



## Original Research

## Horse and Rider Interaction During Simulated Horse Jumping

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## ABSTRACT

This descriptive study uses a biomechanical simulation to illustrate the effect of rider's body position on a horse's motion during the flight phase of a horse jump. Eleven horses were video-recorded performing six jumps each (three with and three without rider) for a total of 66 jumps. A simulation software program analyzed reference points on the riders' and horses' bodies (body position) during the jumps. The rider was modeled as a single-segment trunk with the knee joint fixed to a point on the horse's side, and with the hip and knee free to flex. The program compared the horses' movements with and without riders, with the most significant differences seen in the angles between the horses' necks and bodies. Changes in the angles between the horses' neck and body segments appeared to compensate for the riders' movements, enabling the horses to maintain balance throughout the jump sequences. We concluded that a horse adapts to faulty rider position by changing the angle of its neck relative to trunk. This information is relevant to rider and horse safety and to improve jump training and performance.

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## 1. Introduction

The biomechanics of horse jumping have been researched over the past 15 years, with previous studies focusing on linear kinematics. Elements of those studies have included characteristics of gait [1], limb positions [2], movement of the Center of Gravity (CoG) at jump takeoff and landing [2,3], and reaction forces at takeoff [1]. Clayton [3] explored the importance of the horse's angular momentum, as it might be a factor in improving a rider's trunk movements. To date, however, the impact of a variety of other factors that may influence jumping results, including rider posture, remain unexamined.

The rider's influence on the horse has been researched only sporadically. Schöllhorn et al. [4] examined the interaction of horses and riders during basic movements and control of the horse.

**Animal welfare/ethical statement:** The study was approved by the Charles University research ethics committee and written consent was provided by all participants.

**Conflict of interest statement:** The authors declare no conflicts of interest.

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The authors identified rider-horse interactions by means of data gathered via artificial neural network and analyzed in the time-continuous pattern. They concluded that their time course-oriented approach provided a sensitive tool for quantifying the interaction of the rider and horse.

Galloux and Barrey [5] investigated the influence of the rider and the principal body segments of the horse on the total angular momentum of the horse-rider system. They concluded that the rider and the horse's trunk provided only a small contribution to total angular momentum; however, during the transfer of horse and rider's combined angular momentum in the jumping flight phase, the horse's forelimbs showed an increase in angular momentum, and its head and neck showed a decrease in angular momentum [4,6]. Following this research, Powers and Harrison [6] examined the relative influence of the rider and specific segments of the horse's body on the net angular momentum of the jumping horse. The authors found minimal rider influence on the moment of forces created by the jumping horse. The horse's trunk contributed less to the net angular momentum than did its head, neck, forelegs, or hind legs. Furthermore, the rider added little to the net angular momentum during the flight phase. The authors noted the transfer of the horse's angular momentum among the individual body segments during the flight phase, most obviously demonstrated in the angular momentum increase of the "chest" extremities corresponding to a decrease in the angular momentum of the horse's

head and neck. The net angular momentum was found to be almost constant during the flight phase for the horse under conditions with and without a rider.

The model in this study did not take the horse limb movements into consideration. The simulation was simplified and did not include influences on the flight phase of a jump. However, by omitting the limbs, neck movements were the model horse's only measurable response to perturbations. This is, admittedly, a weakness of this study. Regardless, the simplified simulation's primary purpose was to show the horse's neck ability to respond to incorrect position of the rider during the flight phase. The researchers are aware of this limitation but maintaining this study could become the foundation for further, more precise, horse-and-rider modeling during the flight phase of a jump.

Patterson et al. [7] researched the differences between the experienced and novice riders and described the net head acceleration, arm position, and their overall acceleration. Other authors investigated the interaction between horse and rider at different trots [8], and biomechanics of a jump of a horse over the obstacles with and without the rider was researched by Lewczuk et al. [9].

This study hypothesized that nonzero angular momentum of the rider's body is created during rider movement backward (or forward) at horse takeoff and then the rider's CoG is misaligned with the horse's takeoff force vector. In other words, when the rider moves incorrectly (i.e., movement that changes the common CoG), the horse compensates for the rider's shift by moving its neck and head in the opposite direction.

This study examines the role of the horse's neck in compensating for errors in rider trunk position and independent balanced seat [10] during the flight phase of a jump. The purpose of this descriptive study was to show that simulation confirms that a balanced posture of the rider allows the horse to improve its jumping height ability for 10–20 cm and increase success in clearing obstacles.

## 2. Materials and Methods

The study was approved by the institutional research ethics committee and written consent was provided by all participants. Five male professional riders ( $33 \pm 3.77$  year old) who achieved the "Silver Tour" jumping level volunteered in the study, and 11 horses of various breeds, sex, and age ( $8.55 \pm 0.39$  year old), trained at the medium proficiency level, were used for data collection. Other horses' body parameters include height ( $1.70 \pm 0.06$  m), length ( $1.69 \pm 0.08$  m), trunk circumference ( $1.95 \pm 0.11$  m), length of back ( $1.47 \pm 0.10$  m), and body mass ( $555 \pm 81.27$  kg).

Thirteen retroreflective markers were attached unilaterally on obvious anatomical locations to define rigid body segments of the horse and rider and construct a biomechanical model. The body segments were defined as the horse's neck segment and rider's trunk segment. Markers were placed on the following locations of each horse (chin, ear, withers, shoulder, elbow, tail root, and knee) and its rider (heel, knee, hip, shoulder, and top of head).

The horse and rider body positions were videotaped using one static digital camera (Sony DCR-TRV 110E, Sony Corporation, Tokyo, Japan; shutter speed 1/1000 seconds, video resolution 400 Kpix) that allowed for two-dimensional (2-D) analysis of their motions. The camera, used for qualitative assessment, was placed 13 m distance from the horse and rider, and perpendicular to their movement. The riders, while riding on a horse, were asked to take three body postures by feeling. One was the correct rider position and two were incorrect positions, specifically, ahead of and behind the movement. "Ahead of" (or "behind") the movement indicates the rider leans his trunk more forward (or backward) than the

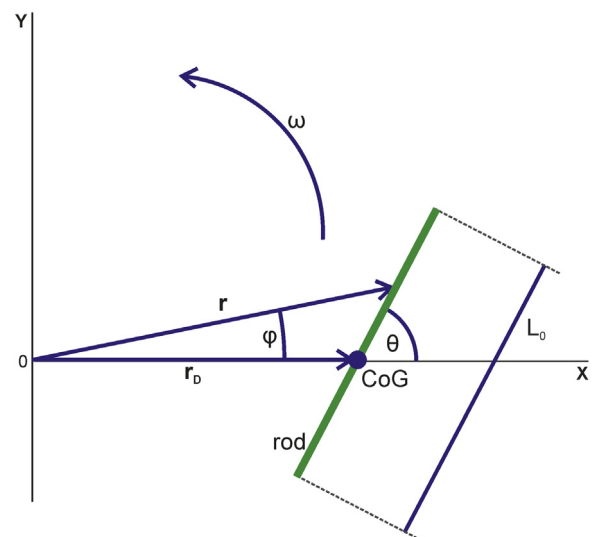
horse's takeoff force vector. These body positions are described in the model that defines the rider's trunk during the flight (Fig. 1).

Each recorded jump trial began one canter stride before the horse's takeoff, continued through takeoff, and the "flight phase" over the obstacle and the landing, and concluded with one full canter stride after landing [3]. The horses were videotaped jumping over obstacles 0.8, 1.0, and 1.2 m in height and six separate recordings were taken of each horse (i.e., once over each of the three obstacle heights with and without a rider), for a total of 66 trials [11] over a 6-day period. In addition, the horizontal distance from a horse's takeoff to its landing was measured using a tape measure and recorded. The three obstacle heights were chosen to see whether the height of the obstacle influenced the jumping style of the horse.

The video images were transferred to the Adobe Photoshop program (version 7.0 CE; Adobe Systems Incorporated, San Jose, CA, USA) to manually digitize the jump-flying sequences. The analysis was twofold: images of the horses alone were analyzed, then the video images of each horse with its rider were overlaid onto the images of that same horse without a rider to compare the horse's neck position during flight during the two different testing states (i.e., with and without rider). Angles between body segments of the horse and rider were measured using a commercially available program (QuickPHOTO Industrial 2.3, PROMICRA s.r.o, Prague, Czech Republic). A script written in MATLAB (MathWorks, Natick, MA, USA) and a program written in C++ (Borland C++ Builder, Embarcadero Technologies, San Francisco, CA, USA) were used to calculate basic kinematic parameters (i.e., linear and angular velocities and accelerations of the horse and rider's trunk). The video and data were used to create a model for analysis, which represented as realistic a situation as possible by combining mechanical measurements and the empirical experience of the rider.

### 2.1. Model of the Horse and Rider Body Systems and Their Simulation

Incorrect rider movements were defined by a model created with the help of a rod to establish the ideal position of the rider's trunk with respect to the horse's neck. Rider errors and ideal



**Fig. 1.** Theoretical model of movement of the rider's trunk, represented by a rod pivoting around the center of rotation. Abbreviations:  $L_0$ , length of rod;  $r$ , position vector;  $r_0$ , vector pointing to the CoG of the rod;  $O$ , center of rotation (origin of the perpendicular Cartesian axes);  $\omega$ , angular velocity;  $\phi$ , angle between position vector  $r$  and axis  $x$ ;  $\theta$ , angle between the rod and axis  $x$ .

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