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The kinematics and kinetics of riding a racehorse: A quantitative comparison of a training simulator and real horses

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ABSTRACT

Movement of a racehorse simulator differs to that of a real horse, but the effects of these differences on jockey technique have not been evaluated. We quantified and compared the kinematics and kinetics of jockeys during gallop riding on a simulator and real horses. Inertial measurement units were attached mid-shaft to the long bones of six jockeys and the sacrum of the horse or simulator. Instrumented stirrups were used to measure force. Data were collected during galloping on a synthetic gallop or while riding a racehorse simulator. Jockey kinematics varied more on a real horse compared to the simulator. Greater than double the peak stirrup force was recorded during gallop on real horses compared to the simulator. On the simulator stirrup forces were symmetrical, whereas on a real horse peak forces were higher on the opposite side to the lead limb. Asymmetric forces and lateral movement of the horse and jockey occurs away from the side of the lead leg, likely a result of horse trunk roll. Jockeys maintained a more upright trunk position on a real horse compared to simulator, with no change in pitch. The feet move in phase with the horse and simulator exhibiting similar magnitude displacements in all directions. In contrast the pelvis was in phase with the horse and simulator in the dorso-ventral and medio-lateral axes while a phase shift of 180° was seen in the cranio-caudal direction indicating an inverted pendulum action of the jockey.

1. Introduction

The modern ‘martini glass’ jockey position was introduced in the 19th century and has been credited with a 5–7% reduction in race times (Pfau et al., 2009). In this position, 90% of the jockeys' mass is distributed over the withers (Fruehwirth et al., 2004), however, it has been proposed that jockeys are able to mitigate any deleterious effects by isolating their centre of mass (COM) movement from that of the horse (Pfau et al., 2009). Consequently, peak force under the saddle (Fruehwirth et al., 2004; Geser-von Peinen et al., 2013), mechanical work of the horse (De Cocq et al., 2013) and extension of the horse's back (De Cocq et al., 2010) are reduced compared to the classical seated trot and canter position, with a proposed reduction in injury risk and work of galloping.

Optimal stability in riding is traditionally ascribed to perfectly synchronous movement of horse and rider. This suggests that the traditional sitting trot and canter are the most stable scenarios (Wolframm et al., 2013; Viry et al., 2013) and the modern jockey position with its isolated centre of mass (COM) (Pfau et al., 2009) the least stable. Despite the apparent instability associated with this modern position, the reduced pressure under the saddle and mechanical work benefits of this position outweigh the reduced stability and increased risk of falls. More skilled riders are known to be at a lower risk of falling (Hitchens et al., 2012) with some studies reporting fewer fatal limb fractures in horses ridden by more skilled jockeys (Parkin et al., 2004). Skill comes with repeated training over time. With the financial burden of horse management and the ever-increasing campaign to improve horse and jockey welfare, the use of simulators to facilitate training and to aid in refining race jockey technique is increasingly common. In some cases racehorse simulators are used during assessment of jockey competency prior to licensing.

The physical effort and stress of riding a simulator have been compared to that of riding a real horse, and found to be significantly different with respect to the work carried out by the jockeys and stress levels associated with each scenario (Ille et al., 2015). Significant differences have also been found between the movement trajectory exhibited, with real horses showing significantly greater dorso-ventral and medio-lateral displacement amplitudes and smaller cranio-caudal displacement amplitudes (Walker et al., 2016). While it is commonly recognised by jockeys that the movement of the simulator is different from that of real horses, to date no studies have quantified the effect of these differences on jockey position and movement. If the position and

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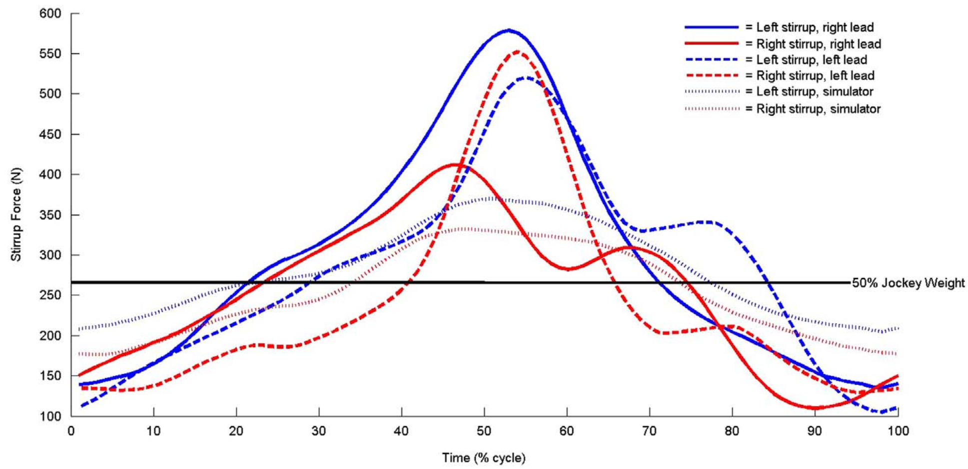

Fig. 1. Mean stirrup forces (blue-left, red-right) during a single gallop cycle for a single jockey during right lead (solid line) and left lead (dashed line) during gallop on a real horse and on a racehorse simulator (dotted line). The solid black horizontal line at 266 N represents half the body weight of this jockey. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Jockey experience categories.

Experience Level	Description
Intermediate	Working full time for over 1 year, holds a licence but less than 20 rides – recently got licence e.g. done Apprentice licence course in last yr.
Experienced	Riding over 3 years, has held licence for more than one year, had over 20 rides and ridden up to 20 winners corresponding to Apprentice Continuation Course.
Elite	Has held a licence for over 3 years, ridden over 20 winners and riding races on a daily basis.

movement of the jockey are comparable between a simulator and real horse this supports the efficacy of simulator use during training.

1.1. Aim

Quantify and compare the kinematics and kinetics of jockeys during gallop riding on a simulator and on real horses.

1.2. Objectives

Quantify displacement of the jockey pelvis and feet and pitch of the trunk relative to movement of the horse/simulator.

Record forces exerted through the stirrups by the jockey on a simulator and real horse.

Compare the parameters recorded from each scenario.

1.3. Hypothesis

Jockeys exhibit larger and more varied force and displacement on real horses compared to simulator trials.

2. Materials and methods

2.1. Data collection

Six jockeys were assigned a category based on their experience (1 Expert, 4 Experienced and 1 Intermediate), according to the criteria in Table 1. All jockeys completed a consent form which had undergone review and approval by the Royal Veterinary College's Ethics Committee as part of the project application.

Each jockey was instrumented with MTw (Xsens Technologies B.V., Enschede, The Netherlands) inertial measurement units (IMU), attached using elasticated velcro straps laterally to the mid-segment of the fifth metatarsi, lumbosacral area of the pelvis (referred to simply as 'pelvis') and sternum of the jockey. An additional sacrum marker was attached to the sacrum of the simulator or horse. A custom-designed stirrup with an integrated force transducer (LCR-750, Omegadyne Inc, Sunbury, USA) and global positioning system (GPS) and data logger were fitted to both sides of the saddle.

An MK9 (Racewood Ltd, Cheshire, UK) racehorse simulator set at the highest speed level was used for all simulator testing. Five Thoroughbred racehorses in regular training at the British Racing School were used for the real horse trials. One horse was used twice with a different jockey on a different day. Inertial and force data were collected from all subjects during simulated gallop and during a real gallop, mean 12.12 $\pm$ 1.28 m/s (27.11 $\pm$ 2.86 mph) on an all-weather seven furlong (0.88 mile) straight track. Valid trials were visually identified as horses galloping in a relaxed rhythm without any obvious trips or perturbations from the team driving alongside in the car. Stirrup force data were collected at 100 Hz and inertial data at 30 Hz. Stirrups were applied to the saddle at equal length, jockeys were able to alter the length of their stirrups after the warm up before the gallop but as far as practically possible none were known to be adjusted asymmetrically.

2.2. Data processing

Acceleration data were calibrated and exported using commercial software (Xsens 'MT manager'). All data were high pass filtered (Butterworth 4th order 0.5 Hz high pass) to remove drift. Accelerations in 3 axes were integrated to velocity and then again to displacement using numerical integration using custom written scripts in Matlab (MathWorks Inc, Cambridge, UK). Displacement data were segmented into strides using minima in dorso-ventral displacement to represent mid-stance of the cycle. Stirrup data were synchronised to inertial data using a GPS time stamped trigger pulse produced when the inertial sensor data collection was initiated. Relative jockey displacements were calculated by subtracting the jockey values from the horse or simulator (sacrum) parameters. Directional stirrup force was calculated by subtracting the right amplitude from left amplitude while non-directional stirrup force was calculated by subtracting the smaller from the larger amplitude.

2.3. Data analysis

Data were collected once for each jockey on the simulator and real horse. Data were collected for over a minute in each condition (e.g. simulator/real horse) providing in excess of 200 stride cycles for analysis. Mean and standard deviation displacement amplitudes in 3 axes, trunk pitch, trunk pitch amplitude and stirrup force amplitude were analysed using a linear mixed effects model in SPSS (IBM SPSS, Hampshire, UK) with condition (simulator or horse), experience level (intermediate – elite) and side (left or right) as fixed factors and jockey as a random factor. The cut off for significance used was $P \leq 0.05$ and where applicable the post hoc test used was least squares difference.

3. Results

Jockey movement patterns during gallop on real horses were significantly different in many respects to those during simulator trials.

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