In C. J, the height of the CM at the end of the propulsion phase is 1.08m, which represents 59.3% of his body height (BH=1.82m). 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 takeoff 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 swing leg during the takeoff phase. C. J. attacks the hurdle with his swing leg extremely aggressively. The velocity of the knee swing of the swinging leg amounts to more than 13 m.s-1, while the velocity of the foot of the swinging leg is 18.2 m.s-1, which is more than double the horizontal velocity of the CM during takeoff.

- The criterion of an efficient hurdle clearance technique is the shortest possible time in the flight phase (hurdle clearance time), since the sprinter loses velocity in the air (Mero and Luhtanen, 1986; McDonald and Dapena, 1991; Arnold, 1995). The length of the flight of the CM of the athlete (Table 1, Fig. 4) is 3.30; the time of the flight phase is 0.36s. For the finalists in the 110m hurdles at the World Champion ships in 1997 (Athens) the average hurdle clearance time at the 4th hurdle was 0.34s (Johnson 0.32, Jackson 0.34, Kovac 0.34, Schwarthoff 0.30, Philibert 0.34, Reese 0.38, Crear 0.36). The height of the CM above the hurdle is indirect correlation with the hurdle clearance times (Dapena, 1991). The higher the trajectory of the flight of the CM, the longer is the flight phase, as a rule. In C. J., this value is 45cm, which in this concrete case does not point to the most efficient trajectory of the CM flight 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 takeoff distance.

PARAMETERS	Unit	R
Rhythmic Units (Hurdle 4 - 5)	$m.s^{-1}$	8.83
Take – off (braking phase)		
Horizontal velocity of CM	$m.s^{-1}$	8.81
Vertical velocity of CM	$m.s^{-1}$	-0.43
Velocity resultant of CM	$m.s^{-1}$	8.82
Height of CM	m	0.95
Center of mass to foot distance	m	0.46
Knee swing velocity	$m.s^{-1}$	13.78
Ankle swig velocity	$m.s^{-1}$	15.13
Take – off (propulsion phase)		
Horizontal velocity of CM	$m.s^{-1}$	9.11
Vertical velocity of CM	$m.s^{-1}$	2.35
Velocity resultant of CM	$m.s^{-1}$	9.41
Height of CM	m	1.08
Center of mass to foot distance	m	0.38
Push-off angle	0	72.9
Knee swing velocity	$m.s^{-1}$	10.99
Ankle swig velocity	$m.s^{-1}$	18.22
Take-off distance	m	2.09
Contact time	s	0.100
Flight		
Flight time	s	0.36
Height of CM above the hurdle	m	0.45
Maximal height CM	m	1.44
Maximal velocity over the hurdle	m^{-1}	9.05
Landing (braking phase)		
Horizontal velocity of CM	$m.s^{-1}$	8.77
Vertical velocity of CM	$m.s^{-1}$	-1.02
Velocity resultant of CM	$m.s^{-1}$	8.84
Height of CM	m	1.15
Center of mass to foot distance	m	-0.05
Knee swing velocity	$m.s^{-1}$	12.65
Ankle swig velocity	$m.s^{-1}$	13.16
Landing distance	m	1.58
Landing (propulsion phase)		
Horizontal velocity of CM	$m.s^{-1}$	8.41
Vertical velocity of CM	$m.s^{-1}$	-1.32
Velocity resultant of CM	$m.s^{-1}$	8.53
Center of mass to foot distance	m	0.65
Knee swing velocity	$m.s^{-1}$	-9.86
Ankle swing velocity	$m.s^{-1}$	-10.56
Contact time	s	0.08

Table 1: Kinematic parameters of clearing the 4th hurdle (C. Jackson-110m H 13.47)

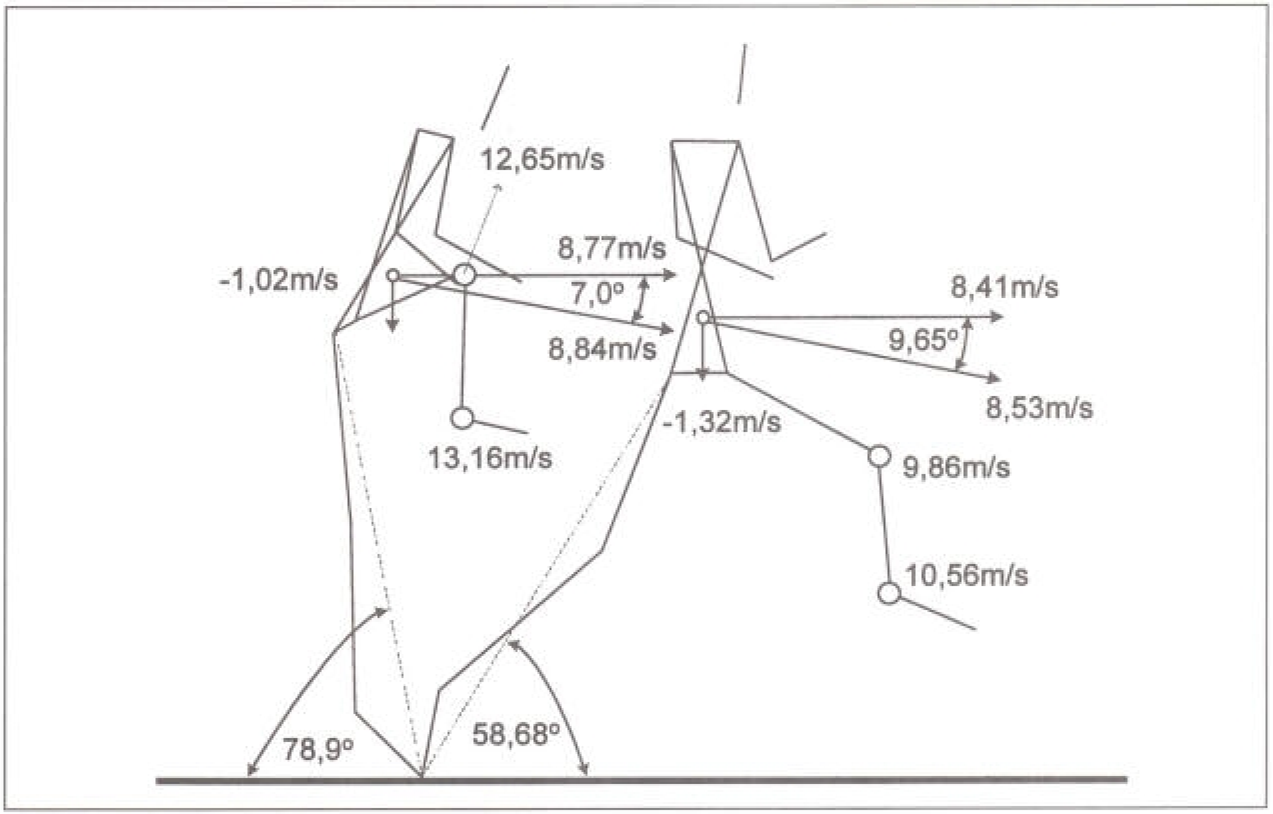

Figure 3: Landing phase (Colin Jackson - 13.47s)

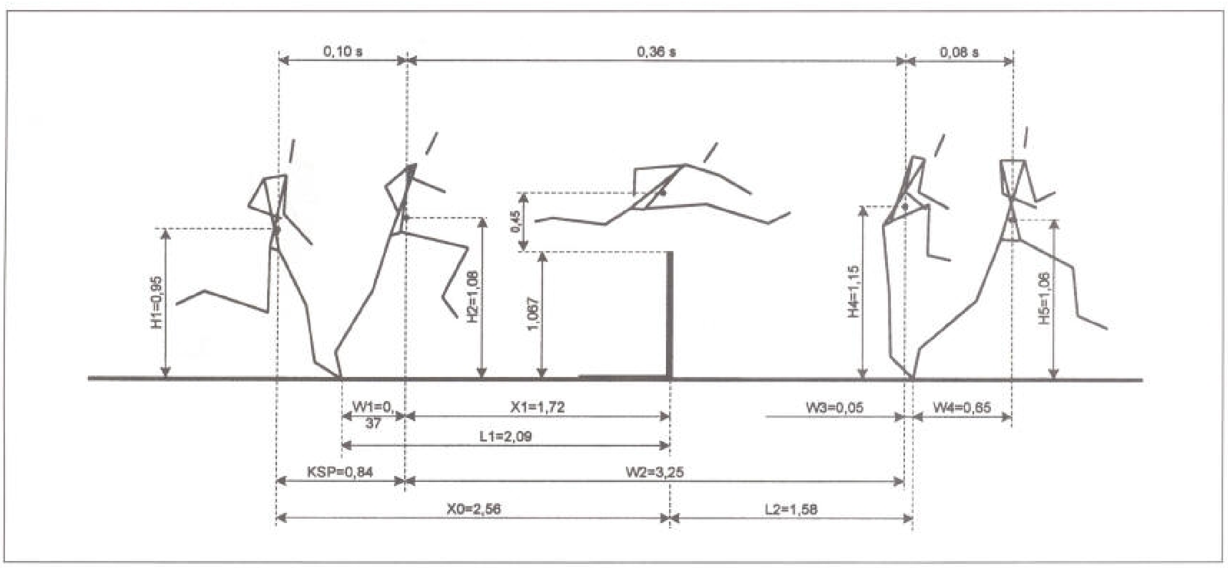

Figure 4: Hurdle clearance (Colin Jackson - 13.47s)

- The landing phase (Fig. 3, Fig. 4) 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 and a high level of motor abilities, such as speed, strength, co-ordination, timing, and balance. In the world record holder (C. J.) the execution of this element is really at the very top level. The contact time in the landing phase lasts only 0.08s.

At landing after clearing the hurdle, the hurdler 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 ground reaction force at that moment (vertical impact force) is 2400-3300N (McLean, 1994). In addition to the correct technique, the ability of the muscular system-known as Short Range Elastic Stiffness (Gollhofer and Kyrolainen, 1991)-is important in order to enable the hurdler to neutralize such a large ground re- action force at landing after clearing the hurdle. This ability manifests itself in muscle preactivation and action of the myotactic and Golgi tendon reflex.

"Soft" landing of the hurdler after hurdle clearance is indicated by the vertical velocity, which is negative and amounts to only -1.02 m.s-1. The high position of the CM, the direction of the knee of the swinging leg, the bending of the trunk forward (37° relative to the vertical), the timing of the arms relative to the swinging leg, and a stable balance are those elements which generate the maintenance of the horizontal velocity of the CM after hurdle clearance. This is a prerequisite for an efficient model of running to the next hurdle. The horizontal velocity of the CM in the landing phase is 8.77 m.s-1, which means that in the hurdle clearance phase a reduction in velocity by 0.34 m.s-1, i.e., by 3.7% occurred in the athlete. On the basis of this parameter it can be established that C. J. has a very efficient hurdle clearance technique, enabling him to develop optimal velocities between the hurdles.

- The model of running between hurdles is defined by the average velocity, by partial velocities of individual strides, by the length of strides, by their mutual relationship, and the path of the individual segments of the hurdler's body. The total length of the three strides between the hurdles is 5.50m, the length of the first stride being 1.51m (27.4%), the length of the second stride 2.01m (36.6%), and the length of the third stride 1.98m (36.0%)-Fig. 5. The first stride after hurdle clearance is the shortest, the second one is the longest, while the third one is again slightly shorter, so that the hurdler can take off at an optimal distance from the next hurdle. The average length of the in-between strides is 1.83m. With respect to the C. J.'s body height (BH=1.82m), the length of the strides allows him to achieve optimal velocity between the hurdles. The average velocity of C. J. between H4 and H5 is 8.83 m.s-1. The horizontal velocity of the CM of the hurdler in the first stride is 8.81 m.s-1, in the second stride it is 9.17 m.s-1, and in the third one 8.53 m.s-1 - Fig . 6. A slightly smaller horizontal velocity in the third stride is the consequence of the athlete's direct preparation for the takeoff in front of the hurdle, where a part of the horizontal velocity of the CM transforms into the vertical velocity. The vertical and horizontal velocity, however, directly define the velocity of the passing of the CM over the hurdle.

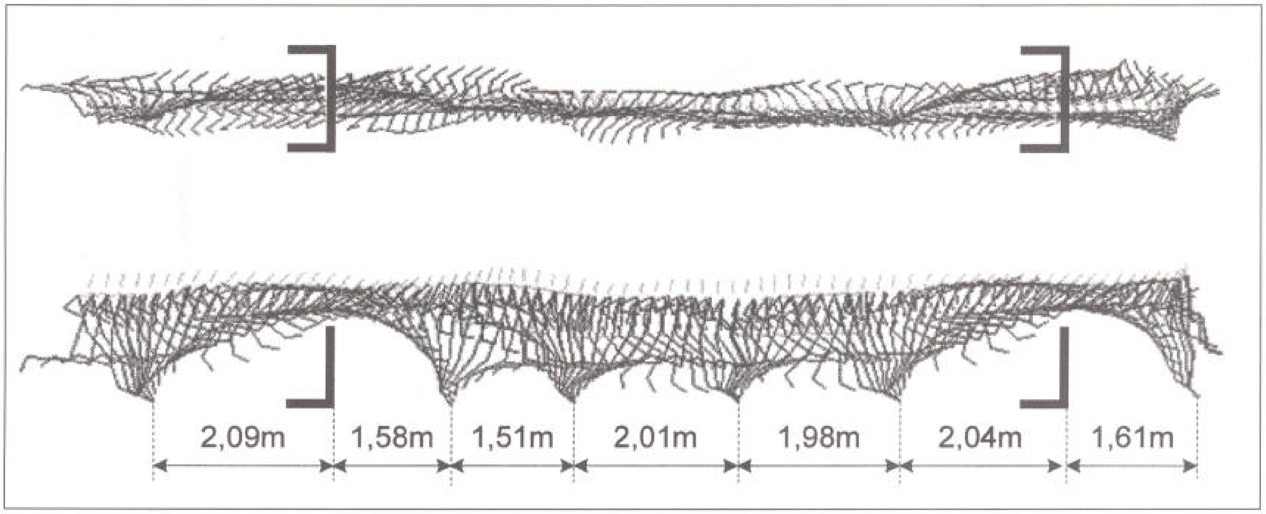

Figure 5: Model of stride length between the 4th and 5th hurdle (Colin Jackson - 13.47s)

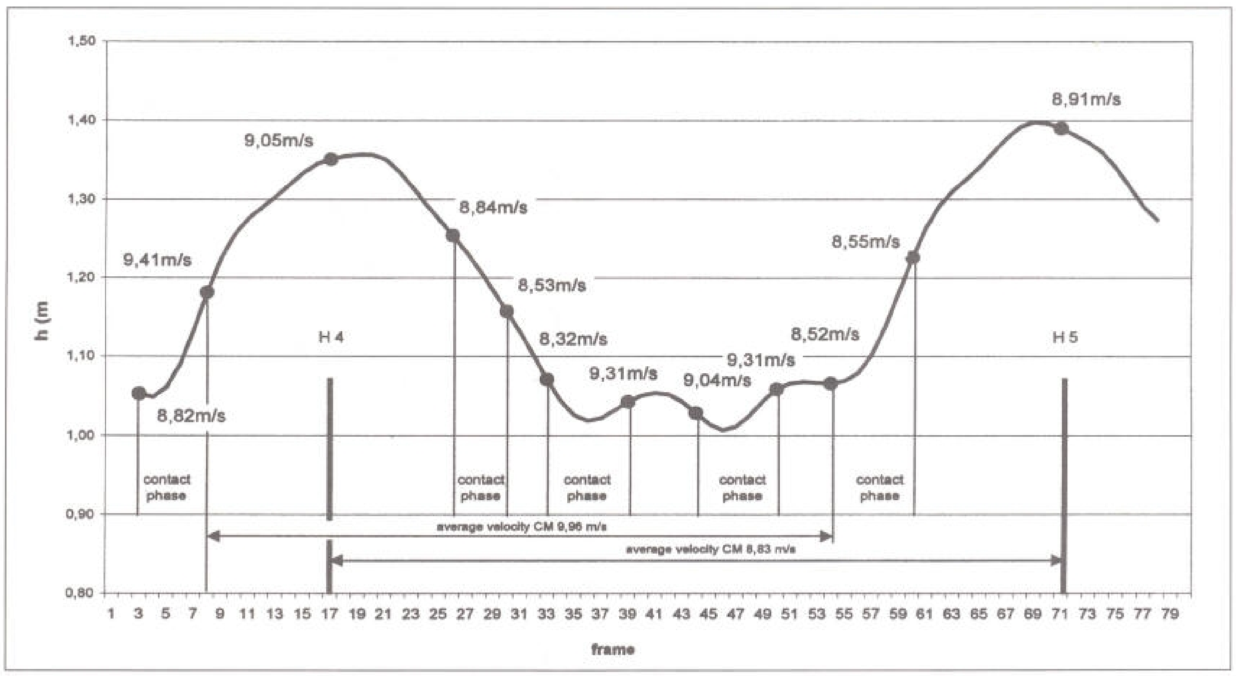

Figure 6: Dynamics of the athlete's CM velocity in clearing the 4th and 5th hurdle (Colin Jackson - 13.47s)

- According to Fig. 7, vertical oscillations of the hips, head, shoulders and CM can be seen in the section between H4 and H5. The efficiency of the technique used by C. J. can also be assessed from the aspect of vertical oscillations of the head and shoulders during hurdle clearance and during the running between the hurdles. These oscillations are in the order of magnitude of +/- 18 cm. When clearing the hurdle, the athlete thus lowers the trajectory of the flight of the CM by strongly bending the trunk forward, creating thereby favourable conditions for an active landing after clearing the hurdle.

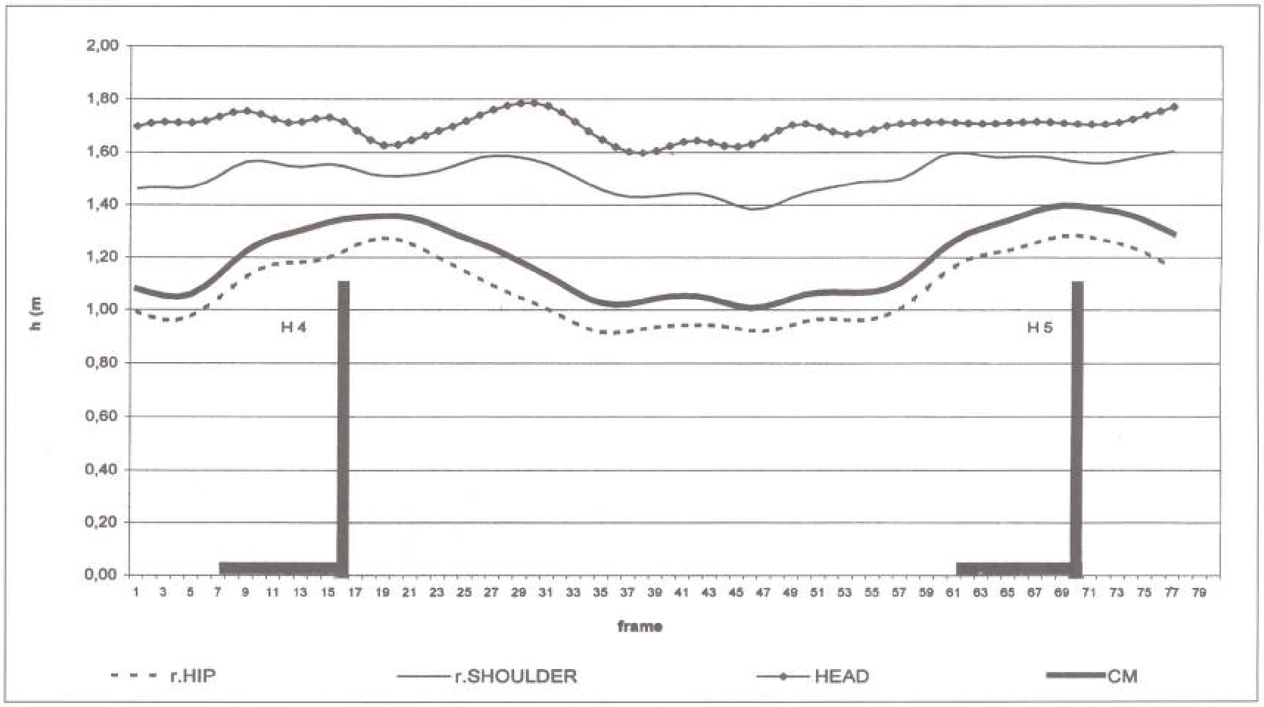

Figure 7: Trajectory of movement of hips, shoulders, head and CM over the 4th and 5th hurdle (Colin Jackson - 13.47s)

CONCLUSION

On the basis of the results obtained by the 3-P kinematic analysis of the 110m hurdles race of the world record holder Colin Jackson, some most important parameters defining a model of hurdle clearance technique have been found. The analysis covered the clearing of the 4th and 5th hurdle. Efficient hurdle clearance can be defined by the horizontal velocity of the CM during the takeoff 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 hips before, during and after clearing the hurdle.

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