THE BIOMECHANICS OF HURDLING: FORCE PLATE ANALYSIS TO ASSESS HURDLING TECHNIQUE

BRIAN MCLEAN

AUSTRALIAN INSTITUTE OF SPORT, BELCONNEN, CANBERRA, AUSTRALIA

INTRODUCTION

Hurdle racing, especially the high hurdles, is one of the most demanding of track and field events. The athlete requires the speed of a sprinter in conjunction with a high level of technical ability to clear ten 1.07m hurdles with minimum loss of velocity. Kinematic analysis has provided insight into hurdling technique, but little data has been reported on the kinetics of hurdling. This paper reports the results of force plate analysis of hurdling and outlines how it was used in the routine assessment of hurdling technique.

METHOD

Two force plates (Kistler Z4852/C) were mounted at floor level in a portion of a 110m Rekortan track which passes through the biomechanics laboratory at the Australian Institute of Sport. The force plates were mounted in the floor so that their top surface when covered with a Rekortan mat was at the same level as the surrounding floor. The protocol involved the athlete starting from starting blocks and clearing three hurdles set at standard distances from the start. Vertical and anteriolposterior ground reaction force data were collected at 1000 hz for the take-off and landing of the second hurdle clearance. Using the impulse-momentum relationship, velocity changes associated with braking, propulsion and vertical impulse were determined, in conjunction with contact times and peak force data. Kinematic data were collected in the sagittal plane by an NAC high speed video camera operating at 200 frames/sec. The distance from the centre of the foot to the hurdle and the centre of the foot to the whole body centre of gravity at the instant of touchdown in the take-off and landing of the second hurdle clearance was determined. Average velocity of each hurdle 'rhythmic unit' was determined by Alge infra-red photocells (Model RLS1/3) and electronic timer (model S3). The photocells were placed at 9.14m intervals with the hurdle midway between each set of cells. These parameters were used in the quantitative assessment of hurdling technique.

RESULTS AND DISCUSSION

Mean data for seven male high hurdlers attending the National Hurdles Camp at the Australian Institute of Sport in January 1994 are shown in Table 1. A representative force-time curve for take-off and landing is shown in Figure 1.

Data for two subjects, A and B, are also shown in Table 1. Comparison of these data with the mean data is useful in assessing the hurdling technique of each athlete.

Hurdler A had a very low change in velocity due to braking and consequently a low total velocity change during the take-off support. By contrast athlete B had a large velocity change during braking and for the entire take-off support. The centre of gravity to foot distance between the two athletes was similar and below the mean for both subjects. Consequently, the positive relationship between this parameter and braking force (Mann and Herman, 1985) is unlikely to account for the large difference in the velocity reduction between the two athletes. Athlete B however had a long contact time and a high percentage of this time spent in braking. The long contact time and high percentage of braking time may be due to a passive landing. In contrast an active landing where the hip is extended rapidly and the foot moving backwards relative to the body at ground contact is necessary to limit braking (**Mann** et **al 1982-83**). Athlete B also showed a large vertical velocity change and vertical impact force during **take-off,** in conjunction with a low foot to hurdle distance. Since the athlete was close to the hurdle at take-off, a large vertical component of velocity was required to clear the hurdle. Tbis scenario is consistent with that described earlier by **LaFortune** (1988).

Table 1. Kinetic and Kinematic parameters describing support phases of take-off and landing in the hurdle clearance .(mean + **s.d.,** n=7; and two representative subjects. A and B)

	mean	± sd	**Sub.A**	**Sub.B**
Rhythmic Units				
Unit **1** (s)	1.17	± .04	1.17	1.20
Unit 2	1.14	± .05	1.11	1.16
Unit 3	1.15	± .06	1.10	1.17
Take-Off				
Braking velocity change **(m/s)**	-0.60	± .09	-0.47	-0.71
Total velocity change **(m/s)**	-0.41	± .07	-..32	-.50
Contact time (s)	0.125	± .008	.112	.130
Braking time (s)	0.072	± .005	.065.	,078
% Braking time	57.8	1 . 8	58.0	60.0
Vertical velocity change **(m/s)**	2.32	1	2.31	2.53
Peak vertical force **(BW)**	5.72	± .90	4.88	7.00
Foot to Hurdle (m)	2.44	± .25	2.36	2.13
C of G to foot (m)	0.33	± .04	.311	.320
Flight time	389	±.020	.393	.396
Landing				
Braking velocity change (d s)	-0.08	± .05	0.0	-.09
Total velocity change (d s)	0.23	± .06	.32	.26
Contact time (s)	0.092	± .011	.076	.094
Braking time (s)	0.018	± .008	.007	,018
% Braking time	18.9	± 6.3	9.2	19.1
Vertical velocity change **(m/s)**	0.97	± .32	1.15	1.10
Peak vertical force (BW)	3.68	± .48	4.21	3.82
Foot to Hurdle (m)	1.26	.15	1.23	1.39
C of G to foot (m)	-0.01	± .04	0.0	0.0
Total velocity change over hurdle **(m/s)**	-0.18	± .09	0.0	-.24

During take-off the horizontal velocity loss in the **braking** phase was greater than the increase in velocity due to propulsion, producing a resultant velocity loss. Similarly the percentage of contact time during which braking occurs is greater than the propulsive phase. The change in vertical velocity during take-off is high when compared to running (1.47m/s at **5m/s** running velocity. Munro et al. 1987) and reflects the athletes requirement to raise their centre of gravity over the hurdle. Consistent with this finding is a high peak vertical impact force.

During landing the ratio of braking to propulsion was reversed to that of the take-off. Braking time was only 19% of total contact time and the athlete has a resultant horizontal acceleration during this support phase. **This** increase in velocity was not sufficient, however, to counteract the loss of velocity incurred during the take-off. Consequently the horizontal velocity change during the take-off and landing support phases of the hurdle clearance was negative. The change in vertical velocity during the landing was much smaller than during the takeoff as was the vertical impact force. With the foot almost directly beneath the body's centre of gravity at landing and with the knee close to full extension (Rash et al , 1990) the vertical component of the ground reaction force in landing represents a controlled lowering of the body's C of G off the hurdle.

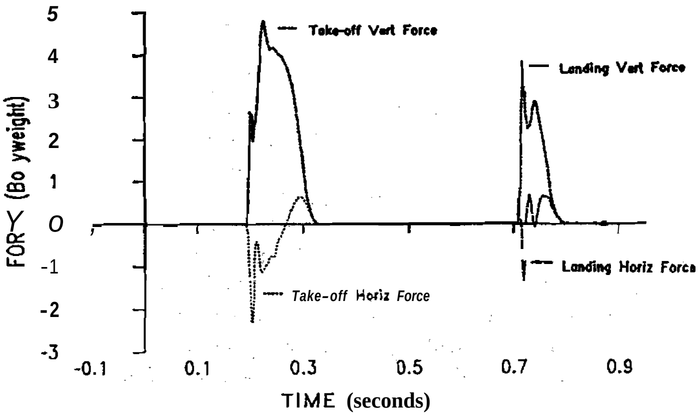

Figure 1. Representative ground reaction force data during take-off and landing support phases of the hurdle clearance.

The landing technique of athlete B was much better than his take-off. The foot was underneath the body C of G at touchdown and the increase in velocity during the landing support was above average. The long foot to hurdle distance at landing was most likely due to the closeness of the athlete to the hurdle during the take-off, since the total flight distance and the flight times were similar for both athlete A and B. However, due to the shortcomings in the take-off, athlete B had a higher than average reduction in velocity during the hurdle clearance.

The landing technique of athlete A was very good showing no loss in velocity due to braking and a large increase in velocity over the support period. For the combined take-off and landing support phases of the hurdle clearance this athlete showed no reduction in velocity, which would be considered ideal when assessing hurdling technique.

In conclusion, this study has shown that force plate analysis can be effectively utilised in the assessment of hurdling technique. The potential for diagnosis of technique shortcomings and effective intervention by the coach and athlete are enhanced by the analysis being performed in conditions similar to the training environment and by the immediate feedback possible with an on-line force plate system.

REFERENCES

LaFortune, M.A. 1988. Biomechanical analysis of 110m hurdles. Track Technique 105, 3355-3356.

Mann, R. and Herman, J. 1985. Kinematic analysis of Olympic hurdle performance: Women's 100 metres. Intemational Joumal of Sport Biomechanics 1, 163-173.

Mann, R., Herman, J., Johnson, B., Schultz, C., and Kotmel, J. (1982-1983) The elite athlete project: Sprints and hurdles. (USOC Tech. Reports 1-11). Colorado springs, CO:USOC Training Centre.

Munro, C.F., Miller,D.I. and Fuglevand, A.J. 1987. Ground reaction forces in running: A reexamination. Journal of Biomechanics, 20, 147-155.

Rash, GAS., Garrett, J. and Voisin, M. 1990. Kinematic analysis of top American Female 100-meter Hurdlers. International Joumal of Sport Biomechanics 6, 386-393.