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A STUDY ON THE TECHNIQUES USED BY UNTRAINED HORSES DURING LOOSE JUMPING

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SUMMARY

Deterministic models[1] developed for the jumping horse indicated the important factors involved when jumping an obstacle.[2] SVHS video recordings were obtained of 31 untrained horses (age: 3–5 years, height: 164.7 ± 4.5 cm) jumping loose over a fence 1 m high by 0.5 m wide. The horses were designated to either a good group or a poor group based on a qualitative evaluation; good horses (n = 18) cleared the fence with ease, and poor horses (n = 13) consistently hit the fence. Video sequences were digitized to provide kinematic data on the horses' center of gravity (CG) and carpal and tarsal angles. Twenty kinematic variables were examined from the approach to the landing. Analysis of Variance (ANOVA) revealed significant between-group differences for the horizontal velocity of the last approach stride (Good: 5.77 ± 0.80 $m.s^{-1}$; Poor: 6.42 ± 0.95 $m.s^{-1}$; p = 0.046). Significant differences were found in the relative carpal angles at take off (Leading limb: Good: 1.02 ± 0.19 rad, Poor: 1.25 ± .0.28 rad; p = 0.010; Trailing limb: Good: 0.92 ± 0.21 rad, Poor: 1.06 ± 0.15 rad; p = 0.046). The height of the CG over the center of the fence was also a significant variable that differed between the groups (Good: 1.83 ± 0.08 m; Poor: 1.71 ± 0.13 m; p = 0.002). Finally the horizontal velocity of the landing was significant (Good: 5.26 ± 0.92 $m.s^{-1}$; Poor: 6.27 ± 0.84 $m.s^{-1}$; p = 0.004) along with the angle of the CG to the ground at landing (Good: -0.45 ± 0.08 rad; Poor: -0.38 ± 0.07 rad). The velocity and CG variables which distinguished good and poor horses are likely to be strongly influenced by a rider; therefore, it is unlikely that these data alone could be used to predict elite jumping horses. The carpal angle data, however, may indicate a certain natural tendency by the young horses in the good group to keep their legs clear of the fence.

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INTRODUCTION

The use of the horse as a sports animal has increased progressively over the past few decades. This has resulted in increased interest in the locomotion and movement of horses in a range of sports like racing, dressage, eventing and show jumping. Kinematics of dressage horses and horses working on the flat has been the subject of much research.[3,4] Several studies have been carried out on kinematic aspects of horse racing,[5,6] eventing[7,8] and elite show jumping.[9–13] Despite this, the whole area of equine biomechanics still lags behind that of human locomotion research. Advances in biomechanical analysis research have changed the way people train, the equipment they use and the way they rehabilitate after injury.

Many potential sport horses are chosen at an early age before any training, and have usually never been ridden. Factors like pedigree and conformation are important considerations when choosing an animal for purchase; however, methods of testing the actual performance ability of the unridden horse are limited to work on the lunge, or loose schooling.

During lungeing, the trainer has some control over the direction the horse takes and the speed at which it moves. However, the horse's true movement may be inhibited, as it is not entirely free to move as it wishes. With loose schooling, the horse is essentially free to move in whichever way it chooses, and this method more accurately portrays its motion and technique.

With jumping, a horse that shows ability when lunged or loose jumped is favored, although this is no guarantee that the animal will become an elite jumper. Only a few horses reproduce, when ridden, what they promised when jumped loose, but even fewer of those horses that show nothing at all on the lunge or loose, become successful jumpers.[14] Thus, jumping on the lunge or loose jumping are probably the only methods of assessing potential ability in the young unridden horse.

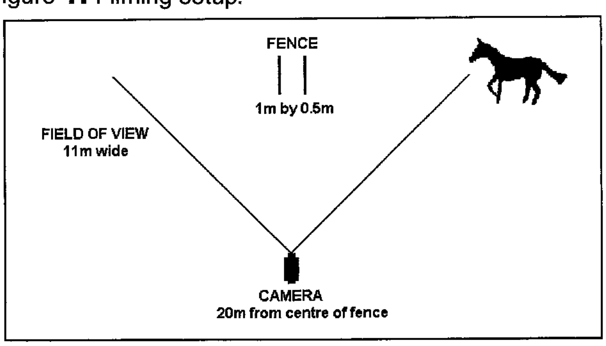
This study aimed to explore specific kinematic factors during loose jumping, and examined the hypothesis that good and poor untrained jumping horses have different kinematics during the jumping sequence.

Biomechanical models developed for the jumping horse[2] were used to identify and aid selection of the analysis variables. The models indicated the importance of the approach, take off and landing phases as part of the whole jump process. The take off is crucial since the trajectory of flight is determined at this point. The model for the horse was adapted directly from the models of Hay,[1] and from other studies in equine jumping kinematics.[15]

MATERIALS AND METHODS

Video recordings (50Hz.) were collected of 35 inexperienced horses jumping loose over a parallel fence measuring 1m high by 0.5m wide. Filming took place in a large, well-lit indoor arena. The owners of these horses signed an informed consent form beforehand, giving permission to videotape their horses jumping this fence, and to use these data for research purposes. The filming set-up is illustrated in Figure 1. A single Panasonic AG450 Camcorder was placed perpendicular to, and approximately 20m from the fence. The field of view was approximately 11m wide. This allowed the recording of one approach stride and the jump stride for each horse, which includes the take off phase, the flight phase and the landing phase. For calibration, a reference pole of length 4m was placed on the ground in the plane of the movement of the horses' jump. This procedure has been found to produce acceptable levels of accuracy using the Biomechanics Workstation©.[16] After videotaping the reference pole, it was removed for the horses' jump attempts.

Figure **1**. Filming setup.

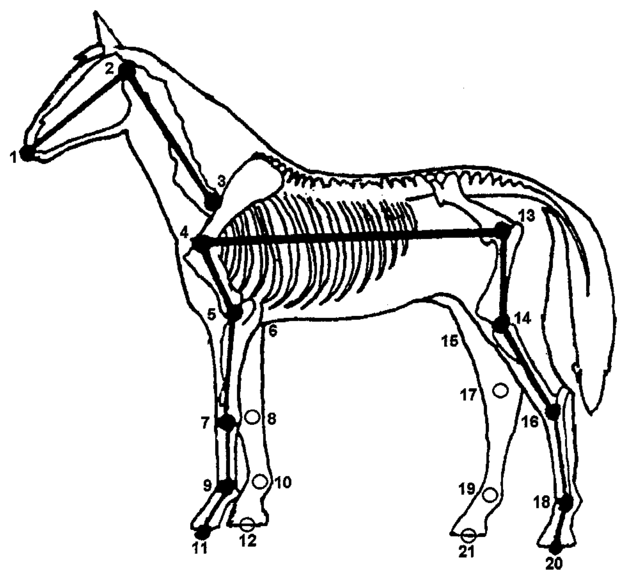


All horses were allowed a short warm-up period involving trotting, cantering and a few practice jumps over some small fences. Three to four recordings were made of each horse attempting the experimental fence. Place poles were used, where necessary, to help some of the horses attain an appropriate distance from the fence at take off. This is a common practice used with young, inexperienced horses. The place poles were positioned at a particular distance from the fence encouraging the horses to take one complete stride between the pole and the fence. The exact distance this pole was from the fence was judged by an experienced horseperson. Several helpers were available to encourage horses to jump the fence; however, none of the horses was forced over the fence. Horses that persistently refused to jump the fence were omitted from the study, i.e. four horses. A total of 31 horses were included for analysis.

Horses approached the fence in an counter-clockwise direction, and were required to jump the fence at a canter. No specification of lead leg was required, as both limb sets of the horse were digitized.

For each horse an appropriate jump trial was selected for digitization. Jump attempts were excluded if a horse refused or if the gait pattern before the fence became disrupted, e.g. if the horse was spooked, or broke into a trot. The video sequences were digitized manually using The Biomechanics Workstation©.[17] This system used an Acorn Archimedis computer, Arvis digitizer and SVHS Panasonic AG7350 video recorder. The system's spatial accuracy has been evaluated according to the guidelines of Pedotti and Ferrigno[18] and has an accuracy of 0.171% of the diagonal field of view.[16]

Figure **2**. Illustration of body segments and anatomical points.[19]



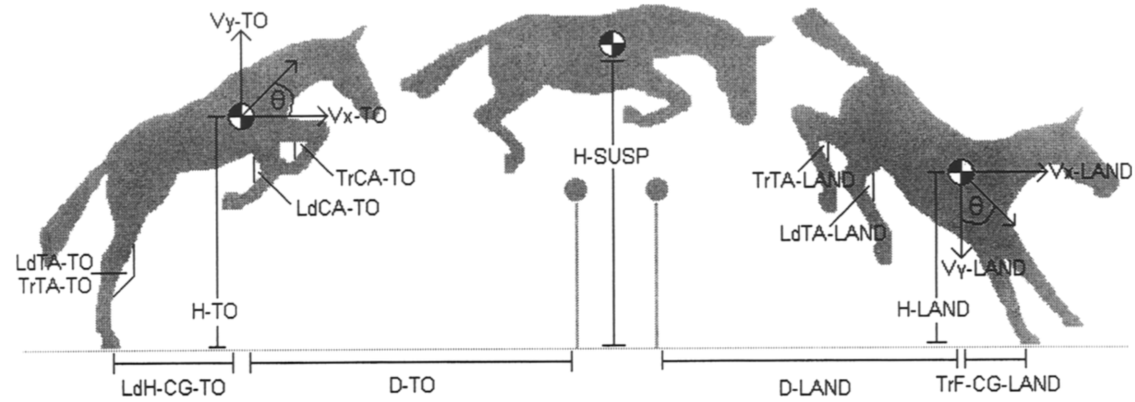


Figure **3.** Illustration of variable abbreviations and definitions.

O = Centre of Gravity
Approach:
VXSTRIDE AI (not shown): Horizontal velocity of the CG in the final Approach Stride
Take Off:
VX_{TO}: Horizontal velocity of the CG
VY_{TO}: Vertical velocity of the CG
O_{TO}: Angle of the CG
H_{TO}: Vertical distance from the CG to the ground
D_{TO}: Horizontal distance from the CG to the 1 st element of the fence
D_{TOOPT} : Compares the D_{TO} of both groups with the mean D_{TO} of the good group
$LdHCG_{TO}$: Horizontal Distance from the Leading Hind Limb to the CG
$LdTA_{TO}$: Leading Tarsal Angle
$TrTA_{TO}$: Trailing Tarsal Angle
$LdCA_{TO}$: Leading Carpal Angle
$TrCA_{TO}$: Trailing Carpal Angle
Suspension Phase:
H_{susp}: Vertical height from the CG to the ground over the center of the fence
Landing:
VX_{LAND}: Horizontal velocity of the CG
VY_{LAND}: Vertical velocity of the CG
O_{LAND}: Angle of the CG
H_{LAND}: Vertical distance from the CG to the ground
D_{LAND}: Horizontal distance from the fence to the 2nd element of the fence
$TrFCG_{LAND}$: Horizontal distance from the CG to the Trailing Forelimb
$LdTA_{LAND}$: Leading Tarsal Angle
$TrTA_{LAND}$: Trailing Tarsal Angle

A total of 22 points defining the joint center loci and body segment parameters of the horse were digitized using the appropriate segmental data for the horse.[19] These points and segments are illustrated in Figure 2. The total body CG was calculated from the joint center loci and body segment parameters using the sum of moments technique recommended by Hay.[20] Markers were glued to the left-hand side of the horse to aid digitizing of the relevant anatomical reference points as recommended by Plagenhof.[21]

Twenty variables were examined and these are defined and illustrated in Figure 3.The distance measurements were calculated from the respective co-ordinate data. (D_{TO}^{OPT} was calculated after D_{TO} was computed for each group. This variable compared the take off distance of each group with the mean D_{TO} of the good group; i.e. this distance was used as an optimum value.) Horizontal and vertical velocities of the CG at take off were calculated from the digitized data. Angles of the carpi and tarsi at take off and landing were also computed from the co-ordinate data. The terms leading and trailing as defined by Leach et al.[22] were used to identify these limbs.

Optimized cut-off frequencies for all co-ordinate data of the jumping horse were calculated by residual analysis.[23] Co-ordinate data were then filtered at the appropriate optimum cut-off values using a 4^{th} Order Butterworth Filter. For the CG variables the optimized cut-off frequency was calculated as 5.66Hz (this was rounded up to 6Hz, as The Biomechanics Workstation© only allows integer number cut-off values.). For the carpal angle data, the cut-off value was 4.89Hz (rounded up to the nearest integer value of 5 Hz), and for the tarsal angles the cut-off value was 6.21 Hz (rounded down to the nearest integer value of 6Hz).

Horses that cleared the fence with ease on each occasion were designated to the 'good' group, while horses that consistently hit or knocked the fence were designated to a 'poor' group. The horses' ages were recorded from January first of that year. Their heights were also recorded and were taken at the withers by means of a measuring stick. ANOVA was used to determine differences in the measured parameters between groups. Descriptive statistics (means and standard deviations) and ANOVA were calculated on Minitab.

RESULTS

From the qualitative assessment, 18 horses were assigned to the good group, and 13 to the poor group. Table 1 gives details on mean age, height of the two groups.

Table 2 provides the descriptive statistics and the results of the ANOVA.

Table **1.** Horses used in the study.

Details	Good	Poor	p-value
Age	3.5 ± 0.7 years	3.8 ± 0.7 years	0.31
Height	165.2 ± 4.5 cm	164.2 ± 4.5 cm	0.54

Table **2.** Descriptive statistics and p-values of the horses in each group.

Variable	Unit	Good horses Mean ± sd	Poor horses Mean ± sd	p-value good =poor
$VX_{STRIDE\ AI}$	$M.S^{-1}$	5.77 ± 0.80	6.42 ± 0.95	0.046
VX_{TO}	$M.S^{-1}$	5.69 ± 0.95	6.41 ± 1.12	0.061
VY_{TO}	m.s	1.58 ± 0.31	1.53 ± 0.41	0.700
O_{TO}	rad	0.28 ± 0.06	0.24 ± 0.05	0.066
H_{TO}	m	1.71 ± 0.09	1.65 ± 0.11	0.616
D_{TO}	m	0.40 ± 0.17	0.33 ± 0.27	0.076
D_{TO}^{OPT}	m	0.12 ± 0.11	0.22 ± 0.17	0.395
$LdHCG_{TO}$	m	1.15 ± 0.15	1.12 ± 0.20	0.084
$LdTA_{TO}$	rad	2.47 ± 0.08	2.70 ± 0.09	0.010
$TrTA_{TO}$	rad	2.85 ± 0.11	2.79 ± 0.11	0.046
$LdCA_{TO}$	rad	1.02 ± 1.25	1.25 ± 0.28	0.186
$TrCA_{TO}$	rad	0.92 ± 0.21	1.06 ± 0.15	0.149
H_{SUSP}	m	1.83 ± 0.08	1.70 ± 0.12	0.002
Vx_{LAND}	m.s	5.26 ± 0.92	6.27 ± 0.84	0.004
Vy_{LAND}	$m.s^{-1}$	-2.48 ± 0.31	-2.44 ± 0.35	0.770
O_{LAND}	rad	-0.45 ± 0.08	-0.37 ± 0.07	0.011
H_{LAND}	m	1.51 ± 0.09	1.47 ± 0.08	0.264
D_{LAND}	m	1.35 ± 0.33	1.57 ± 0.41	0.102
$TrFCG_{LAND}$	rad	0.35 ± 0.28	0.41 ± 0.20	0.505
$LdTA_{LAND}$	rad	1.34 ± 0.24	1.26 ± 0.22	0.535
$TrTA_{LAND}$	rad	1.40 ± 0.27	1.32 ± 0.27	0.484

Approach and Take Off Phases

The first variable examined $Vx_{STRIDE\ A1}$ was found to be significant between the groups, with the mean velocity of the poor group being significantly higher than that of the good group. A similar difference in Vx_{TO} was evident at the point of take off, but this was not significant. Vy_{TO} was similar in all horses in the study. Variable 0_{TO}, which is calculated from Vx_{TO} and Vy_{TO}, appeared to be steeper in the good group but not significant at the 0.05 level.

Differences in variable H_{TO} were evident between the groups, with a greater mean height achieved by the horses in the good group, but the difference was not significant. Variable D_{TO} was greater in the poor horses but again not significant. This may be due to the large spread in scores among the poorer horses. It was decided, therefore, to examine the variable D_{TO}^{OPT}. Again this variable was not significant but the difference in variability between the two groups may imply that the good horses were more accurate in achieving an optimum take off distance. Variable $LdHCG_{TO}$ was similar between the groups and not significant.

Tarsal angles ($LdTA_{TO}$ and $TrTA_{TO}$) of both hind limbs were larger in the good horses, but not significantly different. The carpal angles ($LdCA_{TO}$ and $TrCA_{TO}$), however, were significant between the groups, with the horses in the good group having greater flexion in their forelimbs than their poor counterparts.

Suspension and Landing Phases

During the suspension phase the difference between the groups was highly significant, with the good horses achieving a higher H_{SUSP} value over the center of the fence. At landing Vx_{LAND} was significant between the groups, with the poor horses retaining an increased horizontal velocity. Variable Vy_{LAND} was almost matching for both groups and not significant. θ_{LAND} was significant, with the good horses having a steeper angle of landing.

The horses in the successful group had a higher H_{LAND} than the poor horses, and landed closer to the fence with a lower D_{LAND} value, however none of these variables was significant between the groups. Neither was there a significant difference in variable $TrFCG_{LAND}$.

Little difference was found between the groups for the final two variables examined $LdTA_{LAND}$ and $TrTA_{LAND}$.

DISCUSSION

The horses in the poor group had an increased approach horizontal velocity, and this remained high during the take off and landing phases. This factor may have affected these horses' abilities in achieving more optimum values in some of the other variables, e.g. judgement of speed and distance from the fence.

Other clearly significant variables at take off were the carpal angles, which were smaller in the good horses suggesting that good horses have greater ability and possibly quicker reactions in controling their limb orientations than their poor counterparts. The fact that the poor horses had a higher horizontal velocity at take off may have given them less time to flex at their carpi at take off. The extent of the rider influence on the carpal angles is not known, but it may be improved through suitable training. It may be that good horses have an inherent ability to effectively tuck their legs up during the jump. This theory is supported by the results of Clayton,[24] who examined the kinematics of two groups of cutting horses and found that the elite horses had faster reaction times than non-elite. Clayton[24] suggested that the reaction times could be a useful predictive feature. Our data supports the notion that Clayton's[24] findings may also apply to good and poor young jumping horses.

The highly significant H_{SUSP} is important. This complex variable results from a combination of Vx_{TO}, Vy_{TO}, H_{TO} and D_{TO}. The fact that the good horses achieved a higher position over the center of the fence indicated a successful combination of the take off variables. Various factors may account for the lower height achieved by the poor horses. For example, the increased horizontal velocity of the poor horses during the approach and at take off may have reduced the time necessary to generate sufficient vertical forces during the final touch down of the approach stride, and during the take off itself. Although the Vy_{TO} proved to be insignificant between the groups, factors like the height at take off and the distance from the fence along with the lower Vy_{TO} of the poor horses may have accentuated this. Another possibility may be due to hitting the fence. Those poor horses hitting the fence during the early part of the suspension phase will have reduced their maximum possible flight height due to the loss of vertical velocity. Finally, the orientation of the body segments during the suspension phase would affect the positioning of the CG within the horses.

At landing the horizontal velocity (Vy_{LAND}) was significantly higher in the poor group of horses and this resulted in a significant reduction in their angle of landing (θ_{LAND}). These factors may have resulted in these horses landing further from the fence (D_{LAND}). This would have implications for training and during competition for example if another fence was positioned a stride or two away from the first (this combination of fences is known as a double), which would leave less room for the horse/horse and rider to adjust for the second fence. The importance of this can be appreciated when watching a horse jumping competition, where there may be one or two doubles or trebles to negotiate.

From these results, the tested hypothesis, i.e. the kinematics of good and poor untrained jumping horses are different, is accepted. However, in a study like this, it would be unwise to focus entirely on those variables with statistical significance, and it is worth examining the variables close to the 0.05 level. These variables could indeed warrant further research.

At takeoff, aspects such as H_{TO} and D_{TO}^{OPT}, which were approaching statistical significance, are important mechanical factors in jumping. The difference found between the groups for H_{TO} indicated that the good horses adopted a more suitable body position at take-off than the poor horses. This is considered an important factor since the overall height achieved by a body's CG is influenced by its height at take off.[2]

Although there was little difference in the variable D_{TO}, the difference in D_{TO}^{OPT} between the two groups was interesting. As stated above, place poles were used during the loose jumping in order to assist the horses in their take-off distance; however, even with this assistance, the poor horses were unable to accurately judge an appropriate take off distance, indicating that perhaps their spatial awareness was of a lower level.

Another variable close to significance was θ_{TO}. The successful horses had an increased angle of take off, which is comparable with the results of a study examining water jumpers,[12] in which successful water jumpers had a significantly greater take off angle than their non-successful counterparts. It is worth highlighting that the CG variables found to be most different between the groups during the approach and take off, i.e. $Vx_{STRIDE\ A1}$, Vx_{TO}, θ_{TO}, H_{TO} and D_{TO}^{OPT}, are probably under the control of a rider, and the presence of such may result in somewhat different results. By altering the stride length and stride frequency of the horse an experienced rider can regulate the approach speed, and can 'place' the horse in a chosen position in front of the obstacle to be jumped. In turn this would have an effect on D_{LAND} and Vx_{LAND}. He can also influence the position of the combined horse and rider CG by altering his own body position at take off, and this would affect the height achieved over the fence (H_{SUSP}).

Finally, it is interesting to note that some of those variables that were not significant for the groups in this study have been shown to be important variables in other jumping studies. For example, in this study $LdHCG_{TO}$ showed no significance between the groups. This is contrary to the findings of a study that examined the differences between successful and unsuccessful horses jumping a water jump - here a significant difference ($p<0.01$) was found for the horizontal distance between the leading hind hoof and the CG of the horse at lift off.[15] The different fence type examined in this study, i.e. a water jump, may account for the different findings; and the fact that they examined an elite population of horses would have an influence on the results.

The tarsal angles at take off, although not significant, seemed to imply that the good horses had greater extension in their hind limbs. This would help to increase their body height at take off, and this final push-off by the hind limbs is considered to be the major factor contributing to a successful jump.[11]

CONCLUSIONS

Many of the mechanical differences in the variables between good and poor horses are most likely under rider influence, implying that these data alone would be unsuitable as a means of selecting future elite jumpers. The results from the angle data are perhaps a more promising indicator of talent.

Further research is required in order to select those variables, and the values of such variables, that identify potential elite jumpers at an early age. Nevertheless, the practice of purchasing young, untrained horses based on their breeding, conformation, and a subjective evaluation of their general movement and jumping ability still continues, both privately and at public auctions.

The results of this study indicate that there are very specific factors involved in assessing the jumping ability of different horses, for example, the horizontal velocity of the approach, the body position and distance at take off, the carpal angles at take off and the height achieved over the fence. Using simple video techniques, these factors can be easily evaluated at minimal cost. A video camera and video tape recorder, with frame-by-frame playback facilities, is all that is required to conduct a thorough and useful qualitative analysis. Once these factors have been identified, the trained eye can assess many of these performance characteristics. It should be possible to evaluate visually a horse's consistency in achieving a suitable takeoff distance (this may be an indicator of the horse's spatial judgement). It should also be possible to visually evaluate a horse's ability to raise the CG (this would reflect the horse's strength and technique enabling it to raise and elevate its trunk). Finally the trained eye may also evaluate the quickness in tucking the forelimbs, which has traditionally been favorably regarded. This more systematic evaluation of performance ability should be encouraged, rather than relying on the current methods of evaluation, which appear to rest heavily upon an aesthetic assessment of jumping horses.

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