INTEGRATED KINEMATIC DATA ANALYSIS OF AMERICAN ELITE HURDLERS

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This project consisted of collecting video records of the third hurdle clearance by elite high and low hurdlers while performing a maximal practice run at an Elite Hurdler Development Camp at the USOC training facility. Temporal and kinematic variables were calculated for their performances. The results were presented using an integrated data/video analysis format and were reviewed the following day with the athlete and the coach.

KEY WORDS: integrated kinematic analysis, elite hurdlers

INTRODUCTION: Hurdling is a specialized form of sprinting that requires the negotiation of a series of hurdles. Since the objective of sprinting is to cover the distance in the shortest time possible, in may be concluded that an athlete's success in the event may be influenced by their ability to produce the greatest horizontal velocity. To produce high horizontal velocities it is necessary to produce large amounts of horizontal force while in contact with the ground. Therefore, the horizontal force applied may be expressed by the following formula:

$$\text{Horizontal Force} = \text{Mass} \times (\Delta\text{Horizontal Velocity}) \times \text{Ground Time}^{-1}$$

The application of greater horizontal forces would be indicated by shorter ground contact times and those horizontal forces may only be generated when the hurdler is contact on the ground, therefore long flight times while clearing the hurdle would not be beneficial in achieving fast hurdling times. Large vertical displacements of the hurdler's CM during hurdle clearance would reflect the hurdler jumping over the hurdle rather than striding over the hurdle which would be shown in a long flight time. Additionally, the hurdlers' apex of their CM parabolic pathway should occur while clearing the hurdle and a horizontal displacement between the CM apex and the hurdle would be indicative of improper striding, where the take-off step occurred too close or too far from the hurdle. Other indicators of improper striding would be decelerations in the hurdler's CM during the foot contact prior to take-off and during landing after hurdle clearance (Hay, 1993).

METHODS: Video records were collected at 60 Hz by a Sony Hi8 camcorder from a sagittal view and a front right view of 6 elite high and 3 low hurdlers during a maximal practice run during a winter season Elite Hurdlers Development Camp held at the USOC San Diego training facility. The video records were collected of the high hurdlers while clearing the third hurdle and of the elite low hurdlers' fifth hurdle. Fourteen body data points, 3 hurdle points (top, base, & standard base), and the fixed reference marker on the video images of the hurdle trials were digitized, the coordinate data were scaled using a DLT transformation, and then smoothed using a quintic spline filter. To examine the relationships between horizontal force production, contact time, and flight time, the temporal variables of foot contact time during the stride prior to take-off and flight time were determined. Kinematic data included the horizontal velocity of the CM during foot contact prior take-off, CM at take-off, CM at landing after hurdle clearance, vertical elevation of CM during hurdle clearance from take-off, and horizontal displacement of the CM apex in comparison to hurdle clearance position (See Figure 1). Simultaneous data integration of the hurdler's video records, stick figure reconstruction with the CM traced, and the kinematic data graphs of their hurdling trials were presented to the athlete as illustrated in Figure 2, and an elite hurdle coach provided technique analysis the following day.

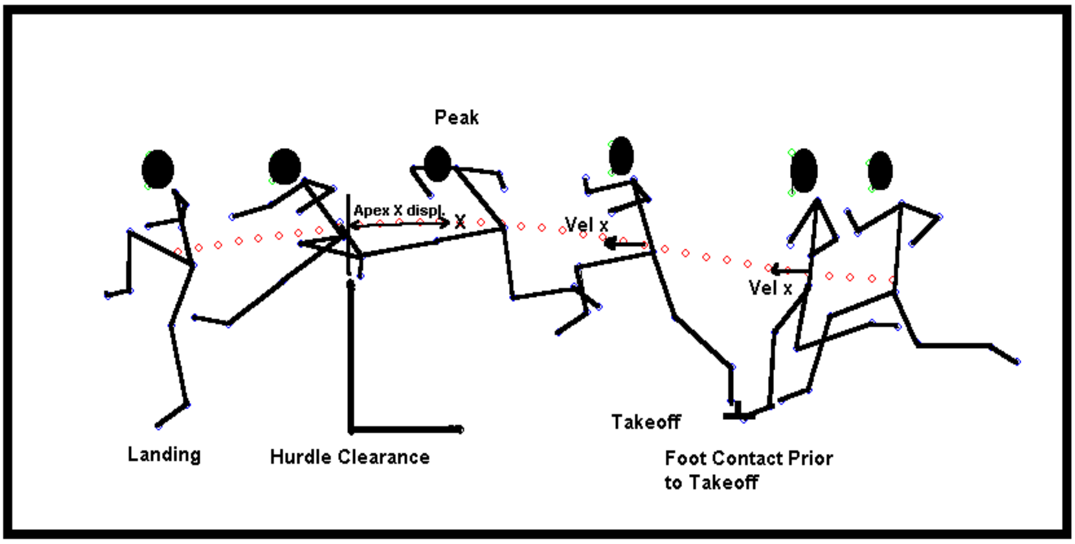

Figure 1 - Kinematic hurdle phases & variables.

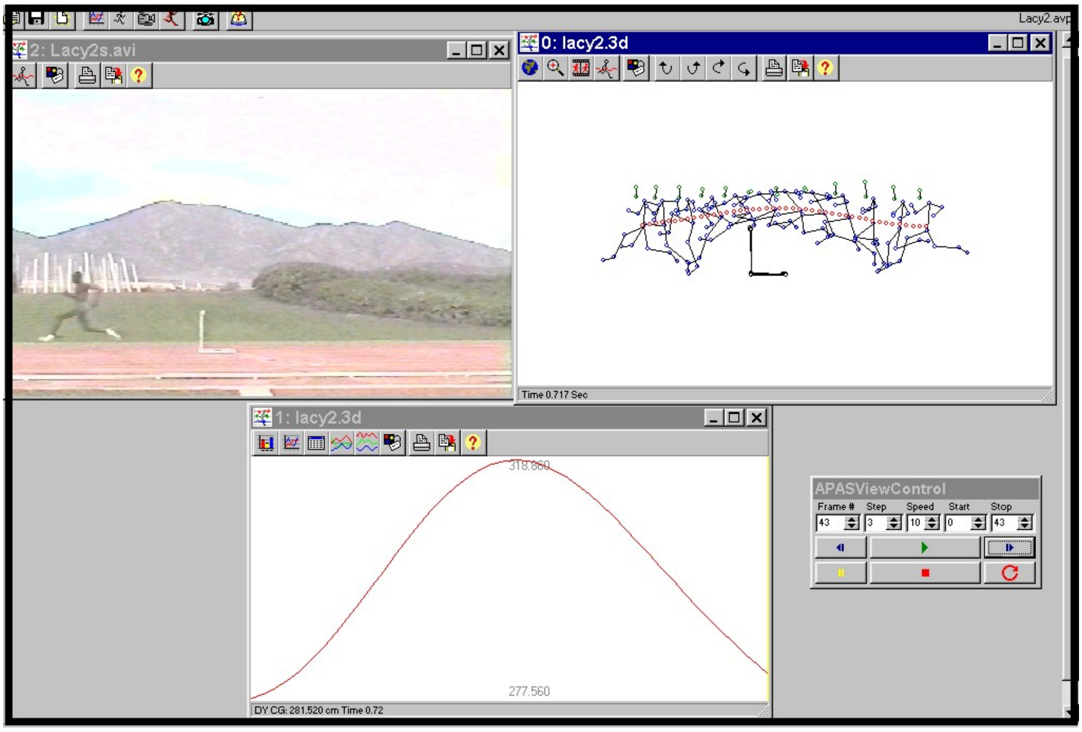

Figure 2 - Integrated elite hurdle analysis.

RESULTS AND DISCUSSION: Means and standard deviations of the temporal and kinematic data of the elite high and low hurdle all-out practice trials were calculated and are presented in Table 1.

Table 1 Temporal & kinematic data for high and low elite hurdlers

Variable	High Hurdlers Mean ± SD	Low Hurdlers Mean ± SD
Contact Time (s)	.122 ± .023	.127 ± .001
Flight Time (s)	.366 ± .032	.367 ± .014
CM Take-off Horizontal Velocity (cm s^{-1})	-18.6 ± 68.5	-8.4 ± 26.6
CM Landing Horizontal Velocity (cm s^{-1})	5.2 ± 54.7	-85.5 ± 54.6
CM Elevation Hurdler Clearance (cm)	18.2 ± 9.0	14.4 ± 9.5
CM Vertical Displacement at Landing (cm)	23.5 ± 24.2	66.9 ± 23.9
CM Apex Horizontal Displacement (cm)	23.5 ± 24.2	66.9 ± 23.9

Foot ground times calculated going into the hurdle for this study's elite high and low hurdlers were slightly faster than the 0.135 s contact times found in the Elite Hurdler Project technical report prepared R. Mann (1993). The flight times determined in the present study found flight times that were similar to the lesser skilled elite hurdlers analyzed in the 1993 project and slower than the reported .31 s flight times found for the good elite hurdlers in the earlier study. The longer flight times may be attributable to the present study's subjects participating in the hurdling training camp early in their indoor track season, whereas the 1993 project occurred at the end of the competitive outdoor season and therefore the current hurdlers' technique may not be completely refined yet. The high hurdlers elevated their CM approximately 18 cm at hurdle clearance above their CM position at take-off and the low hurdlers' CM was raised 14 cm during the hurdling movement. The smaller CM elevation during the low hurdle trials was expected in that the low hurdles are 8 cm lower than the high hurdles. In that only a four cm difference was observed between the low and high hurdle attempts, it may be concluded that the high hurdlers found a more effective method to negotiate over the taller hurdles than the high trajectory pathway used by the low hurdlers. The horizontal displacements between the apex of the CM trajectory and the hurdle found that the low hurdlers' take-off (66 cm) was farther in front of the hurdle than the high hurdlers (23 cm). Therefore, both groups of hurdlers needed to work on their strides going to the hurdle in order to make their CM flight trajectory apex coincide the hurdle clearance position rather than in front. If this alignment of the trajectory peak was made then the hurdlers would not need to produce as great an elevation and shorter flight times would result. Only, two of the high hurdlers' CM peak trajectories coincided with the hurdle clearance as illustrated in Figure 3.

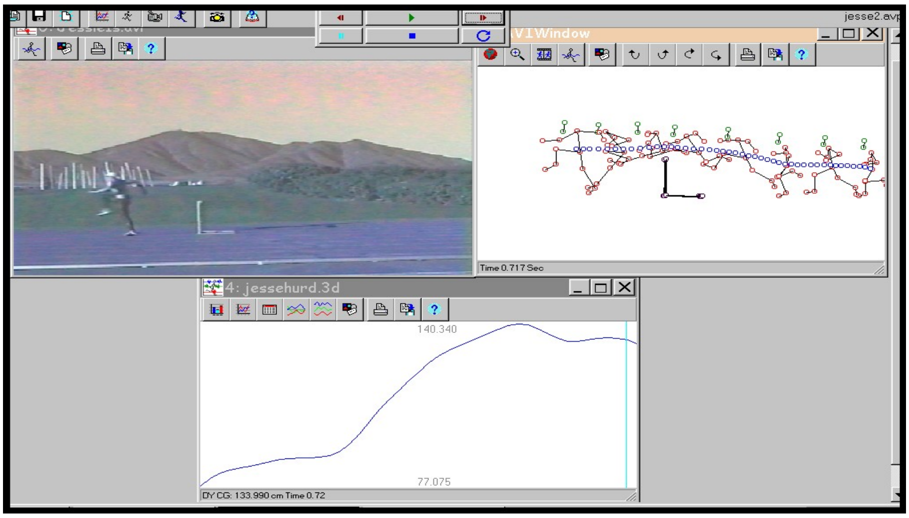

Figure 3 - CM apex position during hurdle clearance.

The alterations in the horizontal velocities of the CM during the take-off found that the high hurdlers slowed down 18 cm s^{-1}, while the low hurdlers increased their CM horizontal velocity by 26 cm s^{-1}. These decelerative changes in the horizontal velocities for the high hurdlers would be indicative of a slow horizontal foot velocity at contact or an overstride prior to take-off which would produce a braking or retarding action during the foot plant. Conversely, the low hurdlers experienced an acceleration of their body during the foot plant prior to take-off. During the landing phase, the high hurdlers experienced a small acceleration (5 cm s^{-1}), while the low hurdlers showed a significant braking action (-85 cm s^{-1}) which resulted from their early take-off.

CONCLUSION: A greater CM deceleration at take-off occurred for the high hurdlers and the low hurdlers showed greater decelerated at landing. Higher CM positions were observed for the high hurdlers than the low hurdlers and both groups reached the apex of their flight prior to the hurdle. The simultaneous integration of video, stick figures and data was an effective visual coaching and research tool for performing a hurdle analysis and providing immediate feedback to the athlete and coach.

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