THE TAKE OFF KINEMATICS OF JUMPING HORSES IN A *PUISSANCE* COMPETITION

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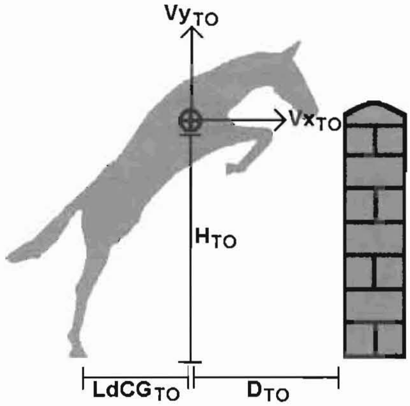
The purpose of this study was to describe the take off kinematics of horses competing in an international *Puissance* competition. A *Puissance* is a high jump competition for horses. Sagittal plane SVHS video recordings (50 Hz.) were made of the 1998 Dublin Horse Show *Puissance* competition. Video sequences were manually digitised and 5 kinematic variables were analysed. For successful performances, fence height was correlated with the following take off variables: vertical velocity of the centre of gravity (CG) ($r = 0.45$, $p = 0.03$); CG height ($r = 0.44$, $p = 0.04$); CG distance from fence ($r = 0.46$, $p = 0.03$); and distance from leading hind limb to CG ($r = -0.61$, $p < 0.01$). The results should help horse riders and trainers improve performance in *Puissance* jumping horses.

KEY WORDS: horse, kinematics, jumping, take off, *Puissance* competition.

INTRODUCTION: The body position and kinematics of a horse's centre of gravity (CG) at take off are important factors determining jump outcome. Few studies have evaluated the CG kinematics in jumping horses. The CG kinematics of horses jumping over relatively small fences (≈1m high) (Powers and Harrison, 2002; Powers and Harrison, 2000) and jumping over a water jump (4.5m wide) (Clayton, et al. 1996) have been evaluated. As an obstacle increases in height, subsequent changes are expected in the take off kinematics. One study examined the effect of fence dimensions on the limb placement of jumping horses, but no analysis was conducted on the CG kinematics (Clayton and Barlow, 1989). For large fence heights (> 1.80m), competition is usually the only source of data. No known study has evaluated the take off kinematics of horses competing in a *Puissance* competition. A *Puissance* competition is a "high jump" competition for show jumping horses, designed to test the ability of a horse to jump a limited number of large obstacles. The first round generally comprises four to six jumps, including a vertical fence, a spread fence and a wall. If more than one competitor clears all these fences, there is a jump-off over the spread fence and the wall only. There can be up to four successive jump-offs, where the height of the wall increases in each round, after which the competition is stopped and equal competitors tie for first place. Currently the *Puissance* record stands at 2.40m set by Franke Sloothaak in 1991. 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, and this study aimed to describe and analyse the linear CG kinematics of take off in horses competing in a *Puissance* competition.

METHOD: SVHS video recordings (50 Hz.) were made of the international *Puissance* competition at the Dublin Horse Show in 1998. A single Panasonic AGDP800 camera (Matsushita Electrical Industrial, Japan) was set up 20m from the centre of the *Puissance* wall. The field of view measured approximately 10m wide and encompassed one full approach stride and the take off phase. Video recordings were manually digitised using Peak Motus 3.2 (Peak Performance Technologies, Colorado, USA). Anthropometrical data of Buchner *et al.* (1997) were used to define the 21 body segments used for digitising and to calculate the location of the horse's total body CG. The riders were not included in the analysis as no information was available on their body masses. In order to scale the measurements in the digitised sequences, the fence height in each round at the point where the horses jumped the wall was taken as the linear reference. Raw coordinate data were smoothed using an optimised cubic spline filter, and the CG velocity and displacement variables were calculated from these filtered coordinates. Five kinematic variables were selected for analysis. These are defined and illustrated in Figure 1, and have been shown in previous studies to be determinants of success in jumping horses (Powers and Harrison, 2000; Powers et al. 1999).



Variable name	Variable description
Vx_{TO}	Horizontal velocity of the horse's CG at take off ($m.s^{-1}$)
Vy_{TO}	Vertical velocity of the horse's CG at take off ($m.s^{-1}$)
H_{TO}	Vertical distance from horse's CG to ground at take off (m)
D_{TO}	Horizontal distance from horse's CG to fence at take off (m)
$LdCG_{TO}$	Horizontal distance from horse's leading hind limb to CG at take off (m)

Figure 1. Variable definitions and abbreviations.

Statistical analyses were conducted in SPSS 10.0 for Windows (Statistical Packages for the Social Sciences, Illinois, USA). Descriptive statistics were calculated for all the measured variables. Pearson's correlation coefficients were calculated to investigate the relationship among the measured independent variables and the dependent variable (fence height) in *successful* horses (i.e. those horses that cleared the fence without making contact). An alpha level of 0.05 was used. Those horses that hit or knocked the fence are referred to as *unsuccessful.*

RESULTS AND DISCUSSION: Nine horses started the competition, and two horses jumped the wall in the fifth and final round. The descriptive statistics of the variables, and the fence height in each round are provided in Table 1. The relationships among the kinematic variables and the fence height are illustrated in Figure 2, along with the calculated correlation coefficients and p-values from the *successful* horses.

Table 1. Descriptive statistics (mean ± sd) of the measured kinematic variables in each round.

Variable (unit)	Round 1 1.80m n = 9	Round 2 1.96 m n = 9	Round 3 2.09 m n = 7	Round 4 2.19 m n = 5	Round 5 * 2.27 m n = 2
Vx_{TO} ($m.s^{-1}$)	5.12 ± 0.77	5.95 ± 0.48	5.71 ± 0.52	5.08 ± 0.37	4.69 & 5.58
Vy_{TO} ($m.s^{-1}$)	3.29 ± 0.77	3.46 ± 0.46	3.71 ± 0.37	3.91 ± 0.30	2.88 & 3.47
H_{TO} (m)	1.92 ± 0.06	1.90 ± 0.05	1.97 ± 0.04	2.01 ± 0.05	1.98 & 2.04
D_{TO} (m)	1.22 ± 0.21	1.39 ± 0.13	1.41 ± 0.16	1.32 ± 0.09	1.56 & 1.58
$LdCG_{TO}$ (m)	0.83 ± 0.08	0.72 ± 0.05	0.67 ± 0.09	0.60 ± 0.11	0.69 & 1.04

* The actual values are provided since there were just two horses in this round

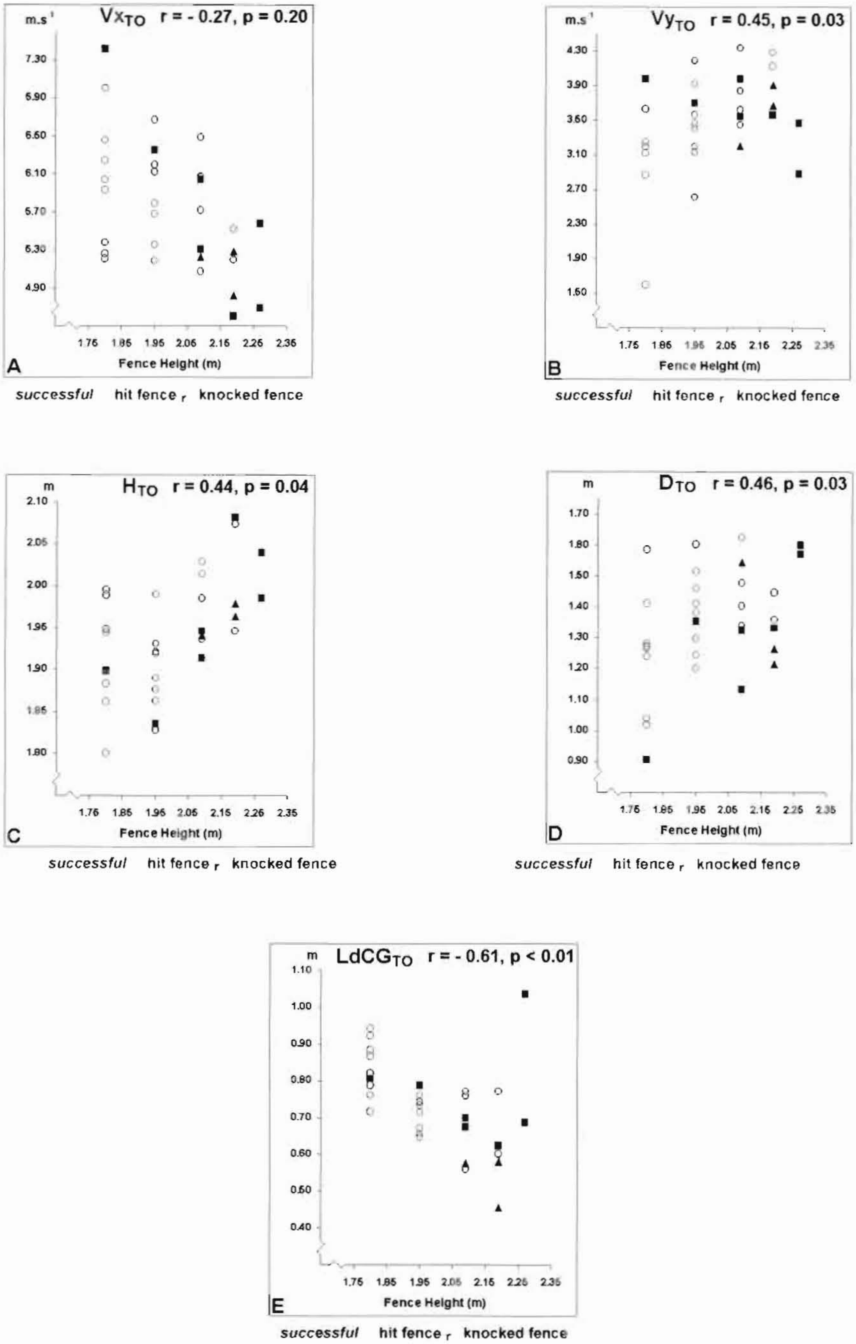


Figure 2. Scatter Plots of Vx_{TO} (A), Vy_{TO} (B), H_{TO} (C), D_{TO} (D) and $LdCG_{TO}$ (E) against Fence Height. Correlation coefficients and p-values are calculated for the *successful* attempts.

The results appear to be most variable in the first two rounds of the competition, and tend to become less variable as the rounds progress. This may indicate that the take off kinematics at the smaller fence heights are not so important, and that horses could clear the fence using quite different velocities and body positions. 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 and Figure 2). As the fence height increased, horizontal velocity (Vx_{TO}) tended to decrease. Vertical velocity (Vy_{TO}) increased with fence height and was significantly correlated with fence height in the *successful* horses ($r = 0.45$, $p = 0.03$). The three body position variables were all significantly correlated with fence height in the *successful* horses. As fence height increased, *successful* horses adopted a more upright body position, by decreased distance between the leading hind hoof and the CG ($LdCG_{TO}$: $r = -0.61$, $p < 0.01$) and increasing take off height (H_{TO}: $r = 0.44$, $p = 0.04$). They also took off further from the fence (D_{TO}: $r = 0.46$, $p = 0.03$). In the final three rounds, the *unsuccessful* horses are inclined to have lower horizontal and vertical velocities at take off (Figure 2A and 2B). This may have reduced the level of impulse required to clear the fence successfully. 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 thrust during take off. As fence height increased, the *unsuccessful* horses seemed have poor body position at take off, with a lower CG height (Figure 2C) and possibly positioned too close to the fence (Figure 2D). These observations are consistent with a previous study on loose jumping horses, which indicated that poor jumping horses have reduced vertical velocities at take off, take off from a lower height and take off closer to the fence that good jumping horses (Powers, et al. 1999).

CONCLUSION: This is the first known study to evaluate the take off kinematics of horses jumping a *Puissance* wall. With increase in the fence height, successful horses increased their vertical velocity at take off, adopted a more upright body position and took off further from the fence. By highlighting the important kinematic variables at take off, riders and trainers should be able to improve the jumping techniques used by horses in *Puissance* competition.

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