A NEW SIMPLE BIOMECHANICAL METHOD FOR INVESTIGATING HORSES JUMPING KINEMATICS

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The purpose of present study was to use a simple mathematical model to investigate horses' kinematical parameters such as initial CG angle and velocity components, horizontal distance to fence and to leading hind limb at take-off and jump height during jumping a spread fences of 100 and 140 cm high. A digital cam- coder was used (25 Hz) along with Ulead Studio program in order to get time and related distance data. The total jump distance and time of flight for each horse were measured to 10^{-2}m and 10^{-2}s respectively. Biomechanical formulae have been established in order to evaluate the kinematic parameters. The results obtained by this simple method agreed well with the results obtained by other researchers with sofisticated method. The simplicity of the method may permit the riders and trainers to to improve fast the jumping techniques for successful jumping.

Key words: horse, jumping, kinematics, take-off

INTRODUCTION:

So far few studies have evaluated the CG (centre of gravity) kinematics in jumping horses. The CG kinematics of horses jumping over relatively small fences (=1m high) has been investigated and reported by Powers and Harrison (1999,2000), and jumping over a water jump (=4.5m wide) has been reported by Clayton et al., (1996). An early study (Clayton and Barlow, 1989) examined the effect of fence dimensions on the limb placement of jumping horses, but no analysis was conducted on the CG kinematics. The take-off kinematics of jumping horses in puissance competition was investigated and reported by Powers (2002). The body position and kinematics of horses centre of gravity at take-off are important factors determining jump outcome. Unlike human athletes, horses are unable to significantly alter their body positions during jumping and therefore need to raise their CGs substantially, in order to clear the fence. The take-off is crucial to the jump outcome. So far there was no biomechanical investigation of horses jumping. The main aim of this study was to describe and analyze the linear CG kinematics of take-off through establishing biomechanical relations.

METHOD:

Video recordings (50 Hz) were made of three top horses and jumps were made over a spread fence of 1.4m and 1m wide. A single Sony camera was set up 10m from the centre of the spread fence. The field of view measured about 6m wide and encompassed one full approach stride and the take-off phase. Video recordings were then transferred into ULead studio program in order to measure the time sequences. The total jump distance (from legs at take-off to hands at landing) was also measured with the tape meter.

FORMALISM:

The total displacement (from legs at take-off to hands at landing) was measured with a precision of 10^{-2} m then with the help of ULead Studio program we were able to measure the CG displacement by watching the CG mark on the horse Figs. 1&2. In fact the horse was considered as a projectile, therefore the CG angle of projection could theoretically be obtained, Shahbazi and Broogeni (1998):

$$\theta = \tan \frac{g t_F^{\ 2}}{2 R_{CG}} \qquad (1)$$

Where T_F is CG time of flight and R_{CG} is CG displacement. The horizontal velocity component was determined by:

$$V_X = V_0 \cos\theta = R_{CG} / T_F \qquad (2)$$

Whereas the initial CG velocity could be determined:

$$V_0 = V_X / \cos\theta = R_{CG} / (T_F . \cos\theta) \qquad (3)$$

The maximum height of CG was determined by

$$H_{CG} = \frac{V_0^{\,2} \sin^2\theta}{2g} \qquad (4)$$

All other kinemetic parameters were calculated on the monitor and with adequate meter to centimeter conversion.

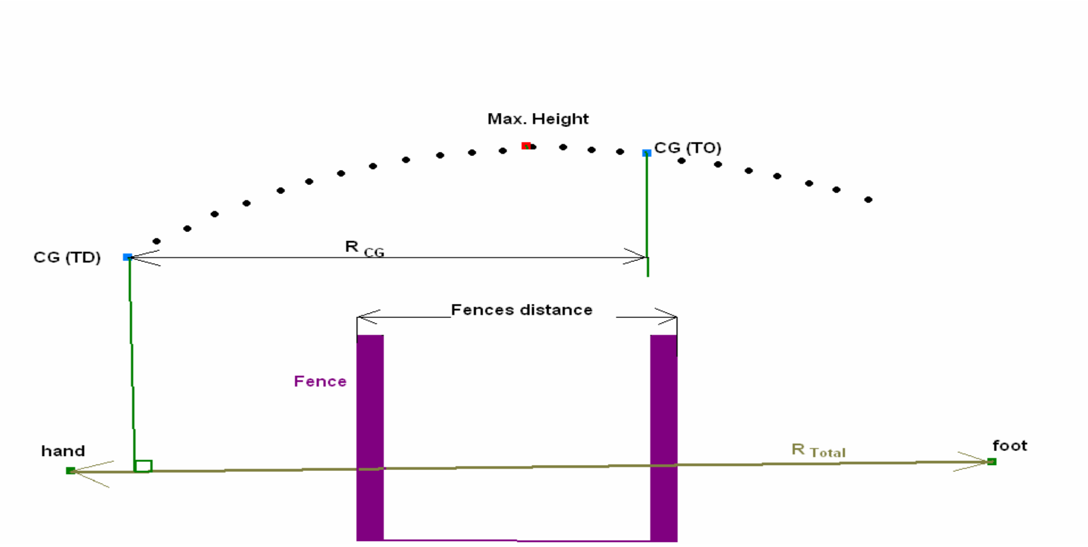

Figure 1 The descriptive schematic of CG displacement relative to total displacement and spread fences

RESULTS AND DISCUSSION:

Three horses jumped the fences at different heights; 1m and 1.4m, three times each. The descriptive statistics of variables and the fence height in each round are provided in Table 1. The first three columns data are dedicated to the fence at 1.4m height, while the next three columns are dedicated to the fence at 1m height. The results indicate that at the take-off kinematics are not so important, and that horses could clear the fence using quite different velocities and body position (Powers, 2002). However, as fence height increased, the kinematic techniques needed to be more precise and consistent. Some obvious trends are evident in the kinematic data (Table 1).

As can be seen, the height of CG in both cases shows that all three horses cleared the fences with quite variable CG angles, horizontal, vertical velocities, total and CG ranges, and time of flights. As the fence height increased, horizontal velocity Vx tended to increase. Vertical velocity Vy has also increased significantly with fence height. The time of flight has also increased significantly with fence height, while the body position did not varry significantly. By increasing the horizontal velocity during the approach, these horses may improve the take-off velocities and therefore the jump outcome, as sufficient forward motion is necessary to generate upward trust during take-off.

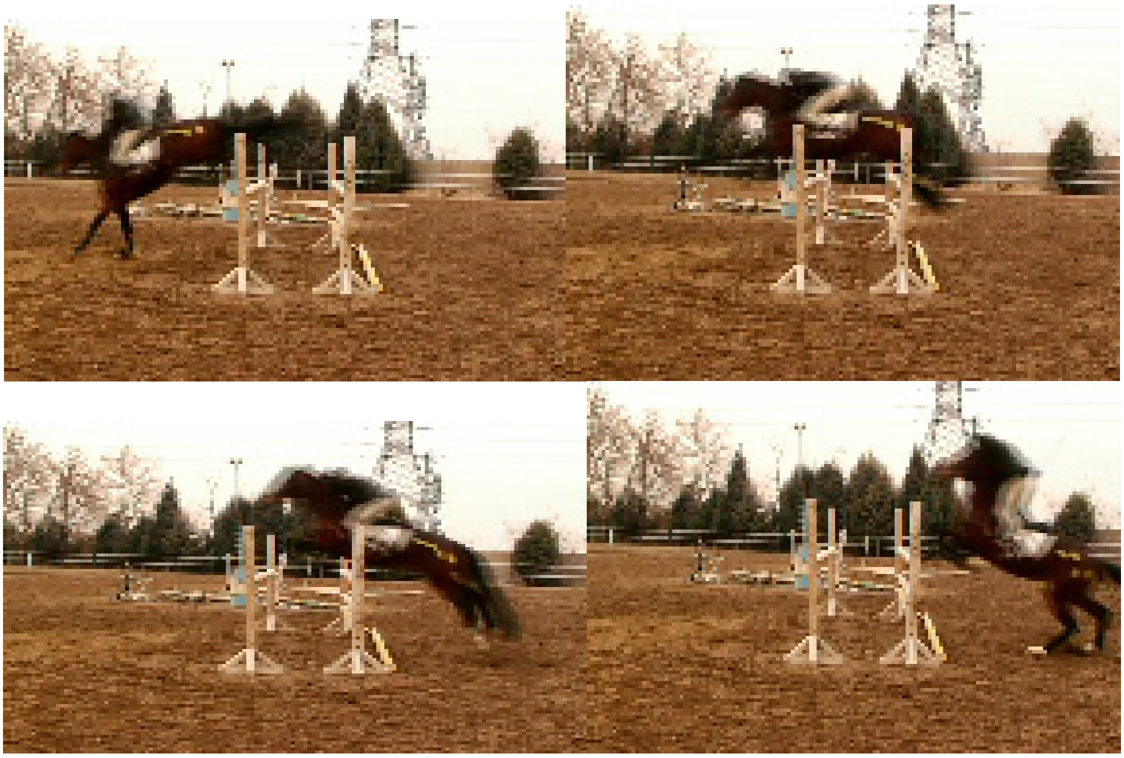

Figure 2 The different sequences of a jump over 140cm height; take-off, flight, and landing phases

Table 1 Variables values ± SD for 1.4m & 1m fences (three rounds)

Rounds	1	2	3	1	2	3
R $_{Total}$ **(m)**	4.80 ± 0.23	4.8 ± 0.26	5.3 ± 0.33	4.12 ± 0.25	4.22 ± 0.12	4.36 ± 0.33
R $_{CG}$ **(m)**	2.65 ± 0.18	3.06 ± 0.21	3.18 ± 0.23	1.52 ± 0.13	1.93 ± 0.02	2.19 ± 0.16
H $_{CG}$ **(m)**	2.05 ± 0.17	1.9 ± 0.19	2.35 ± 0.19	1.97 ± 0.15	2.04 ± 0.23	1.86 ± 0.31
tan θ	0.95 ± 0.06	1.34 ± 0.13	0.98 ± 0.06	0.74 ± 0.03	0.58 ± 0.04	0.79 ± 0.04
Θ (degree)	43.55 ± 1.33	53.35 ± 1.23	44.36 ± 1.33	36.38 ± 1.23	30.12 ± 1.33	38.62 ± 1.38
Vx (m/s)	3.68 ± 0.15	3.32 ± 0.17	3.97 ± 0.18	3.17 ± 0.14	4.02 ± 0.23	3.65 ± 0.37
V (m/s)	5.07 ± 0.32	5.57 ± 0.38	5.56 ± 0.35	3.93 ± 0.33	4.65 ± 0.44	4.67 ± 0.38
Vy (m/s)	3.49 ± 0.23	4.47 ± 0.28	3.89 ± 0.33	2.33 ± 0.15	2.33 ± 0.13	2.91 ± 0.18
X (foot) m	1.75 ± 0.14	1.79 ± 0.13	2.05 ± 0.17	2.00 ± 0.23	1.82 ± 0.27	1.68 ± 0.33
X(hand) m	0.32 ± 0.05	0.08 ± 0.03	0.08 ± 0.04	0.55 ± 0.07	0.53 ± 0.03	0.41 ± 0.08
t $_{flight}$	0.72 ± 0.04	0.92 ± 0.03	0.8 ± 0.05	0.48 ± 0.04	0.48 ± 0.03	0.60 ± 0.03
Δ	0.19 ± 0.02	0.19 ± 0.02	0.19 ± 0.02	0.25 ± 0.03	0.25 ± 0.03	0.25 ± 0.03

CONCLUSION:

A simple method has been introduced to evaluate the take-off kinematics of horses jumping a spread fence. Biomechanic formulae have been established to calculate the kinematic parameters, which agreed well with the results of Powers (2002). By thease kinematic variables at take-off, riders and trainers should be able to improve the jumping techniques used by horses in successful jumping simply by filming, measuring the time of flight, the total jump distance of horse displacement, and using the above formulae.

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Acknowledgement

The authers are thankful to Professor Hassan Gillanpour for the fruitful discussion and Mr. Khosravi for the help he provided regarding data collections, and finally Mr. Assadollah Sarshar for the horses he provided.